DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride

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2 LIST OF ACRONYMS AND ABBREVIATIONS

ADU	Ammonium Diuranate
AGEMCV	Above-Grade Earth-Mounded Concrete Vault
AHF	Anhydrous Hydrogen Fluoride
ANL	Argonne National Laboratory
ANOI	Advance Notice of Intent
ARS	Advanced Recovery Systems, Inc.
ASI	Allied Signal, Inc.
AUC	Ammonium Uranyl Carbonate
AVLIS	Atomic Vapor Laser Isotope Separation
Ca	Calcium
CaF ₂	Calcium Fluoride
CaO	Lime
CEP	Catalytic Extraction Process
CMR	Continuous Metallothermic Reduction
CO ₂	Carbon Dioxide
CRADA	Cooperative Research and Development Agreement
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DU	Depleted Uranium
DUF ₆ , dUF ₆	Depleted Uranium Hexafluoride
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPC	Emulsion Phase Contractors
ES&H	Environmental, Safety and Health
Fe	Iron
FSU	Former Soviet Union
g or gm	Gram
GDP	Gaseous Diffusion Plant
HEU	Highly Enriched Uranium
HF	Aqueous Hydrogen Fluoride
HFC	Hydrofluorocarbon
HTGR	High-Temperature Gas-Cooled Reactor
IAEA	International Atomic Energy Agency
IDR	Integrated Dry Route
IFR	Integrated Fast Reactor
INEL	Idaho National Engineering Laboratory
IP	Implementation Plan
ITR	Independent Technical Reviewer
Kg	Kilogram
KgU	Kilograms-Uranium
LANL	Los Alamos National Laboratory
LEU	Low Enriched Uranium
LLNL	Lawrence Livermore National Laboratory
LLRW	Low-Level Radioactive Waste

LLW	Low-level Waste
LMES	Lockheed Martin Energy Systems
LWR	Light Water Reactor
M&O	Management and Operating
Mg	Magnesium
MgF ₂	Magnesium Fluoride
MgSO ₄	Magnesium Sulfate (Epsom Salt)
MOX	Mixed Oxide
MPC	Multi-Purpose Canister
MPU	Multi-Purpose Unit
MRS	Monitored Retrievable Storage
MSP	Multi-Stage Pyrohydrolysis
MT	Metric Ton
MTU	Metric Tons-Uranium
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NORM	Naturally Occurring Radiation Material
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OCRWM	Office of Civilian Radioactive Waste Management
OECD	Organization for Economic Cooperation and Development
OSHA	Occupational Safety and Health Administration
pCi	Picocuries
Pu	Plutonium
PuO ₂	Plutonium Dioxide
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RFR	Request for Recommendations
ROD	Record of Decision
RPU	Radioactive Process Unit
SAIC	Science Applications International Corporation
SNF	Spent Nuclear Fuel
SWU	Separative Work Unit
U-AVLIS	Uranium-Atomic Vapor Laser Isotope Separation
U _{metal}	Uranium Metal
U ₃ O ₈	Triuranium Octaoxide
UF ₄	Uranium Tetrafluoride
UF ₆	Uranium Hexafluoride
UH ₃	Uranium Hydride
U _{metal}	Uranium Metal
UO ₂	Uranium Dioxide
UO ₂ F ₂	Uranyl Fluoride
UO ₃	Uranium Trioxide
USEC	United States Enrichment Corporation
V/O	Volume Percent
WAC	Waste Acceptance Criteria
WT% or W/O	Weight Percent

3 EXECUTIVE SUMMARY

With the publication of a Request for Recommendations and Advance Notice of Intent in the November 10, 1994 *Federal Register*, the Department of Energy initiated a program to assess alternative strategies for the long-term management or use of depleted uranium hexafluoride. This Request was made to help ensure that, by seeking as many recommendations as possible, Department management considers reasonable options in the long-range management strategy. The Depleted Uranium Hexafluoride Management Program consists of three major program elements: Engineering Analysis, Cost Analysis, and an Environmental Impact Statement. This *Technology Assessment Report* is the first part of the Engineering Analysis Project, and assesses recommendations from interested persons, industry, and Government agencies for potential uses for the depleted uranium hexafluoride stored at the gaseous diffusion plants in Paducah, Kentucky, and Portsmouth, Ohio, and at the Oak Ridge Reservation in Tennessee. Technologies that could facilitate the long-term management of this material are also assessed. The purpose of the *Technology Assessment Report* is to present the results of the evaluation of these recommendations. Department management will decide which recommendations will receive further study and evaluation.

Fifty-seven responses were received in response to the Request for Recommendations. These recommendations included five options that DOE was already considering, but which were not suggested in any of the other responses. Recommendations that were received before the submission deadline, January 9, 1995, were evaluated by five qualified Independent Technical Reviewers. Responses received after the submission deadline were evaluated by the Independent Technical Reviewers, as time allowed, or by Lawrence Livermore National Laboratory and Science Applications International Corporation staff members. All recommendations were reviewed according to specific evaluation factors that were developed with input from the public. The factors included environmental, safety and health; waste management; costs; technical maturity; socioeconomics; and other factors. The *Technology Assessment Report* provides a consolidation of the reviewers' verbatim evaluations of all recommendations received. A summary of the determination of feasibility based on the evaluations is also provided.

The majority of the recommendations were determined to be technically feasible. Only six recommendations were evaluated as technically infeasible. All feasible recommendations were grouped into four categories of options: (1) conversion, (2) storage, (3) recycle/reuse, or (4) disposal. Each of these options includes several sub-options. These categories will facilitate further evaluation of the options in Engineering Analysis and other portions of the Depleted Uranium Hexafluoride Management Program.

Many of the options recommended in response to the Request for Recommendations were already known, while other recommendations contained information on unique technologies and potential uses which had not been previously evaluated. The goal of issuing the Request, to help ensure that Department management considers a wide variety of reasonable options in the long-range management strategy, was therefore achieved. The *Technology Assessment Report* provides a sound basis for the further evaluation of these options.

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INTRODUCTION

The *Technology Assessment Report* completes the Technology Assessment phase of the Depleted Uranium Hexafluoride (UF₆) Management Program conducted by Lawrence Livermore National Laboratory (LLNL) and Science Applications International Corporation (SAIC) for the Department of Energy (DOE). The technology assessment process commenced with the publication of a Request for Recommendations in the November 10, 1994, *Federal Register* (59 FR 56324). The Request for Recommendations asked interested persons, industry, and other government agencies to submit suggestions for potential uses for the depleted UF₆ stored at the gaseous diffusion plants in Paducah, Kentucky, and Portsmouth, Ohio, and at the Oak Ridge Reservation in Tennessee, as well as for technologies that could facilitate the long-term management of this material. Independent Technical Reviewers assessed the technical feasibility of the responses and five other options under consideration by DOE.

The *Technology Assessment Report* provides an overview of the Technology Assessment project, a summary of responses received to the Request for Recommendations, and the results of the Independent Technical Reviewers' evaluations. The feasibility analysis in this report will be used by the DOE in the development of alternative strategies to be considered in the environmental impact statement (EIS) for the long-term management of depleted UF₆.

Reasonability of Recommendations

The Independent Technical Reviewers were asked to conclude their evaluations with a determination as to whether or not the option was reasonable. The term "feasible" and "reasonable" are used interchangeably by the Independent Technical Reviewers. Statements made by the Independent Technical Reviewers regarding the reasonability of submitted recommendations are the judgements of the reviewers. Ultimately, DOE will determine which options are "reasonable" for inclusion in further engineering analyses and "reasonable" for the purposes of the National Environmental Policy Act (NEPA).

5 THE DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

5.1 Background of Depleted Uranium Hexafluoride stored at the Gaseous Diffusion Plants

Uranium is a naturally occurring radioactive element containing several different isotopes, notably uranium-238 (U-238) and uranium-235 (U-235), the latter of which is the fissionable isotope. As found in nature, uranium is about 99 percent U-238, with a U-235 concentration of about 0.711 weight percent. To produce controlled fission in nuclear chain reactions, uranium must be "enriched" in the fissionable U-235 isotope. Enrichment is a process by which the different isotopes are separated and their relative concentrations changed. For example, in uranium for nuclear power reactors, the concentration of the U-235 isotope is typically increased from 0.711 weight percent to between 3 and 5 weight percent, with a corresponding decrease in the percentage of U-238. "Highly enriched" uranium can have concentrations of U-235 ranging from 20 to over 95 percent.

5.1.1 Source of the Depleted Uranium Hexafluoride

The uranium enrichment process used in the United States is called gaseous diffusion, which was first developed in the 1940's as part of the Manhattan Project at the DOE Oak Ridge Reservation in Tennessee. In the 1950's, two more plants were added at Paducah, Kentucky, and Portsmouth, Ohio, to help produce highly enriched uranium for defense purposes as well as low-enriched uranium for making commercial reactor fuel. Gaseous diffusion starts with uranium hexafluoride (UF_6). UF_6 is converted from uranium ore concentrate (yellowcake) by the addition of fluorine. When heated, UF_6 becomes a gas and can be fed into the equipment used for enrichment.

The basis for enrichment by gaseous diffusion lies in the fact that lighter gas molecules move more quickly than heavier gas molecules. Thus, if both heavier and lighter molecules are present in a porous container, the lighter, faster moving molecules will diffuse more readily through the openings, and a higher proportion of the heavy molecules will remain behind. Applying this principle to UF_6 , molecules containing the lighter uranium isotope (U-235) will diffuse, or pass through the openings, more easily than the molecules containing the heavier U-238 isotope. (Fluorine has only one isotope and therefore does not affect the weight difference.)

In a gaseous diffusion stage, a UF_6 "feed stream" is pumped into a porous container, or barrier tube. Aided by large gas compressors, about half the gas diffuses through the tiny holes in the barrier. This diffused stream is called the "enriched stream" because it will have a slightly higher concentration of the lighter U-235 isotope than the feed stream. Conversely, the undiffused gas will have a slightly lower concentration of U-235, and is therefore called the "depleted stream."

Because the weights of U-235 and U-238 are so close, only a very small degree of separation occurs in a single stage. To achieve significant enrichment, gaseous diffusion plants link large numbers of stages into interconnected series known as cascades. The typical reactor fuel enrichment to between 3 and 5 weight percent U-235, for example, requires at least 1,200 stages in series; highly enriched uranium with a U-235

concentration of over 90 percent has to go through more than 4,000 stages. At the end of each stage, the enriched stream is fed to the next higher stage, and the depleted stream is recycled to the next lower stage. When the UF_6 is depleted to between 0.2 and 0.4 percent U-235, it can no longer be effectively recycled and is withdrawn from the cascade. This depleted uranium is usually put into storage by the gaseous diffusion plants. Although customers for the enriched product may take the depleted uranium, most of them choose not to do so.

In 1985, due to a decrease in the need for enrichment services, all diffusion operations at the Oak Ridge plant ceased. In 1992, in response to the reduced requirements of the U.S. defense programs, the production of highly enriched uranium at Portsmouth was discontinued. DOE operated the gaseous diffusion plants until July 1, 1993, when it leased the Portsmouth and Paducah plants to the United States Enrichment Corporation (USEC) as required by the Energy Policy Act of 1992. However, the DOE retains responsibility for the depleted UF_6 produced before July 1, 1993, and stored at all three plant sites.

5.1.2 Current Status

A major consequence of the gaseous diffusion process is the accumulation of a significant amount of depleted UF_6 . Although ratios may vary in practice, producing 1 lb of UF_6 enriched to 3.0 percent U-235 will typically result in 5.5 lb of depleted UF_6 at 0.3 percent U-235. From 1945 through July 1, 1993, approximately 560,000 metric tons of depleted UF_6 have accumulated at the three plant sites. This depleted UF_6 is stored as a solid in a partial vacuum in 10- to 14-ton steel cylinders with 5/16-in thick walls. The majority of the cylinders are approximately 12 ft long and 4 ft in diameter.

The depleted UF_6 occupies a total of about 47,000 cylinders distributed as follows: approximately 29,000 cylinders at Paducah, 13,000 at Portsmouth, and 5,000 at Oak Ridge (K-25 Site). The cylinders are stacked two high, resting on concrete or wooden storage chocks, in open gravel, asphalt, or concrete storage yards. Cylinders are regularly inspected and corrective maintenance activities such as restacking cylinders, lining wooden storage chocks or replacing wooden storage chocks (which can contribute to corrosion by retaining water) with concrete chocks, and replacing or refurbishing cylinders are performed, as needed.

5.2 Rationale for Developing the Depleted Uranium Hexafluoride Management Program

The goal of the Depleted Uranium Hexafluoride Management Program is to select and implement a long-term management strategy for DOE's depleted UF_6 . The need for a long-term management strategy stems from questions that have arisen due to the change in the mission of DOE programs for nuclear materials production and research. These changes have been brought about by the end of the Cold War, by the shift in emphasis mandated by the President's budget requests, and by directives from the Secretary of Energy to reconsider present and future DOE responsibilities.

The unique properties of depleted UF_6 , as well as the large volumes in storage, suggest that the evaluation, analysis, and decisions on the fate of this material be separate from those for other DOE materials that are in storage or awaiting disposition. The Department has determined that this is a major Federal action with potentially significant environmental impacts and therefore requires the preparation of an EIS in accordance with the National Environmental Policy Act (NEPA) of 1969.

5.3 Overview of the Depleted Uranium Hexafluoride Management Program

The first phase of the Depleted Uranium Hexafluoride Management Program, management strategy selection, is composed of several elements: Engineering Analysis, Cost Analysis, and an EIS. The relationship among the program elements is shown in Figure 5.1. LLNL/SAIC has been tasked by DOE to conduct the Engineering and Cost Analysis projects while Argonne National Laboratory (ANL) is developing the EIS.

Technology Assessment is the first component of the program and the precursor to the Engineering Analysis Project. The goal of Technology Assessment is to identify and assess the options which are to be considered in selecting the optimum long-term management strategy for depleted UF_6 . Technology Assessment is discussed in detail in Section 6.

Public Participation is an essential part of the overall Depleted Uranium Hexafluoride Management Program. The intent is to provide multiple opportunities for public involvement in the DOE decision-making process and for effective two-way communication between DOE and its stakeholders. A stakeholder, in this case, is any person or organization who is interested in and/or potentially affected by the Department's activities and decisions concerning the management of depleted UF_6 , or who is interested in the associated issues of potential technologies, environmental protection, and safety and health. A stakeholder list was compiled specifically for this Program with input from DOE Headquarters, public outreach personnel at the three gaseous diffusion plants, attendance lists from public forums, and responses to the Request for Recommendations.

Figure 5.1 Elements of the Depleted Uranium Hexafluoride Management Program

Both the National Environmental Policy Act and existing DOE policy call for public involvement in DOE decision-making. The Depleted Uranium Hexafluoride Management Program, however, has secured that involvement very early in the overall process. The Request for Recommendations published in the *Federal Register* invited all interested parties to submit suggestions for the use or management of the Department's inventory of depleted UF₆. An Advance Notice of Intent (ANOI) to prepare an EIS was published in the *Federal Register* at the same time as the Request for Recommendations. Comments were invited on the scope of the EIS.

To ensure a wide distribution of the Request for Recommendations and Advance Notice of Intent, more than 1,000 packets were mailed out to stakeholders on November 28, 1994. These packets contained a copy of the *Federal Register* notice, fact sheets and a draft list of evaluation factors to be used by the Independent Technical Reviewers in assessing the recommendations.

During November and December 1994, public information forums were held at Paducah, Kentucky, Portsmouth, Ohio, and Oak Ridge, Tennessee. More than 200 people attended these three meetings, which included both presentations and information tables for detailed one-on-one discussions between stakeholders and representatives from DOE. Copies of the Request for Recommendations and the Advance Notice of Intent to Prepare an Environmental Impact Statement were available, as well as the draft list of evaluation factors. Among those giving presentations were Mr. Charles E. Bradley, Jr., DOE Program Manager, who described the Depleted Uranium Hexafluoride Program and answered a variety of questions from the audience. At the Oak Ridge and Paducah meetings, Mr. Scott Patton of LLNL provided a brief orientation on the evaluation factors. A series of general information posters was also located at the information tables at each of the meetings.

To keep the public fully informed about the progress of the Program, the Department has developed several informational documents which will be distributed periodically to stakeholders. Copies will be available at the Environmental Information or Information Resource Centers at the gaseous diffusion plants and at DOE Headquarters. Other public information forums will be held throughout the Program.

5.3.1 Engineering Analysis Project

The Engineering Analysis Project will provide a comprehensive technical analysis of the options which DOE determines are reasonable on the basis of the *Technology Assessment Report* and other factors. Technology options form the basis for the long-term management strategy alternatives. This project will provide the engineering data necessary to describe each option and assess its environmental impacts in the EIS. The analysis will include flowsheets and process descriptions, mass and energy balances, pre-conceptual facility design and layouts, regulatory analysis, and a preliminary description of hazards. Technical data for the Cost Analysis Project will also be provided.

5.3.2 Environmental Impact Statement

The EIS will assess the potential environmental impacts of the alternative strategies for the long-term management of depleted UF₆. The EIS will discuss the impact of general strategy alternatives, including siting potential facilities or transporting materials to or from such facilities. Strategy alternatives will be a unique combination of the various options related to depleted UF₆: conversion, transportation, reuse, storage and disposal. The specific process(es) and the site(s) for conversion, manufacturing, disposal, or storage facilities will be determined in the second phase of the program. Additional NEPA documents would be prepared to consider these specific impacts, if necessary.

The Advance Notice of Intent to prepare an EIS published in the *Federal Register* included a preliminary list of four potential alternatives for consideration in the Environmental Impact Statement: (1) continuation of current storage and management practices; (2) modification of depleted UF₆ storage facilities and procedures; (3) use of depleted UF₆; and (4) disposal of depleted UF₆. This list of alternatives may be modified as a result of the internal DOE and public scoping processes that will precede the environmental impact analysis.

5.3.3 Cost Analysis Project

The Cost Analysis Project will estimate the life cycle costs of the options considered for the long-term management of depleted UF₆, using the information from the Engineering Analysis Project. Estimated costs will include a breakdown of capital, operations and maintenance, waste processing and disposal, decommissioning, and environmental restoration (if applicable). Parametric analysis will include variations to time/schedule, escalation and discount rates, disposal costs, and throughput.

5.4 Management Strategy Selection and Implementation

When selecting a management strategy, the Department will consider the findings of the environmental impact analysis, along with of the life-cycle costs of each alternative presented in the EIS. The strategy selection phase will culminate in a Record of Decision (ROD), which will identify the Department's preferred long-term management strategy, along with the rationale and supporting documentation. The second phase of the program will focus on implementation of the management strategy. This phase will involve the selection of specific technologies and uses, and specific site(s) where implementation is to occur. It is likely that a request for proposals pertaining to the selected technologies and uses will be issued by DOE as part of this phase. Implementation may include the preparation of NEPA documentation for any facility(ies) involved in the strategy selected.

6 TECHNOLOGY ASSESSMENT

6.1 Request for Recommendations

In the November 10, 1994, *Federal Register* (59 FR 56324) (see Appendix 9.1), the Department of Energy published a notice that stated, in part,

. . . DOE is requesting recommendations from interested persons, industry, and other Government agencies for potential uses for the depleted UF_6 stored at the gaseous diffusion plants in Paducah, Kentucky, and Portsmouth, Ohio, and at the Oak Ridge Reservation in Tennessee, as well as for technologies that could facilitate the long-term management of this material.

The *Federal Register* notice had a deadline of December 12, 1994, for submitting responses, but an extension to January 9, 1995, was later announced in public meetings. Responses continued to be received through April 1995 (see Section 6.2.6).

The Department specifically requested recommendations on the following: (1) uses or applications of products or materials that include any form of depleted uranium and (2) technologies that could facilitate the long-term management of depleted uranium. The uses or applications could be for depleted uranium in its current chemical form (UF_6); for any of its individual components; for either the uranium or the fluorine in some other chemical or physical form; or for products made from any form or compound of depleted UF_6 , including alloys, cements, or other materials.

The Department requested as much of the following information as possible for each recommendation:

- description of the use or application
- potential annual and total amounts of depleted UF_6 that would be used
- the technical status of the use or application
- the facilities, equipment, other materials, and labor required
- environmental and health and safety approvals required
- any Government participation or funding required
- estimated costs
- a proposed schedule for implementation

6.2 The Independent Technical Review Process

6.2.1 Purpose of the Independent Technical Reviewers

The Request for Recommendations stated that responses would be evaluated by independent experts. These Independent Technical Reviewers, working without input by or consultation with each other, provided an assessment of the technical feasibility of each recommendation and of additional options currently being considered by DOE for the long-term management of depleted UF_6 .

The evaluations were based on factors developed by LLNL/SAIC with input from the stakeholders. The purpose of the evaluation was to identify the benefits and drawbacks associated with the proposed technology or use, any noteworthy points that would not be evident to non-experts, and any issues that could hamper the technology's application. LLNL/SAIC did not seek a consensus from the Independent Technical Reviewers.

6.2.2 Selection of the Independent Technical Reviewers

6.2.2.1 Criteria

LLNL/SAIC asked members of the scientific, academic, and commercial communities to identify individuals with experience and expertise in the following technical areas:

- technology assessment
- process technology
- uranium processing and fabrication
- research and development programs
- engineering finance/economics
- chemical process engineering
- metallurgical process engineering
- environmental engineering and waste management
- hazards analysis (radiological, chemical, and physical/industrial)
- Nuclear Regulatory Commission (NRC) licensing
- environmental permitting/environmental impact assessments
- regulatory issues

In addition, to ensure that no recommendation received an unfair advantage, the nominees had to be free of any real, perceived, or potential personal or organizational conflict of interest.

6.2.2.2 Final Selection

More than 40 names were submitted to LLNL/SAIC for consideration. No one person could possess skills and experience in all the relevant technical areas, and no effort was made to identify such an individual. Rather, the goal was to assemble a group of people with complementary qualifications, who would collectively meet all the criteria. The only overriding criterion was independence.

The following people were selected as Independent Technical Reviewers: Ms. Mary Glass, Mr. Brian Hajek, Dr. Walter Loewenstein, Mr. Loring Mills, and Mr. Henry Morton. Appendix 9.3 contains their resumes. To protect reviewers' anonymity and independence they were identified only by code letters (U, V, X, Y, and Z). The evaluations were conducted using these code letters.

6.2.3 Evaluation Factors

6.2.3.1 Process for Developing the Evaluation Factors

Evaluation factors were developed to serve as guidelines for the Independent Technical Reviewers in conducting their assessments. The factors were intended to give the reviewers a sense of what issues were most important to the Department in identifying options applicable to development of reasonable alternative strategies to be considered at a later date in the EIS. A draft list of evaluation factors was prepared and presented for comment to DOE and to the public through mailings and public information forums held at the three sites. Public comments were to be returned to LLNL/SAIC by January 9, 1995. Forty-one stakeholders responded to the invitation to comment and their comments were used by LLNL/SAIC in developing the final list of evaluation factors. These comments may be found in Appendix 9.2.

6.2.3.2 Final Evaluation Factors

The following are the final evaluation factors given to the Independent Technical Reviewers, with specific issues to be considered with each factor.

6.2.3.2.1 Environmental, Safety, and Health. Consider the following issues of concern to workers, the public, and the environment:

- *Issues that may arise as a result of operations, transportation, handling, storage, and disposal, including effluents and emissions.*
- *Issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *Design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

6.2.3.2.2 Waste Management. While this factor might well be included in the Environment, Safety, and Health factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed, or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

6.2.3.2.3 Costs. Consider costs that are associated with the development or use of a technology or product, or that could preclude consideration of a recommendation.

- *Capital costs, both initial (including Research and Development) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

6.2.3.2.4 Technical Maturity. For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

6.2.3.2.5 Socioeconomics. Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

6.2.3.2.6 Other factors. Add any other information believed pertinent to the feasibility of the submission.

6.2.4 Orientation and Guidance for the Independent Technical Reviewers

LLNL/SAIC conducted an orientation meeting for the Independent Technical Reviewers on January 31 and February 1, 1995 (see Appendix 9.4). The purpose of the meeting was to introduce the independent technical reviewers to the LLNL/SAIC staff, present an overview of the Technology Assessment Project and the goals of the review, provide evaluation material, and conduct a trial evaluation of a proposed use and management technology for depleted UF₆. DOE had no interaction with the Independent Technical

Reviewers in order to maintain their independence and impartiality in evaluating recommendations. The orientation program included the following:

- an overview of the DOE Depleted Uranium Hexafluoride Management Program
- an overview of the Technology Assessment Project
- the objectives of the independent technical review
- the evaluation factors
- evaluation instructions
- evaluation reporting.

The Independent Technical Reviewers were provided with evaluation materials consisting of an Independent Technical Reviewers' Manual (see Appendix 9.4), a Responses to Request for Recommendations Notebook (see References) containing recommendations that were submitted, Technology Information Packages (see Appendix 9.5), which contained supplemental information, and selected references (see References).

Each Independent Technical Reviewer conducted an independent trial evaluation of a proposed use and management technology. The goal of the procedure was to familiarize the reviewers with the evaluation materials, the evaluation procedures, and evaluation reporting. The following instructions were given to the Independent Technical Reviewers:

- evaluate each response on its own merit;
- do not compare responses;
- seek to identify and discuss the issues that may not be evident to nonexperts;
- note recommendations that are of particular merit;
- evaluate qualitatively;
- base judgment on expertise and experience;
- support opinions clearly and substantially.

In addition to evaluating the responses against the factors discussed in the previous section, the Independent Technical Reviewers were asked to conclude their evaluations with a determination as to whether or not the option was reasonable and to provide a brief justification for their conclusion. The terms "feasible" and "reasonable" are used interchangeably by the Independent Technical Reviewers. Therefore, use of either word should be construed to mean the same thing.

Ultimately, DOE will determine what options are "reasonable" for inclusion in further engineering analyses and "reasonable" for the purposes of the NEPA. In order that they might understand the areas of concern to the Department, the Independent Technical Reviewers were provided with the following guidelines for the assessment of reasonableness:

1. Timing
 - will be operational (at full scale) within 10 years of initiation
 - will be complete within 30 years of becoming operational

2. Programmatic Impact
 - realistically supports disposition of at least 15% (8,400 metric tons) of DOE's depleted UF₆ inventory
3. Environmentally Sensible
 - waste stream is of less volume than depleted UF₆ inventory
4. Cost
 - should be less than \$5 billion to implement
5. Consistent Mission
 - must be consistent with comparable activities within the DOE and other Federal agencies

After conducting their individual trial evaluation, the Independent Technical Reviewers were reconvened to discuss their trial evaluations and to make certain they understood the evaluation procedures and reporting.

6.2.5 Information Provided to the Independent Technical Reviewers

6.2.5.1 Responses to the Request for Recommendations

After publication in the *Federal Register*, the Request for Recommendations and Advance Notice of Intent were mailed to an extensive list of individuals, industries, universities, national laboratories, and interest groups associated with one or more of the gaseous diffusion plants. There was a 60-day period, ending on January 9, 1995, in which the public could submit recommendations. All responses received by DOE were included in the *Responses to Request for Recommendations and Advance Notice of Intent* notebook that is available to the public at the Environmental Information or Information Resource Centers at the three gaseous diffusion plants and at DOE Headquarters.

6.2.5.2 Number and Origin of Responses

In all, 57 responses are included in the *Responses to Request for Recommendations and Advance Notice of Intent* notebook, including five options under consideration by DOE (see Section 6.2.5.3). These responses are indexed as Document Nos. 1 through 57. Table 6.1 and Figure 6.1 illustrate the geographical distribution of responses.

Eleven responses from the public contained proprietary information and were handled confidentially. These proprietary responses are numbered among the 57 responses, but are not included in the notebook unless redacted for non-proprietary dissemination by the submitter. Eight proprietary responses were either redacted or released for publication by the submitter. A number of responses included more than one recommendation, resulting in a total of 70 independent (but not necessarily different) recommendations contained within the 57 responses. (One of the non-proprietary recommendations was submitted as two separate responses—Request for Recommendations/Advance Notice of Intent Document Nos. 1 and 11.)

Of the 57 responses, a total of 31 non-proprietary responses (including the 5 from DOE) and 8 of the proprietary responses were collected in the *Response to Request for*

Recommendations notebook given to the Independent Technical Reviewers during the orientation meeting (see References). There were three categories of responses not forwarded to the Independent Technical Reviewers for review: (1) responses that contained no recommendations, (2) responses containing comments or recommendations relevant to the Advance Notice of Intent, and (3) responses received too late for forwarding (see Section 6.2.6).

The Independent Technical Reviewers were required to handle the proprietary responses separately to maintain confidentiality and, therefore, the proprietary responses were assigned a different set of numbers (P1 through P11) and maintained in a separate notebook. To avoid possible confusion among the Independent Technical Reviewers with respect to the non-proprietary and proprietary document numbers missing from the 57 responses, the numbering system in the Independent Technical Reviewer non-proprietary notebook was re-indexed as Independent Technical Reviewer Nos. 1 through 31. A comparison index or "crosswalk" between the Independent Technical Reviewers' Nos. and Document Nos. is given in Table 6.3 at the end of this section.

**Table 6.1 Responses to the Request for Recommendations
from States with a Gaseous Diffusion Plant (21 Responses)**

State	Number of Responses	State	Number of Responses	State	Number of Responses
Kentucky		Ohio		Tennessee	
Paducah	2	Portsmouth	1	Oak Ridge	7
Benton	1	Akron	1	Erwin	1
Kevil	1	Englewood	1	Jonesboro	2
Clinton	<u>1</u>	McDermott	1	Knoxville	<u>1</u>
		Sardina	<u>1</u>		
Total	5	Total	5	Total	11

The geographical distribution of all the responses received is shown in Figure 6.1.

Figure 6.1 Responses to the Request for Recommendations by State

6.2.5.3 Other Options under Consideration by DOE

In addition to the responses to the Request for Recommendations, five options for long-term management under consideration by DOE were forwarded to the Independent Technical Reviewers. The documents are identified as Document Nos. 49-53 in Table 6.3. These represent conversion technologies and a use for the depleted UF₆ that were not included in the public responses but that the DOE was already considering.

6.2.6 Treatment of Responses Not Forwarded to the Independent Technical Reviewers

The Independent Technical Reviewers were convened at an orientation on January 31, 1995, and any recommendations submitted after that date, were not forwarded to the Reviewers due to schedule constraints. These late responses were evaluated internally by LLNL/SAIC staff (see Section 7.3), using the same evaluation factors used by the Independent Technical Reviewers. Several letters addressed issues specifically related to the EIS, and these were forwarded to ANL, which will be responsible for preparing that document. The following sections address the disposition of responses that did not include recommendations. The numbering system refers to the Document No. in Table 6.3 and to the Document No. in the *Responses to Request for Recommendations and Advance Notice of Intent* notebook.

6.2.6.1 Evaluation of Document No. 3

Document No. 3 was a letter of intent from Cameco Corporation confirming that they will respond with a detailed recommendation after the *Federal Register* deadline of December 12, 1994. A detailed recommendation (Document No. 35) was received on January 9, 1995, and was forwarded to the Independent Technical Reviewers.

6.2.6.2 Evaluation of Document No. 7

Document No. 7 was a letter from M4 Environmental Management Inc., stating that it would send an expression of interest by January 9, 1995, and requesting to meet with DOE representatives to execute non-disclosure agreements and provide proprietary information on their Catalytic Extraction Process. A formal recommendation (Document No. 29) was received on January 6, 1995, and forwarded to the Independent Technical Reviewers after non-disclosure agreements were signed.

6.2.6.3 Evaluation of Document No. 15

Document No. 15 was from the A.B. Machine Company, Ltd. confirming an extension for submission of a detailed recommendation to January 9, 1995. A formal submission (Document No. 36) was made on January 9, 1995, and forwarded to the Independent Technical Reviewers.

6.2.6.4 Evaluation of Document No. 21

Document No. 21 was from the DOE, Office of Demonstration, Testing and Evaluation of the Office of Environmental Management outlining studies conducted on depleted UF₆. It asked that these studies be referenced in the *Technology Assessment Report*. The reports were made available to the Independent Technical Reviewers.

6.2.6.5 Evaluation of Document No. 28

Document No. 28 is from a private citizen who raises concerns about waste from the Oak Ridge Reservation draining into East Fork Poplar Creek, Clinch River, and the drinking water.

6.2.6.6 Evaluation of Document No. 34

Document No. 34 is from the Serpent Mound/Ohio Brush Creek Alliance. It raises concerns about the cultural and environmental resources of the region in relation to the stored UF₆ cylinders at the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio.

6.2.6.7 Evaluation of Document No. 43

Document No. 43 is a non-proprietary summary of a proprietary submission (Document No. 16) by Fluor Daniel Inc., which was forwarded to the Independent Technical Reviewers. No new information was provided, therefore, a re-evaluation was unnecessary.

6.2.6.8 Evaluation of Document No. 44

Document No. 44 is from a private citizen in Oak Ridge who advocates storing depleted UF₆ in cylinders until the year 2030, and then revisiting the issue in 2020 or sooner if a better market develops. This response is similar to the current management plan and was forwarded to ANL for consideration in the EIS.

6.2.6.9 Evaluation of Document No. 46

Document No. 46 is from Nuclear Fuel Services and is a statement of capabilities with regard to their nuclear fuel reprocessing expertise. It is not a detailed recommendation on UF₆ disposition and was therefore not evaluated.

6.2.6.10 Evaluation of Document No. 56

Scientific Ecology Group forwarded a letter dated April 5, 1995, providing DOE with advance notification of Scientific Ecology Group's intent to provide an unsolicited proposal to perform a feasibility study for the restart of Building C-340 at Paducah to process depleted UF₆ into depleted uranium metal for reuse. Although the letter did not respond to the Request for Recommendations, it was included in the Responses to Request for

Recommendations/Advance Notice of Intent notebook for information purposes. No evaluation was performed.

6.2.7 Treatment of Proprietary Information

In accordance with the Request for Recommendations, DOE requested that if any of the information supplied was proprietary, privileged and confidential commercial or financial information, a trade secret, or otherwise exempt from public disclosure, it should be so designated and the Department would protect the information in accordance with its standard procedures as prescribed in 10 CFR 1004.11, *Freedom of Information: Handling information of a private business, foreign government, or an international organization*.

Eleven proprietary recommendations were submitted, and a set of procedures was developed to ensure that this confidential information would not be disclosed either during the evaluation period or later to anyone without authorized access. The DOE Office of Nuclear Energy, through a Document Manager, controlled all submittals that were marked as "Business Protected Information" (e.g., *contains proprietary, confidential, or privileged information or data; company confidential; do not disseminate; trade secret material; shall not be duplicated*; and other similar markings). Upon written permission from the respondents, the Document Manager distributed copies of the submittals to the Independent Technical Reviewers, as well as a limited number to the Technology Assessment Project staff. The copies were accompanied by a copy of the release permission letter. The cover was labeled "Business Protected Information" and carried a Request for Recommendations number and the respondent's name. The Document Manager maintained a tracking log that included the respondent's name and/or company name, the date sent, and the recipient. All recipients of material marked "Business Protected Information" signed an agreement certifying that they would not disclose any information contained in the material. In some instances, respondents had their own confidentiality agreements to be signed by the Independent Technical Reviewers. All such agreements were filed with the Document Manager.

All "Business Protected Information" was locked up when not in use and could be accessed only by individuals with a need to know. Upon completion of the project, all Independent Technical Reviewer review copies were returned to the Document Manager, and any non-deliverable material (e.g., drafts and notes) containing information derived from the "Business Protected Information" was destroyed.

All assessments of proprietary information were provided the same protection. In order to maximize information available to the public, each respondent was requested to review their proprietary assessments and determine which sections, if any, contained actual proprietary information. They were also asked to make as much information as possible available from their original recommendations. Most of the respondents granted their permission to include their original responses (or modification thereof) and the assessments by the Independent Technical Reviewers in the *Technology Assessment Report*.

6.2.8 Technical Information/References**6.2.8.1 Technology Information Packages**

Technology Information Packages were developed for general categories of options, including each option identified by DOE (i.e., those under consideration by DOE but not included among the formal public responses). The Technology Information Packages were intended to provide supplemental technical information to assist the Independent Technical Reviewers in their evaluations, particularly in those cases in which the recommendations did not include all the requested information.

The Technology Information Packages were prepared by conducting literature searches of known references and were written under the direction of the Technology Assessment Project staff experts. Each package has two major sections—the overview and the evaluation factors. The overview describes the process or proposed use, including the input materials, wastes, and anticipated consumption of UF₆. The evaluation factors section cites information pertaining to such issues as environment, safety, and health or technical maturity, which may have had a bearing on the evaluation. Listed at the end of each package are any references used.

The Technology Information Packages were categorized on the basis of the types of recommendations received. Information packages for recommendations on management technologies were labeled with a numeric indicator, while those for recommendations on uses for depleted uranium were given alphanumeric indicators. Table 6.2 shows the Technology Information Packages grouped according to the form of depleted uranium. The Technology Information Packages are included in Appendix 9.5.

6.2.8.2 Other References Available to the Independent Technical Reviewers

A list of core references was provided to the Independent Technical Reviewers, including the documents forwarded by the DOE Office of Demonstration, Testing and Evaluation (see Document No. 21). A depleted UF₆ management library containing over 600 references has been established by LLNL/SAIC and is maintained by SAIC. These references were derived from documents maintained by the management and operating (M&O) contractor for the gaseous diffusion plants (Lockheed Martin Energy Systems), from DOE reference materials and correspondence, and from other sources related to the subject matter (e.g., NRC documents, scientific literature). All references were available to the Independent Technical Reviewers upon request.

Table 6.2 Technology Information Packages

Form of Depleted Uranium	Associated Technologies	Potential Uses	Technology Information Packages Designator No.	
			Management Technologies	Uses
U ₃ O ₈	Hydrofluoric Acid Anhydrous HF	Disposal DUCRETE Storage	1	A1
			2	B1 C1
Depleted Uranium Metal	Improved AMES Plasma Molten Salt	Disposal IFR Fuel Re-Enrichment Shielding Products	3	A2
			4	D1/E1
			5	H1
				I1 J1
UO ₂	Dry Conversion Ammonium Diuranate (ADU) Ammonium Uranyl Carbonate (AUC) Gelation	Disposal DUCRETE	6	A3
			7	B2
		MOX Fuel	8	D1/E1
			9	
UC	Graphite Gelation	HTGR Fuel Shielding	10	F1
			11	I2
UF ₆		Storage Blending Re-Enrichment		C2 G1 H2

**Table 6.3 Depleted Uranium Hexafluoride Management Program
Responses to Request for Recommendations and
Advance Notice of Intent (59 FR 56324)**

Guide to Document Identification

Document No.	Independent Technical Reviewer No.	Respondent
1	1	Mr. A.N. Tschaeche 1693 Claremont Lane Idaho Falls, Idaho 83404 phone number not provided
2	2	Mr. Mark Strauch 48 Glacier Place Livermore, California 94550 phone number not provided
3	n/a	Mr. Peter Lenny Cameco 2121 - 11th Street West Saskatoon, Saskatchewan Canada S7M 1J3 306/956-6200
4	3	Mr. Bert Jody, Jr. President Davis Transport Box 1139 1345 S. 4th Street Paducah, Kentucky 42002-1139 502/444-7224
5	4	Mr. William Quapp Idaho National Engineering Laboratory P.O. Box 1625 Idaho Falls, Idaho 83415 phone number not provided

Document No.	Independent Technical Reviewer No.	Respondent
6	P1	Mr. William Bear Siemens Power Corporation 155 108th Avenue NE P.O. Box 90777 Bellevue, Washington 98009-0777 206/453-4300
7	n/a	Mr. Harry A. Nesteruk M4 Environmental Management, Inc. 151 Lafayette Drive Suite 210 Corporate Center Oak Ridge, Tennessee 37830 615/220-4164
8	24	Mr. Dennis Wright phone number not provided
9	5	Mr. Frank Warner General Atomics 3550 General Atomics Court San Diego, California 92121-1194 619/455-3973 Mr. Sanford Rock Allied Signal, Inc. P.O. Box 8005 Morristown, New Jersey 07962-8005 201/455-3893
10	6	Mr. Frank A. Shallo COGEMA, Inc. 7401 Wisconsin Avenue Bethesda, Maryland 20814-3416 301/986-8585

Document No.	Independent Technical Reviewer No.	Respondent
11	7	Mr. A.N. Tschaeche 1693 Claremont Lane Idaho Falls, Idaho 83404 phone number not provided
12	8	Mr. Dennis R. Floyd Manufacturing Sciences Corporation 3265 Fenton Street Denver, Colorado 80212 303/237-8576
13	9	Mr. Patrick F. Brown 113 Columbia Drive Oak Ridge, Tennessee 37830 615/483-1774
14	10	Mr. Alan Waltar American Nuclear Society 555 North Kensington Avenue La Grange Park, Illinois 60525 708/352-6611
15	n/a	Mr. Steven Pattinson A.B. Machine Company, Ltd. 140 Milner Avenue Unit #2 Scarborough, Ontario Canada M1S 3R3 416/293-0977
16	P2	Dana Lee Fluor Daniel, Inc. 3333 Michelson Drive Irvine, California 92730 714/975-2000

Document No.	Independent Technical Reviewer No.	Respondent
17	n/a	Ms. Diana Salisbury c/o Portsmouth/Piketon Residents for Environmental Safety and Security 3706 McDermott Pond Creek McDermott, Ohio 45652-4688 phone number not provided
18	11	Mr. Steven T. Carter Ohio Valley Regional Development Commission 740 Second Street Room 102 Portsmouth, Ohio 45662-4088 614/354-7795
19	12	Mr. Jeffrey R. Williams Engineering Division Department of Energy 202/586-9620
20	P3	Mr. Tom Roberts Rental Enterprise P.O. Box 7069 Paducah, Kentucky 42002-7069 502/442-4397
21	n/a	Mr. Carl Cooley Department of Energy Office of Demonstration, Testing and Evaluation 301/903-7276
22	13	Mr. Charles R. Schmitt 110 Adelphi Road Oak Ridge, Tennessee 37830 615/483-6922

Document No.	Independent Technical Reviewer No.	Respondent
23	14	Mr. Robert Bernero, Director Office of Nuclear Material Safety and Safeguards United States Nuclear Regulatory Commission Washington, D.C. 20555-0001 301/415-7298 (POC, Michael Weber)
24	P4	Mr. Dennis Lehan Manager, Specialty Products Nuclear Metals, Inc. (NMI) 2229 Main Street Concord, Massachusetts 01742 508/369-5410
25	15	Mr. Charles Montford GenCorp Aerojet P.O. Box 399 Jonesborough, Tennessee 37659 (submittal by Aerojet Ordnance Tennessee (AOT) and Babcock & Wilcox (B&W) 615/753-1200
26	16	Corrine Whitehead Coalition for Health Concern Route 9, Box 25 Benton, Kentucky 42025 502/527-1217
27	17	Mr. N. Dean Eckhoff Kansas State University 137 Ward Hall Manhattan, Kansas 66506-2503 913/532-5624

Document No.	Independent Technical Reviewer No.	Respondent
28	n/a	Ms. Mildred Serra 2110 West Adair Drive Apartment 7 Knoxville, Tennessee 37918 phone number not provided
29	P5	Mr. Harry A. Nesteruk M4 Environmental L.P. 151 Lafayette Drive Suite 210 Corporate Center Oak Ridge, Tennessee 37830 615/220-4163
30	P6	Dr. John D. Hewes Allied-Signal Inc. Research and Technology P.O. Box 1021 Morristown, New Jersey 07962-1021 201/455-3591
31	18	Mr. Thomas McWilliams Chief, Life Cycle Readiness Division Department of the Army U.S. Army Production Base Modernization Activity Picatinny Arsenal, New Jersey 07801-5000 201/724-3049 (POC, George O'Brien)
32	19	Dr. Velma Shearer 124 Chestnut Street, #210 Englewood, Ohio 45322 phone number not provided
33	20	Mr. Ronald Lamb Lamb Wheel Alignment 10990 Ogden Landing Road Kevil, Kentucky 42053 502/462-3495

Document No.	Independent Technical Reviewer No.	Respondent
34	n/a	Ms. Diana Salisbury Serpent Mound/Ohio Brush Creek Alliance 7019 Ashridge Arnheim Road Sardinia, Ohio 45171 513/446-2763
35	21	Mr. Peter L. Lenny Director, Marketing International Cameco Corporation 2121 - 11th Street West Saskatoon, Saskatchewan Canada S7M 1J3 306/956-6287
36	P7	Mr. Stephen Pattinson Export Sales Manager A.B. Machine Company Ltd. 140 Milner Avenue, Unit #2 Scarborough, Ontario Canada M1S 3R3 416/293-0977
37	22	Dr. Charles Forsberg Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, Tennessee 37831 615/574-6783
38	n/a	Mr. Earl Leming Director State of Tennessee Department of Environment and Conservation 761 Emory Valley Road Oak Ridge, Tennessee 37830-7072 phone number not provided

Document No.	Independent Technical Reviewer No.	Respondent
39	n/a	Ms. Sue Whayne Route One Clinton, Kentucky 42031 phone number not provided
40	25	Mr. Victor Ransom Purdue University 1290 Nuclear Engineering Building West Lafayette, Indiana 47907-1290 phone number not provided
41	P8	Mr. Stephen Schutt Executive Vice President Advanced Recovery Systems 1219 Banner Hill Road Erwin, Tennessee 37650 615/743-6186
42	23	Mr. Jerry Hutchison Operational Quality R&R International, Inc. 1234 S. Cleve.-Mass. Road P.O. Box 4383 Akron, Ohio 44321 216/665-3773
43	n/a	Dana Lee Fluor Daniel 3333 Michelson Drive Irvine, California 92730 714/975-2000
44	n/a	Mr. William Tewes 304 E. Forest Road Oak Ridge, Tennessee 37830 615/482-2728

Document No.	Independent Technical Reviewer No.	Respondent
45	26	Mr. Peter MacDowell St. Helen's Trading, Ltd. P.O. Box 911 Azusa, California 91702-0911 818/969-0911
46	n/a	Mr. Archer Haskins Nuclear Fuels Services, Inc. 5096 Boonsboro Road Lynchburg, Virginia 24503 804/384-0113
47	n/a	Mr. Steven Baker EG&G Environmental, Inc. 2128 Hudson Avenue Richland, Washington 99352
48	n/a	Mr. Charles Chisholm PDI P.O. Box 9927 Reno, Nevada 89507 702/342-0200
49	27	Package 5 Continuous Metallurgical Reduction to Uranium Metal
50	28	Package 6,7,8 Conversion to Ceramic UO_2 - Existing Industrial Routes
51	29	Package 9 Conversion to Ceramic UO_2 - Gelation
52	30	Package 10 Conversion to Uranium Carbide - Graphite and Gelation Approaches
53	31	Package F1 HTGR Fuel Fabrication Using Uranium Carbide

Document No.	Independent Technical Reviewer No.	Respondent
54	n/a	Mr. Yoshihiko Sugano Mitsubishi Materials Corporation Energy and Ecosystem Business Division 1-3-25 Koishikawa, Bunkyo-ku, Tokyo 112, Japan
55	n/a	Mr. Charles Montford GenCorp Aerojet P.O. Box 399 Jonesborough, Tennessee 37659 615/753-1200
56	n/a	Mr. William H. Carder Scientific Ecology Group, Inc. P.O. Box 2530 1560 Bear Creek Road Oak Ridge, Tennessee 37831-2530 615/376-8032
57	n/a	Mr. Mike H. West Mr. John FitzPatrick Los Alamos National Laboratory CST-7, G739 Los Alamos, New Mexico 87545 505/665-1761

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7 EVALUATION OF RECOMMENDATIONS AND OTHER OPTIONS

Section 7.1 contains the complete, verbatim Independent Technical Reviewers' evaluations for all recommendations that they reviewed. For better accessibility, the evaluations have been reorganized according to the sequence of the Evaluation Factors.

Section 7.2 contains evaluations of recommendations that were previously proprietary. The proprietary submittals, and corresponding assessments by the reviewer(s) were sent to the respondents for redaction or release as non-proprietary information.

Section 7.3 includes evaluations of responses which were submitted after January 31, 1995.

7.1 Independent Technical Reviewers' Evaluation of Recommendations

The evaluations by the Independent Technical Reviewers are shown by the number assigned (Independent Technical Reviewers' Nos. 1-31) by LLNL/SAIC when the responses were distributed for review. The document number is shown in parentheses. Refer to Table 6.1 for the complete list of responses to the Request for Recommendations and a crosswalk between the Independent Technical Reviewer number and the document number.

Several responses contained multiple recommendations, and some reviewers evaluated each recommendation separately. Each recommendation is identified in the description of the response and in the reviewers' evaluations by italicized option numbers.

Reviewer V provided general comments on the evaluation of the recommendations and identified a number of issues which arose repeatedly. Reviewer V's general comments are reprinted below.

General Comments On Evaluation of Recommendations for Depleted Uranium Hexafluoride ITR V

In reviewing the recommendations regarding the Depleted Uranium Hexafluoride Management Program, a number of issues repeatedly arose with regard to the evaluation of the responses. In some cases, they involve concerns that are common to all, or nearly all the recommendations. In others, they involve concerns not specifically addressed in the evaluation criteria, but which are germane to Program success. Unfortunately, the information and time available to conduct these evaluations precludes addressing these issues in each document. The purpose of this general comment section is to summarize the issues in a concise statement, allowing the individual reviews to focus on the specifics provided in each response. These issues should be considered in determining the feasibility and implementation potential for any option and be included in DOE's evaluation of the overall reasonableness of the option. It is hoped that this discussion will provide useful information to direct future inquiries.

Environment, Health and Safety

Cradle to Grave Assessments. The environmental, health and safety considerations addressed in the recommendations and information packages provided to the evaluators tend to focus on the environmental effects of the specific conversion, storage or use options proposed. A more complete analysis of the precursors to the process and the fate of the outputs need to be presented in future evaluations. For example, all the processing options will require continued storage of DUF₆ at the current sites for some period of time until the material can be converted. This will involve the need to address the environmental, health and safety issues associated with that continued storage. Similarly, if DUF₆ were stored for planned later use as nuclear fuel, the issues associated with power production would need to be addressed.

Cumulative Effects. The environmental, health and safety aspects of each option need to be evaluated in terms of the cumulative effects of the option along with any development directly related to it, as well as any preexisting development in the vicinity of the site. For example, it may be appealing to use sites already involved in the nuclear industry, however, additional activity in an area could raise emissions or effluent levels to a point where, while meeting technical standards, public concern regarding cumulative health effects is aroused. These situations should be considered on a site by site basis.

Applicable Standards. Frequent mention is made of NRC, DOE, EPA or industry standards with regard to health and safety. It is important to note that these standards are changing. Specific options may become more or less feasible or costly as this happens, so changes must be carefully tracked. Also, more stringent standards may be developed as specific process configurations evolve or public opinion dictates.

Cost, Financial and Legal Considerations

Asset Management. Depleted uranium is not simply a disposal problem for which DOE must commit huge amounts of resources. Careful valuation of the DU assets and potential revenues associated with the Government's role in an option should be made to realize the full value of these assets. As development proceeds and contracts are pursued, the Government will need sophisticated asset management expertise to optimize its position and select the most advantageous ownership and contract structure to dispose of the DU inventory. In any case, where DOE is to share in the development costs of a facility it should share in the potential financial benefits as well. Including benefits from sale of by-products and future conversion and use options. (See Future DUF Program Directions below.)

Product Markets. For many of the options, markets for the products are postulated or assumed without real market studies. Development of this information is essential to the evaluation of the viability of any of the recommendations. Consideration should also be given to the role of the U.S. Enrichment Corporation in these markets. They may be a competitor, mentor, supporter or partner for DOE's program. They could influence the markets, prices and costs in many ways by the decisions they make with regard to the DU generated at their facilities. Another important market that is rarely mentioned is the

international market. They present opportunities in conversion technologies, buyers for products produced and purchasers of services developed under the DU program.

Life-Cycle Costing. Each of the options should be evaluated taking into account the full life-cycle costs from today through final disposition. In nearly all options, this means that continued DUF₆ storage costs at the current locations will accrue until the inventory is processed or disposed. Similarly, processes for producing products or by-products, e.g. uranium metal, must explicitly state and account for the costs to dispose of the material or the costs of any ensuing fabrication into useable products. If there are any costs associated with the disposal of materials from those secondary uses of uranium, they too must be tallied. While this is implied in some of the options and identified in many of the evaluations here, it should be more systematically performed in the next stage of program evaluation.

Risk Assumption. The complex operations in many of these options will require a clear definition and assumption of risks, indemnifications, insurance and other legal/financial considerations. It will be important to attribute these risks to the appropriate parties to assure that responsibility and associated costs are properly allocated. In doing this, it may be useful to consider the most economically advantageous means of structuring the relationships to minimize costs to both parties and the appropriate public and private roles to be played in the handling of such an important national resource with such significant environmental considerations.

Siting Costs. A factor that is rarely explicitly considered in the recommendations or information packages is the potential costs of siting facilities involving radioactive materials. Regardless of the relative safety of various options, if opposition occurs, the costs of permitting on site purchase and development costs can balloon well beyond expected levels. The potential of a technology or site to generate strident opposition should be included in costing. The costs of delays must also be factored into the evaluations. Delay of an option due to public resistance could significantly change the relative economic attractiveness of it compared to other options. The cost of a siting failure and the need to start the process anew should also be considered.

Financing. For many of these options it is unclear who would be responsible for providing the financing for the required capital expenses. The choice of financing should be determined based on the ability to obtain financing and the cost of that financing. In some cases, options may not be suitable for private financing at one or more stages of development. Given current budgetary pressures on Federal agencies, however, public funds may be difficult or impossible to obtain also. Increasing pressure is being placed on agencies to find off-budget financing. In some cases, private financing may be obtained if the project is structured in a way that will promote its attractiveness in financial markets.

Opportunity Costs/Externalities. The selection of some options may preclude other uses of DUF₆ in the future. While this is inevitable, it is worthwhile to consider the opportunity costs of a selected option. This was made explicit in the discussions of the option to preserve DUF₆ for future fuel use, but may be applicable to other options. Similarly, the government may realize the best options by simply holding the inventory until conversion

options are developed, thus realizing a lower cost of disposition through better processes. In a related cost issue, there may be costs from program actions that have external cost effects that need to be considered. For example, the development of some options may require investments in infrastructure or other programs by local or state governments.

Socioeconomic Factors

Public Acceptance. This factor is the most significant socioeconomic factor needing consideration in evaluating any of the recommendations. Public sensitivity to environmental risks in general, and radiation exposure risks in particular, have been heightened in recent years. Even in locations where there is broad support for this type of development, well organized opposition can present difficult hurdles slowing project implementation or halting projects completely. As noted by one of the respondents to the call for recommendations, public acceptance is a key factor in their siting considerations and "a widely supported site selection strategy would be of fundamental importance to the overall success of the program." They go on to note that based on their experience disposal siting is a major political, social and regulatory hurdle. While it is tempting to ignore this factor until a specific site is chosen, early identification of the generic issues on which opposition might be based and effective engineering solutions or other responses to these issues is important. If, in some cases, it is found that responses to certain risks are difficult to identify, the technology's appeal relative to options more acceptable to the public can be assessed.

Siting and Permitting. For any new production facility, siting and permitting will be an important issue. Especially in cases where the facility constitutes a new land use in the community, e.g. an industrial or hazardous activity where none existed before, special preparation will be needed. Community participation, education and negotiation will be especially important. Community resistance is a significant cause of failures in siting many new industrial and energy facilities in the U. S. today. The availability of a permitted site or DOE's role in providing one may be a necessary piece in determining the "reasonableness" of a number of options proposed.

Related Industry. In cases where a large conversion facility is built and operated, associated development may occur and amplify the socioeconomic impacts. This development could include supply industries, such as power and chemical plants, and spin-off industries that use the materials produced by the conversion plants. While this development is not part of the conversion option put forward, it should be considered in assessing the magnitude of impacts.

Transportation. In nearly all the recommendations received, some transportation of DUF₆ or materials or products derived from DUF₆, need to be moved from one location to another. The points of origin and destination, the number of trips required and the number of times transportation is required are important in assessing the impact on infrastructure as well as exposure risks from potential accidents. When some of the options are better defined regarding location of facilities and destinations for products, this issue should be reexamined.

Technical Maturity/Timeliness

Public Acceptance. The time needed for the technology to be considered to be technically mature should include the time necessary to inform the public about the process and the implications for its application in the selected location. If a process involves technology that has been or could be highly sensitive, such as breeder reactors in the past, time will be needed to handle public acceptance.

Importance of Technical Characteristics. Based on the relatively large amounts of information made available on the technical characteristics and maturity of the processes under consideration in comparison to the amounts of cost, environmental and socioeconomic information provided as background for technical reviews, it would appear that the former is of greater importance in the evaluation. While information may be scarce on the non-technical characteristics, care should be taken to seek all the information that is available as the evaluation proceeds, and to extrapolate or postulate on the effects from other experiences where no data can be found. An effective DU Management Program is dependent upon non-technical as well as technical factors.

Future DUF Program Directions

Multiple Uses. Given the size of the existing inventory DOE should consider the use of more than one option for disposition of the DUF₆. A combination of storage, conversion and disposal options may offer the greatest overall value in terms of monetary and non-monetary considerations and program goals.

Public vs. Private and Public/Private Partnerships. The appropriate role for the government and private sectors in the management of the depleted uranium inventory is an important consideration for each of the options. In some cases, it may be more appropriate for the federal government to maintain ownership and control of the material, for example, if it were to be saved as a strategic material for nuclear power production in the next century. On the other hand, where the materials are to be used for products sold into the private sector, e.g. HF byproduct sales, or shielding material and fly wheels, it may be possible for DOE to pass much of the responsibility for development and implementation of an option to the private sector. The selection of a public or private ownership pattern on a given option may also significantly effect the economics based on a number of factors including risk assumption, tax effects, etc.

There are many structures that can be used to implement public/private partnerships in the DUF management program. The U.S. Enrichment Corporation is one such option as it has depleted uranium identified as a material it is empowered to handle. Other legislative initiatives that are being considered by private sector groups include multi-purpose quasi-public agencies that could contract with private parties to develop and manage certain facilities and functions now carried on by the Federal government. Existing DOE procurement regulations allow for a number of contract structures for involving the private sector. The use of private asset managers has also been considered and is discussed below.

An Asset Management Alternative for DUF Program Development and Implementation.

Private asset management specialists can assist DUF program managers in identifying highly qualified private development partners for participation in programs to dispose of the existing inventory. The level of private involvement could range from pursuing specific applications for selected options to helping plan and implement a comprehensive program. As already demonstrated in other agencies, the use of a private developer can allow the government to retain control of program direction while allowing private sector/market factors identify the best solutions to the problem. The appeal of this approach for the DUF program comes from the fact that such a development arrangement allows the program to change over time as needs, markets and technologies evolve. The large DU inventory will probably require the adoption of more than one option for disposal and/or use. A general development agreement with a private party could allow them to contract with different parties over the 30 year program to achieve the best disposal options based on DOE criteria at the least cost to the Federal Government, thus making the most of the DUF assets held by DOE.

7.1.1 Evaluation of Document No. 1 (Independent Technical Reviewers' No. 1)

Respondent:

Mr. A.N. Tschaeche
1693 Claremont Lane
Idaho Falls, Idaho 83404

phone number not provided

Description of Response:

This response recommends that the depleted uranium hexafluoride remain in its current form and at its present location and that it be used to make blanket material for breeder reactors for generating electricity and plutonium for use in electric generating nuclear power plants. The responder states that maintaining this material in its current form will allow future generation of plutonium for use in electric generating nuclear power plants.

7.1.1.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.1.1.1 Evaluation by Reviewer U

The recommendation in Document #1 calls for continued storage of the depleted uranium hexafluoride (DUF₆) until the time of future application as blanket material in future breeder reactors. The recommendation incorporates the anticipated future need of breeder reactors as a necessary means to provide energy for the increasing needs of growing populations. The potential energy value of the depleted uranium when used in this manner is indicated as providing electrical generating capacity for several hundred years. There is no indication of when such an application would be economical or could be implemented.

Operational issues include well understood controls for storing and handling DUF₆ until the time for use as breeder reactor blanket material. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. The potential health concerns associated with long term storage of DUF₆ are well known and when properly implemented, effectively controlled.

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Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage. Future activities of converting the DUF_6 to breeder reactor blanket material are not defined and plans for this activity would occur many years in the future.

Overall Federal regulation for safety of DUF_6 storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF_6 is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. A modification in the regulations would be required for NRC licensing long term storage of DUF_6 .

7.1.1.1.2 Evaluation by Reviewer V

The option of storing DUF_6 in its present form to preserve it for later use does not appear to present any major environmental, safety or health issues. The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air, DUF_6 can react to moisture producing HF acid and UO_2F_2 , both hazardous. The HF is an acid that could cause skin burning and damage to the lungs on contact and the fluorides and uranium can have toxic effects if ingested. In addition, the alpha particle emissions from inhaled or ingested uranium could be a health risk. Releases to the environment are most likely to be limited to the storage facility itself. If a large release occurred, however, the potential exists to effect the surrounding area effecting the public, the land, vegetation and domesticated and wild animals.

The handling of the storage cylinders and routine operations at the storage facility raise the possibility of minor environmental risks from accidental releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. Past experience has shown very few incidents of releases, virtually all of which had insignificant health effects. With the aging of the cylinders, however, the potential for increased numbers and severity of accidental releases must be seriously addressed.

The transport of DUF_6 required under this option would be very limited and, therefore, minimize potential exposure of the public. Use of the current sites is probably the least risk approach from an environmental, health and safety perspective. While the public is located in proximity to the facilities, there are no major population centers in the immediate vicinity. Selection of different sites would require licensing, delay and transport of aging cylinders which might pose a greater environmental risk than current storage. Within the existing sites, there may be potential for relocating storage areas to improve storage conditions and minimize hazards of accidental release.

Continued storage at existing sites again would not present a problem technically, however the management of the sites and perhaps the storage techniques may need to be modified. Handling the cylinders for inspection and routine stacking and unstacking can cause

leakage, although in many cases any breaches are self-sealing. The steel cylinders have been stored out-of-doors, some for as long as thirty years which is the estimated useful life expectancy. While high risk cylinders with identified risk potential (about 15,000) are inspected annually, only one fourth of the remaining inventory is inspected annually. Current storage conditions may make it difficult to inspect some cylinders.

Current management programs include cylinder inspections for integrity with repairs and replacements performed as necessary. Some technical assessments of the condition of the cylinders and techniques for maintaining them are underway. In addition, some improvements in cylinder storage facilities are underway including saddle replacement, new cylinder yards at Paducah and Portsmouth, cylinder replacements and a cylinder refurbishment facility. The latter would have the capacity to handle about 1/20th of the existing cylinders per year. The current outdoor storage system is not in compliance with DOE regulations requiring two levels of confinement for all radioactive materials, e.g. use of a container that is protected within a building.

Given the advancing age of the cylinders, increased inspections and refurbishments as well as improved storage systems should be considered. Nearly a third of the cylinders are described as "high risk" and inspected annually due to poor drainage, heavy scale or pitting, suspected leaking valves, etc. The risks of accidental releases should be evaluated given these conditions and additional improvements in storage and handling considered. It has been suggested that covered storage be considered. Other approaches might include a more rigorous and frequent inspections program, an accelerated program for refurbishing and replacing cylinders on a preventive basis and improved yards, saddles and containment systems for all cylinders at an early date.

The proposed use of DUF₆ in breeder reactors in the future presents more complicated environmental, health and safety issues. Such facilities would require the handling of large quantities of radioactive materials and low and high level wastes that require special handling, processing and disposal facilities. The siting of the reactors and related fuel processing facilities would require many years of advance planning and permitting procedures. Given the current public disaffection with nuclear power it is unlikely the planning process would begin in the next decade.

7.1.1.1.3 Evaluation by Reviewer X

Since the current dUF₆ storage program began, six cylinders have been identified to have experienced leaks. All of the leaks were identified long after they occurred because of the early absence of a periodic inspection program. Each leak self-sealed. Four of these leaks were determined to have been caused by cylinders weakened by handling. The remaining two leaks were in cylinders that had corroded. Programs are currently in place to (1) replace cylinders that are at risk, (2) improve cylinders that are weak, (3) inspect all cylinders on a rotating basis, revisiting those at greater risk more often. Apparently, no new leaks have been observed since these programs were implemented. (See EGG-MS-11416, pg. 9.)

The real question relative to risk to workers or the general public is "How rapidly does the dUF_6 react with moisture in the air to cause a cloud with dangerous levels of HF or uranium?" No data was provided to answer this question. However, it was stated that the above-mentioned leaks self-sealed prior to being identified "because the material loss and reaction with atmospheric moisture were so slow." Apparently, no injuries resulted from the leaks. (See EGG-MS-11416, pg. 9.)

Measures to reduce or eliminate leaks during handling include (1) administrative procedures prohibiting transport of liquid-filled cylinders, and (2) modifications of the specifications for the metal used in cylinder construction, including steel with favorable low-temperature impact response and low sulfur content, which improves ductility and impact strength.

Additional programs are in place to provide new stands for some cylinders to improve safety, and to further protect cylinders from contact with standing water.

The present storage method in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. Thus, it is reasonable to expect that construction of new storage facilities could be required. The question is whether the cost is justified by the reduction in risk. Risk should be evaluated based on vaporization rates, dispersion rates, reseal rates, and detection probabilities. If earthquake resistant buildings are built for the cylinders, the second confinement level should preclude release of materials if one or more cylinders become cracked.

Whether an enclosed facility is built or not, it is apparent that many cylinders will need to be moved due to (1) being stored too close together to facilitate inspection, (2) needing to be placed on new moisture resistant cradles, or (3) requiring transfer of the dUF_6 to new cylinders because of cylinder deterioration. This movement also causes a risk of further cracking. Handling practices can minimize serious damage which would produce large releases.

7.1.1.1.4 Evaluation by Reviewer Y

Near term: The documents suggest leaving material in its present form. The only substantive question is the inadvertent release of DUF_6 , which will not have excessive environmental issues beyond those of the immediate release in either solid or gaseous form. A program to maintain the status quo will be required. Monitoring tank corrosion and painting tanks should suffice.

Long term: The documents refer to the latent energy in depleted Uranium for long-term use. The amounts in the context of electricity production are staggering and will have profound environmental benefits to reducing CO_2 and acid rain emissions from fossil plants, particularly as fossil fuels become more costly.

7.1.1.1.5 Evaluation by Reviewer Z

Mr. Tschaeche proposes that the material should be left in present form at the current site and used to make blanket material for breeder reactors for generating electricity and plutonium for use in electric generating nuclear power plants.

The first part of the proposal, that the material be left in its present form for use at a future time as a breeder blanket material, is a continuation of the current practice. As noted in Mr. Tschaeche's RFR, the amount of material presently stored at the plants in Paducah, Kentucky, Portsmouth, Ohio, and at the Oak Ridge Reservation in Tennessee are sufficient to provide fuel for several hundred years. Although the near-term risks associated with continued storage of the material are small, the risks associated with storage and cylinder handling will increase with extended storage due to continued degradation of the cylinders due to corrosion.

The second part of the proposal is that the material be used to make blanket material for breeder reactors for generating electricity and plutonium for use in electric generating nuclear power plants. Implementation of the second part of this proposal would require a chemical processing facility to convert UF_6 to a stable form such as an oxide. In the event it is converted into plutonium in the future, fabricating the breeder blanket or the fuel and recovering plutonium from spent fuel or the blanket for reuse would be done as part of the plutonium fuel cycle. In this evaluation, UF_6 conversion to a stable form for storage is considered.

Processes to convert UF_6 to stable forms such as oxide or metal have been used commercially and environmental impacts are reasonably well known. Current incentives to contain material, to minimize effluents, to recover and recycle wastes, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

Siting a conversion facility would influence transportation issues. Siting a conversion and oxide storage facility adjacent the existing UF_6 storage yards would presumably eliminate a transportation step in the foreseeable future. When transportation is necessary, e.g., to a blanket or fuel fabrication facility, the more stable form would be transported from the site.

Existing UF_6 to oxide processes may be expected to produce a powder or cake form of the oxide. Since the powder or cake may be expected to be dispersible, for long term storage, its containers would need to maintain long term integrity to prevent leakage and potential dispersion. Health and safety provisions will need to be similar to practices at currently authorized concentrate (yellowcake) to UF_6 conversion facilities or UF_6 to oxide fuel fabrication facilities. Containment requirements for dispersible powder form of uranium would need to be about the same as for UF_6 .

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 or oxide powder from its storage vessel and subsequent atmospheric dispersion.

The current technology for converting U^{238} to Pu^{239} would be irradiation in a fast breeder nuclear reactor and recovery of the plutonium in a spent fuel reprocessing plant. That will be a long term prospect, and the environmental, health, and safety issues of the plutonium fuel cycle would not be encountered until the distant future.

7.1.1.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.1.2.1 Evaluation by Reviewer U

Storage cylinder monitoring and maintenance would be required for the DUF_6 . Occasionally, it will be necessary to remove the DUF_6 from defective or degrading cylinders and transfer the DUF_6 to new storage cylinders. During such activity, some limited amount of contaminated waste will be encountered. These wastes could be allocated to disposal at low-level radioactive disposal sites.

Disposal of defective and empty DUF_6 cylinders will be required. A small amount of UF_6 must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal or storage. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites, at a high cost.

7.1.1.2.2 Evaluation by Reviewer V

The waste streams associated with this option are minimal. There would be minor amounts of waste generated from normal maintenance activities including replacing or repairing cylinders, valves and other equipment. The replacement of wood saddles with concrete or other supports will generate quantities of waste that is likely to be disposable in a regular landfill. The cleaning and recoating of canisters will also generate some waste, but there would be limited potential for recycling or waste minimization in any of the operations.

The waste management issues associated with use of DUF_6 for reactor fuels would be much more complicated. If the breeder reactor were implemented, the waste issues associated with use of DUF_6 , would be no greater than those associated with the use of natural uranium. However, significant levels of low and high level waste would need to be processed and placed in appropriate repositories. Many of these issues are still being

resolved with regard to current nuclear activities. Additional radioactive wastes would simply expand the scope of the situation.

7.1.1.2.3 Evaluation by Reviewer X

No additional wastes are expected to be generated from the continued storage of dUF_6 .

7.1.1.2.4 Evaluation by Reviewer Y

Near term: No problems except for accidental releases with minor impacts. Clean-up of accidental releases will be relatively easy.

Long term: Waste from converting DUF_6 to DU or DUO_2 (or DUC) will involve primarily Fluorine compounds which may have some commercial value.

7.1.1.2.5 Evaluation by Reviewer Z

The first part of this proposal is to leave the material in its current form at its present location. This would be a continuation of the current practice. For extended storage periods, the degradation of the cylinders would potentially create additional contamination, thereby creating additional low level waste. This waste would be of the same type as currently present.

A UF_6 conversion (to oxide or metal) facility would produce some radioactive effluent and radioactive waste. The solid radwaste would be expected to be transported to a regional low-level radioactive waste burial facility.

Conversion of UF_6 to an oxide or metal form would release fluorine, a toxic chemical. During the conversion process, the fluorine would need to be captured. It seems more likely that the fluorine would be captured as HF , a commercially valuable chemical, and unlikely to become a waste form. Solid wastes would be mainly contaminated equipment, effluent scrubber sludge, clothing, process maintenance materials and such other materials that become contaminated incidental to processing UF_6 to a more stable form. The heel, or residue, in a UF_6 cylinder that does not vaporize along with the UF_6 contains radioactive progeny of U^{238} and U^{234} , especially protactinium-234. It has much higher radioactive concentration than U^{238} or U^{234} and must be dealt with as a radioactive waste. Storage to allow radioactive decay is usually a waste management practice for the cylinder heels.

In the long, term, conversion of the stable form to Pu^{239} would involve irradiation in a nuclear power reactor and reprocessing steps in the nuclear fuel cycle.

High waste burial costs, state and federal regulation, high costs of disposing of radioactive waste, health hazards of UF_6 and HF that is not contained, high costs of decontaminating and decommissioning facilities and surrounding land that has been contaminated, and recovery of commercially valuable HF are incentives to minimize creation of radioactive

waste during the conversion of UF_6 to a more stable form or to breeder reactor fuel or blanket.

7.1.1.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.1.3.1 Evaluation by Reviewer U

Long term storage of DUF_6 can be achieved based on the extensive knowledge gained from storage over the past several decades. Such costs are expected to be significantly less than all alternatives of converting DUF_6 to another form for storage and/or underground disposal.

The future activities of using the DUF_6 for breeder reactor blanket material are indeterminate for either the time of need, cost of conversion or value achieved with breeder reactors.

7.1.1.3.2 Evaluation by Reviewer V

The costs of this option as estimated by contractors to DOE are low, in the range of \$.22/kgU to \$.34/kgU assuming a storage inventory of only 375,000 MTU, corresponding to life cycle costs of \$83 million to \$129 million. This estimate is based on current storage practices to be used through the year 2020 including planned upgrades of cylinders and yards, new cleaning/coating facilities and current inspection and maintenance. The capital costs for an additional confinement level using indoor storage was estimated at \$360 million for all three sites, with some additional maintenance costs ongoing associated with those facilities. If these estimates are accurate, this would increase the cost of this option by four fold or more. The costs of various containment options should be reviewed, including the use of outside contractors to operate and maintain such facilities. It is generally recognized that some increased costs may need to be incurred to bring the storage option to a higher level of safety.

There would be no additional revenue streams associated with storage unless it were provided with another alternative immediate or future use. The later sale or use of DUF_6 , its products and byproducts could produce some revenues.

The costs of using DU for fuel in breeder reactors is not well known at this time. Until a better understanding of the technology and DU's role can be developed, little can be determined with regard to the cost to the Government of using stockpiled DU in this way.

7.1.1.3.3 Evaluation by Reviewer X

Costs to maintain current storage practices through the year 2020 are estimated to range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional will be required. This double confinement cost will need to be expended to receive public support for continued storage.

It isn't likely that a breeder economy will develop by 2020. Thus, the storage cost will be greater than this amount over the long run. However, it will still be much lower than the cost of converting the DUF_6 to U_3O_8 .

7.1.1.3.4 Evaluation by Reviewer Y

Near term: Costs are modest. Paint, tank monitoring, some tanks replacement and permits to so handle the largely inert material are modest compared to other options.

Long term: The cost will be determined by the particular option to be utilized for conversion of the DUF_6 to the preferred breeder (or near breeder) blanket (e.g., metal, oxides, or carbide). These are estimated to be on the order of a few dollars per pound of DU, less than the cost of natural Uranium ore fuel. Byproduct yields (e.g., anhydrous fluorine) are estimated to be about the same as uncertainty in basic material production (see other more definitive options: 3 and 6).

7.1.1.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Presuming fluorine or HF were recovered, it would be commercially valuable. Costs of eventual utilization of the uranium by conversion to plutonium cannot be assessed by this reviewer.

7.1.1.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.1.4.1 Evaluation by Reviewer U

Storage of DUF_6 has been the practice for several decades. Augmenting the current practices to assure the safety of long term storage--a century or two--appears to be reasonable by transferring the material to new cylinders whenever degradation of the cylinders is encountered. The rate and frequency of degradation is indeterminate, but expected to be easily accommodated.

7.1.1.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. Some additional work on the potential for increased failure of aging canisters may be appropriate. Management can be on the lookout routinely for safer or more economical ways of managing the storage of these materials.

The breeder reactor technology is in commercial use in Europe, however, it has not been adopted in the U.S. Current focus on next generation reactors makes it unlikely that the breeder will be adopted here soon.

7.1.1.4.3 Evaluation by Reviewer X

DOE has stored dUF_6 using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

7.1.1.4.4 Evaluation by Reviewer Y

Near term: This is technically mature with minimal surprises over decades.

Long term: The processes for converting UF_6 have been used for decades to generate fuels of choice with enriched Uranium metal, oxide, and carbide having most past experience (see other options).

7.1.1.4.5 Evaluation by Reviewer Z

Storage of uranium hexafluoride is a mature technology. Long term storage, such as would be required by this RFR would require additional measures to protect the stored cylinders from corrosion, but no new technology would be required.

UF₆ conversion to a stable form such as an oxide is a mature chemical process. UF₆ conversion to U₃O₈, UO₃, and UO₂ has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel. Large scale uranium-to-plutonium breeder reactors have been constructed and operated in other nations. Spent fuel has been reprocessed to recover plutonium in the United States and in other nations on a commercial scale and by the U.S. government installations. Fuel reprocessing and fabrication of plutonium mixed oxide fuel should be considered a developed, and perhaps, mature technology.

7.1.1.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.1.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining storage of DUF₆ would be fairly constant for many decades. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Also, there will be strong objection by some members of the public to a storage mode that would include the use of breeder reactors in the future. Since the storage activity would be a continuation of current practices there does not appear to be a need for seeking significant public involvement or initiating a major public information program.

7.1.1.5.2 Evaluation by Reviewer V

Economics: Storage of DUF₆ using the existing management scheme would not have a significant effect on employment or income in the vicinity of the sites. Maintenance operations as currently planned would require no major increases in labor to handle the monitoring and refurbishing activities.

If major improvements were made in the facilities or maintenance operations were expanded there could be some effects on the local economies surrounding the site. Economic impacts from the construction of a covered storage building(s) at each site could

be in the following ranges, based on the RIMS II regional economic multipliers (U.S. Department of Commerce, 1992):

Total estimated capital costs:	\$360 million
Paducah (62%)	\$232.2 million
Portsmouth (28%)	\$100.8 million
Oak Ridge (10%)	\$ 36.0 million

Net effect on local economy in terms of:

	Total increase <u>direct demand</u>	New earnings <u>to employees</u>	Jobs created <u>(temporary)</u>
Paducah	\$527 million	\$158 million	8,437
Portsmouth	\$255 million	\$ 77 million	3,699
Oak Ridge	\$ 88 million	\$ 28 million	1,300

The impacts actually experienced could vary considerably, however. The economic effects of the operation and maintenance of covered storage on overall storage costs should be neutral or slightly positive in that protection from the elements could slow the degradation of the cylinders and reduce ongoing refurbishment costs.

Siting. Siting could be a significant public acceptance issue. It has been raised in a number of responses to program notices as a concern for at least some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the condition and management of the cylinders needs to be addressed. Requests have been made in some cases to relocate residents closest to the site for their safety. Proposed legislation in Congress requiring Federal compensation to private property owners for actions that constitute "taking" of the economic value of their property as a result of government actions deserves monitoring with regard to this issue.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities under current management practices. Several responses to Request for Response reflect the discontent with the situation as it currently exists and request action. In response to this discomfort, or if public concern for safety increases, additional analysis of the potential risk and education of the public may be beneficial. It may also be useful to involve concerned members of the local community in advisory committees to the storage sites to provide the community with an on-going source of information and a ready mechanism for quickly addressing any current or new concerns.

Transportation. Transportation risks are not expected to be a significant factor of public concern. In fact this option would require less transport of hazardous materials in the short run than some processing approaches. If DUF6 were transported in large quantities for the first time for processing, the number of vehicle trips and potential for accidents will be increased.

Other socioeconomic factors. The land use implications for this option are minimal. The site has been in this use for several decades and is consistent with the general industrial character of most surrounding uses. To the extent that the cumulative effect and acceptability of such uses is a concern to local residents, this use will also be scrutinized. Similarly, the ongoing operation of the storage facility, assuming no routine or accidental releases of hazardous materials, poses no new threats to cultural, historical or archaeological resources.

Nuclear power generation has significant problems with public acceptance at this time. With other conventional sources of electric power readily available at attractive prices, and the prospect of stable or lower electric prices in most areas in the near future, there will be little economic or resource pressure to further develop existing or new nuclear technologies. Public concern about environmental, health, safety and waste disposal issues is likely to retard future efforts to expand nuclear energy unless extraordinary needs exist.

7.1.1.5.3 Evaluation by Reviewer X

The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Improvements to the current practices will be necessary to address these concerns, including the addition of earthquake resistant buildings to provide a second level of confinement, and that will assure containment of any releases from leaking cylinders.

The only employment impact will be during the construction of confinement facilities. The current work force should be able to handle the continuing storage practices.

7.1.1.5.4 Evaluation by Reviewer Y

Near term: No major impact on employment; slight enhancement of monitoring staff. Public acceptance problems minimal, but some outreach efforts to define the relatively benign nature of the material will be required. No real impact on local or regional development anticipated.

Long term: Significant local employment for plant(s) to convert DUF6 to the breeder (or near breeder) blanket choice. Such a plant in a locally depressed area would be a plus if the conversion plant were to be used for both DUF6 and other fuels (e.g., enriched Uranium).

7.1.1.5.5 Evaluation by Reviewer Z

Concerns about the long term storage of the depleted uranium cylinders is the factor which prompted the DOE to initiate this action. Continued long-term storage does not address the present concern.

Concerns about international proliferation of plutonium production and potential diversion of it into nuclear weapons has resulted in a U.S. government policy prohibiting spent fuel

reprocessing and recovery of plutonium. This federal policy would have to be reversed in order to be viable.

7.1.1.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.1.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. According to this recommendation there is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of eventual use--one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.1.6.2 Evaluation by Reviewer V

No additional factors.

7.1.1.6.3 Evaluation by Reviewer X

None.

7.1.1.6.4 Evaluation by Reviewer Y

This (and other proposals) hoping to use DUF_6 in breeder blankets could beneficially look at near breeders for early DUF_6 utilization. The potential for utilizing DUF_6 in concert with other fuels (e.g., U_{233} and Thorium) may suggest some beneficial options. The international Fuel Cycle Studies (INFCE) during the 1970s should provide some insight. For example, the South Koreans are building both LWRs and CANDUs with the hope of an ultimate interactive fuel cycle for more efficient utilization of Uranium in a fossil fuel starved economy.

The potential for whatever process emerges to extract and process natural Uranium from fly ash to merge with this process needs to be evaluated.

7.1.1.6.5 Evaluation by Reviewer Z

The continued long-term storage of the cylinders preserves the investment associated with the purification of the uranium and conversion to UF_6 .

7.1.1.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.1.7.1 Conclusion by Reviewer U

Storage of DUF_6 has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF_6 for a long term period.

The questions of whether or not a need will ever materialize, or be economically acceptable, for the use of breeder reactors using DU to produce electricity, can not be answered now or within the next couple of decades. However, the known potential energy resource value of DU is very large and should be considered as an asset of future value similar to the oil shales and tar sands of the North American continent.

The person providing the comments in Document #1 appears to have considerable knowledge in the potential use of depleted uranium as an energy resource--although the comments do not include any consideration of the economics associated with the use of depleted uranium as fuel in breeder reactors or the anticipated time of the need.

7.1.1.7.2 Conclusion by Reviewer V

Continued storage of DUF_6 appears to be a reasonable option for consideration by DOE. It can be implemented immediately and would handle all of the existing inventory. It creates no significant new environmental issues except the need to improve maintenance of the aging cylinders to avoid accidental releases. The costs would be well within program goals and is consistent with DOE and other Federal activities. A major drawback is the temporary nature of the solution. Eventually this material may require a more final disposition. In the meantime, the material is not being used to produce useful products. On the other hand, it is being preserved as a resource for future uses that may have higher value. This option may be best used in combination with other options. As product or other applications become economically attractive to the government relative to storage, they can be implemented using this material. Preservation of the material solely for use in breeder reactors does not appear to be justified given the uncertainty of the future of that technology. Should the breeder program become active in the future, it would need only a

portion of the stockpiles and natural and other sources could be substituted at the appropriate time.

7.1.1.7.3 Conclusion by Reviewer X

The choice to continue current storage practices is based on the assumption that a future use such as breeder reactor fuel will develop. Conversion of dUF_6 to any other form is an extremely expensive alternative relative to continued storage. To use the uranium after conversion may require converting it back to UF_6 , thus significantly increasing the cost of the end use. Thus, a recommendation to continue storage seems reasonable at this time, but additional uses for the dUF_6 will still need to be found.

The current storage practice in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. To meet this requirement, construction of earthquake resistant buildings into which the cylinders could be moved has been estimated to cost \$360 million. This cost, plus the maximum estimated cost of the present inspection and maintenance program brings the total cost of maintaining the dUF_6 in its present form to slightly less than \$500 million through the year 2020. This is 10% of the cost considered reasonable for a conversion and disposal program. Of course, after expending this amount, one is still left with the original material. Thus, faith that a beneficial use will develop is critical to this recommendation.

It isn't likely that a breeder reactor economy capable of using a major part of the current supply will develop by 2020. Thus, the total cost of storage will exceed the current projections. While the initial load of fuel in a breeder reactor will require about 90 tonnes of dU , reloads will require significantly less. Even with 100 breeders being built, less than 1% of the current inventory of dUF_6 will be used.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should this option be selected. This analysis should result in bases for deciding whether to build confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be prudent, what storage configuration would be safest, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

Construction of secondary confinement facilities and transferring dUF_6 from degraded cylinders to new cylinders will be necessary to achieve public acceptance.

7.1.1.7.4 Conclusion by Reviewer Y

The philosophic content of the option is sound. It is, however, a very brief statement of intent. All of the factors for reasonableness are within reach.

7.1.1.7.5 Conclusion by Reviewer Z

This option has limited merit. The proposal for continued storage of the UF_6 offers the advantage of preserving the considerable investment associated with the purification of the uranium and the conversion to a highly chemically active state.

The option of using the depleted uranium in breeder reactors also has merit, in that there is a tremendous amount of energy potential associated with the material if converted to plutonium in a breeder reactor. However, the recommendation that this be the exclusive use for the material is not practical. As noted in Mr Tschaeché's proposal, the amount of fuel potential associated with this material would be equivalent to several hundred years supply. Because of this, consideration must be given to utilization of some of the material in other applications, or conversion of the material to a more stable form for long-term storage or permanent disposal.

7.1.2 Evaluation of Document No. 2 (Independent Technical Reviewers' No. 2)

Respondent:

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phone number not provided

Description of Response:

This response contains four recommendations for the disposition of the depleted uranium. These include: (1) retention of enough depleted uranium as uranium hexafluoride (UF₆) to blend down the highly enriched uranium from retired nuclear weapons to an enrichment level sufficient for use in nuclear reactors; (2) retention of enough depleted uranium as UF₆ to blend down the highly enriched uranium from the former Soviet Union and its satellite states' retired nuclear weapons and stockpiles; (3) use of depleted uranium in design of any Multi-Purpose Canister (MPC) for storage and disposition of spent nuclear fuel and other high-level waste; and (4) reduction of UF₆ to a metal state for safer long-term storage and management.

7.1.2.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.2.1.1 Evaluation by Reviewer U

Option 1 & 2 - One of the recommendations in Document #2 calls for the use of depleted uranium (DU) to blend down highly enriched uranium (HEU) to power reactor levels of enrichment. HEU blending of both domestic origin and Former Soviet Union (FSU) origin material is recommended. The primary concern being addressed is the potential of nuclear weapons proliferation if FSU material should be diverted to non-weapons states. Performing the blending function would demonstrate to the world the U.S. commitment in reducing the nuclear weapons danger.

While the quantities of HEU are not provided with the recommendation, other published information indicates that a total in the range of 1000 MT of HEU were produced by these two nations during the past several decades--although the actual quantity is classified. Since very little of the HEU has been consumed, essentially all of it is being held in one form or another by these nations. Some quantity would undoubtedly be retained as HEU for national security reasons by both the U.S. and Russia. For assumption of this evaluation, the quantity of HEU released for blending is 1000 MT with an enrichment level of 93 percent ^{235}U .

A quantity of 23 MT of DU would be required to blend 1 MT of HEU to a level of 4 percent ^{235}U , a typical enrichment level for power plant fuel. Thus, the amount of DU consumed for this application would be 23,000 MT to blend down 1000 MT of HEU. The DU and HEU could be blended as uranium hexafluoride (UF_6), as uranyl nitrate or as uranium oxide powder. If blended as UF_6 , the DU could be employed in the present form. Blending in other chemical forms would require processing the DU to those forms prior to blending.

Using the DU as the blend material to produce power plant nuclear fuel would result in the eventual disposal of the blended material as spent fuel in the federal high level waste repository. This may be an appropriate means of achieving controlled disposal of a significant quantity of the DU.

The conversion of DU to the desired form for blending could be done in facilities that presently exist either within DOE or in the private sector. The blending functions are relatively straight forward, however special precautions would be required to prevent criticality of the HEU, the blending operation and the low enriched product. A new blending facility for the quantities involved could be provided at a DOE facility or expanded facilities at a private site where uranium processing is being performed.

Overall Federal regulation for safety could be under the existing DOE regulations when performed at DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," and Part 70 of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for the processing of HEU and the production of power plant nuclear fuels.

Option 3 - One recommendation of Document #2 calls for the use of depleted uranium (DU) as an element of the Multi-Purpose Canister (MPC) program for the storage of spent fuel and other high level nuclear waste. Applicable quantities and the associated costs are not provided.

The Department of Energy (DOE) has provided an estimate for the amount of DU metal that could be envisioned for use as shield plugs for spent fuel canisters and as gamma shielding in the construction of MPC and for transportation casks. Under the maximum scenario, the program may utilize 25,000 to 45,000 metric ton (MT) of DU metal. An internal DOE memorandum indicates a quantity of 4,200 MT as currently available in DOE's inventories that may be allocated for this application. If adopted for this

application, a quantity of 20,000 to 40,000 MT of new uranium metal would need to be produced from the depleted uranium hexafluoride (DUF_6) stockpile. Existing capabilities within the private sector, with reasonable expansion, should be able to produce the quantity of DU metal within the time period of need for this application.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. DU metal has been fabricated into components both internally within DOE and in the private sector for several decades. Large induction and arc melting furnaces, a large rolling mill and extensive machining capability presently in the Y-12 complex of Oak Ridge could be used to fabricate DU shield plugs and components for transportation casks. Containment of the uranium within a stainless steel structure would be needed to prevent excessive oxidation and surface sloughing.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF recovered during the defluorination of DUF_6 . HF is a very active acid that will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, uranium metal processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Transportation of DUF_6 to the defluorination plant for the quantities required probable would be via truck. Truck transport of natural and low enriched UF_6 are a regular part of current nuclear fuel supply. With DU metal production over a ten year period, the number of trucks required to transport the DUF_6 for this application would be about two trucks each day.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal processing could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities.

Option 4 - Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal for long term safety and management as recommended in Document 2 will require the design, construction, operation and eventual decommissioning of at least one new facility. The defluorination and metal production steps have been used to produce uranium metal for several decades. DUF_6 is reduced with hydrogen at a continuous rate in a tower reactor vessel and the resulting uranium tetrafluoride (UF_4) is further reacted with

magnesium metal in a batch metallothermic reduction to produce "derbys" of uranium metal.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium derbys may be stored in sealed containers for long term storage or processed further into a desired uranium metal product. Eventual disposal of DU may require the chemical form of U_3O_8 , requiring a subsequent conversion from the metal to the oxide if a disposal decision is forthcoming in the future.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched uranium is an ongoing part of the commercial supply of nuclear fuel. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium metal could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal production could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the

DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, if the operation is based on the disposal of the DU metal in an underground disposal facility, regulations are not in place and the ability to obtain safety regulatory approval from the NRC is problematic and indeterminate.

7.1.2.1.2 Evaluation by Reviewer V

Option 1 & 2 - These responses suggest the use of DUF_6 to blend down HEU from retired nuclear weapons and any existing stockpiles, in this country and the former Soviet Union, to make LEU for use in nuclear powerplant applications. The environmental, health and safety issues associated with this option would parallel those associated with facilities currently processing highly enriched uranium, such as the gaseous diffusion plants, and those processing low enriched products and depleted materials. These hazards could include radiological and hazardous materials risks, as well as risks from potential industrial accidents (e.g. fire, explosion, injuries). Environmental, health and safety standards would be enforced and provide mitigation of most risks. The processes would include oxidation, fluoridation, purification, blending and fabrication steps that would each need to be carefully controlled. The HEU would require special safety precautions for workers and the volatile nature of DUF_6 would require careful handling procedures. None of the processes is new, so standards and techniques should be well known.

Siting would be a key concern. Use of existing facilities could ease some permitting issues, however, resistance to potential increases in exposures in areas already effected may occur. If use could be made of existing plant equipment and land, the new resources used to implement this option would be minimized. If environmental concerns limit the use of LEU in nuclear powerplants, the demand for this fuel may decrease.

Option 3 - This responses suggests the conversion of DUF_6 to metal for use in fabrication of Multi-Purpose Canisters (MPC) for the storage and disposition of spent nuclear fuel (SNF). DOE is sponsoring research on these concepts in which DU metal would be used for shielding material in the lid's shield plug and the transportation cask body. They are likely to be used in dry storage systems licensed by the NRC. The environmental health and safety impacts of various techniques for converting DUF_6 to DU metal are discussed in Documents 4-3, 8, 27 and 30. The level of impact can vary by process, however, each approach will have some effects. These hazards could include radiological and hazardous materials risks, as well as risks from potential industrial accidents (e.g. fire, explosion, injuries).

The fabrication of MPC's is not expected to present significant environmental issues. Control of the exposure of workers to airborne particles will be a key concern. Environmental, health and safety standards would be enforced and provide mitigation of most risks.

Siting could be a concern, however, use of existing facilities could ease some permitting issues. The use of MPC's in the handling of LEU wastes may attract more attention to their fabrication techniques, however, no unusual issues are expected. If environmental concerns limit the use of LEU in nuclear powerplants, it is unclear how the demand for these canisters will be effected. Transportation of the DUF_6 to the conversion site and the metal to the fabrication plant are not expected to cause any significant public health concerns.

Option 4 - Several options for converting DUF_6 to uranium metals have been analyzed in Documents 21-3 (improved Ames), 4 & 8 (plasma reduction) and 27 (continuous metallothemic). While each of these processes has some inherent risk associated with the processing, none is expected to have insurmountable environmental problems. The uranium metal is chemically less stable than some other forms of uranium oxides if it is exposed to the air or moisture. Unless it is encapsulated, it would present some environmental risks with regard to toxicity and the potential to react chemically. If the metal reacts with water it can form UO_2 and UH_3 , both of which are highly toxic and spontaneously flammable. The uranium metals need control for their radiological characteristics as well as chemical toxicity. Long term storage of these metals is discussed in Document 15-3. As suggested here, the U_3O_8 form may be a more stable, although less space efficient, form for disposal. U_3O_8 , without encapsulation would be safer to workers and the public than uranium metals.

7.1.2.1.3 Evaluation by Reviewer X

Option 1 & 2 - There are two questions here. The first is continued storage of dUF_6 in its present form, and the second is the blending process.

Since the current dUF_6 storage program began, six cylinders have been identified to have experienced leaks. All of the leaks were identified long after they occurred because of the early absence of a periodic inspection program. Each leak self-sealed. Four of these leaks were determined to have been caused by cylinders weakened by handling. The remaining two leaks were in cylinders that had corroded. Programs are currently in place to (1) replace cylinders that are at risk, (2) improve cylinders that are weak, (3) inspect all cylinders on a rotating basis, revisiting those at greater risk more often. Apparently, no new leaks have been observed since these programs were implemented. (See EGG-MS-11416, pg. 9.)

The real question relative to risk to workers or the general public is "How rapidly does the dUF_6 react with moisture in the air to cause a cloud with dangerous levels of HF or uranium?" No data was provided to answer this question. However, it was stated that the above-mentioned leaks self-sealed prior to being identified "because the material loss and reaction with atmospheric moisture were so slow." Apparently, no injuries resulted from the leaks. (See EGG-MS-11416, pg. 9.)

Measures to reduce or eliminate leaks during handling include (1) administrative procedures prohibiting transport of liquid-filled cylinders, and (2) modifications of the specifications for the metal used in cylinder construction, including steel with favorable

low-temperature impact response and low sulfur content, which improves ductility and impact strength.

Additional programs are in place to provide new stands for some cylinders to improve safety, and to further protect cylinders from contact with standing water.

The present storage method in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. Thus, it is reasonable to expect that construction of new storage facilities could be required. The question is whether the cost is justified by the reduction in risk. Risk should be evaluated based on vaporization rates, dispersion rates, reseal rates, and detection probabilities. If earthquake resistant buildings are built for the cylinders, the second confinement level should preclude release of materials if one or more cylinders become cracked.

Whether an enclosed facility is built or not, it is apparent that many cylinders will need to be moved due to (1) being stored too close together to facilitate inspection, (2) needing to be placed on new moisture resistant cradles, or (3) requiring transfer of the dUF_6 to new cylinders because of cylinder deterioration. This movement also causes a risk of further cracking. Handling practices can minimize serious damage which would produce large releases.

The second question involves the blending process. Since weapons, especially the newer ones, are primarily plutonium, both HEU and plutonium blending must be considered.

Blending of dUF_6 with HEU and/or plutonium involves no new processes, although the blending process has not been performed on a large scale in the U.S. The primary concerns will involve transporting of the HEU and plutonium to the blending sites. Material will need to be handled to assure that in case of accidents, criticality will not occur. The primary radiation hazard is from alpha particles, so shielding is not a major issue.

Blending with plutonium may require additional controls since the plutonium metal is pyrophoric. Since reprocessing is done in Europe and mixed oxide (MOX) fuels are used in their reactors, considerable experience already exists with this technology.

Option 3 - Once dUF_6 has been converted to uranium metal, fabrication of parts is a process with which the industry has had considerable experience. Depleted uranium has been used for shielding material in transportation casks for a number of years.

Fabrication methods and facilities account for the hazards of working with uranium. No new hazards are anticipated.

Depleted uranium used in MPCs or the multi purpose units (MPUs) would be clad to keep the uranium from oxidizing. This would provide personnel protection as well.

Any MPC or MPU would need to be designed to meet NRC and DOT requirements for transportation of radioactive materials.

Option 4 - Converting the DUF_6 to a metal would produce a more stable form for long-term storage. Storing this material for possible future uses rather than disposing of it would preserve a resource that may become more valuable with time as the earth's fossil energy resources become less available.

No specific conversion technology is recommended and so none is evaluated here. Several that have been proposed are stated to produce little or no additional waste streams, and so no additional hazards should be anticipated.

7.1.2.1.4 Evaluation by Reviewer Y

Blending down domestic and foreign HEU from retired nuclear weapons to water reactor fuel levels of enrichment is an environmentally acceptable approach that can be and has been safely accomplished. Usually, the production of oxide fuel has blended natural and enriched Uranium. If domestic DUF_6 is used to blend down foreign HEU, what happens to foreign stocks of DU, possibly in the DUF_6 configuration? This could raise a problem elsewhere while solving a domestic problem. The plea to obviate an EIS for blending down is unlikely to be honored since it is different from the simple transfer of foreign HEU to a domestic site. The plan for early blenddown to demonstrate US commitment is sound, but unlikely to be an eloquent public statement of cutting proliferation risk.

The health and safety issues implied by the proposal are manageable pending the definition of DU as waste or as a resource. Remember, circa 1830 at least one man was hung in London, England, for burning coal!

The MPC proposal is fragmentary, and will, if fully implemented, solve only a small fraction of the DUF_6 inventory.

Metal storage is environmentally sound because of low storage volume requirement for high-density material with low surface to volume ratio.

7.1.2.1.5 Evaluation by Reviewer Z

Mr. Strauch submitted a four part proposal. The first two parts of the proposal can be evaluated together regarding the potential environmental, safety and health issues. The first part of the proposal is that enough depleted uranium (DU) be retained as UF_6 to blend down Highly Enriched Uranium (HEU) from retired nuclear weapons to reactor fuel levels of enrichment. The second part of the proposal relates to blending down HEU from weapons of the former Soviet Union and former Soviet States.

The environmental, safety and health issues related to this option are well understood and no new issues are anticipated if this option were elected. The primary safety issue would be related to the handling of the HEU. The HEU from the weapons would have to be removed and converted into a form in which it could be blended. This could be either a reduction to an oxide for blending, probably UO_2 , or possibly conversion back to UF_6 for blending in a gaseous diffusion process. In either case, nuclear criticality would be a

primary concern, but not one which has not been addressed effectively by current technology.

The third part of the proposal is that the DU will be used in Multi-Purpose Canisters (MPC) for the storage and disposition of spent nuclear fuel and other high level nuclear waste. No specifics were given regarding the form of the DU to be used in the MPCs. This option has the potential of providing increased shielding of the high activity waste due to the higher density of the uranium. This would be an enhanced health and safety factor due to lower radiation levels to those individuals handling the MPCs.

Part four of this option proposes that the remaining UF_6 be reduced to metal state because the long term safety and management of this material will be easier in the metallic form rather than as gas. This option does not have merit due to the pyrophoric and oxidation properties of metallic uranium. No further evaluation of this option is performed.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 or oxide powder from its storage vessel and subsequent atmospheric dispersion.

7.1.2.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.2.2.1 Evaluation by Reviewer U

Option 1 & 2 - Waste streams would entail those associated with a conversion plant for the DUF_6 and the associated fuel production plant.

Chemical cleaning of empty DU cylinders may be sufficient to permit them to be scraped, melting and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites.

Option 3 - For each metric tonne (MT) of uranium metal produced by the conventional Ames process, approximately 0.5 to 1 MT of solid waste is produced, mostly in the form of MgF_2 . This solid waste must be allocated to low level waste (LLW) disposal or processed to remove essentially all of the uranium to permit it to be disposed in a sanitary land fill.

Disposal of empty DUF_6 cylinders will be required. Input to the defluorination process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal of the depleted uranium remaining as cylinder heels. Chemical cleaned of empty cylinders may be sufficient to permit them to be scraped, melting and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites.

Option 4 - The DUF_6 conversion to uranium metal should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. The reduction to metal uranium produces a large volume of magnesium fluoride slag that contains a considerable amount of uranium. The uranium must be removed from the slag to achieve a usable magnesium by-product. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low level radioactive waste, requiring disposal at dedicated low level waste disposal sites.

Fluorine liberated from the uranium should be captured in a useful chemical form. Anhydrous HF (AHF). There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

The disposal of the empty DUF_6 cylinders is a waste issue. Removal of UF_6 heels from cylinders, cleaning of the cylinders and their eventual disposition will be required. Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the recovered metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites, at a high cost.

7.1.2.2.2 Evaluation by Reviewer V

Option 1 & 2 - Each of the process steps mentioned above have their own set of waste management issues. The wastes have been characterized as being like those from a GDP - low level wastes. The wastes would need disposal in an approved facility, of which there currently is a shortage. A more detailed characterization of the waste streams is needed for a complete waste management analysis. In the long run, the LEU will eventually become a waste requiring disposal unless recycling of these fuels is adopted.

Option 3 - The waste issues associated with conversion to DU metal are discussed in the documents listed above. In most cases, significant recycling occurs and the wastes that are generated can be disposed of in low-level waste facilities. This disposal capacity may be a significant issue. The fabrication of the MPC's will generate only minor amounts of wastes from machining, casting and/or cutting fluid residues. The use of the DU metal in the MPC's itself is significant recycling of material that is otherwise a disposal problem. Should the canisters not be needed at some future time, they would need to be disposed of in a facility appropriate to their risk level.

Option 4 - Each of the conversion processes mentioned above have their own set of waste management issues. The largest for each is the possibility that the metal, if not converted into useful products, will constitute a waste disposal problem because of the limited number of low-level waste disposal facilities and the relatively large amount of waste that the depleted uranium would contribute to the demand for such capacity.

7.1.2.2.3 Evaluation by Reviewer X

Option 1 & 2- Both the storage of dUF_6 and the blending of dUF_6 with HEU or plutonium involve practices and processes already performed at the three GDPs or in Europe. Thus, no unknown waste streams will result.

Option 3 - A major advantage of using depleted uranium in MPUs is that it will be disposed of along with the high level wastes or spent fuel contained within the MPUs. Thus, it won't add to the waste stream. In fact, this use will reduce the total waste stream from conversion of dUF_6 .

Wastes generated in the machining and fabrication process (cuttings) can be recycled into the casting stream.

An estimated 10,000 MPCs will be needed over the next 20 years if the MPC concept is adopted. Each shield plug is estimated to require two MT of depleted uranium, and the transportation cask is estimated to require up to 20 MTUs. The Office of Civilian Radioactive Waste Management (OCRWM) thus estimates that up to 45,000 MTU could be required for this program alone. This represents about 12 percent of the dUF_6 inventory that would be permanently removed from the waste cycle. Because of uranium's effectiveness as a gamma shield, the size of the MPCs would be significantly reduced over the size from using other materials such as DUCRETE, thus reducing the size of a permanent or retrievable high-level waste facility.

Option 4 - The only disposal option for uranium metal is deep burial because of the high specific activity that precludes its disposal in near-surface facilities. However, disposal of the metal would require only about one-fifth the space required by similar disposal of U_3O_8 .

If the metal is placed in long-term storage rather than a permanent disposal facility, then it will be available for future use in products such as shielding, counterweights, or breeder reactors.

If long-term storage rather than disposal is selected, then the Above-Grade Earth-Mounded Concrete Vault (AGEMCV) might be considered.

For storage purposes, it will be necessary to stabilize the metal, possibly with a plastic coating, to prevent oxidation. This would save costs in the long run, and would eliminate the source of another waste stream.

If used in products, the ultimate lifetime of any uranium product produced will need to be considered. Controls will need to be implemented to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices.

If the metal can be used for breeder reactors, by the time a breeder economy becomes accepted by the public, new methods for handling the waste streams from reactor operation will have been developed. If a concept such as the Integrated Fast Reactor (IFR) is found to be economically feasible, problems with actinide production, plutonium proliferation, and long-term high-level reactor waste disposal will be minimized.

7.1.2.2.4 Evaluation by Reviewer Y

Waste products are those for accomplishing the production of metal or oxide, the most likely use forms in the proposal. The Fluorine products can be considered waste if there is no market or if refining Fluorine to have no contamination from the DU or other metal products becomes too expensive. Impurities could significantly impact the Fluorine market costs! Such possible impurities, even if they are not there, possibly could have impact on the environmental acceptance and the market.

7.1.2.2.5 Evaluation by Reviewer Z

Parts one and two of this proposal would involve the blending down of HEU to make a reactor grade enrichment. This process would likely involve the conversion of the HEU into UF_6 or an oxide to be blended with the depleted UF_6 . Although a small amount of waste would be generated, which might have traces of high enriched uranium, this waste would not be unlike waste which are currently handled throughout the fuel cycle industry.

The potential waste streams for the third option, use of the material in the construction of MPCs, would be dependent upon the chemical form of the depleted uranium used in the construction. This would probably be either a metallic or oxide form, or possible conversion to a uranium-silicon glass mixture. Any of these forms would produce some amount of waste, but it should be similar in characteristics to waste currently encountered at fuel cycle facilities.

7.1.2.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.2.3.1 Evaluation by Reviewer U

Option 1 & 2 - If the blending is performed as UF_6 , the DU may be used in its present form. However, if conversion of DUF_6 to a different chemical and physical form is required for blending, it would entail processes that are similar to those currently used for nuclear fuel production and the cost can be defined reasonably accurately. Using the blended material as power plant nuclear fuel has a significant commercial value that is substantially higher than the cost of conversion and blending. Thus, a net economic gain could be realized through the release of HEU to be blended with DU for commercial nuclear fuel.

Option 3 - The cost of converting DUF_6 to uranium metal with the Ames process is well defined. The processing cost, metal fabrication costs and waste disposal costs would be included in the value of the metal components. This overall cost may result in a high value that cannot be justified for the application. Since the DUF_6 has a liability cost associated with eventual disposal, it may be desirable for the processing costs for metal production to be offset in the amount of the future liability cost for disposal of DUF_6 . Doing so would maintain a neutral position of overall cost to DOE.

Option 4 - Since the conversion of DUF_6 to uranium metal has been performed for several decades, the cost of scaled up facilities and the operation of the facility can be reasonably well defined. However, the cost of recovering the fluorine as AHF is not well known and the processing of the slag to recover uranium and useful magnesium entail undefined costs. AHF is the only salable product from the operation. The market value of the recovered materials would be only a fraction of the overall cost of building facilities and performing the conversion operations.

Slag cleaning and disposal will be a major cost factor for this recommendation. Research and development efforts appear to be needed to define the preferred means of slag cleaning and disposal. The added cost and time required for R&D and pilot plant demonstration of slag cleaning appear to be reasonable with high probability of success.

The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility could be torn down with all contamination removed from the site. The site could be returned to uncontrolled use. Decontamination and decommissioning costs for a DUF_6 to metal conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of uranium metal should be less than the cost of storing DUF_6 over the next one to two hundred years. Removal of the fluorine component will result in an overall weight reduction of about one third. Since the density of uranium metal is very high, the volumetric reduction would be in the order of a factor of six. To minimize oxidization and prevent the sloughing of the oxide film, it appears necessary to place the uranium metal in stainless steel containers for long term storage. The cost of new metal

containers for the uranium metal would be a significant added cost over that of continuing to keep the DUF₆ in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of uranium metal while outdoor storage of DUF₆ cylinders appears to be adequate.

If a decision is made at a future date to dispose of DU in a geologic disposal facility, uranium metal may not be an acceptable form and it may require conversion to uranium oxide for disposal. The present worth value of retaining the DU as DUF₆, with conversion to uranium oxide in the future for disposal, would be considerably less than performing the conversion to metal in the near term and subsequently converting it to the oxide later.

7.1.2.3.2 Evaluation by Reviewer V

Option 1 & 2 - Information provided in Information Package G1 suggests that a generic plant for blending LEU using DUF₆ would cost \$30 to \$100 million to build and \$262 million to operate over its life. The net value of the product LEU after blending costs is estimated at \$1.5 to \$2.0 billion. The plant would only use about 258 MT of HEU(50% assay). It is unclear how large the total stockpile of HEU discussed in this option would be. It is also unclear how large the market will be for the LEU and how this new fuel production might affect prices paid. All the cost estimates need further clarification.

Option 3 - Information provided in Information Package I1 estimates that the total costs associated with producing the MPC's that will be required for commercial SNF could be \$5 billion. The additional costs associated with the use of DU metal are not identified. Beyond the conversion costs for DU metal, it is not clear how much of the fabrication costs might be attributable to the DUF management programs or how the cost savings from recycling the DU metal would be incorporated. The market for these MPC's over time is not well documented. The costs are early estimates and need further clarification.

Option 4 - Information provided in Information Package A2 suggests that a generic cost for conversion to uranium metal would be \$3.6 billion for the entire inventory. Storage or disposal would be in addition to this amount. Storage would require some sort of encapsulation or packaging to seal the material against air and water intrusion and would probably need to provide two levels of containment. Costs will be mitigated by the ability to sell the metal for product applications and sale of by-products.

7.1.2.3.3 Evaluation by Reviewer X

Option 1 & 2 - Costs to maintain current storage practices through the year 2020 are estimated to range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional will be required. This double confinement cost will need to be expended to receive public support for continued storage. An improved storage program may need to be implemented independent of the end use for the dUF₆ since any process or combination of processes will require ten or more years to deplete the current supply.

Costs to build a blending plant have been estimated to be \$100 million or less, with life cycle operating costs less than \$300 million.

The value of the blended material is estimated to exceed \$2.5 billion. Thus, sale of a blended fuel, requiring less than 10% of the dUF_6 inventory, can help fund the conversion of the rest of the dUF_6 to an oxide or metal form for long-term storage or disposal.

Option 3 - Cost avoidance is the primary concern of this criterion. The total cost of DOE's MPC/MPU program is estimated to be \$5 to \$12.6 billion. However, this is not associated with the cost of the dUF_6 disposal program. More importantly, this program would avoid the cost of ever having to dispose of the depleted uranium. At least \$32 million would be saved in disposal costs using estimates from Hertzler (1994) for shallow land burial at NTS. More reasonable cost avoidance would be for deep geological burial. This would probably be at least triple the shallow land burial cost.

Option 4 - The cost of converting dUF_6 to metal is estimated to be three to five times greater than conversion to U_3O_8 . For long-term storage considerations, it is certainly greater than leaving it as dUF_6 .

Storage or disposal as uranium metal will cost about one-fifth as much as storage or disposal as U_3O_8 , and will be relatively equivalent to the cost of a long-term storage and monitoring program for the dUF_6 in currently used cylinders. The major cost difference will be in the conversion cost.

7.1.2.3.4 Evaluation by Reviewer Y

The blending process (e.g., coprecipitation or mechanical mixing of powders) will impact costs. Blending in the metal state (e.g., pyrometallurgical) will impact cost. The proposal is silent on these and on the implied obligation for foreign DUF_6 where foreign HEU is blending with domestic DUF_6 . There is an implication in the last paragraph of the proposal that favors the metal state for long-term storage; probably a favorable cost option if U_3O_8 will not be the ultimate end-product. This storage is probably most favored for future retrieval costs for breeder or converter reactors.

7.1.2.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. There are cost advantages to consider for both the blending of the DU with HEU, and for the use of the DU in the construction of MPCs.

7.1.2.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.2.4.1 Evaluation by Reviewer U

Option 1 & 2 - Conversion of DUF_6 to the desired chemical and physical form for blending should be with processes that are well developed and considered mature. The blending function is unusual, but relatively straight forward and is sufficiently well understood to be considered practical with current technology. Using the blended material as fuel in power plant production of electricity is well developed and would be equivalent to the established high volume business of nuclear fuel production.

Option 3 - Production of DU metal from DUF_6 has been achieved for decades. The process and parameters are well understood. Metal casting and fabrication of large depleted uranium components have been accomplished for an extended period. Overall, the maturity of the approach is sufficient to provide high confidence of success. Some research effort appears appropriate to develop the most effective means to remove essentially all uranium from the slag produced during metal reduction.

Option 4 - The process requirements for the recommended production of uranium metal are well defined. New approaches for slag cleaning will need further R&D and pilot demonstration before proceeding with a commercial facility.

The collection of AHF from the process will require technical development. Storage of the recovered uranium metal can be reasonably well defined and implemented with known techniques. Permanent disposal of depleted uranium metal may not satisfy the desired material stability for long term disposal and considerable R&D would be required to define whether metal is an acceptable form for disposal.

7.1.2.4.2 Evaluation by Reviewer V

Option 1 & 2 - The technologies for blending HEU with DUF_6 to produce LEU are in commercial use, although they have not been combined in this way. It is not likely that extensive development would be needed to implement this option.

Option 3 - Some technologies for producing DU metal are commercial while others are within reasonable development range. The use of DU metal in the MPC's should not

cause any significant issues. The MPC's themselves are currently undergoing feasibility evaluations, but environmental analyses are already underway. The technology for fabricating the containers is commercial.

Option 4 - The conversion technologies for uranium metals range from mature processes with years of demonstrated commercial use to processes still being tested at the bench-scale. It is certainly possible to start converting the depleted uranium as soon as excess capacity is available or new plants can be licensed and built. Improved processes could be introduced as available over the next ten years.

7.1.2.4.3 Evaluation by Reviewer X

Option 1 & 2 - DOE has stored dUF_6 using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

Blending of dUF_6 with HEU and weapons material is not a current industrial practice. However, in Europe, mixed oxide fuels are produced in the fuel recycling process for use in their light water reactor program. So handling of mixtures of depleted uranium, enriched uranium, and plutonium is a normal practice on an industrial scale.

Option 3 - The technology for fabrication of uranium using both casting and wrought techniques is well established.

Uranium metal has been used for several years in the U.S. for shielding casks.

Dry storage systems for spent nuclear fuel have recently been licensed by the NRC.

Option 4 - The current process for converting dUF_6 to dUF_4 and then to metal is a mature process. However, requirements for reducing the contaminated waste stream will add to uncertainties in the maturity of the process. Further, alternate processes that haven't been fully tested may be necessary to meet regulatory and environmental concerns.

The AGEMCV is not a developed technology, but only proposed. However, metal disposal in this type facility should pose no new hazards or engineering challenges.

7.1.2.4.4 Evaluation by Reviewer Y

There is experience with all aspects implied by the proposal. Coprecipitated and mechanically mixed oxides, pyroprocessing for metal, and classic metal production processes are state-of-the-art. Some demonstrations will be needed pending specific process decision not cited in the proposal.

The regulatory process for using DU in the MPC may require some demonstrations.

7.1.2.4.5 Evaluation by Reviewer Z

Blending of uranium of different enrichments is a mature technology which is within the capabilities of current facilities.

The use of DU in the construction of Multi-Purpose Canisters is a technology that has been developed, but not implemented on a commercial scale.

7.1.2.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.2.5.1 Evaluation by Reviewer U

Option 1 & 2 - Employment at a facility to convert DUF_6 to the chemical and physical form for blending and performing the blending function would be at a steady level for several years to accommodate a reasonable use rate of the HEU as commercial fuel--probably over a ten to twenty year period. There would be a temporary increase in skilled construction employment over two to five years for modification of existing facilities or the construction of new facilities for the conversion and blending functions. However, the size of facilities required for these activities is relatively modest.

No change in employment would be encountered at current fuel fabrication plants. However, there would be a reduction in employment for uranium mining, the conversion of natural uranium to UF_6 prior to enrichment and for the enrichment functions that would produce fuel material if the HEU is not deployed for nuclear fuel.

Performing DUF_6 conversion operations at one the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable. Decreasing the threat of nuclear weapons proliferation should be viewed as very positive by the public and strong support for this application is anticipated.

Option 3 - Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a fairly steady rate for about a decade to provide the needed material. Performing uranium processing operations at a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the operations are carried out at a location performing similar operations, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

Option 4 - Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the chemical components of the process entail relatively low pressure and temperature. The batch metallothermic reduction process is a high temperature step that is limited by batch size to achieve controllability. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment. A major hurdle to overcome is the history of the Fernald uranium metal production plant. Considerable uranium contamination was experienced with this plant, operated for the Federal Government for several decades. Much better material control technology would be employed at a new plant. However, the extensive challenges at Fernald establish a difficult threshold to overcome.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not

outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the metal production at one of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. Such an operation may be helpful for encouraging related locality development of processing uranium metal to finished products.

7.1.2.5.2 Evaluation by Reviewer V

Option 1 & 2 - It is difficult to estimate the impact the construction of facilities for fuel blending will have. If existing conversion facilities are redesigned or reused, the impact could be significantly reduced. The amount of land required to site these facilities is not known. Siting may face problems with public acceptance due to the presence of highly radioactive materials depending on the community selected. Traffic, including uranium transport to and from the site, will be examined. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

Option 3 - A conversion plant could constitute a significant industrial construction and operation project with direct and indirect impacts, if most of the inventory is converted for this application. If existing plants are used or only a small portion of the inventory is used, impacts would be mitigated. The conversion facility may arouse public scrutiny, but is likely to be accepted. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

If existing fabrication facilities are used, the impact could be minimal. The amount of land required to site all the facilities is not known. Siting could face problems with public acceptance in sensitive communities. Traffic from uranium transport to and from the various conversion and fabrication sites would increase. The fabrication activities should not cause significant public concern.

Option 4 - The construction of conversion facilities to process the 28,000 tons/year of uranium metal required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. The amount of land required to site these facilities is not known. Siting may face problems with public acceptance depending on the technology chosen and the community selected. Traffic, including uranium transport to and from the site, will be examined. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.2.5.3 Evaluation by Reviewer X

Option 1 & 2 - The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Improvements to the current storage practices will be necessary to address these concerns, including the addition of earthquake resistant buildings to provide a second level of confinement, and that will assure containment of any releases from leaking cylinders.

The only employment impact will be during the construction of confinement facilities. The current work force should be able to handle the continuing storage practices.

Public acceptance of a program to eliminate HEU and weapons material would be expected to be high relative to other alternatives.

Option 3 - Fabrication facilities are currently available at Oak Ridge, the Army's Kinetic Energy Penetrator Production Base, and in several private companies. Cask construction would provide additional work for these facilities.

Public resistance to transportation of any nuclear material is likely to be resisted. However, the potential for the synergistic permanent disposal of depleted uranium should receive a positive response.

Option 4 - If existing conversion facilities are used or expanded, a trained work force should be available, and the impact on communities should be minimal. Demand for product will need to be carefully evaluated to assure that plant is not over built.

Siting of a storage/disposal facility will need to be done in accordance with current regulations, and will have to include design considerations that not only assure environmental and public protection, but also encourage public confidence and acceptance.

7.1.2.5.4 Evaluation by Reviewer Y

Some level of employment is likely to result without marked impact on local or regional development. Full employment for the proposal will require ~200 employees at one site plus the support for transportation, etc. Capital expenditures for the proposal items (not including fuel fabrication) is likely to be ~\$2B.

Public acceptance for the proposal is likely to be high initially. Continuing public acceptance activities will be required for support of HEU transport to site.

7.1.2.5.5 Evaluation by Reviewer Z

This reviewer has no specific information regarding the effects of this application on either employment or local/regional development. A factor which should be considered is the negative impact on the mining and milling industry, as well as the uranium conversion facilities. For every ton of HEU blended down, approximately 25 tons of natural uranium will not need to be processed through the front end of the fuel cycle.

Concerns about the potential diversion of nuclear weapons should result in a favorable reaction to the options of using the DU to blend down weapons grade HEU.

7.1.2.6 **Evaluation Factor Six - Other factors**

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.2.6.1 **Evaluation by Reviewer U**

Option 1 & 2 - Will the national security requirements of the U.S. and Russia permit the release of HEU for other uses, such as blending down with depleted uranium for use as commercial nuclear fuel? Certainly, the deployment of FSU material in this manner to decrease the potential for nuclear weapons proliferation should be favorable for national security of the U.S.

Option 3 - A primary factor is the question of whether a demand for uranium metal radiation shielding components will be forthcoming. The universal containment system for nuclear spent fuel is being considered by those responsible for nuclear waste disposal. The shielding material requirements will be defined by the lowest cost approach to achieve shielding. Materials other than depleted uranium metal may be used for the shielding. Further development of the shielding requirements and a better definition for the cost of producing depleted uranium metal components are required before a reasonable estimate can be forthcoming on the practical use of uranium metal in this application.

Option 4 - Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years as DUF_6 . If and when a need for metallic uranium components is defined for shielding, enrichment, metallic fuels or other uses, then would be the proper time to decide on facilities to convert DUF_6 to metal. The size of the conversion facility should be appropriate to match the need for metal products and not sized to convert of the existing DUF_6 .

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in some other form of uranium is greater than the cost of converting the DUF_6 to that form at an early stage.

7.1.2.6.2 **Evaluation by Reviewer V**

See General Comments.

7.1.2.6.3 Evaluation by Reviewer X

Option 1 & 2 - It should be noted that weapons material consists of both HEU and plutonium. No information is available to determine the relative amounts of the two materials. However, the HEU is almost certainly enriched to 93 % or more. If there are 20,000 weapons, each with 6 kg of HEU, then to blend the 60 metric tons of weapons material would require about 1300 MT of dU. Added to the estimate provided that 5500 MT of dU would be needed to blend down the HEU released by DOE, a total of 6800 MT of dU, or 10,000 MT of dUF_6 , would be needed. This represents about 2% of the current inventory of dUF_6 .

Another question involves the amount of plutonium that must be recycled out of the weapons program. To use this material will require a mixed oxide (MOX) reactor design. MOX fuels aren't currently used in the U.S. where reprocessing of spent fuel isn't done. However, European reactors do use this fuel since reprocessing provides significant amounts of plutonium. Depleted uranium would compete with natural uranium as a blending agent for weapons grade uranium (HEU) or plutonium.

For this option to meet DOE guidelines for being reasonable, it would need to be shown that the availability of dUF_6 has a significant cost advantage over the use of natural uranium for blending, a MOX fuel cycle for current generation LWRs would have to be licensed, and possibly a breeder cycle would need to be developed.

However, any program to convert dUF_6 to an oxide or metal form for long-term storage or for permanent disposal will require many years to complete. There are 47,000 cylinders in storage. If a conversion plant is built with 10 process streams, it will handle about 20 cylinders per day. Thus, one plant would require over six years operating around-the-clock to convert the entire inventory.

The dUF_6 inventory not yet converted would be available for use in other processes such as a blending process. Thus, a decision to begin a conversion process will not preclude a blending process that can continue in parallel with other dUF_6 depletion activities.

Option 3 - None.

Option 4 - None.

7.1.2.6.4 Evaluation by Reviewer Y

The prospect of blending foreign HEU with domestic DU is bound to create some new initiatives, precedents, and problems if done on large scale.

7.1.2.6.5 Evaluation by Reviewer Z

None.

7.1.2.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.2.7.1 Conclusion by Reviewer U

Option 1 & 2 - The application of DU as material to blend HEU to an appropriate level of enrichment for use as commercial nuclear fuel is a favored use for the material and it should be pursued. The quantity that would be required for this application--a maximum of 23,000 MT--is much less than the amount provided as a guideline for reasonable use. However, the relative ease of using DU in this manner and the disposition of material used for this purpose in the planned federal high level waste repository as spent fuel provides a very reasonable path for disposition of a portion of the DUF₆. An economic assessment should be pursued to determine whether DU is a preferred blend material compared to the use of natural uranium for blending down HEU.

The person making the recommendation in Document #2 appears knowledgeable on potential applications for the use of DU. However, the quantities and economic considerations are not provided as a part of the recommendations.

Option 3 - Conversion of DUF₆ to metal could readily be achieved to provide the quantity of material needed for the recommended application. The quantity of 20,000 to 40,000 MT is less than the guideline amount to be considered reasonable (i.e., 84,000 MT). However, since the amount should be obtainable with modification of existing capabilities within the DOE and private industry, this application should be viewed as a responsible potential application. The technology is developed to a point where it could provide quality production of uranium metal components in the near term with existing technology and with modification of existing facilities.

The person providing the recommendation in Document #2 appears to be knowledgeable on potential uses of DU. However, the amount of DU appropriately associated with each application is not defined by the recommendation, nor is information provided on the potential costs.

Option 4 - This option of converting DUF₆ to uranium metal appears to be reasonable if a decision is made that continued storage of DUF₆ is unacceptable. However, the conversion to metal probably should be done only when a useful metal product is determined. Converting DUF₆ to metal for long term storage purposes does achieve a much lower volume of material. Alternative processes may be appropriate for the conversion of DUF₆ to metal such as continuous casting from a molten salt bath or plasma metal production. A detailed study of the alternatives and associated research and development of the new technologies would be appropriate before a decision is made to use the past conventional processes. Although, conversion to an oxide for long term storage may be preferable and more economical than the conversion to uranium metal.

Since the market value of the marketable AHF, is less than the overall cost of recovery from DUF_6 , there is a net added cost over the current storage mode cost base.

The person making the recommendation in Document #2 appears to be knowledgeable on potential applications for DU. However, the recommendation does not provide a supportable justification for the stated improved safety with uranium metal compared to DUF_6 for long term storage.

7.1.2.7.2 Conclusion by Reviewer V

Option 1 & 2 - The idea of blending depleted uranium with HEU to produce LEU is consistent DOE program goals in several program areas. There does not appear to be any major environmental, safety, health or siting concern that would rule out this option, although the risks will need to be carefully managed. The major issue of concern is the small amount of DUF_6 which would be converted through this option and the unknown quantity of HEU available. On the positive side, if this option proved to be as lucrative as is suggested, it could provide revenue to other program options. In general, it would appear that this option is reasonable enough to deserve further attention.

Option 3 - The idea of using DU metal for MPC's is consistent with DOE program goals in several program areas. There do not appear to be any major environmental, safety, health or siting concerns that would rule out this option, although the risks will need to be managed. The major issues of concern are better definition of costs and the amount of DUF_6 which would be converted through this option. In general, it would appear that this option is reasonable enough to deserve further attention.

Option 4 - The idea of converting depleted uranium into uranium metal is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues that would rule out this course of action, although the effects will depend on the process(es) chosen. Uranium metal is not the most stable chemical form for disposal. Cost would probably be within the range allowed as would the time to implement. In general, it would appear that this option would be reasonable.

7.1.2.7.3 Conclusion by Reviewer X

Option 1 & 2 - The choice to continue current storage practices is based on the assumption that a future use such as breeder reactor fuel will develop. Conversion of DUF_6 to any other form is an extremely expensive alternative relative to continued storage. To use the uranium after conversion may require converting it back to UF_6 , thus significantly increasing the cost of the end use. Thus, a recommendation to continue storage seems reasonable at this time, but additional uses for the DUF_6 will still need to be found since a breeder program won't require the entire inventory.

The current storage practice in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. To meet this requirement, construction of earthquake resistant buildings into which the cylinders could be moved has been estimated to cost \$360 million. This cost, plus the maximum estimated cost of the present

inspection and maintenance program brings the total cost of maintaining the dUF₆ in its present form to slightly less than \$500 million through the year 2020. This is 10% of the cost considered reasonable for a conversion and disposal program. Of course, after expending this amount, one is still left with the original material. Thus, faith that a beneficial use will develop is critical to this recommendation. (Note that the cost of buildings may be higher than the estimate if analysis shows that stacking is an unacceptable seismic risk.)

Construction of secondary confinement facilities and transferring dUF₆ from degraded cylinders to new cylinders will be necessary to achieve public acceptance.

Blending dUF₆ with HEU and weapons materials is an activity that can occur in parallel with conversion activities or other dUF₆ depletion activities. If conversion for long-term storage or permanent disposal is selected, the entire process will take at least ten years and probably longer. During this time, continued dUF₆ cylinder storage and cylinder management activities will be necessary. Blending activities, just as other commercial uses of depleted uranium, will help to deplete the inventory during this time.

Option 3 - This option would remove about 12% of the dUF₆ from the waste stream by enabling depleted uranium to be disposed of along with SNF and high level wastes while serving a beneficial purpose.

A disposal cost savings of as much as \$100 million will be incurred over the 20 year projected time schedule of the MPC program.

Option 4 - Long-term retrievable storage is a reasonable alternative if the surface of the metal can be stabilized and a future need for the element exists. The most reasonable shape would be square or rectangular to minimize the required storage volume and water infiltration. Surface treatment would need to be thick and strong enough to withstand handling damage. If the storage facility is designed to be monitored, repair of damaged surfaces could be done until the uranium is removed for use in a product. Monitored retrievable storage options are only in a conceptual stage at the present time.

Production of uranium metal using available technology is estimated to be three to five times higher than the cost of oxide production. Thus, unless the cost decreases due to performing an improved Ames process less expensively or through development of another less expensive process, this option seems prohibitive.

The need for preserving this resource is dependent on future non-energy applications and decisions to use the metal in breeder type reactors. It is an invaluable resource for future energy needs. It may have too many drawbacks for extensive use in other applications. As long as enrichment of uranium for power generation purposes is required, there will be a sufficient supply of DU for current applications.

7.1.2.7.4 Conclusion by Reviewer Y

This option is "reasonable" in that many uses we suggested and more are implied by the suggestions. The proposal is very brief and raises as many questions as it attempts to answer. Only the proposal to blend down foreign HEU is "unique" among many other proposals. All other aspects are contained with more substance in other proposals.

7.1.2.7.5 Conclusion by Reviewer Z

There is a great amount of merit in parts one, two and three of this option. Parts one and two of this option provide an application which has the potential for using several thousand tons of depleted UF_6 , while at the same time removing a large amount of weapons grade material from storage both in the United States and in the former Soviet Union. The HEU is an issue which must be addressed, and this proposal presents a viable option for the use of the depleted uranium hexafluoride.

The third option of this proposal provides an option for the use of substantial quantities of depleted uranium in an application which provides specific benefits of radiation shielding and stabilization for high level radioactive waste in the form of spent nuclear fuel and high level radioactive wastes.

Part four of this option proposes that the remaining UF_6 be reduced to metal state because the long term safety and management of this material will be easier in the metallic form rather than as gas. This option does not have merit due to the pyrophoric and oxidation properties of metallic uranium.

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7.1.3 Evaluation of Document No. 4 (Independent Technical Reviewers' No. 3)

Respondent:

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Description of Response:

This response provides seven specific opinions about the depleted uranium stockpiles in general. Three of these opinions were interpreted as recommendations, including utilization of the oxide reduction program offered by Allied/GA; reduction of a portion of the stockpile to metal for storage through CMI at Barnwell, SC; and a variation of the oxide reduction program to include running the anhydrous hydrogen fluoride waste stream back through Allied's UF₆ plant, sending resultant waste solids to the Nevada Test Site (NTS) for disposition.

7.1.3.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.3.1.1 Evaluation by Reviewer U

Option 1 - The recommendations in Document 3 is predicated on a perceived near term need to remove the DUF₆ from the current cylinders because "the light wall storage cylinders are not doing well, and that disposal must be effected much sooner than anticipated." The recommendation letter states that "I do not believe that we have the time frame of 2020."

A detailed evaluation of DUF₆ cylinder integrity is being pursued at the present time. At this point, there does not appear to be a sound basis to believe that cylinder integrity is

rapidly deteriorating or that an urgent need exists to remove the DUF_6 from the present cylinders.

Document 3 supports the recommendation offered by Allied/GA for the conversion of DUF_6 to uranium oxide. Processing of large quantities of depleted uranium hexafluoride (DUF_6) to uranium oxide will require the design, construction, operation and eventual decommissioning of at least one new facility. Uranium oxide compounds are relatively inert chemical forms of uranium (dry powder) with low reactivity and low solubility.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of natural UF_6 has been performed for 25 years by the organization providing this recommendation, via specialized N14.30 equipment. The mode of transport is truck and this has been the general mode of transport for natural and low-enriched UF_6 . While truck transport is reasonable for DUF_6 , the large quantities involved may be more economically transported via rail.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

Option 2 - The recommendation in Document #3 is predicated on a perceived near term need to remove the DUF_6 from the current cylinders because "the light wall storage cylinders are not doing well, and that disposal must be effected much sooner than anticipated." The recommendation letter states that "I do not believe that we have the time frame of 2020."

A detailed evaluation of DUF_6 cylinder integrity is being pursued at the present time. Based on experience with cylinder integrity, there does not appear to be a sound basis to believe that cylinder integrity is rapidly deteriorating or that an urgent need exists to remove the DUF_6 from the present cylinders.

One recommendation in Document #3 calls for conversion of the DUF_6 to uranium metal. Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal will require the design, construction, operation and eventual decommissioning of at least one new facility. Document #3 recommends an approach of converting a portion of the DUF_6 to metal to reduce the storage area. Specifically, the recommendation supports the use of CMI at Barnwell, SC for the conversion. The large volume of waste in the form of magnesium fluoride is recognized and the use of new technology to alleviate this problem is mentioned without specific process details.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. Uranium derbys may be stored in sealed containers for long term storage or processed further into a desired uranium metal product.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of natural UF_6 has been performed for 25 years by the organization providing this recommendation, via specialized N14.30 equipment. The mode of transport is truck and this has been the general mode of transport for natural and low-enriched UF_6 . While truck transport is reasonable for DUF_6 , the large quantities involved may be more economically transported via rail.

Since the CMI facility already exists, the considerations on site restrictions would entail any needed additions or modifications. No information was provided on the capability or capacity of the CMI facility. For this review, an assumption is made that facilities are in place for small quantities of conversion of DUF_6 to metal.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and production of uranium metal in a privately owned facility would fall under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). These basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities.

7.1.3.1.2 Evaluation by Reviewer V

Option 1 - The Allied/GA oxide reduction process recommended in this response is discussed in Document 5. The option of reprocessing DUF_6 to produce marketable AHF

and U_3O_8 for storage or disposal does not appear to present any insurmountable issues. While the processing of DUF_6 has environmental risks, U_3O_8 is a far more stable chemical form for storage or disposal. The AHF, being hazardous and corrosive, will have its own set of handling, storage and transportation issues that again should not present unique or new technical issues.

The permitting for environmental, health and safety issues is not expected to present problems, but again should be carefully thought through and checked in the material licensing process. Siting this large an industrial facility with hazardous materials should be carefully planned to protect environment, health and safety in the surrounding community.

The processed U_3O_8 will require transportation and storage or disposal in quantities that are much larger than previously encountered. Disposal would not present a problem technically, however, the availability of sites might be an issue requiring further development or design to make sites more acceptable in new locations.

Option 2 - The recommendation suggests the production of uranium metal to reduce the volume of material to be stored or disposed. They further suggest that new technology is available to do this without the large quantities of MgF_2 produced in current conversion processes. This appears to be a reference to the improved Ames process as discussed in detail in Document 21-3. The metallothermic reduction process will have many of the same environmental issues as uranium oxide production as discussed in Document 5. No major new issues are anticipated because the first two steps of the proposed process are now in commercial use. Only the MgF_2 slagging to remove the uranium will constitute a new process. This process does require large quantities of sulfuric acid, but they will be handled according to industry standards. The slagging process is not expected to create any unique environmental hazards. Siting and design considerations are very similar to those for the options in Document 21-3. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks.

7.1.3.1.3 Evaluation by Reviewer X

Mr. Jody asks why DOE is spending millions of taxpayers dollars for storage pads if the current cylinder storage is safe, and answers his question with the statement that the storage cylinders are not doing well, and that disposal is required. The answer actually is two fold. First, safety is a function of the condition of the cylinders. To maintain the cylinders, continuous monitoring, repair, and appropriate maintenance is required. This includes providing storage conditions that do not encourage corrosion and deterioration. Second, DOE requires double confinement of all radioactive materials, including depleted uranium (DOE 1988, DOE 1993 - IP#C2). These issues are discussed in the response to RFR 10.

Mr. Jody recommends consideration of the option for disposal proposed by GA/ASI for conversion of dUF_6 to U_3O_8 . This option is discussed in the response to RFR 5. Also, similar conversion processes are discussed in the responses to RFR 21-1 and RFR 21-2.

Finally, Mr. Jody recommends consideration of conversion to uranium metal. This option is discussed in the response to RFR 21-3.

Mr. Jody also states that transport of the cylinders has been done safely for 25 years, and notes that his company has been involved in transport dUF_6 for Allied, Comeco, and DOD. This is apparently between the Paducah and Allied sites. Such transport has apparently been carried out in accordance with current regulations without incident. Liquid UF_6 is not transported in accordance with administrative procedures.

7.1.3.1.4 Evaluation by Reviewer Y

This option is a commentary that implies there may be environmental issues if the material is classified as waste. The statement "No one can afford to have EPA call the material waste" is the heart of this topic. If it is classified as a "resource," all aspects of the option can be implemented, with minimal implications for environmental, safety, and health issues. These will have minimal substantive concerns but will require dialogue and documentation. Transportation on public highways will be an issue.

7.1.3.1.5 Evaluation by Reviewer Z

Mr. Jody provided comments, but proposed no specific options to be evaluated. Therefore, a detailed evaluation was not performed. See Section 7.1.7.5.

7.1.3.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.3.2.1 Evaluation by Reviewer U

Option 1 - The DUF_6 conversion to uranium oxide should be achievable with minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components.

The recommendation does not include the details of processing steps or the cleaning and disposition of old cylinders after the DUF_6 is removed. It does recommend the recycle of recovered anhydrous HF through Allied's UF_6 plant and the disposition of solid waste at the NTS in Nevada.

Option 2 -The DUF_6 conversion to uranium metal should be achievable with minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. The reduction to metal uranium produces a magnesium fluoride slag that contains a considerable amount of uranium. The uranium must be removed from the slag to achieve a usable magnesium by-product. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low level radioactive waste, requiring disposal at dedicated low level waste disposal sites.

The recommendation does not include the details of processing steps or the cleaning and disposition of old cylinders after the DUF_6 is removed. Cylinder disposition is a waste issue.

7.1.3.2.2 Evaluation by Reviewer V

Option 1 - See Document 5 for a detailed description of the waste issues. This option recycles anhydrous HF back into commercial uses. In addition, the process recycles flows within itself to minimize effluents, emissions and waste production. The NRC has recommended deep geologic disposal because of the waste volume involved, so the disposal of this material must be carefully considered. Additional uses for this material could be sought. U_3O_8 storage would not be expected to generate any additional wastes except those associated with construction of the containers and buildings used to store it.

Option 2 - For waste reduction, as well as cost considerations, alternative processing of wastes is needed. The processes for leaching discussed would decrease the volume of low-level wastes needing special handling. However, large volumes of uncontaminated waste would still need disposal in a sanitary landfill. The potential to recycle more anhydrous HF and uranium need better definition and markets need to be identified, but the potential reduction in volume and ability to dispose of decontaminated MgF_2 in a sanitary landfill are important cost factors. No significant new waste streams would be expected from storage or disposal of the uranium metal.

7.1.3.2.3 Evaluation by Reviewer X

Waste management is not directly addressed in Mr. Jody's letter. He states that new methods are available for handling the Mag-Fluoride waste stream produced by conversion to the metal form. This is addressed further in the response to RFR 21-3.

7.1.3.2.4 Evaluation by Reviewer Y

This very brief proposal focuses upon waste treatment that emphasizes program flexibility to minimize and process waste. The referral to deal with Mag-Fluoride from metal production may be optimistic. The option is primarily geared to providing services to support the activities.

7.1.3.2.5 Evaluation by Reviewer Z

See Section 7.1.1.7.5.

7.1.3.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.3.3.1 Evaluation by Reviewer U

Option 1 - The recommendation provides no cost information. However, the cost of converting DUF_6 to oxide is significantly greater than the market value of recovered products.

Option 2 - The recommendation provides no cost information. However, the cost of converting DUF_6 to metal is significantly greater than the market value of recoverable products. When there is a defined need for uranium metal, it may be cost effective to contract with CMI for the conversion. Conversion costs in the existing CMI facility would undoubtedly be lower than cost of conversion if a new facility is required.

7.1.3.3.2 Evaluation by Reviewer V

Option 1 - The costs proposed for this option are discussed in Document 5. The demonstration phase would cost of \$20 to \$50 million over 2 to 3 years and an additional \$80-\$100 million is needed to construct a production-scale plant capable of processing the inventory in 15-20 years. At \$2.20 per kg UF_6 processed, the facility would receive over \$1.2 billion to process the inventory. The cost for disposal could range from \$170 to \$658 million. The costs for storage are not identified, however, construction of buildings to store the current inventory of DUF_6 is \$360 million. The overall revenue streams associated with saleable byproducts need to be identified.

Option 2 - Although the conventional Ames process is commercial, no costs are presented for this variation. Estimates from Information Package 3 suggest the cost for the metal production would be \$10/kg uranium metal. Assuming 1.5244 kg DUF_6 input to each kg metal, the overall cost of conversion alone would be about \$850 million. Information must be collected on the real cost to DOE of this alternative before any serious evaluation can be made. Similarly, the current market production seems to be 7,000 tons per year. Conversion of even a part of the inventory, would significantly increase the supply to a market where prices are very sensitive to demand. A better analysis of potential users

needs to be made. Another cost item of concern for this option remains the cost of disposal. Even with reduced quantities, the cost of packaging, transport and disposal can be significant. Other by-products such as HF may help offset some costs, but markets and prices need to be clarified.

7.1.3.3.3 Evaluation by Reviewer X

Capital and operating cost issues are discussed in the responses mentioned in Part 7.1.3.1.3 above.

7.1.3.3.4 Evaluation by Reviewer Y

The option raises the question of prudence for the DOE program of constructing storage pads for tanks. The proposal to use the byproduct anhydrous HF in the Allied UF₆ plant may be a very sensible way of dealing with this material that is probably slightly contaminated with DU; this would minimize clean-up or purification costs for the HF.

7.1.3.3.5 Evaluation by Reviewer Z

See Section 7.1.1.7.5.

7.1.3.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.3.4.1 Evaluation by Reviewer U

Option 1 - The process requirements for the production of uranium oxide are well defined. The collection of AHF and recycle at the UF₆ plant of Allied appears reasonable.

Option 2 - The process requirements for the production of uranium metal are well defined. The storage of recovered uranium metal could be implemented with known techniques. Recovery of the HF from the conversion of relatively small quantities of metal production may not be economical. The treatment of magnesium fluoride slag to significantly reduce the waste volume is an area that requires considerable development.

7.1.3.4.2 Evaluation by Reviewer V

Option 1 - This option seems to be well developed technically and leaves little significant concern regarding its feasibility. The potential for additional uses for the waste streams and products needs development but should not inhibit the immediate adoption of the option. Some uncertainty remains regarding the cost to operate the plant. Some uncertainty regarding storage or disposal techniques still exists.

Option 2 - This option seems to be well developed technically and leaves little significant concern regarding its feasibility. While individual processes are mature, the new combination requires piloting, now estimated at 12-24 months. The potential for additional uses for the waste streams and products needs development but should not inhibit the immediate adoption of the option. Some uncertainty regarding storage or disposal techniques still exists.

7.1.3.4.3 Evaluation by Reviewer X

Continued storage with monitoring and repair is a mature technology.

Conversion of dUF_6 to U_3O_8 and anhydrous HF (AHF) uses newly patented processes only tested in the laboratory. However, no new equipment is required, and pilot plant testing should identify any unidentified problems. These are further discussed in the responses to RFR 5, RFR 21-1, and RFR 21-2.

Several options for conversion to the metal have been proposed. All options include methods for reducing or eliminating the waste stream. Some of these have yet to be proven, and are discussed further in the response to RFR 21-3.

7.1.3.4.4 Evaluation by Reviewer Y

The heart of the option, that of transportation technology, is in hand and can be easily realized.

The statement that the "light wall storage cylinders are not doing well" is without substantiation. If correct, the option's sense of urgency is justified. However, the option as presented has no basis for the statement. In addition, even if the tanks, or some fraction thereof, begin to leak, no environmental disasters are reasonably expected for the nominally solid material.

Earthquake robustness of the tank systems or transportation technology is conspicuous by its absence.

7.1.3.4.5 Evaluation by Reviewer Z

See Section 7.1.1.7.5.

7.1.3.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.3.5.1 Evaluation by Reviewer U

Option 1 - Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires. Operation may continue for several decades after the DOE material is processed since the generation of DUF_6 is being continued by others.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and temperature. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the defluorination operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

Option 2 - Employment at CMI for the conversion of DUF_6 to metal would be subject to up and down processing rates for metal where the operation is dependent upon demand for the service or changing customer desires.

General public acceptance should be achievable in the locality of the present CMI plant since the operation would be viewed as an extension of on-going activities. Such an operation may be helpful for encouraging related locality development of processing uranium metal to finished products.

7.1.3.5.2 Evaluation by Reviewer V

Option 1 - The project seems likely to have positive economic benefits for the local economy around the site, as discussed in detail in Document 5. Siting could be a significant public acceptance issue. If a new low-level disposal facility were required, additional siting time and effort would be required. Transportation risks might also be a significant factor inducing public concern. The land use implications for this option could be significant. The processing facility and the additional land required for disposal somewhere in the country must be evaluated in light of other demands.

Option 2 - The project seems likely to have positive economic benefits for the local economy around the site. Siting could be a significant public acceptance issue. Transportation risks might also be a significant factor inducing public concern. The land use implications for this option could be significant. The processing facility and the additional land required for disposal somewhere in the country must be evaluated in light of other demands.

7.1.3.5.3 Evaluation by Reviewer X

Conversion to a more stable matrix should be well received by the public, especially if the waste stream from the selected process is minimal.

Specific data for the conversion processes has not been provided. However, from various estimates in the RFRs and IPs, a new $\text{dUF}_6/\text{U}_3\text{O}_8$ conversion plant would employ between 150 and 300 personnel. These employees may come from existing plants reducing their work force due to lower activity levels. Thus, if a new plant is built in the vicinity of current plants, it would be a stabilizing influence in the community, and it could be staffed with workers who have experience with similar processes and with handling the hazardous materials.

7.1.3.5.4 Evaluation by Reviewer Y

Full implementation of the actual and philosophic items in the option would provide significant employment in the localities for processing the DUF_6 into other forms. The actual items of transportation would provide some enhanced employment, not a major factor.

Public acceptance would need attention particularly for movement of materials on public highway.

7.1.3.5.5 Evaluation by Reviewer Z

See Section 7.1.1.7.5.

7.1.3.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.3.6.1 Evaluation by Reviewer U

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF₆ appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in some other form of uranium is greater than the cost of converting the DUF₆ to that form at an early stage.

7.1.3.6.2 Evaluation by Reviewer V

See General Comments.

7.1.3.6.3 Evaluation by Reviewer X

None.

7.1.3.6.4 Evaluation by Reviewer Y

Earthquake safety of existing storage and transportation methods needs to be looked at, particularly if DUF₆ is transported on public roads. While the risk is minimal, the concern needs to be addressed, particularly for transportation into and out of seismic areas.

7.1.3.6.5 Evaluation by Reviewer Z

None.

7.1.3.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.3.7.1 Conclusion by Reviewer U

Option 1 - This option of converting DUF_6 to oxide and the recovery of anhydrous HF appears to be reasonable. There is no market for depleted uranium oxide. Thus, the oxide would need to be stored or a decision made with regard to permanent disposal. The conversion to oxide at this stage should not be pursued unless a decision is made that continued storage of DUF_6 is unacceptable.

Since the market value of the anhydrous HF is less than the cost of conversion, there is a net added cost over the current storage mode cost base.

The organization making the recommendation in Document #3 has experience in the transportation of UF_6 , but has no experience in the conversion of DUF_6 to oxide.

Option 2 - This option of converting a portion of the DUF_6 to uranium metal appears to be reasonable. However, the amount of conversion that could be achieved at the CMI facility is unknown and is believed to be much less than the designated amount of the existing DUF_6 to be considered reasonable according to the guidelines. Conversion to metal probably should be done only when a use for uranium metal product is defined.

Since the market value of the uranium metal is unknown and believed to be low and any recoverable byproduct is less than the cost of conversion, there is a net added cost over the current storage mode cost base.

The organization making the recommendation in Document #3 has experience in the transportation of UF_6 , but has no experience in the conversion of DUF_6 to metal.

7.1.3.7.2 Conclusion by Reviewer V

Option 1 - This option seems reasonable with regard to DOE guidelines. The costs are within bounds and the technology would be operational to meet processing deadlines for inventory disposal. The main concern is the cost of storing or disposing of the U_3O_8 after processing. This could increase overall program costs but provide significant environmental and economic benefits in the long run over continued DUF_6 storage.

Option 2 - This option seems reasonable with regard to DOE guidelines. The costs are within bounds and the technology would be operational to meet processing deadlines for inventory disposal. The main concern is the cost of storing or disposing of the metal after processing. This could increase overall program costs but provide significant environmental and economic benefits in the long run over continued DUF_6 storage.

7.1.3.7.3 Conclusion by Reviewer X

Mr. Jody emphasizes that action should be taken to alleviate the current storage problems. Specifically, he recommends conversion to either U_3O_8 for disposal or uranium metal since it can be stored in a small area. These options are discussed in greater detail in the

responses to RFRs 5 and 21, respectively. Either is a viable option and should be able to be implemented within the cost guidelines provided by DOE.

7.1.3.7.4 Conclusion by Reviewer Y

The essence of the option is flexible disposal. This is good providing DOE with flexibility pending programmatic needs. However, capital costs for several facilities (e.g., oxide reduction, metal reduction) would be exacerbated. Capital cost proration to part of the inventory would probably bring the per pound cost to near that of natural Uranium. This may not be justified; a "best choice" option is probably warranted to minimize capital expenditures.

7.1.3.7.5 Conclusion by Reviewer Z

This response provided comments regarding current storage issues as well as comments on other options which might have potential for addressing the current issue. It does not propose any specific options regarding the use or disposition of the depleted UF₆ material. A detailed evaluation of this option is not warranted.

7.1.4 Evaluation of Document No. 5 (Independent Technical Reviewers' No. 4)

Respondent:

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phone number not provided

Description of Reponse:

This response consists of three recommendations on use and one technological recommendation for disposal of the depleted uranium stockpile. The recommendations on use include: use of uranium hexafluoride (UF_6) to produce DUCRETE, which can be used instead of conventional concrete as the shielding material in the fabrication of storage containers for use with spent nuclear fuel; conversion of depleted uranium into metal for use in energy storage flywheels; and, conversion of depleted uranium to a metal using an Idaho National Engineering Laboratory (INEL) plasma process and using the metal as feedstock for the Atomic Vapor Laser Isotope Separation (AVLIS) enrichment process. A DUCRETE storage container is also stated as suitable for spent fuel shielding at the monitored retrievable storage (MRS) site or as lag storage at the repository prior to emplacement. The respondent suggests that due to the smaller diameter of the DUCRETE storage container, it could be emplaced at the repository with the MPC inside, thus, eliminating the need for remote handling and reducing worker radiation doses and costs. The fourth recommendation is utilization of a conversion process developed at INEL in support of DUCRETE efforts, wherein the conversion process of UF_6 to triuranium octaoxide (U_3O_8) would produce a high density stabilized uranium oxide rock for direct disposal at sites requiring stabilization.

7.1.4.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.4.1.1 Evaluation by Reviewer U

Option 1, 2 & 3 - Three potential uses for depleted uranium (DU) were outlined in the recommendations of Document #4: 1- aggregate in DUCRETE, 2- energy storage flywheels and 3- feedstock for the uranium AVLIS enrichment process. The first would require the conversion of depleted uranium hexafluoride (DUF_6) to uranium oxide and the other two would require conversion to uranium metal. A unique approach for direct conversion from DUF_6 to metal using a plasma is suggested, without a detailed discussion of the process.

The specific application for the use of DUCRETE would be in storage and multipurpose containers (MPC) for highly radioactive spent nuclear fuel. The uranium oxide, either as a sand and/or pellets would be used as the aggregate within the concrete mix in place of sand and gravel. A large new conversion plant to produce the uranium oxides would be required, including associated siting and Federal safety licensing steps. Eventual disposition of the DUCRETE after the useful life of the storage containers, would require approved disposal criteria for uranium containing material. However, if disposal is as a component of a low level waste disposal operation or a component of the high level waste repository, this may be an appropriate means of achieving disposal of a significant quantity of the DU.

Transportation regulatory requirements for spent fuel containers, probably would not permit a brittle concrete structure such as DUCRETE to be used for shielding during transportation of spent fuel. However, storage structures at utility sites, a monitored retrievable storage site and at the repository may be applicable for the use of DUCRETE.

Energy storage flywheels is a novel concept that has received renewed interest in the past few years. Generally, the application of flywheel storage is associated with mobile devices, cars, trucks and buses. Using depleted uranium metal in a large number of mobile energy storage flywheels presents several areas of concern; material control to assure proper eventual disposition, recovery of depleted uranium components from accident scenes and when a vehicle is no longer in use, and maintenance control for flywheel components.

Using DU as feed stock for additional uranium enrichment with the AVLIS process appears possible, but may not be practical within a time frame of several decades. The AVLIS process has been under development for approximately thirty years without achieving necessary results to permit the process to be deployed commercially. The only new uranium enrichment plant that has been proposed in the U.S. during the past fifteen years, employs the developed centrifuge process. While the AVLIS process may turn out to be a dependable low cost means for enriching uranium, a significant pilot plant operation would be required to prove out the technology on a commercial scale. Relatively large quantities of good grade uranium ore have been defined in Canada and Australia that can be developed to provide low cost natural uranium feedstock for uranium enrichment, equivalent to projected needs for many decades. Stripping ^{235}U from the DU would be higher in cost than from natural uranium. To deploy this use, two new large facilities would be required; 1- conversion of DUF_6 to metal and 2- AVLIS enrichment plant.

At this point, the plasma process for converting DUF_6 to metal is in an early development stage. Considerable time and effort will be required before a determination can be made on deployment of this technology.

Overall Federal regulation for safety could be under the existing DOE regulations for the conversion of DUF_6 to oxides or to metal when it is performed at DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). No basic regulations are in place for commercial use of uranium as aggregate in concrete and a lengthy process may be encountered to establish such regulations. Basic regulations have been in place for several decades and several licenses granted by the NRC for the production of uranium metal. However, regulations for the operation of an AVLIS facility would need to be developed. Storage of commercial spent fuel is regulated by the NRC and the use of DUCRETE in storage or transportation structures would require NRC approval.

Option 4 - One recommendation of Document #4 indicates disposal of depleted uranium (DU) as a high density uranium oxide "rock". Processing of large quantities of depleted uranium hexafluoride (DUF_6) into triuranium octoxide (U_3O_8) will require the design, construction, operation and eventual decommissioning of at least one new facility. A recommended defluorination process is not described in Document #4. However, additions to the basic technology that has been employed for several decades in the U.S. should achieve nearly complete recovery of the HF to minimize the solid residues. Commercial defluorination of uranium hexafluoride is employed in conjunction with the conversion of low enriched UF_6 to uranium dioxide (UO_2) at commercial nuclear fuel production plants. The process should be modified to recover anhydrous hydrofluoric acid (AHF) from the first stage of the process and from the neutralized calcium fluoride. Document #4 indicates a means for the U_3O_8 powder to be compressed and sintered to provide stabilized pellets with a density exceeding 7 g/cm^3 . This higher density provides a material that would permit a disposal volume 60% less than achieved with bulk oxides. However, a decision to dispose of the DU at an early date brings into play a host of new considerations and considerable uncertainty.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder) with low reactivity and low solubility. Research would be required to determine if U_3O_8 is the appropriate material for disposal and whether it may be disposed off as a packaged powder, a compressed cake, medium density "rock" or high density pellets. Also, a decision is required on the means of disposal--near surface or deep underground--and the packaging requirement.

Operational issues for defluorination include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Document #4 discusses the disposal of the U_3O_8 after defluorination. The accompanying report on depleted uranium disposal indicates that disposal is probably to be performed at one of two DOE sites; Nevada Test Site and Hanford. That report also indicates that additional solidification would be necessary for the uranium oxide powder such as cement or polyethylene binders. Such a step would increase the volume by a factor of two. This additional solidification probably should be performed adjacent to the disposal site.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from other sites could be transported via rail or truck to the new facility. Rail transport of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is an on-going mode for current nuclear fuel activities. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites. If the decision of site location for the processing is predicated on the location of the final disposal site location, considerable time delay would undoubtedly be involved. Rail transport would be the preferred mode and rail access would be required for the disposal/defluorination site to permit efficient transportation of the DUF_6 .

The conversion process is amenable to a closed system that would minimize any liquid effluent streams and provide scrubbing for all gaseous effluents. Essentially all residues could be in the form of solid wastes that may be disposed of as a component of the U_3O_8 or in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone defluorination facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and disposal could be under DOE regulation if the functions were performed at DOE facilities and a DOE site such as Nevada Test Site or Hanford defined as the designated site for disposal. However, because of perceived public interest and concern with safe disposal and since there would be no national security aspects with the disposal of this material, Congress may direct these activities to be performed under regulation of the Nuclear Regulatory Commission (NRC). Thus, the operation of defluorination would probably be regulated under 10 CFR Part 40, "Domestic Licensing of Source Material," by the NRC and the disposal under 10 CFR Part 61. These basic regulations are in place and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the defluorination operations appears relatively straight forward without the need for time consuming development of new regulations. However, regulations are not in place that define the acceptable form for disposal of depleted

uranium or means for approval of disposal sites, and the ability to obtain safety regulatory approval from the NRC within a reasonable time period is problematic and indeterminate.

7.1.4.1.2 Evaluation by Reviewer V

Option 1 - This option proposes the production of shielding material that incorporates DUF_6 that has been converted to uranium oxides. The shielding material would be a form of concrete called Ducrete which would contain UO_2 pellets made from DUF_6 in place of aggregate in concrete. The environmental, health and safety effects of the conversion process from DUF_6 to uranium oxides are likely to be the most significant concerns for this option. These are discussed in detail Documents 5, 6 and 13, as well as others. All the processes for converting DUF_6 to another form of uranium have the potential for radiological or toxicological risks. The production of UO_2 pellets and their incorporation into Ducrete shielding materials would have relatively less environmental impact. The UO_2 powder would need to be controlled to protect workers from exposure during pelletization and Ducrete preparation. The risks are expected to be minimal if carried out in plants licensed for this type of activity that follow required safeguards. The Ducrete will most likely be used in containers for storing, transporting and/or disposing of spent nuclear fuels (SNF). It is thought that the radiation attenuation efficiency of the Ducrete may make some SNF handling activities safer for workers. Construction of any new plants to fabricate containers would have some environmental effects.

If new facilities are needed to fabricate the multi-purpose containers, it is not expected to cause significant siting controversies. Siting the UO_2 conversion plant may create more controversy depending on the location and issues such as the effect of radioactive shipments to and from the site via roadways. If the MPC's are not put into perpetual storage, they may eventually need to be dealt with as a low level waste.

Option 2 - This option proposes the use of depleted uranium in energy storage flywheels to improve storage of kinetic energy by 20%. This would require the use of uranium metal in the flywheels at proportions that are not identified. The conversion of DUF_6 to uranium metal has the same environmental issues as Document 5 regarding the handling of DUF_6 and AHF, hazardous and radioactive materials. The environmental, health and safety concerns regarding this option will parallel those experienced in the uranium metals industry in general. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen. This is particularly true for the slag processing options. The major difference is the use of the existing or an improved Ames process to convert the DUF_6 to metal using magnesium. Conventional Ames processes leave significant quantities of magnesium sludge which must be treated as a low-level waste. In the improved Ames process, sulfuric acid is used to remove uranium to the point where the sludge can be handled in a sanitary landfill. The sulfuric acid will be handled according to industry standards. In either case, these wastes would be the major effluent and could be handled in an environmentally responsible way.

Workers safety concerns would be the most significant environmental issues for flywheel fabrication. There is the potential for exposure to radiological and hazardous material risks during the fabrication process, however, properly controlled operations should keep these at acceptable levels for health maintenance.

Careful siting and design taking into account public concerns about these facilities will be needed. The permitting for environmental, health and safety issues is not expected to present problems, but again should be carefully thought through and checked in the material licensing process. Transportation of DUF_6 , uranium metals and uranium metal products will need to be conducted under applicable safety requirements.

The overall risks from conversion and metals fabrication are expected to be minimal if carried out in plants licensed for this type of activity that follow required safeguards. After the flywheels are retired from the application in which they are used, careful disposal will be required. To the extent flywheels are more efficient in storing kinetic energy, they may have positive environmental impacts from reducing energy requirements for the applications in which they are used.

Option 3 - This option for the production of U metal would have greater environmental, health and safety risks than processes currently in use. The use of hydrogen and high temperatures increases the potential for leaks and explosions. While all the processes for converting DUF_6 to another form of uranium have the potential for radiological or toxicological risks, this advanced process has additional risks that will require a great deal of work in design, siting, operations, transportation and materials handling. A hydrogen facility will need to be located nearby or provided from offsite in some way. Conversion to a metal form would make the DUF_6 more stable for future use or disposal, making it environmentally safer but would increase the radiological hazard. Like all conversion options, the transport of DUF_6 to the site could entail certain environmental risks. Shipping the metal and HF from the site would present some environmental, health and safety issues regarding potential for accidents.

The AVLIS process itself has some environmental, health and safety concerns. Prevention of accidental criticality at the plant and protection of workers from airborne uranium oxide particulates are the chief ones noted. In addition, typical operational risks associated with any large industrial facility must be considered as potential risks. Use of DU tailings would reduce the amount of natural uranium mining required and depletion of that resource.

Option 4 - This option proposes the conversion of DUF_6 to uranium oxides that would be stabilized into a "rock" that can be accepted at disposal sites requiring stabilization. The processes for converting DUF_6 to uranium oxides is discussed in detail in Documents 5, 6 and 21. They all have environmental issues associated with the handling of DUF_6 and HF, hazardous and radioactive materials. The increased production of uranium oxides will require the handling, transportation, conversion and ultimate disposal or use of these materials which also have radiological and toxicological risks. Uranium oxides are, however, the most chemically stable forms in which to handle depleted uranium.

UO₂ is the preferred form for this application. After it has been "sintered" at 1000°C to form dense cylindrical pellets, this material is stabilized making it less susceptible to further oxidation and largely insoluble in the weak acids and bases found in soils and groundwater. It is similar to U₃O₈ in its radioactivity levels, which could exceed acceptable radiological dose limits in shallow burial disposal situations, according to the NRC. UO₂ in a sintered ceramic form should perform better in disposal, but this has not been analyzed or demonstrated. The safest form of disposal according to the NRC is likely to be deep geologic facilities. It is suggested by some that near-surface disposal may be possible under the right conditions with no unacceptable health or environmental risks. It is unclear what specific construction techniques or disposal containers might be needed for this application to be acceptable.

Workers safety concerns would include exposure to radioactive or toxic material during conversion, densification, transport or disposal. There are safety standards in place for each of these activities and no unusual risks are expected. Transport of the depleted uranium to the conversion site and finally to the disposal site will increase potential risks of exposures due to accidents. The reduced volumes of this material may decrease the number of vehicle trips, thereby reducing the public risks.

Careful siting and design taking into account public concerns about these facilities will be needed, especially with regard to the disposal sites. The permitting for environmental, health and safety issues is not expected to present unique problems, however, public resistance in some areas would not be unusual. This option overall would present relatively low risks with regard to environmental, health or safety concerns.

7.1.4.1.3 Evaluation by Reviewer X

Option 1 - INEL proposes to use DUCRETE in spent fuel storage casks. They don't state whether their proposal or data is for DUCRETE made from U₃O₈ or from UO₂. Except for differences in production of the raw material (U₃O₈ or UO₂, both referred to as *oxide material*), other aspects of the manufacturing process should be the same.

Any manufacturing site will need to be licensed to handle the oxide source material. The primary concern for worker safety is internal radiation exposure due to inhalation rather than to direct external exposure.

U₃O₈ is a relatively low density potentially dispersible powder. Thus, unlike conventional concrete plants, the DUCRETE plant will need to be completely enclosed, including the location for storage of the raw materials (oxides). Since the oxides will represent the bulk of the final product, this represents a lot of indoor storage space.

Since the oxide material will be handled at the site in large bulk quantities, the potential for significant amounts of dust to be produced is high. Thus for worker safety, the manufacturing facility will need to be appropriately configured for air handling, airborne radiation detection, and filtering, and the workers will need to be trained in procedure and equipment use.

All effluents will need to be monitored and filtered to protect the general public.

Container design will need to consider decay of the uranium and the production of gases in material. These gases as well as gases produced by radiolysis in the application will need to be vented from within the metal cladding.

Option 2 - Uranium metal oxidizes in air possibly releasing oxide dust into the atmosphere. Therefore, flywheels will need to be clad to preclude airborne hazards.

Existing facilities at Oak Ridge are currently under utilized and may be available for manufacturing. However, the size of their furnaces may be too small for some applications, and new facilities may need to be built. Also, depending on demand, new facilities may be necessary. Any new facilities will require NRC licensing to handle source material.

Option 3 - The proposed process uses large amounts of hydrogen in the presence of extremely high temperatures, thus requiring high quality engineering design, well qualified operating procedures and practices, and a well trained crew to preclude explosive operating conditions.

Option 4 - INEL has submitted a study Depleted Uranium Disposal Options Evaluation (EGG-MS-11297) by SAIC published in May 1994 (referred to as the INEL/SAIC study). This report evaluated the disposal options for dUF_6 and concluded that U_3O_8 in a low bulk density U_3O_8 powder that is then stabilized in pellets or DUCRETE is the best form for disposal. The report further concludes that the Nevada Test Site is the only available site for near surface or surface disposal. They state that stabilization in DUCRETE has the potential to increase the bulk density to greater than 7 gm/cm^3 in the form of sintered uranium oxide pellets, but that further research is required. The objective is to decrease the total volume of material for disposal, thus reducing total disposal costs by as much as 60%.

Their analysis has determined that the Nevada Test Site (NTS) is the only viable disposal site at this time for shallow land disposal. However, they encourage investigation of other options such as disposal of U_3O_8 in abandoned uranium mines and in existing uranium mill tailing impoundments.

The INEL/SAIC analysis is internally inconsistent in that it states the Waste Acceptance Criteria (WAC) for several sites including NTS, demonstrating a consistency among the sites of a maximum concentration for depleted uranium activity of about 100,000 pCi/gm (pg. 33). However, they reference a specific activity for depleted U_3O_8 of 310,000 pCi/gm when using a bulk density of 3 gm/cm^3 (pg. 40). Increasing the bulk density to 7 gm/cm^3 to reduce transportation and disposal costs will only exacerbate the acceptability problem.

Thus, to be consistent with their analysis, the only available option for disposal is deep disposal as NRC concluded and reported in NUREG-1484.

7.1.4.1.4 Evaluation by Reviewer Y

The option's Ducrete as a shielding material awaits only the formalities of application for NRC license. This is an environmentally sound approach to getting rid of DUF6 if it cannot be used for its energy content.

The option's proposed use of DU in storage flywheels will require regulatory formalities since DU is a special nuclear material. This is not likely to be a major problem since the flywheels will not be in a facility that has extensive public exposure. However, malfunctions could lead to public exposure of special nuclear material that may be avoided if other high-density materials (e.g., W) are used.

The AVLIS process obviates the production of contaminated MgF. The idea of extracting U235 from the DU may be environmentally sensitive in a time frame permitting more environmental "selling" of the Plutonium as a breeder fuel. The U235 so extracted could beneficially augment natural Uranium fuel for lowered CO₂ and acid rain emissions.

7.1.4.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. W. J. Quapp, provides two options for use of the depleted uranium hexafluoride. A third option is presented for the reduction of depleted UF₆ to uranium metal, with possible applications being for refeeding the depleted tails through the AVLIS system.

The first option proposes using the depleted uranium in the fabrication of DUCRETE, to be used as a shielding material for spent nuclear fuel. DUCRETE is a take-off on conventional concrete, where the large aggregate is replaced by an aggregate fabricated from depleted uranium. The DUCRETE offers the advantage of providing more shielding capability with less volume and less weight than normal concrete shielding. The DUCRETE has both high and low atomic mass units, thereby providing shielding for both neutron and gamma radiation.

An additional advantage which affects the safety and health issues is that multipurpose containers (MPC) constructed from DUCRETE can fit inside a steel overpack. This will provide additional protection in the event of transportation or handling accidents, as well as providing additional shielding to personnel handling the containers.

The second option proposes to use the depleted uranium in the production of energy storage flywheels. Potential environmental, safety and health effects associated with applications of depleted uranium as a dense material include the health effects of inhalation or ingestion of uranium dust. Uranium metal is pyrophoric, especially when divided into small fragments such as machine shavings or filings. This causes additional concerns regarding potential for fires as well as dispersment of uranium oxides into the atmosphere.

Uses of uranium in applications such as energy storage flywheels would require that the material be clad in order to prevent exposure of the material to the atmosphere whereby it

could become airborne. This would require an evaluation of the potential for exposing the uranium due to damage to the cladding.

A final factor which must be considered is the final disposal of the device. This material would have to be recycled or disposed of as low level waste, and it is not evident at this time what the long term disposal options will be. If disposed improperly, the uranium could present health or environmental concerns.

The third option proposed is that the tails could be further depleted utilizing the Atomic Vapor Laser Isotope Separation Process (AVLIS). It is specifically proposed that the UF_6 be converted to metallic uranium by use of a plasma process for direct conversion. Environmental, safety and health issues associated with the plasma conversion process would be similar to those encountered in other areas of the nuclear fuel cycle. No new issues would be expected.

The primary safety issue for this option, as with any enrichment process, is an unplanned criticality, which can be addressed using standard industry practices.

7.1.4.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.4.2.1 Evaluation by Reviewer U

Option 1, 2 & 3 - Waste streams would entail those associated with a conversion plant for the production of uranium oxides and/or uranium metal from DUF_6 . In addition, eventual disposal of DUCRETE after the structure has completed its useful life presents a new disposal challenge. Breaking up large DUCRETE structures for disposal would undoubtedly result in the shattering of uranium particles requiring containment and area cleanup tasks. Disposal of DUCRETE spent fuel storage containers as an intricate part of the high level waste repository may be an appropriate means to dispose of DU in a useful way.

Disposal of uranium metal flywheel components would entail material collection controls as well as satisfying approved disposal regulations.

Disposal of DU metal after being stripped of U_{235} would entail the same disposal issues as imposed for disposal of DU metal without stripping. The difference in the total amount of material would be very small--less than three percent. While it may be acceptable to

dispose of metal in a disposal facility, regulations may require disposal to be in the form of uranium oxide. This will not be resolved until disposal decision's are made.

Operation of plasma technology may permit the conversion of DUF_6 to metal without the production of magnesium fluoride slag. Development of this process is warranted if there is a demand for uranium metal.

Option 4 - The DUF_6 conversion to U_3O_8 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may added to the U_3O_8 product packages for disposal.

The recommendation anticipates disposal of U_3O_8 at near surface facilities at either Nevada Test Site or Hanford. While U_3O_8 may be defined in time as the accepted form for disposal, extensive time is anticipated to resolve the many questions that will be raised about the acceptable form for disposal, the need for deep disposal versus shallow land burial and the requirements for a suitable disposal site. Sites other than the two referenced may need to be considered.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

No mention is provided for the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to U_3O_8 . Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites, at a high cost. Another use may be to modify them for use as storage containers for the U_3O_8 .

7.1.4.2.2 Evaluation by Reviewer V

Option 1 - The choice of conversion technique will effect the waste streams that will need to be controlled. It is likely that HF will need to be recycled or disposed. This is discussed in Documents 5 and 6. It is reported that no hazardous or radioactive wastes are produced during fabrication of the MPC's. The only new waste will be the Ducrete after it is no longer in use, which will have to be treated as a low-level waste and disposed of in a licensed facility. The volume of waste in this final disposal form will be very efficient since the UO_2 form is very dense and the Ducrete pellets will be replacing the aggregate.

Option 2 - As discussed above the major waste stream of concern is the magnesium sludge from metal production. If it is a low-level waste, disposal capacity will need to be located for it. The volumes are unknown at this time. The HF produced in the conversion

process is likely to be recycled into industrial uses. The fabrication process would produce small amounts of slag and lubricants that also would need to be disposed of in a low-level waste facility or sanitary landfill depending on the radioactivity levels of the material. Similarly, the flywheels will need to be disposed of in appropriate facilities. These volumes would be relatively small, DU metal is a very dense form in which to store this material.

Option 3 - While the conversion option will not have any major waste streams, it will have secondary wastes from air pollution control and other support activities, e.g. cylinder washing. The metal itself could become a waste stream unless acceptable uses can be found for the quantities that will be produced. The metal form will be a more efficient form for disposal, however, it would need to be placed in a specially designed facility for this type of waste. If it is used in the AVLIS process, only 10% will actually be incorporated into the enriched uranium, the remaining 90% in tailings will need disposal. There will also be other low-level wastes from operations and maintenance. There will be small amounts of ethanol which is a hazardous waste and non-hazardous waste streams from routine operations, e.g. cooling tower blow-down.

Option 4 - As discussed above, the major waste streams would result from the conversion of DUF_6 to uranium oxides. Most of the waste streams would be recycled and the remaining wastes could be easily managed and disposed. The major issues to be resolved are the level of disposal required for this material and the availability of sites capable of providing that disposal. If shallow burial in low-level waste sites is acceptable, then the availability and costs of these sites will be a question. If deep geologic disposal is required due to the radioactivity of the material, then new sites and disposal techniques will need to be defined. The volume of material needing disposal is much reduced by this approach and no additional wastes of significance would be generated.

7.1.4.2.3 Evaluation by Reviewer X

Option 1 - A requirement for about 3500 containers is projected. Once the containers are no longer required for spent fuel storage, if they cannot be recycled into containers for permanent spent fuel disposal, they will need to be disposed of as low-level radioactive waste (LLRW). Since the DUCRETE manufacturing process will have concentrated the uranium such that activity levels will likely be higher than acceptable at LLRW disposal sites, there is a concern for selection of a disposal alternative.

This should result in no different an alternative from disposal of U_3O_8 directly, but should only postpone the process. Thus, a disposal option should be identified prior to manufacturing the containers so that funds for disposal can be set aside. These costs may involve separating the DUCRETE from its metal containers and breaking it into smaller pieces for handling and burial. The U_3O_8 or UO_2 will already be in a stabilized matrix.

Option 2 - Controls will need to be implemented to assure that when the flywheels are no longer needed, disposal will occur in accordance with appropriate safety practices.

Option 3 - A stated advantage of this process is the elimination of all waste streams. The process produces only uranium metal and anhydrous HF for sale as a product.

If disposal of the metal is required, then additional processing will be required, and the costs will have to be reconsidered.

Option 4 - The INEL/SAIC report states that both U_3O_8 and CaF_2 will require disposal. Others have reported that CaF_2 or other process chemicals will be recycled through the process so that no waste will be generated, and thus will not add to the waste stream.

Stabilizing the waste in a rock or DUCRETE matrix at a specific activity level low enough to meet the WAC at NTS would enable the material to be acceptable at other sites as well. It may also enable the material to be shipped without being placed in small containers such as 55 gallon drums.

7.1.4.2.4 Evaluation by Reviewer Y

Ducrete would be potentially advantageous for utilizing DU if it is not deemed useful for its latent energy content; probably an unfortunate use as waste for future generations. Densification of DUF6 would be good for minimization of waste volume. Unfortunately, Ducrete would be very hard to recycle for beneficial use of DU in generation applications.

If the AVLIS process does not meet expectations, the MgF byproduct may be a difficult waste to handle with no beneficial results.

The densification proposals in the option would minimize waste volume.

7.1.4.2.5 Evaluation by Reviewer Z

The first option of this proposal is to use the depleted uranium in the production DUCRETE to be used as shielding for spent nuclear fuel. This application is not expected to result in waste streams which are different from current low level wastes in either volume or characteristics. If the DUCRETE is used in the construction of MPCs, then it is likely that it will be disposed of along with the high level waste. Should this not occur, then the DUCRETE would have to be disposed of as low level waste at the time it was no longer used. The advantage is that it is in a form that is readily suited for disposal.

The second option is to use the depleted uranium in the production of energy storage flywheels. It would be anticipated that any waste generated would be similar in composition to those currently seen in the industry. A more specific waste management consideration for this option is the final disposition of the flywheels after their normal lifetime. This application would require the licensing and tracking of each item in order to ensure that it was properly disposed at the end of life. An additional consideration would be the method of disposal. This is an uncertainty at this point due to the lack of licensed burial sites, and a questionable schedule for the completion of the interstate compact sites.

The third option proposed is to further deplete the UF_6 utilizing the AVLIS process. This process utilizes uranium in a metallic form, alloyed with iron. The final product is metallic uranium. The selection of this option would therefore produce large amounts of metallic uranium alloy. The iron content in the depleted uranium could be a detriment to the use of the uranium for other applications, or may require an additional process to separate the iron from the uranium before the uranium could be used.

The plasma process proposed for the conversion of the UF_6 to metallic uranium would produce anhydrous HF as a byproduct. There is a relatively well established market in the United States for anhydrous HF, therefore, this should not become a waste stream.

7.1.4.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.4.3.1 Evaluation by Reviewer U

Option 1, 2 & 3 - Conversion of DUF_6 to oxides and/or metal would entail a cost greater than the value of recovered usable HF. However, this conversion cost may be required at some time in the future for eventual disposal of DU if it is determined that uranium oxide is the proper form for disposal. Using uranium oxide in DUCRETE would then entail only the added cost of processes to provide the proper aggregate sizes and the production of the DUCRETE structures. Special controls would be required to contain the radioactive aggregate during the construction of DUCRETE structures. Conventional aggregate materials are low cost sand and gravel with limited need for environmental contain control. Substituting uranium oxides for the conventional low cost aggregates will result in much higher cost. Thus, the only advantage of using DUCRETE is where applications that require shielding also are space or weight limited.

Cost of fabricating uranium metal energy storage components is unknown. Until such applications are better defined, applicability and cost estimates are speculative.

Relatively low cost estimates for uranium enrichment have been made by the research organization developing the AVLIS process. However, the overall cost of obtaining enriched uranium from DU through the use of AVLIS is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

The cost of converting DUF_6 to uranium metal should be significantly lower with the plasma concept compared to the present process and it should eliminate the generation of

large slag volumes. However, the actual cost of such an operation can not be defined until considerable development work has been completed.

Option 4 - Since the defluorination process is currently in use within the U.S., the costs are reasonably well defined for both the processing plant and its operation. Costs associated with the recovery of AHF and the processing of the waste streams are not well defined and must be developed to a greater degree before achieving a reasonable estimate of such costs.

AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Cleanup residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

If a decision is made to dispose of the large quantity of DU as a waste material in the form of U_3O_8 , considerable time may be required for the selection and approval of a disposal site. The assumption that the site would be either Nevada Test Site or Hanford appears reasonable but not determinate. An elaborate site selection process may be directed by Congress. The cost included for disposal in the reference document is optimistic. Overall cost of an approach of early disposal, including site characterization, public acceptability and regulatory approval, could be substantially more than the estimate provided.

7.1.4.3.2 Evaluation by Reviewer V

Option 1 - According to the engineering estimates, the cost of converting the entire depleted uranium inventory to U_3O_8 would be about \$3.0 billion. Assuming that conversion to UO_2 would be in the same order of magnitude, this would be the major expense associated with this option. It is estimated that UO_2 costs \$1 per pound to pelletize and complete Ducrete fabrication costs \$.055 per pound. It is believed that use of Ducrete could reduce operating costs to other government and private sector programs by lowering the cost of container fabrication and operating costs in handling containers. The respondent claims that the size of the cylinders could be reduced by 30% and the weight by 23% using Ducrete rather than concrete. They also claim that the superior gamma ray control would reduce workers exposures and reduce the amount of remote handling by automated equipment which would be required. It is not clear how much Ducrete can be effectively used in the markets and how much of the depleted uranium inventory could be used. A rough calculation estimates that only half at most might be used, given expected demand for containers. Competition from other materials and handling and disposal techniques for SNF is not well characterized to be able to estimate the markets. The costs of ultimate disposal of the Ducrete is not known, however, it may require disposal in low-level waste facilities at the prevailing price at the time of disposal.

The life-cycle costs of this disposal option could be quite high and must be balanced against the value of the services provided at each step. Participation by the U.S. Enrichment Corporation or other private parties might be considered in deciding whether to proceed with this option.

Option 2 - A general estimate of the cost to produce and cast uranium metal is \$11/kg. No information has been presented regarding the cost of flywheels using conventional metals. To the extent they increase the efficiency of the flywheels, some credit for energy costs savings can be taken. The disposal costs for the conversion by-products and the retired flywheels are not known but will effect overall cost.

Option 3 - According to the engineering estimates, the life-cycle cost of the plasma reduction option would be \$1.2 billion. With credit for HF sales, this cost could be reduced slightly. These costs need to be verified as the process undergoes development. The cost of H_2 and electricity inputs should be carefully checked over time. The market value of U metal is sensitive to demand, so potential revenues deserve further assessment. The estimated cost for an AVLIS plant is \$1.2 billion, with operations costing \$147 million annually to produce \$600 million in revenues. It would take two plants 20 years to convert the entire DU inventory to enriched uranium and tailings. This would produce the equivalent of 1,000 reactor-year of fuel supply. The availability of markets for these fuels and the effect on the markets is not known. Some gas diffusion plants with higher costs might be forced to close.

Option 4 - A general estimate of the cost to convert the current inventory of depleted uranium to U_3O_8 is \$3.0 billion; UO_2 is likely to be similar. Production of the UO_2 pellets is expected to cost about \$1.00 per pound of UO_2 powder. Estimates for disposal of UO_2 pellets range from \$40 million to \$304 million, depending on the site and waste acceptance criteria. Given current trends in disposal requirements and site availability, it is unlikely that the lower figure will be the cost experienced.

7.1.4.3.3 Evaluation by Reviewer X

Option 1 - The costs for manufacturing DUCRETE containers will be higher than for concrete containers due to the costs of raw materials (conversion of dUF_6 to U_3O_8 or UO_2), extra handling in manufacture, and eventual disposal.

Option 2 - The facilities at Oak Ridge are currently underutilized and may be available to handle any initial new demand. However, depending on overall demand, additional facilities may be needed.

Option 3 - No cost estimates are provided in the submittal. A cost study is referenced and stated to have found that the life-cycle cost can possibly be reduced by 65%. The question is what this savings is relative to. The disposal cost of U_3O_8 is about 25% of the total cost of converting and disposing of the dUF_6 inventories according to EGG-MS-11297 (Hertzler, 1994) attached to the submittal letter. Cost for the conversion of dUF_6 to U_3O_8 is given as \$8.40/kgU and of dUF_6 to metal as \$10.00/kgU based on the reviewed technology. Other estimates using newer but as yet unproven (on a production scale)

technologies are between \$1.00 and \$5.00/kgU. Thus, the cost provided in IP#4 of \$4.30/kgU is on the order of other estimates using more proven technologies.

Option 4 - The INEL/SAIC study provides detailed cost data for potential disposal at either NTS or Hanford. Their conversion (dUF_6 to U_3O_8) cost estimates are more than double those estimated by others (GA/ASI, Cogema, Cameco for example). This is an interesting situation. INEL is not a party having an interest in building or operating a conversion facility. All the others are. Thus, the INEL/SAIC data may provide the most accurate estimates based on then current technology. The "proprietary" estimates may be based on implementation of new technology. Most of the others have proposed piloting efforts. However, the Cogema estimate should be a close estimate since they are currently operating a production level plant in France.

Also, in selecting NTS and using NTS costs of \$10/ft³ (increased 19% to correct for full-cost recovery), which were current for 1993, even while providing the higher costs for other facilities, their final estimates are further distorted. It may not be possible to determine a cost for burial until the time actually arrives because of the changing regulatory, public acceptability, and site availability environments. If DOE accepts its own "waste" on one of its own sites, it may be reasonable to expect that an unreasonable surcharge won't be placed on the U_3O_8 . However, costs at Hanford of \$58.70/ft³ are likely to be more realistic numbers. Using the Hanford burial costs and the INEL/SAIC conversion costs provides an upper bound estimate of about \$7.8 billion.

If the U_3O_8 is stabilized in a rock or DUCRETE matrix, the cost of containers may not be required. For example, the Envirocare facility in Utah removes all waste from its containers prior to disposal. Bulk shipping without containerization would also reduce the transportation costs.

Summing costs projected by Cogema of \$3.00/kgU for conversion, costs at Hanford of \$1.81/kgU for disposal, transportation costs, environmental compliance costs, and container costs, the total cost is projected to be about \$5.50/kgU, or about \$3.9 billion for conversion and disposal of the entire inventory. Using GA/ASI's production level estimates after a piloting effort would reduce the total costs to about \$2.7 billion.

7.1.4.3.4 Evaluation by Reviewer Y

With DU being a SNM, costs for licensing might well exceed benefits of using non-nuclear materials in Ducrete and flywheels. The AVLIS enrichment process for DUF6 appears promising for development to ascertain costs particularly if AVLIS can be used beneficially in applications other than for DUF6 processing. If so, the use of very low U235 assays in Ducrete should facilitate environmental acceptance with minimal health and safety implications at modest cost.

7.1.4.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, operating or maintaining facilities necessary to execute the options outlined in this alternative.

Factors to be considered in the evaluation of the costs of the use of DUCRETE as a shielding material is the lower volume and weight associated with MPCs constructed with DUCRETE. Additional factors would include the fact that the MPC can fit inside a steel overpack, and that the smaller and better shielded containers may eliminate the need for remote handling systems at the high level waste repositories.

Regarding the option for refeeding the material through the AVLIS system, if the presence of iron in the depleted material after feeding through the AVLIS system does not affect the use in other applications, or if the iron can be removed economically, then the AVLIS option should be considered for any material which will be used in metallic form. The recovery of the residual U^{235} would help to offset the costs of processing.

7.1.4.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.4.4.1 Evaluation by Reviewer U

Option 1, 2 & 3 - Construction of concrete structures using conventional aggregate materials is fully mature. Substitution of uranium oxides as the aggregate requires the development of techniques to achieve the appropriate aggregate sizes, distribution within the matrix, consistent uniformity, defining structure strength and establishing controls during construction to assure containment of the uranium oxides. Concrete construction is a rough and tumble type of activity that does not entail the need for highly skilled personnel. Using uranium oxide aggregates where substantial controls would be required would entail a culture change of significant magnitude in the construction of such concrete structures. This significant change in how the materials must be controlled and structures constructed will be difficult to achieve.

Fabrication of uranium metal components has been performed for decades. Thus, such fabrication is considered to be mature. However, using uranium in an application where material strength is important to allow high rotation speeds needed for rotating energy storage devices will undoubtedly require the development of composite structures, such as carbon fiber wheel rims, to retain structural integrity. Considerable development would be required to achieve the desired structure.

Direct conversion of DUF_6 to uranium metal with a plasma process will require considerable development to determine whether it is practical and to define operating characteristics and conditions.

While considerable development has been completed for the AVLIS uranium enrichment process, practicality is yet to be determined. Obtaining enriched uranium from DU should be considered as a long term possibility, not a near term use.

Option 4 - The chemical process requirements for defluorination are reasonably well defined since many steps of the process have been in operation in the U.S. on a relatively large scale for several decades. Technical maturity is sufficient to permit its use after the operation of a pilot plant to prove out the details for collection of all HF as AHF and the process of the neutralizing waste stream. A relatively small amount of research and development appears needed to finalize process design for defluorination.

Early disposal of U_3O_8 would require extensive development efforts to define the acceptable waste form, site suitability and overall acceptability. Although the task should be much less demanding than the one being pursued for the disposal of high level radioactive wastes, there are many public questions that will be raised and whether an acceptable program could be achieved in a reasonable period is problematic.

7.1.4.4.2 Evaluation by Reviewer V

Option 1 - The conversion process is fairly well known, however the use of UO_2 in Ducrete is still in development. With DOE currently funding process development for large-scale, low-cost fabrication methods, this process is likely to be available within the ten year implementation horizon. Proof of commercial operation will still need to be completed.

Option 2 - The conversion process for uranium metal is commercial. Flywheel applications are in very early development stages. Experimental work still needs to be conducted and the efficacy of this application needs to be proven. Fabrication is not expected to present significant hurdles.

Option 3 - This process is still in very early development. Proof of commercial potential is still to be completed with no definite time frame proposed. The AVLIS process is close to commercial with full specific scale tests completed.

Option 4 - The conversion processes to produce uranium oxides are commercial. Conventional methods for producing pellets are available, however, it is not clear if new capacity will be required to handle this application. Low-cost through-put methods are not developed. Shallow disposal techniques already exist or would need limited re-engineering to accomplish disposal. Deep disposal would require more development, but could be put into practice within the program's time requirements.

7.1.4.4.3 Evaluation by Reviewer X

Option 1 - According to information provided, large scale production of DUCRETE has not been satisfactory. Further testing is being performed.

Option 2 - Considerable experience exists with founding, casting, and milling processes.

The actual use of uranium metal flywheels has not been tested. INEL, in their recommendation, states that "very limited preliminary studies have shown improvements of over 20% compared to current advanced high speed flywheel concepts." It's not clear whether these studies are computer model studies or actual equipment tests using uranium flywheels. However, modeling studies should be sufficient for justifying a testing program preliminary to manufacture.

Option 3 - The process has only been demonstrated on a bench scale. Further development leading to a pilot scale test is required to demonstrate the viability of the method on a commercial scale.

Option 4 - The estimates in the INEL/SAIC report are based on mature technologies. Lower cost estimates rely on technologies requiring further testing and piloting.

7.1.4.4.4 Evaluation by Reviewer Y

Ducrete under development but largely untested.

Storage flywheels with DU largely conceptual.

AVLIS bench scale studies demonstrated.

All the factors in the options are conceptually feasible and technically promising.

In terms of using DUF6 as an energy resource, the AVLIS process should be pursued for further promise.

7.1.4.4.5 Evaluation by Reviewer Z

The production of DUCRETE has been through preliminary testing, but remains largely undeveloped. Actual applications will depend upon the results of achieving densities of uranium oxides which approach theoretical densities.

The AVLIS technology has not been commercially deployed. The U-AVLIS technology is in the final stages of engineering and has been successfully tested at full specific scale.

7.1.4.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.4.5.1 Evaluation by Reviewer U

Option 1, 2 & 3 - Employment at a facility to convert DUF_6 to U_3O_8 or uranium metal and HF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. However, if the operation is dependent on the use of oxides in DUCRETE structures or metal as flywheel structures, up and down employment cycles would occur depending upon demand for the service or changing customer desires. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility.

Construction of DUCRETE structures would likely be performed at the site where spent fuel storage containers are needed. This would result in employment cycles that depend on the need for such structures at each site.

Use of uranium metal in flywheel application in vehicles such as cars, trucks or buses would raise the specter of safety with the public. Whether the public concerns in this regard could be satisfied is an open question.

Development of the plasma technology requires considerable research and if employed on a commercial basis, would require the construction of a new facility. Commercial nuclear material processing facilities will be viewed by the public with considerable interest and probably organized opposition to acceptance of such a facility in any locality.

Stripping of fissionable uranium isotopes from the DU by the AVLIS process would be a long term project of facility operation of several decades.

Performing uranium processing operations at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a

significant public information program is essential to describe operations and the reasons for performing the tasks.

Option 4 - Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires. Operation may continue for several decades after the DOE material is processed since the generation of DUF_6 is being continued by others.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and only one step is at a high temperature (750C). Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable for the defluorination operation. However, obtaining public acceptance for a waste disposal site will be a major challenge. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 and very unlikely that open approval could be obtained for a disposal site. Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the defluorination operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

Proceeding with disposal of the U_3O_8 , will result in significant public involvement and many challenges associated with the location of a disposal site. The outcome is indeterminate at this stage.

7.1.4.5.2 Evaluation by Reviewer V

Option 1 - A uranium oxide conversion plant would constitute a significant industrial construction and operation project with direct and indirect impacts. The container fabrication facility would have fewer impacts. If the plants were located in rural rather than developed areas, the magnitude of the impact would be greater. Some new employment will be created. It is likely that there will be some traffic impacts. The conversion facility is likely to arouse more public scrutiny than the fabrication plant, however, neither is likely to be rejected. The issue of handling SNF is an ongoing controversy that, while not a direct part of this program, may influence public perceptions on acceptability.

Option 2 - A conversion plant could constitute a significant industrial construction and operation project with direct and indirect impacts, if a large volume of metal is required for this application. If existing plant are used, impacts would be insignificant. The metal fabrication would have fewer impacts, especially if existing facilities are used. There may be some traffic impacts. The conversion facility may arouse public scrutiny, but is likely to be accepted.

Option 3 - This plant would constitute a major industrial construction and operation project with significant direct and indirect impacts. If the plant were located in rural rather than developed areas for safety reasons, the magnitude of the impact would be greater. With the high electricity and hydrogen demands for this option, it may be necessary to co-locate other industrial facilities including a powerplant, thereby expanding the economic impact and regional development effects. Powerplants have been known to have their own siting difficulties depending on their design characteristics. This option would not necessarily be more likely to attract spin-off industries compared to other options. Spin-off industries will be a function of the location of the conversion plant, its products, its supply needs and the underlying economic base of the region.

An AVLIS plant would have a significant economic effect in most areas. The \$1.2 billion in construction, the \$147 million in annual operating costs and the estimated 1100 new jobs created would be a stimulus to the regional economy. The AVLIS plant is likely to meet some resistance in locating an acceptable site.

Option 4 - A conversion plant could constitute a significant industrial construction and operation project with direct and indirect impacts, if most of the inventory is converted for this application. If existing plant are used, impacts would be mitigated. There may be some traffic impacts. The conversion facility may arouse public scrutiny, but is likely to be accepted. Siting new low-level disposal facilities or deep geologic disposal facilities has been problematic in many cases.

7.1.4.5.3 Evaluation by Reviewer X

Option 1 - No information is available to assess this evaluation factor.

Option 2 - If existing facilities are used or expanded, a trained work force should be available, and the impact on communities should be minimal. Demand for product will need to be carefully evaluated to assure that plant is not over built.

Option 3 - A plant built near or on the site of an existing dUF_6 storage facility would employ workers that otherwise might be unemployed from a declining enrichment industry.

Option 4 - The INEL/SAIC report assumes that U_3O_8 will be transported from the current production facility sites. The report did not consider conversion plant siting in any other way. Conversion plants built at the current production sites would have the advantage of utilizing an experienced workforce from plants that are likely to reduce their operations in the near future. Also, public acceptance of new plants may be high because of the positive impact of further employment, and due to conversion of the dUF_6 to a more stable matrix along with shipping it off-site.

7.1.4.5.4 Evaluation by Reviewer Y

Any industrialized AVLIS facility would provide some employment, possibly at less than the level of some currently retired related facilities (e.g., K-25). It is assumed the facility would provide services beyond those for the DUF_6 requirement. It would be of benefit to a local development.

The Y-12 facility might be beneficially used for the DU metal fabrications for high-density Uranium applications (e.g., shields, flywheels).

7.1.4.5.5 Evaluation by Reviewer Z

This reviewer has no specific information on the socioeconomic impacts for the use of depleted uranium in the fabrication of DUCRETE or in the production of energy storage flywheels.

This reviewer has no specific information on the socioeconomic impacts for the option of feeding the depleted uranium through the AVLIS process. One effect which should be considered is that the additional U^{235} removed from the depleted tails will reduce the need for natural UF_6 feedstock, which might impact companies on the front end of the fuel cycle, such as mining, milling and uranium conversion.

7.1.4.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.4.6.1 Evaluation by Reviewer U

Option 1, 2 & 3 - The depleted uranium does contain potentially recoverable energy values that could be captured with the deployment of breeder reactors. While the economic value of the energy resources is insufficient to recover the values in the near term, economic recovery may be achieved at some future date—possibly one hundred years or more hence. Thus, an important factor may be an assessment of potential energy values recoverable through isotope separation or as fertile material in future energy programs.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 with associated impacts.

Option 4 - Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 with associated impacts.

7.1.4.6.2 Evaluation by Reviewer V

See General Comments.

7.1.4.6.3 Evaluation by Reviewer X

Option 1 - In Ohio, state regulations require a standard yard of concrete to contain 3800 pounds of dry ingredients. Raw materials consist of about 1600 pounds of sand, 1600 pounds of #57 course aggregate (about 3/4" crushed limestone), 600 pounds of cement, and 30 gallons of water (250 pounds). The water combines with the cement providing the binding. Extra water added for handling (slip) mostly evaporates, leaving a finished product of about 4050 pounds/yard³.

A typical DUCRETE container will contain about 19 yards of DUCRETE weighing Seventy-nine percent of finished concrete is sand or aggregate. Thus if this is completely replaced with uranium oxides, and we ratio container weights in the recommendation (a DUCRETE container weighs 100 tons and a standard concrete container weighs 130 tons),

Option 2 - None.

Option 3 - Prior to converting dUF_6 directly to uranium metal, the potential market for the end product should be evaluated. The annual capacity for U metal production by the two current U.S. producers (Nuclear Metals Inc. (NMI) and Aerojet Ordinance Tennessee (AOT)) from depleted UF_4 has been estimated to be about 7000 tonnes (IP#3, pg. 4). Any process having the potential to double this capacity would significantly impact the market. If the market cannot absorb the new production, the uranium price would drop precipitously, and/or the material would have to be stored long-term or disposed of. Disposal, though requiring less volume than U_3O_8 , would either cost about the same as disposal of U_3O_8 , or could be more expensive if only a deep burial option is available.

The RFR states that the metal product would be useful as feedstock for the AVLIS process, especially the depleted uranium having a U_{235} assay of 0.4 to 0.5 percent. We were told at the February 28, 1995, meeting that the assay of the dUF_6 was 0.2 to 0.3 percent U_{235} . Thus, unless determined otherwise, little of the produced metal would be useful for this purpose.

Option 4 - None.

7.1.4.6.4 Evaluation by Reviewer Y

It is conceivable that relatively small amounts of Ducrete might be used to detune civil concrete structures for seismic waves (e.g., something like optical interference filters). Any material other than conventional concrete might be used but the potential high density of Ducrete makes it most desirable if its long-term behavior is demonstrated.

7.1.4.6.5 Evaluation by Reviewer Z

The option of using depleted uranium for the production of energy storage flywheels would require additional evaluation. A factor to consider is the regulation under 10 CFR 40.22 which grants a general license to commercial and industrial firms for the possession of 15 pounds of uranium for research, development education, commercial operational purposes. Amounts of uranium in excess of 15 pounds require licensing by the Nuclear Regulatory Commission. Regulatory changes may be required for specific applications which would allow the possession of amounts of uranium in excess of 15 pounds for specific purposes.

7.1.4.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.4.7.1 Conclusion by Reviewer U

Option 1, 2 & 3 - DUCRETE structures that serve a valuable shielding function as a component of the high level waste disposal repository should be given consideration. Using DU aggregate in concrete may be appropriate for structures within low level radioactive waste disposal sites. DUCRETE structures for utility site storage of spent fuel or for multipurpose transport and storage containers for spent fuel do not appear to be promising applications. General application of DUCRETE for shielding structures is not attractive because of the need for eventual disposition and the perceived difficulties of contamination control when the structures are built and eventually removed.

Energy storage flywheel technology is in early phases of development. The high density of uranium metal provides an attractive attribute. However, composite material containment of the uranium and the potential perceived safety aspects with the use of uranium in vehicles are difficult hurdles to overcome. Only applications for stationary energy storage flywheels should be considered and the timing for such applications is unknown.

Using DU as feedstock for AVLIS enrichment steps may be appropriate within a time span of one to two hundred years when the available low cost natural uranium ore resources are depleted. Such use does not appear appropriate within the next few decades.

Development of plasma technology for conversion of DUF_6 to metal should be pursued if a demand for uranium metal is identified. The technology is not developed to a point where it could be relied upon as a commercial process in the near term.

The organization making the recommendation in Document #4 is devoted to research and the development of nuclear technology.

Option 4 - This option of converting DUF_6 to U_3O_8 and AHF is reasonable, acceptable and the Federal regulatory requirements are understood. Most of the process steps are well defined. Operation of a pilot demonstration of the steps to provide AHF and the processing of waste streams should be performed to provide the final information needed to assure an effective commercial plant operation. Since the value of the marketable AHF is less than the overall cost of recovering it from UF_6 , there is a net added cost. Conversion of DUF_6 to U_3O_8 should only be performed if a determination is made that continued storage of DU as DUF_6 is not satisfactory.

The concept of final disposal of DU as U_3O_8 will take considerable time to obtain the necessary national acceptance and approval to proceed with final disposal. It does not appear to be resolvable within a near term period. Permanent disposal of DU should not be undertaken for a period of a century or more, not until a decision is made that DU is not needed in the future as an energy resource.

The organization making the recommendation in Document #4 is devoted to research and the development of nuclear technology. However, no one has a reasonable handle on the overall requirements and approach to siting and obtaining approval for a large volume nuclear waste disposal facility within the U.S.

7.1.4.7.2 Conclusion by Reviewer V

Option 1 - Based on DOE criteria, the use of Ducrete as advanced nuclear shielding material is a reasonable option. Further development under the auspices of DOE is underway to provide more solid information on the technology operating at the commercial scale. Cost is the key area of concern, particularly the life cycle cost.

Option 2 - Based on DOE criteria, the use of uranium metal to produce flywheels would not be a reasonable option on its own. The volumes of metal required do not seem likely to require large amounts of DUF_6 . If, in combination with other dense material applications or through the development of broader markets, this application would consume more of the inventory, it could be considered. Further development may be appropriate to provide more solid information on the technology. Cost is the key area of concern, particularly the life cycle cost.

Option 3 - Based on DOE criteria, the plasma reduction option would be considered reasonable if it were more technically mature. Further development may be warranted under the auspices of this or other DOE programs, and it may be included in the implementation program at a later date. More solid information is needed on the technology operating at the pilot scale and its characteristics in commercial operation. Cost data needs verification. At this time, it does not seem reasonable to include this option among the near-term solutions. The AVLIS process is more technically ready but is not limited to DU metal to begin operations. The U. S. Enrichment Corporation is proceeding with commercialization if AVLIS technology.

Option 4 - Based on DOE criteria, the conversion of DUF_6 to uranium oxides to be pelletized for disposal seems generally to be a reasonable option. It has the potential to dispose of all or most of the inventory, if required. The costs associated with this option are fairly high and should be carefully reviewed, but they appear to fall within the program limits. A key concern will be defining and locating an acceptable disposal site.

7.1.4.7.3 Conclusion by Reviewer X

Option 1 - If DUCRETE is found to be a stable matrix using either U_3O_8 or UO_2 , it should work well for spent fuel container use and provide an option separately from immediate disposal of the uranium oxide material. However, the manufacturing process, including raw material storage, will need to be completely contained due to the potential for dust creation and dispersal. Also, the containers themselves will require provision for venting of gases likely to be formed in the DUCRETE material from uranium decay and radiolysis.

Eventual disposal of used containers will require a fund to pay the cost when the time comes.

If a single container uses 60 tons of U_3O_8 , then 3500 containers will deplete about half the current inventory of dUF_6 .

This option will increase the cost of the containers due to the greater expense of managing the process because of the potential radiological hazards of the U_3O_8 . However, it will decrease the overall dUF_6 disposal cost by about \$.50 to \$2.50/kgU (according to projections in EGG-MS-11297). The cost of conversion shouldn't be considered in the cost of the containers since the conversion would take place anyway (assuming that a decision to convert is made). As a raw material, U_3O_8 has a lesser value than sand and crushed limestone. Also there will be value added to the containers themselves due to their smaller size and lighter overall weight, both of which will make handling and storage easier.

Option 2 - No market projections have been provided by INEL for the use of depleted uranium flywheels. A projection by AOT (RFR # 15) is less than 12,500 tons over a ten year period. Thus, this application will contribute to the disposition of depleted uranium metal from conversion of dUF_6 , but won't be a major factor by itself.

The increased cost for use of uranium metal over other materials will need to be offset by other factors such as the need for smaller components and equipment.

The ultimate lifetime of any uranium metal product produced will need to be considered. The proposed use for the metal is in the civilian community. Thus controls currently in place for military applications won't be appropriate in the new environment. Controls will be required to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices and regulations. This is a problem today with some materials. Since the proposed uranium metal applications require large masses of uranium, a requirement for stamping or engraving the disposal requirements into the finished product might be established.

Option 3 - This is an attractive process due to the lack of a waste stream. However, the conversion costs must be verified through further development and construction of a pilot plant.

The lack of a waste stream also is dependent on the existence of a market for the uranium metal. INEL proposes that the metal having a U_{235} assay of 0.4 to 0.5% be used as feedstock for the AVLIS process. However, it is this writer's understanding that the U_{235} assay of the dUF_6 in storage is 0.2 to 0.3%. Even if all the dUF_6 is used for feedstock, less than 10 percent would be consumed. Thus, other markets must be found.

Thus, before any process that produces uranium metal is selected, projections for the depleted uranium market should be developed. A full-scale effort that more than doubles the current U.S. capacity could adversely affect the market if uses for the additional uranium do not exist.

Option 4 - The INEL/SAIC report on conversion of the dUF_6 and disposal of U_3O_8 provides an upper bound on costs projected by several sources. Combining cost estimates from all sources thus produces a range of from about \$2.7 to \$7.8 billion.

The report also focuses on potential disposal at NTS in a near surface or surface facility. Such disposal would require considerable processing to lower the specific activity of the uranium. The INEL recommendation is to increase the bulk density of U_3O_8 from 2.7 to 7 gm/cm³, thus increasing its specific activity. The objective is to reduce disposal volume and costs by as much as 60%. However, this process will preclude near surface burial, even at NTS, and thus require deep disposal technologies to be considered. This latter conclusion is consistent with NRC's conclusion in NUREG-1484. Further, the disposal and transportation costs, both of which would benefit from decreasing the volume of material to be disposed, are considerably less than the cost of conversion. Thus, the emphasis should be placed on reducing the conversion costs.

7.1.4.7.4 Conclusion by Reviewer Y

All aspects of the option are reasonable (perhaps the flywheel option would not meet the "15%" criterion).

Most promising is the AVLIS technology, but its large-scale demonstration is lacking. If energy potential in DUF6 is discounted, Ducrete seems like a promising way to deal with large quantities of DUF6.

7.1.4.7.5 Conclusion by Reviewer Z

There appears to be a great deal of merit for the option of using depleted uranium in the production of DUCRETE. The option offers the advantage of providing better shielding with less weight and less volume. These will provide additional advantages in the handling, transportation and ultimate disposal of the high level waste, whether it be in a permanent disposal facility or monitored retrievable storage.

There is some possible merit in the option of using the depleted uranium for the production of energy storage flywheels. Evaluation of this option must include consideration of the changes in regulations, control of licensed material, and ultimate disposal of the product after its useful life.

There also appears to be merit in the option which proposes that the depleted tails be fed through the AVLIS process. Although this reviewer does not have information related to the efficiency and cost of operation of the AVLIS process, it appears that the efficiency of the AVLIS process is adequate to recover additional U^{235} sufficient to make the process cost effective. Also, the use of the plasma process for direct conversion of UF_6 to metallic uranium has merit in that it produces anhydrous HF, which has a readily available market, and it also appears that it will not produce other waste streams which will require disposition.

7.1.5 Evaluation of Document No. 9 (Independent Technical Reviewers' No. 5)

Reponent:

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201-455-3893

Description of Response:

This response recommends use of a conversion process patented by General Atomic, wherein the conversion of depleted uranium hexafluoride (UF_6) to triuranium octaoxide (U_3O_8) will produce anhydrous hydrogen fluoride, a commercially valuable product. Research and development of the patented process is defined as complete. Processing the 560,000 metric ton DOE stockpile over 15 years is stated to produce 190,000 metric tons of anhydrous hydrogen fluoride. The 12,667 metric tons produced each year is estimated to supply approximately 5% of the annual US market requirements. The respondent states that it would need Government financing in the amount of \$20 to \$50 million for construction of a demonstration plant. Private financing of a full scale production facility is possible if a long-term contract for reprocessing is executed with DOE. Construction of a production scale plant is estimated to cost between \$80 and \$100 million.

7.1.5.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.5.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into triuranium octoxide (U_3O_8) and the recovery of anhydrous hydrofluoric acid (AHF) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities at different sites. The process described in Document 5 is a reasonable expansion of technology that has been in operation for several decades in the U.S.. Basic concepts have been developed and used in conjunction with the conversion of natural uranium to uranium hexafluoride (UF_6) for the uranium enrichment step and the conversion of UF_6 to uranium dioxide (UO_2) at commercial nuclear fuel production plants. The unique component of the process as proposed relates to the direct recovery of AHF as an integral set of steps when the DUF_6 is converted to U_3O_8 .

U_3O_8 is a relatively inert chemical form of uranium (dry black powder or compressed cake) with low reactivity and low solubility. Long term storage of U_3O_8 should be acceptable within stainless steel containers. The U_3O_8 powder produced with the recommended process is a relatively fluffy powder and compacting by some means appears to be needed to achieve a higher density product for storage or disposal. A weather protection building would probably be required for storage of the containers of U_3O_8 .

The process as proposed recovers AHF, a material with considerable demand in the U.S. Pilot plant demonstration of the unique components would be required. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current storage sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades, and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system with minimal liquid steps or a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal

facilities or, for sufficiently clean materials, in sanitary land fill. Gas effluent streams may be scrubbed to remove noxious components.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities to process uranium compounds, including UF_6 . Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.1.5.1.2 Evaluation by Reviewer V

The option of reprocessing DUF_6 to produce marketable AHF and U_3O_8 for storage or disposal does not appear to present any insurmountable issues. The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air it can react to moisture producing HF acid and UO_2F_2 , both hazardous. The uranium is a toxic heavy metal that is quite hazardous. However, the reprocessing of DUF_6 also has environmental risks. The increased handling and operation of the processing facility raises issues regarding the potential for releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. The AHF , being hazardous and corrosive, will have its own set of handling, storage and transportation issues that again should not present unique or new technical issues.

In its favor, the process proposed in this option is not new, however, the scale at which it is to be applied may require additional attention to changes in the scale of design or operations to assure the highest level of safety, as in any first time commercial process. The permitting for environmental, health and safety issues is not expected to present problems, but again should be carefully thought through and checked in the material licensing process. Siting this large an industrial facility with hazardous materials should be careful planned to protect environment, health and safety in the surrounding community.

The processed U_3O_8 will require transportation and storage or disposal in quantities that are much larger than previously encountered. This will create risks for accidental releases of the material, however, they are less likely to present a large hazard due to the stability of this chemical form. Disposal would not present a problem technically, however, the availability of sites might be an issue requiring further development or design to make sites more acceptable in new locations. If the option proposed by the NRC for deep mine disposal is adopted, special precautions to protect groundwater will be needed. Storage of U_3O_8 would not present significant environmental, health or safety risks if designed in a manner similar to those in Europe where metal containers are housed in above-ground buildings. Accidental releases could adversely effect workers if they came in contact with the material, but its largely inert chemical form makes the hazard minimal. Releases to surrounding areas are unlikely.

7.1.5.1.3 Evaluation by Reviewer X

GA/ASI proposes to place the pilot plant in close proximity to the Paducah Gaseous Diffusion plant to minimize transportation concerns. They also propose that other potential sites would be on or near the other DOE production facilities.

Even though the ASI site in Metropolis, Illinois, is already licensed for handling raw uranium ore and UF_6 , GA/ASI would still have to obtain license approval for handling larger quantities of feedstock, and also for the U_3O_8 product. The licensing process will be subject to public hearings and comment, and is thus likely to be opposed.

7.1.5.1.4 Evaluation by Reviewer Y

These issues are minimized because adaptation of existing facilities are envisaged. Existing regulatory requirements are largely met or can be for less severe service conditions.

Long-term storage and/or disposal are not existing and presumably will require some E,S&H permits. LLW sites could be used but probably not cost effective.

Permits for the demonstration may markedly impact the schedule.

7.1.5.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. Warner and Mr. Rock proposes a private, joint venture between General Atomics (GA) Allied Signal Inc. (ASI) to process the depleted UF_6 through a patented process to convert the UF_6 directly to U_3O_8 and recover anhydrous hydrofluoric acid (AHF).

This options would not present any environmental, safety or health issues which are different that those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion.

The currently licensed ASI site, which is proposed for the pilot plant, meets current regulatory requirements. No other special siting requirements are anticipated.

7.1.5.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.5.2.1 Evaluation by Reviewer U

The DUF_6 conversion to U_3O_8 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. A limited volume of solids would be collected from processing and they may contain traces of uranium. Special purification steps could be performed to remove the uranium or the solids may be disposed of in low level radioactive waste disposal facilities.

There is no current use for separated depleted U_3O_8 . Possible use in Ducrete in the future may be achieved. The practicality of Ducrete is yet to be determined. Eventual disposition of Ducrete after the useful life of the structure constructed with Ducrete, may entail disposition in low level radioactive sites at a high cost.

With no practical use for the U_3O_8 at this time, it must either be stored or disposed of as a waste. To achieve lower overall volume and minimize the space required for storage or disposal, some means to achieve higher density of the powder appears to be desirable. The powder or compressed cake may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Final disposition may require deep underground disposal to satisfy safety regulations that are yet to be defined. Such disposal should be less demanding than disposal of high level radioactive wastes although considerable controversy is anticipated for the disposal of large quantities of depleted uranium as U_3O_8 .

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process discussed will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered

this way will require a small side stream operation for conversion to U_3O_8 . Chemical cleaned of empty cylinders may be sufficient to permit them to be scraped, melting and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites. Another use may be to cut the cylinders in half and weld flat end caps over the open ends to provide upright cylindrical storage containers for U_3O_8 .

7.1.5.2.2 Evaluation by Reviewer V

This option seems to have the benefit of recycling at least a part of the DUF_6 back into commercial uses. In addition, the process recycles flows within itself to minimize effluents, emissions and waste production. According to the flow diagram, O_2 is the only emission to the environment that would need to be reviewed. Careful review of the process should be made to assure that no water or thermal discharges are involved. The U_3O_8 waste stream seems to be relatively pure and may be capable of being handled at low level disposal sites using shallow burial. However, the NRC has recommended deep geologic disposal because of the waste volume involved, so the disposal of this material must be carefully considered. Additional uses for this material could be sought. It may be possible to use it in Ducrete or other products. Disposal alternatives for U_3O_8 need to be better defined, but the options that have been mentioned would not be likely to create significant wastes. Empty DUF_6 cylinders will need to be recycled or disposed of in an acceptable manner. U_3O_8 storage is not expected to generate any additional wastes except those associated with construction of the containers and buildings used to store it.

7.1.5.2.3 Evaluation by Reviewer X

No additional waste streams (other than U_3O_8) will be created in the GA/ASI process. The AHF will be sold in the commercial marketplace.

However, GA proposes to dispose of the U_3O_8 in a low level radioactive waste (LLRW) facility. Note that NRC has excluded near surface disposal as an option in NUREG-1484.

Considering the difficulty the several LLRW Compacts are having with obtaining enabling legislation in host states and siting these facilities, such an option is not likely to be available in a Compact facility. Also, DUF_6 is considered to be DOE waste under current law. It is not likely that states will allow this to become industrial waste in a transfer process to a conversion contractor. Thus, it will still need to be disposed of or stored as DOE waste.

Considering the situation in Ohio, it should be noted that the proposed Ohio facility will have both a time restriction of 20 years operation and a volume restriction of 2,250,000 cubic feet ($63,713 \text{ m}^3$), only about one-third the required volume for the current inventory of dUF_6 .

Illinois, the proposed state for the conversion plant site, has essentially restarted its LLRW siting process at Square One since it based its original process on a single volunteer site that has since been abandoned.

Several potential non-Compact sites are mentioned by GA/ASI. One of these is the Envirocare of Utah, Inc., site. However, this site has a limit on contained uranium in its waste of 110,000 pCi/gm, which according to NUREG-1484 is far less than the activity in the U_3O_8 waste stream from Claiborne (I calculate this to be about 300,000 pCi/gm, but it could be higher, depending on how you treat the numbers.). The NTS in Nevada is offered as an alternative ultimate disposal site. Its Waste Acceptance Criteria limits transuranic concentrations to less than 100,000 pCi/gm for consideration as LLRW (See EGG-MS-11297, pg. 33, with RFR #4). Thus, the U_3O_8 would need to be contained in some matrix, such as Ducrete. Also, Envirocare empties all containers. So the matrix must be stable.

ASI has a ready facility for recycling the anhydrous HF in its UF_6 production process. However, it didn't make clear the amount of AHF that would be used in this process, only that the total production of AHF would satisfy 5% of the U.S. market requirement.

GA/ASI state that no other waste stream will be produced.

7.1.5.2.4 Evaluation by Reviewer Y

The process, as defined, precludes significant waste streams.

Long-term storage of U_3O_8 in shallow pits seems an optimistic view for today.

NO SECONDARY WASTE STREAMS ENVISAGED.

Chemical purity to lead to commercial acceptance of AHF could lead to some unforeseen wastes. Similarly, pending U308 containers, impurities in U308 could impact container lifetimes resulting in waste.

7.1.5.2.5 Evaluation by Reviewer Z

The process proposed in this option is not anticipated to generate waste streams which are different in characteristics than what is currently seen at operating fuel cycle facilities.

The process would produce AHF, which is used by ASI in the production of UF_6 . AHF also has a ready market in the United States, and it is not expected that there would be an excess AHF to be handled as waste.

The proposal is to produce U_3O_8 to be suitable for disposal in either permanent or retrievable disposal areas.

7.1.5.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.5.3.1 Evaluation by Reviewer U

Since several elements of the process are currently in use within the U.S., the costs are reasonably well defined for both the processing plant and the operation. Since the processes for the direct recovery of AHF are yet to be demonstrated, the cost of this step is not well defined. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Since uranium enrichment activities are continuing in the U.S., the buildup of DUF_6 is continuing. Thus, after the DOE material has been converted, the facility may be used for conversion of DUF_6 generated by others. The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the DUF_6 , although the volumetric space would depend on the amount of compacting achieved with the powder. Rectangular containers of U_3O_8 would pack and stack in a space more efficient than the cylindrical containers of DUF_6 . The cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of U_3O_8 , while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of retaining the DU as DUF_6 , with conversion to U_3O_8 one hundred years

hence for disposal, may be considerably less than performing the conversion within the next few decades.

7.1.5.3.2 Evaluation by Reviewer V

The costs proposed for this option need careful consideration. The demonstration phase cost of \$20 to \$50 million over 2 to 3 years is a very high capital investment for the Government. An additional \$80-\$100 million will be needed to construct a production-scale plant capable of processing the inventory in 15-20 years. The costs will be far higher than the estimated costs of \$10 million/year for continued DUF_6 storage at existing sites. The option should be examined for potential cost sharing opportunities, especially in light of the extensive use of existing equipment. If DOE is to fund the entire development cost, it should share in the future financial benefits from the plant.

For the commercial plant, careful examination of costs should be made. At \$2.20 per kg UF_6 processed, the facility would receive over \$1.2 billion to process the inventory. This would exceed the potential costs to store the material as DUF_6 and would still leave a disposal or storage site that would need to be managed indefinitely into the future. The cost for disposal could range from \$170 to \$658 million. The costs for storage are not identified, however, construction of buildings to store the current inventory of DUF_6 is \$360 million. U_3O_8 storage in buildings should be in the same general range or less due to the decreased volume. The overall revenue streams associated with all potentially saleable byproducts need to be identified and the long-term costs to government adjusted appropriately.

7.1.5.3.3 Evaluation by Reviewer X

GA/ASI claim that a pilot plant could be constructed and operated for about \$4/lb of dUF_6 . They further claim that a production plant would operate at a substantially lower price, estimated to be about \$1.00/lb of dUF_6 . However, it's not clear what fraction of this is for U_3O_8 waste disposal, which they claim will be in a LLRW disposal facility (See above discussion).

If long term above ground retrievable storage in accordance with DOE regulations is required, the cost will be about \$0.75/lbU (Ref IP C2, pg. 6). Thus, even after converting the dUF_6 to U_3O_8 , the long-term storage cost cannot be averted.

The projected costs are significantly less than \$5 billion. However, to substantially reduce the total quantity of dUF_6 during a period of continued production, a larger plant than projected will need to be built. While a larger plant should not increase the unit costs, the initial capital costs, and thus financing costs will be higher than projected. According to GA/ASI projections, capital costs are about 10% of the total costs.

Since GA/ASI have considerable experience handling dUF_6 and AHF, their cost estimates are likely to be accurate. However, since a pilot plant has yet to be built and operated, their methodology for arriving at the proposed figures should be carefully scrutinized prior to acceptance.

7.1.5.3.4 Evaluation by Reviewer Y

These are detailed in the proposal and seem a bit on the high side. Program seems stretched out? Facility operating factors (e.g., one- or three-shift operations) will impact. AHF cost recovery seems reasonable, but it may be the "tail wagging the dog." However, AHF cost recovery is predicated on commercial acceptability (e.g., no Uranium impurities). This assurance, not assured at this time, could cost money beyond cited costs.

7.1.5.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative.

7.1.5.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.5.4.1 Evaluation by Reviewer U

The chemical process requirements for the production of U_3O_8 are reasonably well defined since many steps of the process have been in operation in the U.S. on a relatively large scale for several decades. Technical maturity is considered to be sufficient to achieve a highly reliable operation. It will be necessary to construct and operate a pilot plant to prove out some of the details of converting aqueous HF to AHF. A relatively small amount of research and development appears needed to finalize process design.

7.1.5.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. The potential for additional uses for the waste streams and products needs development but should not inhibit the immediate adoption of the option. Some uncertainty must be attributed to the commercial scale operation. There is more regarding the cost to operate the plant. Some uncertainty regarding storage or disposal techniques still exists.

7.1.5.4.3 Evaluation by Reviewer X

The proposed patented process has only been tested in the laboratory to verify the reactions. A pilot plant is proposed to prove the process on a commercial scale. Equipment for the process is available from the Sequoyah Fuels Corporation in Gore, Oklahoma, commercially, or is based on equipment currently in use for dUF_6 production.

7.1.5.4.4 Evaluation by Reviewer Y

Conceptually and experimentally, this makes sense. There will be new problems in scaling to the demonstration. Conventional confining materials can probably be used,

Large scale will require new vigilance on product and process quality.

Two to three years may not be enough for a demonstration. Large-scale design can be initiated before demonstration is complete.

U308 is the preferred choice for storage because "other chemical forms...have been evaluated by DOE and found to be less desirable..." An energy balance is conspicuous by its absence. This might make other forms of DU more interesting for potential future use.

7.1.5.4.5 Evaluation by Reviewer Z

The technology proposed for the implementation of this option is a new technology which has not been tested. This reviewer is not aware of the status of the laboratory scale testing.

7.1.5.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.5.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low temperature and low pressure and the amount of material within the process inventory at any particular time is relatively small. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small. One step of concern is the vaporization of the DUF_6 from old cylinders that may have experienced age deterioration. Special precautions should be established to contain any material leakage from this step.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a new conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.5.5.2 Evaluation by Reviewer V

The project seems likely to have positive economic benefits for the local economy around the site. Economic impacts from construction of a production facility costing \$80 to \$100 million could ultimately be two to three times the amount of the capital costs. To the extent that labor and materials are purchased in the local economy, a major effect could be seen in a rural location. During operation, the creation of a large number of highly skilled jobs would have a positive effect on disposable income in the immediate area and would create secondary service jobs. Ongoing purchases of materials and services for operation would also improve the local economy. Construction of storage or disposal facilities could also have positive economic impacts, but the impact of their operation would be minimal.

Siting could be a significant public acceptance issue. Even in locations where processing, storage or disposal facilities are already in operation, growing concerns about the project specific and cumulative effects of such facilities could prolong or endanger the permitting process. The NRC permitting process as well as state and local reviews that would be

necessary for this option must be seen as potential barriers to implementation. If a new low-level disposal facility were required, additional siting time and effort would be required. Where possible, existing sites should be used to minimize the costs required to permit, including Federally-owned sites.

Transportation risks might also be a significant factor inducing public concern. If DUF6 is to be transported in large quantities for the first time, and the AHF and U_3O_8 then transhipped to other locations, the number of vehicle trips and potential for accidents will be increased. Questions are already being raised about radioactive shipments in certain areas and at certain times because of high traffic volumes. Within the immediate vicinity of the processing activities, the communities may have serious concerns regarding transportation safety and impacts on roads.

The land use implications for this option could be significant. The processing facility would be a large industrial site. Even if it is located on an existing site, the increased intensity of use could present problems. Similarly, the cumulative effect of the additional land required for disposal somewhere in the country must be evaluated in light of other demands for disposal capacity.

7.1.5.5.3 Evaluation by Reviewer X

GA/ASI state that a fully trained work force is available at the Metropolis site. Thus, should the UF_6 production mission be scaled back, the proposed plant will provide continued employment for current workers, and local job stability.

7.1.5.5.4 Evaluation by Reviewer Y

No large overall impact on employment. The good news is there are people trained in the technologies available at most probable sites, presumably they live in the "neighborhood," facilitating local acceptance. The projected New Mexico facility would provide some new employment in an economically depressed area.

7.1.5.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.1.5.6 Evaluation Factor Six - Other factors

<p>. Add any other information believed to be pertinent to the feasibility of the submission.</p>

7.1.5.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to

store the material in a retrievable manner for a few hundred years, either as DUF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 with associated impacts.

7.1.5.6.2 Evaluation by Reviewer V

See General Comments.

7.1.5.6.3 Evaluation by Reviewer X

None.

7.1.5.6.4 Evaluation by Reviewer Y

This proposal is quite well developed. Product quality is a "sleeper" on cost and acceptability. AHF from DUF_6 in the refrigerator next to food may take some doing! This DU308 is not in the national interest when there is potential for using DU metal or DUO_2 as an energy source in the future.

7.1.5.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.1.5.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.5.7.1 Conclusion by Reviewer U

The option of converting DUF_6 to U_3O_8 and AHF is reasonable, acceptable and the Federal regulatory requirements are understood. Many of the process steps are well

defined. Operation of a pilot plant for AHF recovery would provide the final information needed to assure an effective commercial plant operation for the steps to recover AHF. Since the value of the marketable AHF is less than the overall cost of recovering it from DUF_6 , there is a net added cost over the current storage mode cost base. There is no practical use for the U_3O_8 , and it will need to be stored until a decision is made that DU is not needed as a potential energy resource. Conversion of DUF_6 to U_3O_8 should only be performed if a determination is made that storage of DU as DUF_6 is unsatisfactory.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the overall volume. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued. In all cases, the approach should be to seek recovery of useful and valuable by-products.

The organizations submitting the recommendations in Document #5 are well experienced and competent in the processing of uranium, UF_6 and AHF.

7.1.5.7.2 Conclusion by Reviewer V

This option seems reasonable with regard to DOE guidelines. The costs are within bounds and the technology would be operational to meet processing deadlines for inventory disposal. The main concern is the cost of storing or disposing of the U_3O_8 after processing. This could increase overall program costs but provide significant environmental and economic benefits in the long run over continued DUF_6 storage.

7.1.5.7.3 Conclusion by Reviewer X

The proposed process is reasonable in that it has been proven in the laboratory and is stated to require only proven technology in a commercial plant. However, this has yet to be proven in operation of a pilot plant. The proposed commercial plant would deplete the current inventory in 15 years.

The waste stream will consist only of U_3O_8 . Disposal options for the U_3O_8 haven't yet been determined. GA/ASI proposes to dispose of it as LLRW. But this reviewer doesn't consider this to be a viable option. The total volume also hasn't been determined since the final disposal matrix hasn't been determined. The most conservative projection is that it will need to be stored in the same manner as dUF_6 is currently stored. The main advantage of the process is that U_3O_8 is considerably more stable than dUF_6 .

The projected costs are well within the guidelines for reasonableness. Except for long-term storage or disposal, the cost is estimated by GA/ASI to be about \$1.00/lb of dUF_6 on a commercial scale. Long-term storage requirements could double this cost.

7.1.5.7.4 Conclusion by Reviewer Y

The proposal is reasonable IF the objective is to make U_3O_8 .

Costs seem soft as is the schedule. However, the demonstration cost range is reasonable and with no unforeseen market blunders an early commercial product (AHF) could emerge. Provision for ultimate long-term energy use of U_{308} should be honestly stated vis-a-vis energy required to turn U_{308} to UO_2 , UC or U metal.

7.1.5.7.5 Conclusion by Reviewer Z

This option has a great deal of merit, and should be considered. This option has the potential for converting large amounts of depleted UF_6 to a more stable form for use in other applications, for long-term storage, or for burial. This option includes the conversion of the material to a more stable, less chemically reactive form, and suggests a final disposition for the U_3O_8 would be burial in either permanent or retrievable disposal areas.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form, or that will be disposed of in burial areas.

7.1.6 Evaluation of Document No. 10 (Independent Technical Reviewers' No. 6)

Respondent:

Mr. Frank A. Shallo
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Description of Response:

This response recommends construction and operation of a conversion facility for long-term storage in the form of triuranium hexafluoride (U_3O_8) and the recycling of hydrogen fluoride into the United States commercial market.

7.1.6.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.6.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into triuranium octoxide (U_3O_8) and aqueous hydrofluoric acid (HF) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly several smaller duplicate facilities. The process described in Document 6 has been in operation for several years in France. Thus, it is fully developed and would require very little additional development. Major issues of concern with the proposed process have been defined and addressed in France.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder or compressed cake) with low reactivity and low solubility. The U_3O_8 powder produced with the process is relatively low density and some means of compacting appears to be desirable to achieve a lower overall volume. Long term storage of U_3O_8 should be acceptable in stainless steel containers. A weather protecting building would probably be required for container storage.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as recommended recovers the HF as aqueous HF. There is a limited market for this form in the U.S.. To recover anhydrous HF, a material with greater demand, the process would need to be augmented. This change appears manageable. If converted to AHF it could be sold and transported as a commercial chemical. However, if a lower cost operation results in trace amounts of uranium, then it may be appropriate to allocate the HF for use in the conversion of natural uranium to UF_6 prior to the enrichment step. The recommendation does not indicate the efficiency of recovering the fluorine, or whether a portion of the fluorine is discharged in some other chemical form. Additional process details are required to determine the content of all waste streams.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of UF_6 has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is an on-going step of the nuclear fuel supply industry. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be stored on the surface at the present locations of the DUF_6 .

The conversion process is amenable to a closed liquid system with no requirement for dispose of liquid effluents—however, the recommendation does not indicate that to be the case.. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or for sufficiently clean materials in sanitary land fill.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the

facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.1.6.1.2 Evaluation by Reviewer V

The option of reprocessing DUF_6 to produce U_3O_8 and an aqueous HF byproduct for long term retrievable storage does not appear to present any serious issues. U_3O_8 is a far more stable form of uranium for storage, with the chemical largely inert and insoluble in typical ambient storage conditions. Once converted, it would pose far less risk to workers and the public than DUF_6 . The reprocessing of DUF_6 has environmental risks, however. The increased handling and operation of the processing facility raise issues regarding the potential for releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation.

In their favor, the processes that would be used are well known and in commercial operation in France. The scale at which the operations would be carried out would be similar. The processes are similar to fuel preparation processes in the U.S., so that worker safety procedures could be easily developed and implemented. The siting for this processing facility could present an issue for development. It is estimated that 2.5 to 4.0 km^2 might be needed for such a facility. This is a large industrial site and would raise environmental and public health questions depending on the location. Use of an existing site at one of the current storage facilities might minimize siting issues. The permitting for environmental, health and safety issues is not expected to present problems but again should be carefully thought through and checked in the material licensing process. With more than a decade of operating experience, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility.

Aqueous HF is very hazardous and corrosive and has its own set of handling, storage and transportation issues that, while not unique, will require attention if markets for the material cannot be found. Depending on the processing location, the processed U_3O_8 may require transportation and special storage conditions. Long term storage in steel containers in metal frame buildings is used in France with no apparent problems. Because U_3O_8 has a higher specific gravity, its storage volume is greatly reduced. Storage of U_3O_8 would not present any significant additional environmental, health or safety effects. It is much more chemically stable, so the potential for worker or public health effects discussed are diminished.

The availability of disposal sites might be an issue requiring further development or design to make sites more acceptable.

7.1.6.1.3 Evaluation by Reviewer X

Cogema makes the point that U_3O_8 is the most inert chemical form of uranium, making it the best choice for long-term retrievable storage or disposal.

The proposed technology is in use in France. Thus the issues of worker safety and emissions affecting public safety have been addressed and demonstrated to be manageable. NRC in NUREG-1484, determined that any radiological releases from an enrichment facility using UF_6 feedstock would result in doses to the public that are small fractions of applicable limits and of the dose received from natural background. Since a dUF_6/U_3O_8 conversion would employ similar containment technology, a similar impact study would probably result in similar findings.

The question of HF emissions, however, was not addressed in NUREG-1484. Thus, this question needs to be analyzed. This is of particular interest because any plant dealing with radioactive materials will need to be safer than an operating non-radioactive materials chemical plant in order to satisfy public concerns. NUREG-1391 states that the primary concern with an HF release would be damage to the respiratory tract, which could lead to death following massive exposures. What is the operating history of currently operational chemical plants that produce HF?

IP#1 states the non-condensable gases released during the process to the atmosphere contain less than 3 ppm of HF. This should be stated in terms of EPA allowed release concentrations, expected atmospheric dilution, and the effect of such concentrations on the environment and public health.

The currently operating plant is in France. If UF_6 is to be shipped to France for processing and conversion, and U_3O_8 back to the U.S., then transportation risks over the seas will require consideration.

If the conversion plant is to be built in the U.S., shipment of full UF_6 cylinders to the plant, and shipment of product will need to be considered. These have been evaluated in NUREG-1484 also, and the accident risks are reported to be nearly inconsequential.

Since the market for aqueous HF is in Europe, transportation safety for both land and sea shipment should be considered.

7.1.6.1.4 Evaluation by Reviewer Y

This experience-based proposal seeks to provide the most inert form of DU as U_3O_8 . Is the most inert form necessary to assure environmental, safety, and health? There is no domestic market for aqueous HF, therefore would an ancillary process to produce anhydrous HF be needed? No unusual issues in this category are anticipated beyond regulatory licenses and worker safety provisions. Public safety can only reasonably be impacted by transportation requirements.

7.1.6.1.5 Evaluation by Reviewer Z

Mr. Shallo proposes that the depleted uranium hexafluoride be converted to U_3O_8 for safe long-term storage, pending future decisions concerning reuse or disposal, and that the aqueous HF be recycled into the U.S. commercial market. As stated in Mr. Shallo's letter, this is a process which is currently operating on a commercial scale in Europe. Specific issues related to operations, transportation, and handling are well understood. Current incentives to contain material, to minimize effluents, to recover and recycle waste, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experienced to date.

7.1.6.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.6.2.1 Evaluation by Reviewer U

The DUF_6 conversion to U_3O_8 and HF should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

There is no current use for separated depleted U_3O_8 . Possible use in Ducrete in the future may be achieved. The practicality of Ducrete is yet to be determined. Eventual disposition of structures made from Ducrete may require elaborate disposal control and disposition at a prohibitively high cost. With no practical use for the U_3O_8 at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Disposal of U_3O_8 in underground repositories may be required for effective long term disposition with an indeterminate cost at this time. The task should be much easier and less contentious than the current problems associated with high level waste disposal. Disposition should be at a dry site or one that is impervious. Returning the U_3O_8 to the original uranium mines has been suggested. This does not appear practical since most of these mines are wet sites in sand stone rock formations that are quite pervious.

There is limited demand for aqueous HF. Thus, it would be a highly toxic material that would require strict storage or disposal as a toxic waste. However, if converted to AHF it should be marketable.

A special effort will be required for emptying, cleaning and disposing of the DUF_6 storage cylinders. The recommended process removes nearly all of the DUF_6 from the cylinders. However, a small amount will remain in the cylinder as a heel that must be removed by washing the cylinders. Conversion of material recovered this way may be achieved as a slip stream into the main process at some point or it may require a separate side stream process. Cylinder cleaning should be sufficient to allow the metal to be recycled, melted and used for other metal applications. If cleaning is insufficient to permit recycle, the cylinders may need to be disposed of at low level radioactive waste sites. Alternately, the cylinders may be modified and used as storage containers for U_3O_8 .

7.1.6.2.2 Evaluation by Reviewer V

This option would have no major waste streams if the aqueous HF could be recycled back into commercial uses. The process itself has no liquid effluents and minor air emissions. According to the information provided, the only emissions to the environment would be small amounts of HF (3ppm) and insignificant traces of uranium particulate. Careful review of the process should be made to assure that no other discharges are involved. The U_3O_8 waste stream seems to be relatively pure and capable of being placed in retrievable storage as suggested in this option. As uses for U_3O_8 are developed, it can be removed from storage and recycled into products or other uses. No significant additional wastes would be created by storage. If disposal of U_3O_8 is chosen, then appropriate licensed sites would need to be located, but no significant increase in wastes would be generated. The original storage cylinders for the DUF_6 will need to be recycled into some other use or disposed of after conversion.

7.1.6.2.3 Evaluation by Reviewer X

A principal advantage of the proposed conversion method is that no hazardous materials are involved other than the feed stock and end product. Thus, no intermediary hazardous wastes will be produced. The HF end product may be sold as a commercial product, and the U_3O_8 may be stored, used, or more safely disposed of than the feedstock.

Further, since the only additional required process chemicals are water and hydrogen, the effect on the environment to obtain them will be minimal.

A market for aqueous HF must either be created in the U.S. or the aqueous HF product must be shipped to Europe to avoid an additional waste stream.

7.1.6.2.4 Evaluation by Reviewer Y

This is the extreme process for creating waste. Extraction of useful material from U_3O_8 would require considerable energy. This could be avoided by creating DUO_2 that is

somewhat more active chemically but still essentially stable. The potential for recycle is high, but at unreasonably high cost.

7.1.6.2.5 Evaluation by Reviewer Z

This option would produce U_3O_8 and aqueous HF. Due to the limited market for aqueous HF in the United States, this could lead to a waste disposal problem with aqueous HF in excess of the amount required to fulfill market demands.

7.1.6.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.6.3.1 Evaluation by Reviewer U

Since this process is currently in use in France, the costs are reasonably well defined for both the processing plant and the operation. Conversion of the recovered aqueous HF to AHF is the only means to achieve a salable product from the operation and this will be an added cost for the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

The operational and use period for the facility for the conversion of DOE material of about two decades may be a normal life of such chemical facilities. However, since uranium enrichment operations are continuing in the U.S., additional DUF_6 is being generated. Extended use of the plant may be achieved for conversion of this additional material. After the facility has reached full economic life, it would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the DUF_6 , although the volumetric space would be less and dependent upon the amount of compacting achieved with the U_3O_8 powder. Rectangular containers of

U_3O_8 would pack and stack in a space more efficient than the cylindrical containers of DUF_6 . However, the cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be required at an added cost for storing containers of U_3O_8 , while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of continued storage as DUF_6 for one hundred years and delayed conversion to U_3O_8 for disposal may be considerably less than performing the conversion within the next few decades. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes. However, the cost of final disposal is indeterminate at this time.

7.1.6.3.2 Evaluation by Reviewer V

The costs proposed for this option need much better characterization. The data on the French experience should be available in some form to make better projections of the potential in this country. At \$3.00 per kgU for conversion, this is far higher than the estimates of current costs for continued storage of DUF_6 at existing sites. If all 560,000 MT were converted at \$3.00/kg of DUF_6 , the overall cost of conversion alone would be about \$1.7 billion. This assumes credit for sale of aqueous HF to commerce which is not proven, but for which markets may be developed. This deserves additional research. To these costs must be added the cost of retrievable storage in appropriate facilities or disposal. This should require less space and monitoring than DUF_6 storage, but construction of storage buildings alone could cost several hundred million. Should the facilities be sited in more than one location, the costs may vary. Capital cost could be effected by the degree of public acceptance. Some costs may be associated with the disposal of the empty DUF_6 cylinders. Transportation costs at \$.10/per drum seem quite low. Disposal in deep mines or shallow burial on land, would add significant costs but probably would not exceed program limits.

7.1.6.3.3 Evaluation by Reviewer X

Cogema doubled its capacity from 10,000 MT/yr to 20,000 MT/yr in 1993. What was the cost of this increase, and what would it cost to double capacity again? IP#1 states that about 1000 acres is needed for a 4550 MT/yr conversion plant. Would it be linearly increased as capacity is increased? Cogema should be able to provide a projection. As plant capacity increases, do unit costs decrease linearly or do they stabilize?

Note that the Cogema plant capacity is equal to the amount of UF_6 projected to be produced annually in the U.S. with the current 100 reactor economy. Thus, a similarly sized plant would not reduce the total UF_6 on hand, but would merely maintain the total inventory.

The amount of aqueous HF produced by Cogema is 30% of Europe's current needs. A U.S. plant large enough to reduce the current UF_6 inventory would produce 60% or more of Europe's current needs. How does this compare to the U.S. need? What are the projections for future production requirements, especially with the concerns for future use of fluorocarbons? Any decision to adopt this option should include an analysis of these requirements. Otherwise, a potential exists for creating another waste product, and one that is possibly more hazardous than the current form.

Cogema recommends that the HF be recycled into the U.S. market. The feasibility of this should be investigated given that the primary market in the U.S. is for non-aqueous HF.

7.1.6.3.4 Evaluation by Reviewer Y

No detailed costs available in the proposal. It is likely that this option will require a few dollars per pound with small benefits from the sale of anhydrous HF. Essentially no R&D costs required. Other costs should become available if the option is on a "short list" based on experiences. A simple headcount of the COGEMA facility would serve as a partial check on their proposal. Is this to be a single- or multi-shift operation?

7.1.6.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. A general estimate may be derived from the commercial operation of the Cogema facility in Europe, however, since the market of aqueous HF in the United States is limited, consideration must be given to the fact that the aqueous HF produced may become a hazardous waste rather than a marketable commodity. There are significant costs associated with the purification and conversion of uranium to UF_6 . Depending upon the decision for ultimate disposition of the depleted uranium, a substantial cost may be incurred in the exercise of this option if the material is reduced to U_3O_8 and later converted to another chemical form.

7.1.6.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.6.4.1 Evaluation by Reviewer U

The chemical process requirements for conversion to U_3O_8 are well defined since the process has been in operation in France on a relatively large scale for a decade. Technical maturity is sufficient to permit its use with minimal research and development. Additional effort will be required to refine the approach of producing anhydrous HF instead of aqueous HF.

7.1.6.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. The potential for additional uses for the products show greater need for development. Commercial scale operation, is proven and could be implemented as soon as siting and permitting is completed. The best options for permanent disposal need to be determined. The NRC supports deep disposal, while less expensive shallow land burial is also receiving support.

7.1.6.4.3 Evaluation by Reviewer X

The Cogema plant has been in operation since 1984. Thus, the process is proven on a scale on the order of one necessary to reduce the U.S. inventory.

However, the Cogema plant in France is only half the capacity of a plant in the U.S. that would be necessary to actually reduce the current inventories with a continued production economy. Thus, two similar plants could be built. On the other hand, a single large plant would have the benefit of economies of scale if scale is technologically prudent.

7.1.6.4.4 Evaluation by Reviewer Y

This is a technically mature proposal if hard to retrieve material is the desired end product. The process is one approaching standard industrial practice. The regulatory process in France is different and a technology for dealing with this needs development for domestic operations. Seismic concerns have been considered for storage.

7.1.6.4.5 Evaluation by Reviewer Z

The conversion of depleted UF_6 is a standard industrial practice, with a commercial plant in operation. As such, this is considered to be a mature technology.

7.1.6.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.6.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to U_3O_8 and HF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure for much of the processing. High temperature (about 750C) is encountered in the pyrohydrolyzing step with only a limited amount of material at the elevated temperature at any one time. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small. Special precautions should be applied for the DUF_6 vaporization step to accommodate the aged cylinders that may have been weakened by corrosion.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a new locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.6.5.2 Evaluation by Reviewer V

The project would have positive economic benefits for the local economy around the site. Economic impacts from construction of a conversion plant would ultimately be two to three times the capital cost. To the extent that labor and materials are purchased in the local economy, a major effect could be seen in a rural location. During operation, the creation of a large number of highly skilled jobs would have a positive effect on disposable income in the immediate area and would create secondary service jobs. On-

going purchases of materials and services for operation could also stimulate the local economy. Construction and operation of storage facilities could have significant short term and minor long term impacts on the community.

Siting could be a significant public acceptance issue. Even in locations where processing facilities are already in operation, growing concerns about the project-specific and cumulative effects of such facilities could prolong or endanger the permitting process. The NRC permitting process, as well as state and local reviews that would be necessary for this option, must be seen as potential barriers to implementation. Similarly, if a new storage facility were required, additional siting time and effort would be required. Where possible, existing sites should be used to minimize the costs required to permit, including Federally owned sites. Disposal sites will also be a factor, however, the relatively low level of risk may make finding a suitable location easier.

Transportation risks might also be a significant factor inducing public concern. If DUF_6 is to be transported in large quantities for the first time, and the AHF and U_3O_8 are then transshipped to other locations, the number of vehicle trips and potential for accidents will be increased. Questions are already being raised about radioactive shipments in certain areas and at certain times because of high traffic volumes. Within the immediate vicinity of the processing activities, the communities may have serious concerns regarding transportation safety.

The land use implications for this option could be significant. The processing facility would be a large industrial site. Even if it is located on an existing site, the increased intensity of use could present problems. Similarly, the cumulative effect of the land required for storage must be evaluated in light of other demands.

7.1.6.5.3 Evaluation by Reviewer X

Because the currently operating Cogema plant is half the capacity needed for a U.S. effort, two plants could be built - for example, one at Portsmouth and one at Paducah. Such siting at the two sites where the bulk of UF_6 is currently stored would minimize the transportation concerns, and would provide continuing employment for the already trained work forces available from reduced enrichment activities.

7.1.6.5.4 Evaluation by Reviewer Y

The option will provide employment in depressed areas. Headcount information from COGEMA would provide insights.

It is unlikely that this is a public acceptance "plus" since the public does not distinguish between U308 and UO2 .

Obviously, a new plant of this magnitude would provide for significant regional development in a depressed area near currently retiring related facilities.

7.1.6.5.5 Evaluation by Reviewer Z

This reviewer has no specific information regarding the impact of this option on employment, public acceptance or local/regional development.

7.1.6.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.6.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.6.6.2 Evaluation by Reviewer V

See General Comments.

7.1.6.6.3 Evaluation by Reviewer X

None.

7.1.6.6.4 Evaluation by Reviewer Y

This option is commendable in that seismic concerns are addressed, although the necessity for U308 storage is doubtful. The cost of retrieving DU from DU308 is likely to approach the cost of creating DU308 from the DUF_6 . The ultimate overall economics of retrieving the DU from U308 would be a very long-term proposition that could not be considered until fossil fuel costs would be higher than if other options for storage are considered. Of course, more extreme environmental costs for lesser fossil fuel emissions could hasten retrieval time.

7.1.6.6.5 Evaluation by Reviewer Z

None.

7.1.6.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.6.7.1 Conclusion by Reviewer U

The option of converting DUF_6 to U_3O_8 and aqueous HF is reasonable, acceptable and the Federal regulatory requirements are understood. However, to achieve a marketable form of HF it appears necessary to modify the process to provide AHF.

Most of the process steps are well defined. Some development and demonstration appears needed to evaluate the conversion of aqueous HF to AHF prior to construction of a commercial facility. Since the value of the marketable AHF is less than the overall cost of recovering it from DUF_6 , there is a net added cost over the current storage mode cost base.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the overall volume. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued. In all cases, the approach should seek to recover useful and valuable by-products.

Conversion of DUF_6 to U_3O_8 should be pursued only if a decision is made that continued storage of DU as DUF_6 is unacceptable. DU should be retained in a retrievable form and considered to be a potential future energy resource.

The organization submitting the recommendation in Document #6 is well experienced and competent in the processing of uranium, UF_6 and HF.

7.1.6.7.2 Conclusion by Reviewer V

According to the DOE guidelines for reasonableness, this option is viable. It could be implemented easily within a few years and could handle the inventory within 20 years with no significant adverse environmental impacts. Its characteristics are known and technically mature, having been in commercial operation for more than a decade. This approach is

technically consistent with DOE's programs. The only question would be one of cost. At \$3.00/kg UF_6 processed, it would cost about \$1.7 billion to convert the existing inventory, if credit for aqueous HF sales could be achieved. Then, in addition, there would be storage or disposal costs. Total system costs should fall within the guidelines for reasonableness but should be carefully reviewed for accuracy.

7.1.6.7.3 Conclusion by Reviewer X

Cogema offers a proven process for conversion of dUF_6 to the more stable form of U_3O_8 , and the potentially salable aqueous HF byproduct. The primary concerns are whether the dUF_6 would be more valuable than the U_3O_8 in the future should a breeder reactor economy develop, and whether the aqueous HF will be salable in the U.S. If no U.S. market develops for the aqueous HF, then shipment to Europe or disposal of this hazardous material will be necessary.

At a conversion cost of \$3.00/kgU as dUF_6 , the cost of this process is within the reasonableness guidelines.

Since the process is already being used on a commercial scale in France, its implementation in the U.S. should be feasible except for the constraints of the public hearing process. However, a plant that will actually deplete the total inventory of dUF_6 while additional dUF_6 is being produced will have to be larger than the plant in France.

7.1.6.7.4 Conclusion by Reviewer Y

The option is reasonable on all counts except one. That relates to the cost of retrieving DU for energy production needs. Assuming that our society will ultimately use DU for energy production, it would be highly preferable to convert DUF_6 to UO_2 for long-term storage. On this basis, the option should be ruled out in favor of a similar cost option to produce UO_2 for long-term retrieval storage.

The option might also run into "Buy American" considerations. It does seem ludicrous for the country that developed this technology to go overseas for a debilitating solution.

7.1.6.7.5 Conclusion by Reviewer Z

This option has merit. It addresses the primary issue of reducing the volume of uranium hexafluoride and converting it into a much more stable form. The primary limitations are the production of large amounts of aqueous HF, which has a limited market in the United States, and the potential added costs associated with reducing the UF_6 to U_3O_8 without a decision regarding the ultimate disposition of the material. Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form, or that will be disposed of in burial areas.

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7.1.7 Evaluation of Document No. 12 (Independent Technical Reviewers' No. 8)**Respondent:**

Mr. Dennis R. Floyd
Manufacturing Sciences Corporation
3265 Fenton Street
Denver, Colorado 80212

303-237-8576

Description of Response:

This response recommends direct reduction of uranium hexafluoride (UF₆) to metal, by-passing the uranium tetrafluoride (UF₄) stage, by using a technique that involves reduction by hydrogen in a high temperature plasma. Metal from this process is stated as usable as radiation shielding for a universal containment system for spent nuclear fuel. Collaboration between the responder and Los Alamos National Laboratory (LANL) has led to refinements of the concept and detailed planning for the process's demonstration and implementation through a Cooperative Research and Development Agreement (CRADA). The responder would like to use this opportunity to solicit funds from DOE to support LANL's share of this effort.

7.1.7.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.7.1.1 Evaluation by Reviewer U

A unique approach for direct conversion from DUF₆ to metal using a plasma is suggested in Document #8 and a development program is outlined for the process. The potential advantage of producing uranium metal with a high temperature plasma compared to the well developed magnesium reduction process is significant and worthy of further development and demonstration if metal uranium components are in demand. The potential lower production cost and elimination of the large volume of slag waste makes the concept

appear attractive. However, the stage of development is insufficient to define whether the process will work at all and whether it is amenable to reasonable large scale operation.

High temperature plasma development has been a research curiosity for decades on a number of potential applications. The probability of success for large quantity conversion of DUF_6 to metal is indeterminate at this stage. Several research organizations have expressed a desire to proceed with the development of plasma conversion. A detailed evaluation of the alternate approaches should be performed to define which approach has the highest probability of success. Without a comparative assessment of the various approaches, a determination can not be made on whether to support the approach proposed by this recommendation.

A few of the basic areas of concern with high temperature conversion include; containment of the very hot plasma, controlling hydrogen in a dynamic high temperature process, containment of very corrosive hot AHF and control of hot fine particles of pyrophoric uranium metal.

Uranium metal fines are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium fines produced with the plasma process require protection from oxidation and would require close coupled melting, probably in an induction furnace, to permit casting of the metal into ingots. The uranium metal ingots may be stored in sealed containers for long term storage or processed further into a desired uranium metal product. This recommendation assumes a large need for depleted uranium radiation shielding applications in a universal container system for spent nuclear fuel.

Operational issues are unique with the high temperatures of a plasma and the cooling of large quantities of metal and AHF. Since the uranium is depleted, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers AHF, a material with considerable demand in the U.S. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport is an on-going step for natural and low enriched uranium in the supply of nuclear fuel. A site independent and away from the existing storage sites could be used with rail transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for disposal of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium metal could be stored on the surface at the present locations of the DUF_6 .

Highly skilled workers would be required for this challenging operation. Experience in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal processing could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations will require significant review to assure proper control of this unique processing technology.

7.1.7.1.2 Evaluation by Reviewer V

This option for the production of U metal would have greater environmental, health and safety risks than processes currently in use. The use of hydrogen and high temperatures increases the potential for leaks and explosions. While all the processes for converting DUF_6 to another form of uranium have the potential for radiological or toxicological risks, this advanced process has additional risks that will require a great deal of work in design, siting, operations, transportation and materials handling. A hydrogen facility will need to be located nearby or provided from offsite in some way. Conversion to a metal form would make the DUF_6 more stable for future use or disposal, making it environmentally safer but would increase the radiological hazard. Like all conversion options, the transport of DUF_6 to the site could entail certain environmental risks.

Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen. Careful siting and design taking into account public concerns about these facilities will be needed. According to

the material provided by the respondent, the plant would significantly reduce the quantities of low-level wastes produced by three-quarters. This would decreased the environmental hazards from transport and disposal of this material. There would be small new effluent streams that would need careful treatment to avoid public health and environmental issues.

7.1.7.1.3 Evaluation by Reviewer X

The proposed process uses large amounts of hydrogen in the presence of extremely high temperatures, thus requiring high quality engineering design, well qualified operating procedures and practices, and a well trained crew to preclude explosive operating conditions.

7.1.7.1.4 Evaluation by Reviewer Y

The option appears to provide environmental relief requiring minimal regulatory intervention. The safety issues are the conventional industrial ones supplemented only by the special nuclear materials designation of DU. Since the process is largely plasma based, runaways lending to major releases are highly unlikely, if not preempted.

7.1.7.1.5 Evaluation by Reviewer Z

Mr. Floyd proposes the reduction of depleted UF_6 to uranium metal utilizing reduction by hydrogen in a high temperature plasma system. It is proposed that the resulting uranium metal be used as radiation shielding in a universal containment system for spent nuclear fuel.

The environmental, safety and health issues associated with the reduction process would be similar to those encountered at other nuclear fuel cycle and chemical facilities. No new environmental, safety or health issues are anticipated.

The use of the uranium metal as shielding material for a universal containment system for spent nuclear fuel would present a series of environmental, safety and health issues, some of which are related to the use of the metallic uranium, others related to the storage of spent nuclear fuel.

The pyrophoric effects of metallic uranium must be considered in any application utilizing uranium metal. Additional concerns relate to the atmospheric and environmental dispersion of uranium oxides which may result from oxidation of metallic uranium which becomes exposed to the natural environment.

7.1.7.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.7.2.1 Evaluation by Reviewer U

Operation of plasma technology may permit the conversion of DUF_6 to metal without the production of magnesium fluoride slag. Development of this process is warranted if there is a demand for uranium metal. The extent of the waste is unknown at this point because of the preliminary nature of development of the proposed technology.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process discussed will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal of the depleted uranium remaining in the heels. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites.

7.1.7.2.2 Evaluation by Reviewer V

According to the data provided with the response, low-level wastes would be generated at 1/4 the rate of current metals production thus minimizing the wastes created in the process that would require disposal. The potential for recycling the HF would be beneficial if markets can be identified and the HF is provided in a commercial form. While this option will not have any major waste streams, it will have secondary wastes from air pollution control and other support activities, e.g. cylinder washing. The metal itself could become a waste stream unless acceptable uses can be found for the quantities that will be produced. The metal form will be a more efficient form for disposal, however, it would need to be placed in a specially designed facility for this type of waste.

7.1.7.2.3 Evaluation by Reviewer X

A stated advantage of this process is the elimination of all waste streams. The process produces only uranium metal and anhydrous HF for sale as a product.

If disposal of the metal is required, then additional processing will be required, and the costs will have to be reconsidered.

7.1.7.2.4 Evaluation by Reviewer Y

The process will markedly reduce waste at projected operating conditions. The metal that cannot be immediately used can be stored for future use at costs less than or similar to those at the present time for DUF₆. Possible alloying of the DU for applications and storage may produce small amounts of ancillary waste.

7.1.7.2.5 Evaluation by Reviewer Z

The option proposed is to convert the depleted uranium to a metallic form utilizing high temperature plasma. The final product is metallic uranium. The selection of this option would therefore produce large amounts of metallic uranium. The uranium metal would then be used as shielding material for spent nuclear fuel.

The conversion process itself would result in metallic uranium and anhydrous HF. A predetermined use has been proposed for the uranium metal, and if produced only in quantities required to fill the predetermined needs, then no waste material would result.

The plasma process proposed for the conversion of the UF₆ to metallic uranium would produce anhydrous HF as a byproduct. There is a relatively well established market in the United States for anhydrous HF, therefore, this should not become a waste stream.

If the uranium metal is used for shielding material for spent nuclear fuel, no additional waste streams are anticipated. If the uranium metal is used for other applications, each application would require individual evaluation.

7.1.7.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.7.3.1 Evaluation by Reviewer U

The cost of converting DUF₆ to uranium metal should be significantly lower with the plasma concept compared to the present process and it should eliminate the generation of large slag volumes. However, the actual cost of such an operation can not be defined until considerable development work has been completed. The cost estimate provided with the

recommendation may be a potential cost, but the stage of development is insufficient to accept such costs as definitive.

7.1.7.3.2 Evaluation by Reviewer V

The response identifies costs of \$10.5 million to construct a plant capable of processing 2.4 million lbs. of U metal annually. This would be the equivalent of about 3,000 T/year, using a very small portion of the existing inventory. Operating costs are expected to be \$2.6 million annually, or \$1.10 per lb. U processed. With credit for HF sales, this cost could be reduced slightly. These costs need to be verified as the process undergoes development. The cost of H₂ and electricity inputs should be carefully checked over time. The market value of U metal is sensitive to demand, so potential revenues deserve further assessment. The respondent notes that potential markets exist for the metal product in other DOE programs that will require large quantities of shielding material for spent nuclear fuel. This process would need to be scaled up significantly to be useful. Information must be collected on the real cost to DOE of this alternative. Some private sector interest in funding the research and development as well as commercial operations has been expressed.

7.1.7.3.3 Evaluation by Reviewer X

The costs projected by MSC in their submittal are internally inconsistent and significantly lower than costs projected by others, or that are reasonable for a plant of the physical size needed to handle the required production levels. MSC projects a full-scale plant capital cost of only \$10,525,000, and an annual operating cost of less than \$3 million. This is one-thirtieth the capital cost projected for the INEL plasma method (\$347 million), and 15 times less than the capital costs projected for improved dUF₆/U₃O₈ conversion plants. The operating costs are indicative of an operating, maintenance, and administrative crew of only 10 to 15 individuals.

Also, projected operating costs are based on the plant being on line 90% of the time during the year. This is a reasonable estimate for a production level facility if there are several independent plasma reaction trains in the plant so that the entire plant doesn't need to be shut down for maintenance. At least ten independent trains would be needed to assure this capacity factor.

The projected plant will produce 2,396,000 pounds of uranium metal per year. This production level would require 3,523,529 pounds, or 1,600 MT of dUF₆ per year of feedstock. This plant would require more than 330 years to deplete the current inventory.

The resulting operating cost is estimated by MSC to be \$1.10/lbU produced, or \$2.44/kgU. This projected cost does not include the amortization of development costs, pilot plant testing, or capital invested in the production facility.

The value of AHF produced is estimated to be \$54,972 for every 148 T of dUF₆, or 100 T of uranium metal. Thus, the sale of AHF represents a significant contribution to the overall savings from this method if the above cost projections are reasonable.

Finally, due to the highly explosive conditions that could exist if a process leak should occur, an added cost for safety systems and for training personnel should be included.

A major advantage of this process is the lack of a waste stream. Thus if a market exists for the resultant depleted uranium metal so that disposal costs associated with the metal are avoided, the only cost is that of conversion.

7.1.7.3.4 Evaluation by Reviewer Y

The costs are provided in some detail for both operations and capitalization. They seem reasonable but are probably on the low side considering the current stage of development. It is reasonable to discount the benefits of the commercial HF to reflect uncertainty on the total product costs. Even then, the projected costs are reasonable.

7.1.7.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, operating or maintaining facilities necessary to execute the options outlined in this alternative. Presuming AHF were recovered, it would have a commercial value.

7.1.7.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.7.4.1 Evaluation by Reviewer U

Direct conversion of DUF_6 to uranium metal with a plasma process will require considerable research and development to determine whether it is practical and to define operating characteristics and conditions. While conceptual work provides a favorable assessment, whether the concept will work for large quantities on a reliable basis and whether it will be practical are yet to be determined.

7.1.7.4.2 Evaluation by Reviewer V

According to the response, development and design of the full scale system could be completed within three years. Piloting would then begin. Background material in the information packages implies that this is a process still in early development. Significant

questions remain and a considerable period of time may be needed to be ready for commercial use at the scale required for this program.

7.1.7.4.3 Evaluation by Reviewer X

The process is currently in a laboratory analysis phase. It isn't clear whether actual tests have been performed or whether only computer modeling has been done.

MSC proposes to develop the process and construct a pilot plant in parallel. A three-year schedule has been provided, with the process demonstration to occur in the last half of the third year, and the pilot plant to be operational at the end of three years. If another three years are allowed for construction, a full-scale production plant could be operational within an additional five to six years.

7.1.7.4.4 Evaluation by Reviewer Y

The process seems technically sound, though requiring more than conceptual demonstration. The national laboratories, including LLNL and LANL, have much experience with large-scale new technology plasmas. On the downside, this is new technology requiring pilot scale demonstration that could be dovetailed with plant construction if time is of the essence.

The concept is very promising with reasonable development time if the work is well managed among the various participant groups. CRADAs have not generally covered themselves with glory.

7.1.7.4.5 Evaluation by Reviewer Z

The reduction of UF_6 to uranium metal using hydrogen in a high temperature plasma is a new technology. Laboratory experiments have demonstrated feasibility. Selection of this option would require pilot scale tests and full scale production facilities.

7.1.7.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.7.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. However, if the

operation is dependent on the use of uranium metal as radiation shielding components, up and down employment cycles would occur depending upon demand for the product.

Development of the plasma technology requires considerable research and if employed on a commercial basis, would require the construction of a new facility. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. Commercial nuclear material processing facilities will be viewed by the public with considerable interest and probably organized opposition to acceptance of such a facility in any locality.

Performing uranium processing operations at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

7.1.7.5.2 Evaluation by Reviewer V

The construction of a facility costing \$10.5 million and having \$2.4 million in operating costs is unlikely to have significant economic effects. If the project were scaled up to the 28,000 tons/year required to meet the inventory reduction goal, economic effects would become significant.

The siting of such a facility may face problems with public acceptance. Environmental risks of this new process would need to be carefully explained. There is likely to be close scrutiny of the public health risks and environmental effects. Traffic, including uranium transport, to and from the site will be examined. While the proportion of low-level wastes generated would be reduced, the overall quantity would contribute to an on-going problem. The LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.7.5.3 Evaluation by Reviewer X

A plant built near or on the site of an existing dUF_6 storage facility would employ workers that otherwise might be unemployed from a declining enrichment industry.

7.1.7.5.4 Evaluation by Reviewer Y

Significant employment benefits would result especially if the process can be more widely used for activities beyond those for DUF₆ conversion. Public acceptance about the same as with anything involving SNM.

7.1.7.5.5 Evaluation by Reviewer Z

This reviewer has no specific information on the socioeconomic impacts for the use of this option.

7.1.7.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.7.6.1 Evaluation by Reviewer U

A primary factor is the question of whether a demand for uranium metal radiation shielding components will be forthcoming. The universal containment system for nuclear spent fuel is being considered by those responsible for nuclear waste disposal. As indicated by the Memorandum from DOE dated December 19, 1994 by Williams, the amount of DU that could be used for this application is about 25,000 to 45,000 MT. The shielding requirements will be defined by the lowest cost approach to achieve shielding. There are materials other than depleted uranium metal that may be used for the shielding. Further development of the shielding requirements and a better definition for the cost of producing depleted uranium metal components are required before a reasonable estimate can be forthcoming on the practical use of uranium metal in this application.

7.1.7.6.2 Evaluation by Reviewer V

See General Comments.

7.1.7.6.3 Evaluation by Reviewer X

Prior to converting dUF₆ directly to uranium metal, the potential market for the end product should be evaluated. The annual capacity for U metal production by the two current U.S. producers (Nuclear Metals Inc. (NMI) and Aerojet Ordinance Tennessee (AOT)) from depleted UF₄ has been estimated to be about 7000 tonnes (IP#3, pg. 4). Any process having the potential to double this capacity would significantly impact the market. If the market cannot absorb the new production, the uranium price would drop precipitously, and/or the material would have to be stored long-term or disposed of. Disposal, though requiring less volume than U₃O₈, would either cost about the same as disposal of U₃O₈, or could be more expensive if only a deep burial option is available.

7.1.7.6.4 Evaluation by Reviewer Y

While developmental in nature, this technology seems like a good bet because of its reasonable time scale, reasonable cost, and minimal waste streams. It is not clear what BNFL brings to this party! Will "Buy American" be a problem?! An overseas CRADA may not be acceptable!

7.1.7.6.5 Evaluation by Reviewer Z

If more of the depleted uranium is to be transformed to a metallic state than what has been designated for a specific use, such as shielding material, the decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.1.7.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.7.7.1 Conclusion by Reviewer U

Development of plasma technology for conversion of DUF_6 to metal should be pursued if a reasonably large demand for uranium metal is identified (i.e., greater than 84,000 MT). The potential use in the high level radioactive waste program is considerably less than this amount. The technology is not developed to a point where it could be relied upon as a commercial process to produce uranium metal in the near term.

It does not appear desirable to convert DUF_6 to metal for long term storage or disposal. Uranium oxides are the preferred form, if a determination is made that continued storage of DU as DUF_6 is unacceptable.

The organization making the recommendation in Document #8 has experience in the production of depleted uranium metal components and it is cooperating with a very capable research organization on the development of the proposed plasma technology.

7.1.7.7.2 Conclusion by Reviewer V

It is difficult to assess the reasonableness of this option, because of the early stage of development. If the proponents' costs, timing and technical representations can be verified, and the process can be scaled up to handle a larger portion of the DUF_6 , then it deserves further consideration. The public acceptance of siting such a conversion plant

may be problematic. Overall, at this time it does not seem reasonable to include this option among the near-term solutions.

7.1.7.7.3 Conclusion by Reviewer X

The lack of a waste stream advantage of this process merits further consideration. However, significant cost and capacity questions exist in the MSC proposal. Since the process is effectively in the conception stage, considerable research will be required to prove its viability. Due to the time required to complete these studies, the potential for cost savings, and the relatively low cost of the laboratory studies, consideration should be given to funding the study.

With a three-year period projected for completing process development and building a pilot plant, time to bring a production level plant on-line should be less than ten years.

MSC, however, is proposing a plant that would deplete only about 10% of the existing dUF_6 over the next 30 years. Thus, for the process to be truly viable, a much larger plant would have to be built. Also, the projected capital and operating costs for a production facility appear to be too low. These should be refined and resubmitted.

Finally, before any process that produces uranium metal is selected, projections for the depleted uranium market should be developed. A full-scale effort that more than doubles the current U.S. capacity could adversely affect the market if uses for the additional uranium do not exist.

7.1.7.7.4 Conclusion by Reviewer Y

A good bet that provides flexibility in use for the future. Even if cost estimates are low, total cost seems reasonable with product flexibility.

7.1.7.7.5 Conclusion by Reviewer Z

There appears to be some merit in the direct reduction of UF_6 to metallic uranium. The option offers the advantage of conversion directly to metallic form, thereby eliminating several steps in the reduction process. It also eliminates the possibility of several waste streams.

One primary consideration in the selection of this option is the final use or disposition of the uranium metal. If a use is designated, such as shielding material for spent nuclear fuel, and excess amounts of uranium metal are not produced, then the application appears desirable. Selection of this option must be based on satisfactory completion of laboratory testing to verify viability on a production scale.

If a final use or disposition for the uranium metal is not determined, this option will produce metallic uranium which has unique storage and handling problems due to the pyrophoric nature and oxidation characteristics of the metal. Also, the reduction of the

uranium to metallic form could prohibit the economical use of the material in other applications at a later time.

7.1.8 Evaluation of Document No. 13 (Independent Technical Reviewers' No. 9)**Repondent:**

Mr. Patrick F. Brown
113 Columbia Drive
Oak Ridge, Tennessee 37830

615-483-1774

Description of Response:

This response recommends that DOE do research on direct conversion of UF_6 to fluorine compounds and uranyl nitrate and on low cost isotope separation of uranyl nitrate solutions. It also suggests DOE and a consortium cooperatively designing and building a prototype breeder reactor. The respondent suggests several possible applications: processing and conversion of depleted UF_6 to a beneficial form (i.e., fluorine compounds and uranyl nitrate); conversion of ^{238}U to an innocuous oxide and storage for use of future generations in producing breeder reactor electricity; and recovery of the ^{235}U that remains in the depleted uranium.

7.1.8.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.8.1.1 Evaluation by Reviewer U

Option 1 - The recommendations in Document #9 indicate three potential uses of the depleted uranium hexafluoride (DUF_6); 1- recovery of 150,000 metric tons of fluorine, 2- converting 400,000 metric tons to an innocuous uranium oxide and store for use in future breeder reactors, and 3- recovery of 800 metric tons of uranium isotope-235 for current nuclear fuel.

While no specific defluorination processes are included in the recommendation, the objective indicated is to produce a valuable fluorine compound at low or reasonable cost. The recommendations call for DOE to contract with a fluorine manufacturing company to convert the DUF_6 to produce a salable fluorine product and uranyl nitrate.

The uranyl nitrate would then be processed through emulsion phase contactors to achieve recovery of the uranium isotope-235 as a low enriched fuel for commercial nuclear reactors.

The further depleted uranyl nitrate would be processed through microwave denitration to produce uranium oxide that could be stored for future use in breeder reactors.

These steps would require at least one new processing facility or perhaps several duplicate facilities to process the 560,000 metric tons of DUF_6 . Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality when processing the DUF_6 . Criticality concerns are involved with the enrichment operation that would restrict the size of processing equipment. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for fluorine compounds, which can burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current storage sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium oxide could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities to process uranium compounds, including UF_6 . Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

Option 2 - Contracting with a consortium of U.S. nuclear utilities to use depleted uranium (DU) as feed stock for additional uranium enrichment to recover more of the uranium isotope-235 (^{235}U) with a unique emulsion phase chemical enrichment process is recommended in Document #9. Uranium enrichment technology has been researched and implemented for over six decades and the probability of success with this unique technology is unknown.

Congress, in legislation during 1992, designated that a Government Corporation be established to perform all future uranium enrichment activities by the Federal Government and the legislation provided the framework for the corporation to be privatized. The existing depleted uranium hexafluoride (DUF_6) was retained as DOE material and not allocated to the new corporation. However, DOE could contract with the new corporation, or with any other enriching organization to perform further separation of the ^{235}U .

Gaseous diffusion uranium enrichment has been performed in the U.S. and in other countries for several decades and is the only process used for commercial uranium enrichment in the U.S. Other means of uranium enrichment have been developed. A centrifuge separation process is used in Europe and a production plant using the centrifuge process is planned for construction in Louisiana. Both the gaseous diffusion and centrifuge processes use UF_6 as the feed material form. A unique AVLIS uranium enrichment process, using uranium metal as the feedstock, has been under development at Lawrence Livermore National Laboratory for nearly three decades. While the new Uranium Enrichment Corporation is evaluating the AVLIS process, it is unknown at this time whether it can or will be deployed commercially. The recommended unique emulsion phase contactor approach of this document would require extensive and lengthy research program to determine if it could become practical.

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranyl nitrate and subsequent chemical enrichment would require two large facilities, one for defluorination of the DUF_6 and a second for the enrichment process. Each would require the design, construction, operation and eventual decommissioning.

U.S. nuclear utilities are very unlikely to be willing to participate in a venture to extract additional ^{235}U from depleted uranium. Such a function is not in their line of business and prior attempts by utilities to expand into fuel supply activities, both with fossil and nuclear fuel have been notoriously unsuccessful. Utilities have available to them existing suppliers of uranium enrichment at a reasonable cost. While electric utilities are seeking alternative business opportunities, the prior unsatisfactory efforts in the competitive fuel supply arena dictates other types of investments. This investment decisions are heavily impacted by the financial regulatory conditions that are imposed on electric utilities at the state level.

The determination of the amount of enrichment function performed, that is the level of ^{235}U remaining in the depleted uranium, has been made on the basis of process limitations and overall economic assessment that includes factors of uranium cost, cost of electricity for the enrichment process and the other costs associated with uranium enrichment. Nominally, about seventy percent of the ^{235}U is recovered within the low enriched uranium fuels produced for use in nuclear energy plants. The remaining thirty percent is retained in

the DUF₆. The ²³⁵U content of most of the DUF₆ is in the range of 0.2 to 0.3 percent. A decision on whether or not to recover more of the ²³⁵U should be based on the economics of recovery. If the recovery cost is lower than the cost of producing enriched uranium from natural uranium then it should be pursued and sold on the commercial market. Recovery of more of the ²³⁵U from DUF₆ does not appear to be economically attractive in the near term.

Relatively large quantities of good grade uranium ore have been defined in Canada and Australia that can be developed to provide low cost natural uranium feedstock for uranium enrichment, equivalent to projected needs for many decades. Stripping ²³⁵U from the DU appears to be higher in cost than the enrichment of natural uranium at this time. However, high grade ores are finite and when they have been depleted, recovery of ²³⁵U from DU may be economical. Such an economic basis may not be experienced for many decades.

Overall Federal regulation for safety of uranium enrichment operations is evolving. Temporarily, the new Uranium Enrichment Corporation is operating under DOE regulations that will be coordinated with the Nuclear Regulatory Commission (NRC). The private centrifuge facility is being licensed by the NRC. The unique nature of an emulsion phase chemical separations process would require additional regulatory evaluation by the NRC.

Option 3 - One recommendation in Document #9 calls for the establishment of a consortium to cooperatively design and build a prototype breeder power reactor to demonstrate the use of depleted uranium as a fuel source in breeder reactors.

A cooperative program to build and operate a demonstration breeder reactor was a major element of the federal energy program during the 1970's and early 1980's. However, the dramatic change in the demand growth rate for energy overall and for electricity specifically, and opposition to the breeder reactor program by some elements of society were main reasons for the demise of that program. While breeder reactors may become important elements of future energy generation, the time period for such a need is many decades if not a century or two away.

Overall Federal regulation for safety of breeder reactors will undoubtedly be the domain of the Nuclear Regulatory Commission (NRC). Initial review of breeder reactor safety has been performed by the NRC. However, a full set of new regulatory reviews would be required for the technology to be demonstrated and deployed.

Option 4 - Considerable concern is expressed in Document #9 on the integrity, handling, cleaning and eventual use of recovered metal from the depleted uranium hexafluoride (DUF₆) cylinders. Straddle carriers with enclosed cabs are recommended for moving the cylinders. Also, the recommendation calls for roads to be cleared of personnel when the cylinders are moved, that the move be at night and during cold months for the oldest and risky cylinders. The recommendation calls for a new vaporization facility with special attention provided for siting and a special vaporization station for leaking cylinders. Associated recommendations call for training for accidents and possible large inflatable buildings over the oldest cylinder yards--liquid nitrogen retained for control.

There does not appear to be a supported basis for the significant concern expressed with regard to DUF_6 cylinder integrity or fragility. Quite the opposite is apparent with the several decades of cylinder control. While elaborate precautions are appropriate for handling, moving and vaporizing the DUF_6 , the concerns expressed and the extensive steps recommended do not appear to be justifiable.

Cylinder cleaning and the recovery of the metal from the DUF_6 cylinders for the fabrication of rust resistant steel boxes for the long term storage of uranium oxides is included in the recommendations of Document #9. This would require a metal processing and fabrication shop, including melting, casting, rolling and welding. The quantity of cylinders is about 47,000 and over a twenty year period, this could be performed with modest expansion of existing capability of facilities in the Oak Ridge complex.

Overall Federal control for safety of DUF_6 storage and handling is currently under DOE regulations. A DOE facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities the include handling of UF_6 . Adaptation of these existing regulations for the storage and handling of DUF_6 appears to be relatively straight forward without the need for time consuming development of new regulations.

7.1.8.1.2 Evaluation by Reviewer V

This option suggests an overall program including a number of technologies that are experimental or commercial to convert DUF_6 into uranium oxides for short term use in reactor fuel or long term storage as potential fuel for breeder reactors. This option also suggests the sale of fluoride compounds produced as byproducts to the chemical industry. The option of reprocessing DUF_6 to produce uranyl nitrate and fluoride compounds does not appear to present any unresolvable issues using existing processes. All conversion processes for DUF_6 have a set of serious operational issues that would be addressed as the plant is designed and commissioned.

Uranyl nitrate is a very dangerous, unstable form of uranium. The yellow crystals are toxic, explosive, soluble in water and melt at 60°C . This material would need special handling during all stages of processing to avoid accidents and assure worker safety. If the proposed new conversion processes are used, the environmental effects are not well identified at this time. It is suggested that they will produce less wastes, but it is not clear if other risks to environmental values or public or worker safety will be associated with the new technology.

It is not clear if isotope separation will be conducted using conventional or the new uranyl nitrate solution processes in research and development at DOE as mentioned in the response. Each of these will also have implications for environment, health and safety. Fuel preparation processes for the U-235 oxides are commercial and environmental and

safety guidelines established. Their operations have some minor environmental and health effects. The use of these fuels in existing reactors have environmental effects and require waste disposal for low and high level wastes. Breeder reactors are still in development for this country and the environmental effects are unknown, however, public resistance has been high in the past.

The siting for the conversion, processing and power facilities could present an issue for development. Use of existing sites at one of the current conversion or storage facilities might minimize siting issues. The permitting for environmental, health and safety issues is not expected to present problems but again should be carefully thought through and checked in the material licensing process. With more operating experience, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility.

For the large volume of U-238 that would need disposal under this program, it is suggested that the oxides be packaged in Cor-Ten steel boxes that are shipped to western disposal sites. The transportation would present some public safety risks and the location of a low level waste site has proven problematic. Also, depending on the volume of material needing storage and its characteristics, a specially designed site could be required.

7.1.8.1.3 Evaluation by Reviewer X

A process for converting the dUF_6 to fluorine compounds and uranyl nitrate is proposed. No process information is provided. The objective is to minimize fluorine waste materials. However, the process is not tested, and so requires R&D to determine its feasibility, waste stream, and health and safety issues. If the process doesn't work, then direct conversion to an oxide is recommended.

No additional health and safety issues are anticipated for this process other than those already familiar for handling and storing uranium compounds and other hazardous chemicals.

Several recommendations are made for the handling of the storage cylinders, including the use of straddle carriers with enclosed cabs, emergency communications, and off-hour movements. These recommendations would reduce the risks should an accident occur. However, they need to be evaluated relative to the actual risks involved. It is proposed that all processing take place in a new facility to be built in a western arid region of the country. This practice would increase the transportation risks and costs over those experienced if the materials were processed on or near the current storage sites.

The recommendation for isolating each of a group of at least 10 vaporization facilities would assure that if a leak occurs during vaporization, the entire process stream would not be shut down.

Converting the dUF_6 to an oxide form, such as U_3O_8 , would produce a more stable form for long-term storage. Storing this material for possible future uses rather than disposing

would preserve a resource that may become more valuable with time as the earth's fossil energy resources become less available.

7.1.8.1.4 Evaluation by Reviewer Y

Very thoughtful perception of this topic in the context of a potential "neighbor" of a facility to process DUF₆. Several "scare" words on this topic by a sophisticated specialist on subjects beyond his immediate specialty. The issue might be on the relative impact of Nitrogen versus Fluorine compounds. Option less than clear on this.

7.1.8.1.5 Evaluation by Reviewer Z

Mr. Brown provided several worthwhile comments. All of the options proposed by Mr. Brown have been assessed in detail in response to other recommendations. Therefore, a detailed evaluation was not performed. See Section 7.1.8.7.5.

7.1.8.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.8.2.1 Evaluation by Reviewer U

Option 1 - The DUF₆ conversion to uranium oxide and fluorine compounds should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. A limited volume of solids would be collected from processing and they may contain traces of uranium. Special purification steps could be performed to remove the uranium or the solids may be disposed of in low level radioactive waste disposal facilities.

Empty DUF₆ cylinders would need to be cleaned and may be melted and the metal reused for other applications. If cleaning is not sufficient for alternate use of the metal, the cylinders may require disposal at a low level waste disposal site.

Option 2 - Waste generation associated with further enrichment using an emulsion phase contactor process would be minimal.

Assuming recovery of one half of the U₂₃₅ in the form of 3 percent enriched product, the reduction in DUF₆ would be about 27,000 MT. Thus, the amount of DUF₆ that would

need eventual disposition would be reduced by about 2-3 percent--not a significant reduction.

Option 3 - The recommendation of a breeder reactor consortium entails operations of fuel fabrication and spent fuel reprocessing that will generate a broad range of waste disposal issues.

Option 4 - Control of DUF_6 cylinders will not entail significant waste products. Recovery of the metal from the DUF_6 cylinders and using it for other purposes eliminates the need for disposal of bulky cylinders.

Cleaning of cylinders, melting and metal processing to fabricate rust resistant metal boxes for the storage of uranium oxide would produce a limited amount of waste that would be in the form of non-radioactive solid wastes.

7.1.8.2.2 Evaluation by Reviewer V

This option would produce waste streams from each of the steps discussed above. Without more detailed process data, it is impossible to define the waste streams. Care will need to be taken with all effluents and emissions given the toxic, hazardous and radioactive nature of many materials involved. The fluoride compounds from DUF_6 conversion could be recycled. The program proposed also includes the reuse of metal from emptied DUF_6 cylinders for fabricating new multi-hundred year storage boxes. Large amounts of U-238 oxides would need disposal or storage at approved waste sites. No significant additional wastes would be created by storage or disposal.

7.1.8.2.3 Evaluation by Reviewer X

Insufficient information is available to assess the production of wastes from the conversion of dUF_6 to an oxide form through a uranyl-nitrate stage.

Part of the recommendation is to use the uranyl nitrate in a patented isotopic separation process (emulsion phase contractors (EPC)) that would remove the ^{235}U for use in current LWRs. This would render the remaining material less radioactive because of the longer half life of ^{238}U . Thus, storage, disposal, or use in non-reactor applications would be safer. Since the only reaction components are nitrates, no serious waste products are projected.

The recommendation also proposes that the oxide be stored in Cor Ten steel boxes constructed from refabricated cylinders. This would potentially eliminate a small non-radioactive waste stream. Storage of these boxes is estimated to require a 10 square-mile LLRW landfill to be established preferably in a western desert.

7.1.8.2.4 Evaluation by Reviewer Y

The option is not specific on this topic. However, it is likely that nitrates of some kind will be contained within waste products. Beyond this, the option has about the same waste

considerations as most other options. The inflatable buildings to "protect" do not solve any problems of long-term concern.

7.1.8.2.5 Evaluation by Reviewer Z

See Section 7.1.8.7.5.

7.1.8.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.8.3.1 Evaluation by Reviewer U

Option 1 - Cost estimates for the defluorination process, the enrichment process and the conversion to oxide are not included in Document #9. The value of the recovered fluorine compounds will be less than the cost of defluorination. The value of the recovered low enriched nuclear fuel is expected to be less than the cost of the enrichment step. Since the uranium oxide has no economic use, it will be stored for an extended period at a cost expected to be about the same as the cost of DUF₆ storage.

Overall cost for the recommended operations is greater than the value of the recovered usable products.

Option 2 - Assuming recovery of one half of the ²³⁵U in the form of 3 percent enriched product, the enriched product would be about 27,000 MT. This is a significant amount of nuclear fuel material, equivalent to about seven years of fuel supply for the nuclear energy plants operating in the U.S.—a value of several billions of dollars. However, the cost of the further enrichment function is estimated to be greater than the value of the recovered low enriched material.

Considerable research, development and demonstration are required to determine whether the recommended chemical separation process will work on a large scale. The recommendation suggests the operating cost would be lower than other enrichment processes. No basis for this comment is provided in the document. The practicality and the overall cost of obtaining low enriched uranium from DU through the emulsion phase contactor process is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

Option 3 - Costs of a breeder reactor demonstration program would entail expenditure of many billions of dollars. At some point in the future, breeder reactor technology may be economical and essential to serve the needs of a growing world population. At that time, depleted uranium would be viewed as a valuable energy resource that can provide a large amount of relatively clean energy.

Option 4 - There would be added cost for the storage and handling of DU if the supplemental steps recommended in this Document are instituted. The amount of additional cost is indeterminate at this point.

Cost for the recovery of the metal from the DUF_6 cylinders is not defined. However, it should be economically attractive to recover the metal as recommended. Even greater economy may be realized by converting the cylinders to oxide storage containers by cutting them in half and welding flat plates over the ends.

7.1.8.3.2 Evaluation by Reviewer V

The costs proposed for this program need much better characterization. The costs of the conversion processes and the isotope separation are not defined or totalled. The postulated \$5 billion value of the 800 MT of U-235 assumes a market that may exist, but has not been identified. Products and markets for the fluoride compounds are not defined. The costs for research and development need to be reviewed and confirmed. The cost of retrievable storage in appropriate facilities or disposal must be added to these costs. Capital cost could be affected by the degree of public acceptance. Disposal in deep mines or shallow burial on land, would add significant costs.

7.1.8.3.3 Evaluation by Reviewer X

Insufficient information was provided to assess the capital and operating costs for conversion facilities. Costs for reenrichment using the patented EPC process are stated to be significantly less than current GDP technology, centrifuge technology, or AVLIS. However, no data was provided. A recommendation for a DOE R&D program is included.

The recommendation proposes to produce HF and more valuable HFC products from the conversion process for resale to reduce costs.

Reenrichment for use of the ^{235}U in today's LWRs is not a cost-effective option based on GDP technology. The tails contain 0.2 to 0.3 percent ^{235}U for a reason. To reduce the ^{235}U content to 0.1% using natural uranium as the initial feedstock costs nearly 50% more in expended Separative Work Units (SWUs). To reduce the ^{235}U in the current inventory of dUF_6 to 0.1% would cost two to four times as many SWUs as the original enrichment process. To reduce it to 0.05% or less would cost at least five times as many SWUs. See Table 1 for the cost comparison. Unless natural uranium became extremely rare, these costs could not be justified. Even if less expensive enrichment technologies became available, competition with natural uranium would dominate the market. Only if the cost per SWU would decrease to a few dollars each could the extraction of the remaining ^{235}U

be cost justifiable. Further, extraction of the ^{235}U would only deplete the total inventory of dUF_6 by about 0.15%.

Long-term storage of the oxide for future use in a breeder reactor economy is likely to be nominally more expensive than disposal. Whether all this material would ever be used, however, may be questionable but should be investigated. Eventual sale of the oxide for fuel should cover the increased costs for storage.

Table 1. Enrichment Cost in Separative Work Units for Different Concentrations of Product, Feed & Tails (Source: ORO-684, Appendix 1)

		Concentration (x) in %	Concentration (x) in %	Concentration (x) in %
Concentration of Product	x _p =	3	3	3
Concentration of Feed	x _f =	0.711	0.711	0.711
Concentration of Tails	x _t =	0.3	0.2	0.1
Feed/Unit of Product	F/P=	6.5693431	5.4794521	4.7463175
Unit Values of Uranium at each stage	V(x _p)=	3.2675328	3.2675328	3.2675328
	V(x _f)=	4.8688834	4.8688834	4.8688834
	V(x _t)=	5.7713017	6.1877557	6.8929413
SWUs		3.4245263	4.3064746	5.9814129
		Concentration (x) in %	Concentration (x) in %	Concentration (x) in %
Concentration of Product	x _p =	3	3	3
Concentration of Feed	x _f =	0.3	0.3	0.2
Concentration of Tails	x _t =	0.2	0.1	0.1
Feed/Unit of Product	F/P=	28	14.5	29
Unit Values of Uranium at each stage	V(x _p)=	3.2675328	3.2675328	3.2675328
	V(x _f)=	5.7713017	5.7713017	6.1877557
	V(x _t)=	6.1877557	6.8929413	6.8929413
SWUs		8.7404897	12.638366	16.824974
		Concentration (x) in %	Concentration (x) in %	Concentration (x) in %
Concentration of Product	x _p =	3	3	3
Concentration of Feed	x _f =	0.3	0.2	0.2
Concentration of Tails	x _t =	0.05	0.05	0.01
Feed/Unit of Product	F/P=	11.8	19.666667	15.736842
Unit Values	V(x _p)=	3.2675328	3.2675328	3.2675328
of Uranium	V(x _f)=	5.7713017	6.1877557	6.1877557
at each stage	V(x _t)=	7.5928019	7.5928019	9.2083983
SWUs		17.168434	23.307307	41.594511

7.1.8.3.4 Evaluation by Reviewer Y

It is not likely that the emulsion phase contactor technology will be significantly less costly than the AVLIS technology. "If it sounds too good to be true, it probably is not!"

It is highly unlikely that any domestic utilities will invest for production and storage of 3% enriched Uranium unless there is a cost benefit for this option; this benefit is elusive. It must be significant for utilities to risk existing commitments, regulations, and rates.

7.1.8.3.5 Evaluation by Reviewer Z

See Section 7.1.8.7.5.

7.1.8.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.8.4.1 Evaluation by Reviewer U

Option 1 - Production of fluorine compounds from DUF_6 would entail reasonably well defined technology. Some research and development would be required to define the most cost effective fluorine compounds and the technology to achieve the desired product.

The application of emulsion phase contactors for isotope separation is a concept that would require considerable research and development to determine whether the process would work effectively and be economical.

Producing large quantities of uranium oxide with a microwave denitration process would require considerable development. Storage of uranium oxide is reasonably well defined. Development of an economical breeder reactor concept to use the depleted uranium oxide would take several decades at a very high cost and there is little need for the technology at this time.

Option 2 - Considerable research, development and demonstration are required to determine whether the recommended chemical separation process will work on a large scale. Obtaining enriched uranium from DU should be considered as a long term possibility, not a near term use of depleted uranium. Chemical separation of the uranium

isotopes has been pursued in several countries with unsatisfactory results. There is little likelihood that emulsion phase contactors will prove to be practical or economical.

Option 3 - Major research programs have been ongoing with breeder reactor technology for several decades. Still, breeder reactor research and demonstration would need to proceed for many additional decades to define reasonable operating parameters and to develop an economical system. As other energy resources are depleted and if global climate change becomes a significant problem, breeder reactors may become a welcome energy resource.

A research breeder reactor has operated and the conversion of ^{238}U to plutonium is predictable and possible. The energy value of the ^{238}U and plutonium is reasonably well documented.

Option 4 - With the extensive experience of storage and handling of DUF_6 cylinders, the need of augmented practices is reasonably well understood. Cylinder cleaning and metal processing are established technologies that may be applicable to recovery of metal from the cylinders.

Some research would be appropriate to determine if the metal from the cylinders is appropriate for long term storage of uranium oxides.

7.1.8.4.2 Evaluation by Reviewer V

The proposed program includes technologies currently in early development, requiring scale-up and testing. It is estimated that the research and development will take two years. It is not clear if piloting or large scale demonstrations will be needed after this stage. In some cases, alternative commercial processes are available. Breeder reactor technology is not expected to result in significant commercial applications in the thirty year time frame of the DU program and would not require large amounts of DU input. The best options for permanent disposal need to be determined. The NRC supports deep disposal, while less expensive shallow land burial is also receiving support.

7.1.8.4.3 Evaluation by Reviewer X

The recommended EPC process is patented but apparently not tested on a pilot or production scale.

No information on conversion of dUF_6 to oxides using a process involving a uranyl nitrate intermediate stage has been provided. It is not possible to evaluate this process.

Extraction of the remaining ^{235}U from dUF_6 has not been performed due to the significantly higher costs using today's technology. Insufficient information has been provided to assess cost savings using new technology.

7.1.8.4.4 Evaluation by Reviewer Y

The emulsion phase contactor technology is at an early stage requiring much development, demonstration, and large-scale processing. The stated perceptions on breeders are incorrect:

- a) U235 is a "converter," not a breeder fuel.
- b) 0.1% U235 in Uranium needs a higher enriched fuel to drive the breeder. 0.1% U235 by itself cannot be brought critical. The Canadians bring natural Uranium systems critical in CANDU systems with D2O moderator with very limited reactivity lifetimes.
- c) Converter concepts (e.g., U235, U238 → Pu239, or U235, Th → U233) are feasible but only for specially designed systems with acceptable neutron spectra and neutron leakages, and optimized fuel cycles.

There are a lot of beneficial details about handling used and new tanks that bear consideration.

If the emulsion phase contactors are not feasible, the option proposes UO₂ storage. This technology is sound and bears consideration.

The suggestion for ultrasonic inspection of tanks is within the state of the art requiring mainly calibration and standardizing within the technology.

Considering the size of K-25, there may be specious factors in the proposal that should be evaluated by specialists. The very small molecular weight difference argue that if the concept is feasible, more stages than assumed in the option are likely to be required.

The multifaceted option is technically naive in a strategic sense, but does provide specific sound technical details.

7.1.8.4.5 Evaluation by Reviewer Z

See Section 7.1.8.7.5.

7.1.8.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.8.5.1 Evaluation by Reviewer U

Option 1 - Employment at a facility to convert DUF_6 to uranium oxide and fluorine compounds would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low temperature and low pressure and the amount of material within the process inventory at any particular time is relatively small. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small. One step of concern is the vaporization of the DUF_6 from old cylinders that may have experienced age deterioration. Special precautions should be established to contain any material leakage from this step.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a new conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

Option 2 - Converting DUF_6 into uranyl nitrate and subsequent chemical enrichment at one or all three of the existing sites where DUF_6 is stored should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

Option 3 - There will be strong objection by some members of the public to the continued or expanded development of breeder reactors technology.

Option 4 - DUF₆ cylinder handling and control and the recovery of metal from the cylinders at or near one or all three of the existing sites where DUF₆ is stored should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

7.1.8.5.2 Evaluation by Reviewer V

It is difficult to estimate the socioeconomic effects of the proposed program until the technologies and their characteristics are better defined. If a large scale program is implemented, there will be economic effects but the location of impacts could be dispersed.

Siting could be a significant public acceptance issue. Even in locations where processing facilities are already in operation, growing concerns about the project-specific and cumulative effects of such facilities could prolong or endanger the permitting process. The NRC permitting process, as well as state and local reviews that would be necessary for this option, must be seen as potential barriers to implementation. Similarly, if a new storage facility were required, additional siting time and effort would be required. Where possible, existing sites should be used to minimize the costs required to permit, including Federally owned sites.

7.1.8.5.3 Evaluation by Reviewer X

The recommendation proposes to establish a storage and processing facility in a western desert. Without information on specific processes and a specific location, no assessment of socioeconomic factors can be done.

7.1.8.5.4 Evaluation by Reviewer Y

The complete strategic package provides for much employment, a serious public acceptance crisis (e.g., the breeder), but does provide a basis for local development in an economically depressed area.

The tactical chemical engineering package would provide modest employment, but significant in a depressed area. Doing something with the DUF₆ to produce DUO₂ has merit when seeking public acceptance.

7.1.8.5.5 Evaluation by Reviewer Z

See Section 7.1.8.7.5.

7.1.8.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.8.6.1 Evaluation by Reviewer U

Option 1 - Defining the potential energy value of depleted uranium is an important factor. There is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, uranium oxide, is greater than the cost of converting the DUF_6 to uranium oxide with associated impacts.

Option 2 - The depleted uranium does contain potentially recoverable energy values in the form of ^{235}U . While the economic value of the energy resource is insufficient to recover the values in the near term, economic recovery may be achieved at some future date when high grade uranium ores are depleted. Thus, an important factor may an assessment of potential energy values recoverable through isotope separation either in the near term or at some point several decades in the future.

Option 3 - Defining the potential energy value of depleted uranium is an important factor. There is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

Option 4 - A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to uranium oxide with associated impacts.

7.1.8.6.2 Evaluation by Reviewer V

See General Comments.

7.1.8.6.3 Evaluation by Reviewer X

None.

7.1.8.6.4 Evaluation by Reviewer Y

The submission is a mixture of chemical and mechanical engineering with strategic nuclear power generation and deployment. The submission is enthusiastic, but technically in error on some details.

With the advent of deregulation, "wheeling" of electricity from low-cost into high-cost generation areas is feasible. This may be the factor that makes breeders attractive in the future.

It is highly unlikely that any consortia would enter into any of the facets without significant DOE subsidy.

7.1.8.6.5 Evaluation by Reviewer Z

None.

7.1.8.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.8.7.1 Conclusion by Reviewer U

Option 1 - While all three of the recommended uses of DUF₆ appear to be feasible in one form or another, the limited amount of information provided in Document #9 on the specific details of processing only allows the evaluation to be cursory in nature as a view of the general concepts. There is a potentially large amount of fluorine that could be used in other compounds. However, the cost of recovery appears to be greater than the value of the fluorine recovered.

It does not appear to be appropriate to pursue additional enrichment steps using an undeveloped chemical process. The potential of economical recovery of low enriched nuclear fuel with such a process appears to be remote.

The recommendation to store the DU for potential use in breeder reactors in the future appears to be appropriate. The time of such use is indeterminate. The open question is the material form for long term storage. The recommendations of fluorine compound extraction and conversion to uranium oxide in Document #9 may be applicable if a decision is made that continued storage of DUF₆ is not acceptable.

The person providing the recommendations in Document #9 appears to have considerable knowledge on the value and processing of uranium compounds.

Option 2 - On the basis of prior unsuccessful experience with attempts to pull together electric utility consortium arrangements for uranium enrichment facilities, there is essentially no possibility to assemble such a consortium for extracting low enriched uranium from depleted uranium.

Obtaining low enriched nuclear fuel material by further enrichment of the DUF_6 does not resolve the problem of what to do with most of the depleted uranium. At best, such an activity would reduce the amount of DUF_6 by an amount of 1-3 percent. There is considerable doubt that the recommended emulsion phase contactor process will work on a large scale or ever be economical if it does work. This recommendation of further enrichment provided in Document #9 should not be pursued unless the recovered value of the low enriched product is greater than the cost of conversion and separation. Such does not appear to be the case.

The person making the recommendation in Document #9 appears to be knowledgeable in the processing of uranium compounds.

Option 3 - Proceeding with a consortium to build and operate a demonstration breeder reactor is not practical and is inappropriate at this time. Based on the experience and results of the prior Clinch River Breeder Reactor project, there is essentially no possibility of assembling a consortium for the design, construction and operation of a demonstration breeder reactor within the next several decades.

The person providing the recommendations in Document #9 appears to have considerable knowledge on the value of and processing technology for uranium compounds.

Option 4 - Careful control is essential for the handling and moving of DUF_6 cylinders, and vaporization of DUF_6 from the storage cylinders. However, the extensive controls recommended for handling cylinders with the use of carriers with enclosed cabs, clearing of personnel, moving at night and in the cold months of the year do not appear to be justifiable.

Recovery of the metal from the DUF_6 cylinders does appear to be appropriate and the recommendation should be considered along with alternative uses for the cylinders and/or recovered metal.

The person making the recommendation in Document #9 appears to be knowledgeable in the processing of uranium compounds.

7.1.8.7.2 Conclusion by Reviewer V

According to the DOE guidelines for reasonableness, this option, taken as a whole, does not seem viable at this time. The data provided suggests that the processes need a great deal of further development. The costs of the multiple stages have not been identified and could total more than the program guidelines. The demand for nuclear fuel feedstocks is not certain. Some social resistance to this option could be anticipated. While the

proposed program may not meet the current DU management program criteria, many ideas presented deserve consideration, in particular, the cylinder safety recommendations.

7.1.8.7.3 Conclusion by Reviewer X

Conversion of dUF_6 to oxides for long-term storage rather than disposal would preserve the option to use the uranium in future reactor applications while rendering the material safer than in its present form. Production of HF and HFC products during the conversion process would alleviate the costs.

Extraction of the remaining ^{235}U will be extremely expensive using current technology. New technology must reduce the enrichment process to less than 10% of its current cost to justify this extraction on a cost basis, and even then it may not be justifiable if natural uranium reserves remain plentiful. Even if it is extracted, it will use up less than 1% of the total dUF_6 inventory.

Use of the ^{238}U in an FBR economy will require only 2% of the current inventory for the initial fuel loads in a 100-FBR economy, something not likely to occur for more than 100 years from now. Reloads will require only about 2% of this amount (0.05% of the current inventory). Thus, continuing production of fuel for current LWR operation will provide more than adequate amounts of ^{238}U , and use of the dUF_6 in other applications will need to be considered to utilize any significant amounts of what is available.

Development of a conversion site in a western desert far from the current storage sites would introduce excessive transportation hazards. Conversion of the dUF_6 to oxides or metal on or near the current sites would minimize the risk of damaging cylinders resulting in material releases.

Vaporization of the solid dUF_6 may be one of the most hazardous phases of any utilization process. More than one vaporization system will be needed in a production facility. Thus, the recommendation to enable each vaporization system to be isolated from all others in case of a leak should be implemented in any new facility. This would preclude having to shut down an entire plant should a leak occur.

7.1.8.7.4 Conclusion by Reviewer Y

Without some early R&D demonstration, one might feel comfortable about the chemical engineering aspects of this option. It is likely that the UO_2 production is "reasonable." The Fluorine marketing makes sense. The isotope separation, while technically meritorious, is likely to be more expensive than envisaged.

While breeders make a lot of sense in the long term, this particular submission raises technical questions of feasibility on very complex issues.

7.1.8.7.5 Conclusion by Reviewer Z

This response proposed several worthwhile options regarding the conversion of the UF_6 to a more stable oxide form, and recommends the recovery of the fluorine in a useful form. Mr. Brown also proposes options for the use and/or storage of the material in order to recover or preserve the economic value of the material. All of the options proposed in this response have been evaluated in detail in response to other proposals, therefore, a detailed evaluation is not being performed.

7.1.9 Evaluation of Document No. 14 (Independent Technical Reviewers' No. 10)**Respondent:**

Mr. Alan Waltar
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708-352-6611

Description of Response:

This response recommends that management of the depleted uranium continue in the present mode of storage. The responder states that depleted uranium could be used as blanket material for breeder reactor production of electricity at some future date.

7.1.9.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.9.1.1 Evaluation by Reviewer U

The recommendation in Document #10 calls for continued storage of the depleted uranium hexafluoride (DUF₆) until the time of future application as blanket material in breeder reactors. The recommendation incorporates the need for breeder reactors as a necessary means to provide energy for the increasing populations. The potential energy value of the depleted uranium when used in this manner is indicated as greater than the energy available from all the oil under the Saudi peninsula. There is no indication of when such an application would be economical or could be implemented. Although, the recommendation does state that over a period of years the entire inventory of DUF₆ would be used.

Operational issues include well understood controls for storing and handling DUF₆ until the time for use as breeder reactor blanket material. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is

the heavy metal toxicity potential. The potential health concerns associate with long term storage of DUF_6 are well known and when properly implemented, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage. Future activities of converting the DUF_6 to breeder reactor blanket material are not defined and plans for this activity would occur many decades in the future.

Overall Federal regulation for safety of DUF_6 storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF_6 is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. A modification in the regulations would be required for NRC licensing long term storage of DUF_6 .

7.1.9.1.2 Evaluation by Reviewer V

The option of storing DUF_6 in its present form to preserve it for later use as a blanket material to make fuel in breeder reactors does not appear to present any immediate environmental, safety or health issues. The major issues will be associated with the environmental health and safety concerns regarding use of the breeder technology in this country in whatever form it is proposed in the future.

The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air, DUF_6 can react to moisture producing HF acid and UO_2F_2 , both hazardous. The HF is an acid that could cause skin burning and damage to the lungs on contact and the fluorides and uranium can have toxic effects if ingested. In addition, the alpha particle emissions from inhaled or ingested uranium could be a health risk. Releases to the environment are most likely to be limited to the storage facility itself. If a large release occurred, however, the potential exists to effect the surrounding area effecting the public, the land, vegetation and domesticated and wild animals.

The handling of the storage cylinders and routine operations at the storage facility raise the possibility of minor environmental risks from accidental releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. Past experience has shown very few incidents of releases, virtually all of which had insignificant health effects. With the aging of the cylinders, however, the potential for increased numbers and severity of accidental releases must be seriously addressed.

The transport of DUF_6 required under this option would be very limited and, therefore, minimize potential exposure of the public. Use of the current sites is probably the least risk approach from an environmental, health and safety perspective. While the public is located in proximity to the facilities, there are no major population centers in the immediate vicinity. Selection of different sites would require licensing, delay and

transport of aging cylinders which might pose a greater environmental risk than current storage. Within the existing sites, there may be potential for relocating storage areas to improve storage conditions and minimize hazards of accidental release.

Continued storage at existing sites again would not present a problem technically, however the management of the sites and perhaps the storage techniques may need to be modified. Handling the cylinders for inspection and routine stacking and unstacking can cause leakage, although in many cases any breaches are self-sealing. The steel cylinders have been stored out-of-doors, some for as long as thirty years which is the estimated useful life expectancy. While high risk cylinders with identified risk potential (about 15,000) are inspected annually, only one fourth of the remaining inventory is inspected annually. Current storage conditions may make it difficult to inspect some cylinders.

Current management programs include cylinder inspections for integrity with repairs and replacements performed as necessary. Some technical assessments of the condition of the cylinders and techniques for maintaining them are underway. In addition, some improvements in cylinder storage facilities are underway including saddle replacement, new cylinder yards at Paducah and Portsmouth, cylinder replacements and a cylinder refurbishment facility. The latter would have the capacity to handle about 1/20th of the existing cylinders per year. The current outdoor storage system is not in compliance with DOE regulations requiring two levels of confinement for all radioactive materials, e.g. use of a container that is protected within a building.

Given the advancing age of the cylinders, increased inspections and refurbishments as well as improved storage systems should be considered. Nearly a third of the cylinders are described as "high risk" and inspected annually due to poor drainage, heavy scale or pitting, suspected leaking valves, etc. The risks of accidental releases should be evaluated given these conditions and additional improvements in storage and handling considered. It has been suggested that covered storage be considered. Other approaches might include a more rigorous and frequent inspections program, an accelerated program for refurbishing and replacing cylinders on a preventive basis and improved yards, saddles and containment systems for all cylinders at an early date.

The proposed use of DUF₆ in breeder reactors in the future presents more complicated issues. Such facilities would require the handling of large quantities of radioactive materials and low and high level wastes that require special handling, processing and disposal facilities. The siting of the reactors and related fuel processing facilities would require many years of advance planning and permitting procedures. Given the current public disaffection with nuclear power it is unlikely the planning process would begin in the next decade.

7.1.9.1.3 Evaluation by Reviewer X

Since the current dUF₆ storage program began, six cylinders have been identified to have experienced leaks. All of the leaks were identified long after they occurred because of the early absence of a periodic inspection program. Each leak self-sealed. Four of these leaks were determined to have been caused by cylinders weakened by handling. The remaining

two leaks were in cylinders that had corroded. Programs are currently in place to (1) replace cylinders that are at risk, (2) improve cylinders that are weak, (3) inspect all cylinders on a rotating basis, revisiting those at greater risk more often. Apparently, no new leaks have been observed since these programs were implemented. (See EGG-MS-11416, pg. 9.)

The real question relative to risk to workers or the general public is "How rapidly does the dUF_6 react with moisture in the air to cause a cloud with dangerous levels of HF or uranium?" No data was provided to answer this question. However, it was stated that the above-mentioned leaks self-sealed prior to being identified "because the material loss and reaction with atmospheric moisture were so slow." Apparently, no injuries resulted from the leaks. (See EGG-MS-11416, pg. 9.)

Measures to reduce or eliminate leaks during handling include (1) administrative procedures prohibiting transport of liquid-filled cylinders, and (2) modifications of the specifications for the metal used in cylinder construction, including steel with favorable low-temperature impact response and low sulfur content, which improves ductility and impact strength.

Additional programs are in place to provide new stands for some cylinders to improve safety, and to further protect cylinders from contact with standing water.

The present storage method in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. Thus, it is reasonable to expect that construction of new storage facilities could be required. The question is whether the cost is justified by the reduction in risk. Risk should be evaluated based on vaporization rates, dispersion rates, reseal rates, and detection probabilities. If earthquake resistant buildings are built for the cylinders, the second confinement level should preclude release of materials if one or more cylinders become cracked.

Whether an enclosed facility is built or not, it is apparent that many cylinders will need to be moved due to (1) being stored too close together to facilitate inspection, (2) needing to be placed on new moisture resistant cradles, or (3) requiring transfer of the dUF_6 to new cylinders because of cylinder deterioration. This movement also causes a risk of further cracking. Handling practices can minimize serious damage which would produce large releases.

7.1.9.1.4 Evaluation by Reviewer Y

Near term, the recommendation is to continue storing and monitoring existing DUF_6 , inventory pending a need to provide DU or DUO_2 for breeder reactors. The technology for monitoring and enhancing the existing storage exists and is a low-cost option with limited, if any, impact on environment safety and health. The enhanced use of nuclear fuel for making electrical via breeder reactors will markedly reduce CO_2 and acid rain emissions from fossil fuels. The French experience is an eloquent statement on this.

7.1.9.1.5 Evaluation by Reviewer Z

Mr. Waltar proposes that the material be left in its present form for use at a future time as a breeder blanket material. This would be a continuation of the current practice. Although the near-term risks associated with continued storage of the material are small, the risks associated with storage and cylinder handling will increase with extended storage due to continued degradation of the cylinders due to corrosion.

The second part of the proposal is that the material be used to make blanket material for breeder reactors. Implementation of the second part of this proposal would require a chemical processing facility to convert UF_6 to a form to be used as breeder blanket material. In the event it is converted into plutonium in the future, fabricating the breeder blanket or the fuel and recovering plutonium from spent fuel or the blanket for reuse would be done as part of the plutonium fuel cycle.

Processes to convert UF_6 to stable forms such as oxide or metal have been used commercially and environmental impacts are reasonably well known. Current incentives to contain material, to minimize effluents, to recover and recycle wastes, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

Siting of a conversion facility would influence transportation issues.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 or oxide powder from its storage vessel and subsequent atmospheric dispersion.

The current technology for converting U^{238} to Pu^{239} would be irradiation in a fast breeder nuclear reactor and recovery of the plutonium in a spent fuel reprocessing plant. That will be a long term prospect, and the environmental, health, and safety issues of the plutonium fuel cycle would not be encountered until the distant future.

7.1.9.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.9.2.1 Evaluation by Reviewer U

Storage cylinder monitoring and maintenance would be required for the DUF_6 . Occasionally, it will be necessary to remove the DUF_6 from defective or degrading cylinders and transfer the DUF_6 to new storage cylinders. During such activity, some small amount of contaminated waste will be encountered. These wastes could be allocated to disposal at low-level radioactive disposal sites.

Disposal of defective and empty DUF_6 cylinders will be required. A small amount of UF_6 must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for its capture and disposal or storage. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites.

7.1.9.2.2 Evaluation by Reviewer V

The waste streams associated with this option are minimal. There would be minor amounts of waste generated from normal maintenance activities including replacing or repairing cylinders, valves and other equipment. The replacement of wood saddles with concrete or other supports will generate quantities of waste that is likely to be disposable in a regular landfill. The cleaning and recoating of canisters will also generate some waste, but there would be limited potential for recycling or waste minimization in any of the operations.

The waste management issues associated with use of DUF_6 for reactor fuels would be much more complicated. If the breeder reactor were implemented, the waste issues associated with use of DUF_6 , would be no greater than those associated with the use of natural uranium. However, significant levels of low and high level waste from the breeder would need to be processed and placed in appropriate repositories. Many of these issues are still being resolved with regard to current nuclear activities. Additional radioactive wastes would simply expand the scope of the situation.

7.1.9.2.3 Evaluation by Reviewer X

No additional wastes are expected to be generated from the continued storage of dUF_6 .

7.1.9.2.4 Evaluation by Reviewer Y

Maintaining and enhancing status quo has no near term waste management requirements. When conversion to DU, DUO_2 , or DUC is required, byproducts and wastes will have to be considered, a minimal matter. If there is a viable market for Fluorine, and DU is not classified as "waste," the response is amenable to implementation.

7.1.9.2.5 Evaluation by Reviewer Z

The first part of this proposal is to leave the material in its current form at its present location. This would be a continuation of the current practice. For extended storage periods, the degradation of the cylinders would potentially create additional contamination, thereby creating additional low level waste. This waste would be of the same type as currently present.

A UF_6 conversion (to oxide or metal) facility would produce some radioactive effluent and radioactive waste. The solid radwaste would be expected to be transported to a regional low-level radioactive waste burial facility.

Conversion of UF_6 to an oxide or metal form would release the fluorine, a toxic chemical. During the conversion process, the fluorine would need to be captured. It seems more likely that the fluorine would be captured as HF, a commercially valuable chemical, and unlikely to become a waste form. Solid wastes would be mainly contaminated equipment, effluent scrubber sludge, clothing, process maintenance materials and such other materials that become contaminated incidental to processing UF_6 . The heel, or residue, in a UF_6 cylinder that does not vaporize along with the UF_6 contains radioactive progeny of U^{238} and U^{234} , especially protactinium-234. It has much higher radioactive concentration than U^{238} or U^{234} and must be dealt with as a radioactive waste. Storage to allow radioactive decay is usually a waste management practice for the cylinder heels.

In the long term, conversion of the stable form to Pu^{239} would involve irradiation in a fast breeder nuclear reactor and recovery of the plutonium in a spent fuel reprocessing plant.

High waste burial costs, state and federal regulation, high costs of disposing of radioactive waste, health hazards of UF_6 and HF that is not contained, high costs of decontaminating and decommissioning facilities and surrounding land that has been contaminated, and recovery of commercially valuable HF are incentives to minimize creation of radioactive waste during the conversion of UF_6 to a more stable form or to breeder reactor fuel or blanket.

7.1.9.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.9.3.1 Evaluation by Reviewer U

Long term storage of DUF_6 can be achieved based on the extensive knowledge gained from storage over the past several decades. Such costs are expected to be significantly less than all alternatives of converting DUF_6 to another form for storage and/or underground disposal.

The future activities of using the DUF_6 for breeder reactor blanket material are indeterminate for either the time of need, the cost of conversion or the cost of energy produced with breeder reactors.

7.1.9.3.2 Evaluation by Reviewer V

The costs of this option as estimated by contractors to DOE are low, in the range of \$.22/kgU to \$.34/kgU assuming a storage inventory of only 375,000 MTU, corresponding to life cycle costs of \$83 million to \$129 million. This estimate is based on current storage practices to be used through the year 2020 including planned upgrades of cylinders and yards, new cleaning/coating facilities and current inspection and maintenance. The capital costs for an additional confinement level using indoor storage was estimated at \$360 million for all three sites, with some additional maintenance costs ongoing associated with those facilities. If these estimates are accurate, this would increase the cost of this option by four fold or more. The costs of various containment options should be reviewed, including the use of outside contractors to operate and maintain such facilities. It is generally recognized that some increased costs may need to be incurred to bring the storage option to a higher level of safety.

There would be no additional revenue streams associated with storage unless it were provided with another alternative immediate or future use. The later sale or use of DUF_6 , its products and byproducts could produce some revenues.

The costs of using DU for fuel in breeder reactors as they might be adopted in this country are not well known at this time. Until a better understanding of the technology and DU's role can be developed, little can be determined with regard to the cost to the Government of using stockpiled DU in this way.

7.1.9.3.3 Evaluation by Reviewer X

Costs to maintain current storage practices through the year 2020 are estimated to range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional will be required. This double confinement cost will need to be expended to receive public support for continued storage.

It isn't likely that a breeder economy will develop by 2020. Thus, the storage cost will be greater than this amount over the long run. However, it will still be much lower than the cost of converting the dUF_6 to U_3O_8 .

7.1.9.3.4 Evaluation by Reviewer Y

This is a least cost proposal in the near term. The long-range usage of DU for breeding (or Pu recycle in thermal reactors) will depend on availability of fossil fuels, their cost, and the degree of required capture of fossil fuel emissions. As capital costs rise for environmental acceptance, the nuclear option will be economically attractive and with pressure to produce new nuclear fuel with breeders or near breeders.

7.1.9.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Presuming fluorine or HF were recovered, it would be commercially valuable. The cost of the eventual utilization of the uranium by conversion to plutonium cannot be assessed by this reviewer.

7.1.9.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.9.4.1 Evaluation by Reviewer U

Storage of DUF_6 has been the practice for several decades. Augmenting the current practices to assure the safety of long term storage—a century or two—appears to be reasonable by transferring the material to new cylinders whenever degradation of the cylinders is encountered. The rate and frequency of degradation is indeterminate, but expected to be easily accommodated.

Basic breeder reactor technology has been developed and research reactors operated that illustrate that the conversion of ^{238}U to plutonium is predictable and possible. The energy value of the plutonium has been defined. Large scale demonstration of breeder reactors will be necessary before they can be deployed commercially.

7.1.9.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. Some additional work on the potential for increased failure of aging canisters may be appropriate. Management can be on the lookout routinely for safer or more economical ways of managing the storage of these materials.

The breeder reactor technology is in commercial use in Europe, however, it has not been adopted in the U.S. Current focus on next generation reactors makes it unlikely that the breeder will be adopted here soon.

7.1.9.4.3 Evaluation by Reviewer X

DOE has stored dUF_6 using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

Breeder reactor technical aspects have already been demonstrated in the U.S. and abroad, and are in commercial use abroad. The IFR concept is being demonstrated on a pilot scale in the EBR-2 in Idaho with some fuel operating for 30 years without experiencing cladding leaks. EBR-2 is currently fully fueled with pyroprocessed and electrowinning fuel (U-Pu-Zr with contained actinides). Since a pure plutonium product isn't possible with this process, the fuel is self-protecting from a nuclear proliferation perspective.

7.1.9.4.4 Evaluation by Reviewer Y

The proposal is technically mature. The first small breeder experimental reactor operated in the USA in 1950. Since then, various breeder reactors operated in the USA, Great Britain, France, Japan, and Russia. All used liquid metal (mostly sodium) coolant. Current obstacles to further development are low cost of Uranium determined by low cost of fossil fuels and an improved economic construction climate and culture.

7.1.9.4.5 Evaluation by Reviewer Z

Storage of uranium hexafluoride is a mature technology. Long term storage, such as would be required by this option would require additional measures to protect the stored cylinders from corrosion, but no new technology would be required.

UF_6 conversion to a stable form such as an oxide is a mature chemical process. UF_6 Conversion to U_3O_8 , UO_3 , and UO_2 has been practiced commercially for about three

decades in the fabrication of light-water-cooled nuclear power reactor fuel. Large scale uranium-to-plutonium breeder reactors have been constructed and operated in other nations. Spent fuel has been reprocessed to recover plutonium in the United States and in other nations on a commercial scale and by the U.S. government installations. Fuel reprocessing and fabrication of plutonium mixed oxide fuel should be considered a developed, and perhaps, mature technology.

7.1.9.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.9.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining storage of DUF₆ would be fairly constant for many decades. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Also, there will be strong objection by some members of the public to a storage mode that would anticipate the use of breeder reactors in the future. Since the storage activity would be a continuation of current practices, there does not appear to be a need for seeking significant public involvement or initiating a major public information program.

7.1.9.5.2 Evaluation by Reviewer V

Economics: Storage of DUF₆ using the existing management scheme would not have a significant effect on employment or income in the vicinity of the sites. Maintenance operations as currently planned would require no major increases in labor to handle the monitoring and refurbishing activities.

If major improvements were made in the facilities or maintenance operations were expanded there could be some effects on the local economies surrounding the site. Economic impacts from the construction of a covered storage building(s) at each site could

be in the following ranges, based on the RIMS II regional economic multipliers (U.S. Department of Commerce, 1992):

Total estimated capital costs:	\$360.0 million
Paducah (62 %)	\$232.2 million
Portsmouth (28 %)	\$100.8 million
Oak Ridge (10 %)	\$ 36.0 million

Net effect on local economy in terms of:

	<u>Total increase direct demand</u>	<u>New earnings to employees</u>	<u>Jobs created (temporary)</u>
Paducah	\$527 million	\$158 million	8,437
Portsmouth	\$255 million	\$ 77 million	3,699
Oak Ridge	\$ 88 million	\$ 28 million	1,300

The impacts actually experienced could vary considerably, however. The economic effects of the operation and maintenance of covered storage on overall storage costs should be neutral or slightly positive in that protection from the elements could slow the degradation of the cylinders and reduce ongoing refurbishment costs.

Siting. Siting could be a significant public acceptance issue. It has been raised in a number of responses to program notices as a concern for at least some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the condition and management of the cylinders needs to be addressed. Requests have been made in some cases to relocate residents closest to the site for their safety. Proposed legislation in Congress requiring Federal compensation to private property owners for actions that constitute "taking" of the economic value of their property as a result of government actions deserves monitoring with regard to this issue. Siting a breeder reactor would be very difficult in the foreseeable future.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities under current management practices. Several responses to Request for Response reflect the discontent with the situation as it currently exists and request action. In response to this discomfort, or if public concern for safety increases, additional analysis of the potential risk and education of the public may be beneficial. It may also be useful to involve concerned members of the local community in advisory committees to the storage sites to provide the community with an on-going source of information and a ready mechanism for quickly addressing any current or new concerns. The breeder reactor does not have a high level of public acceptance at this time.

Transportation. Transportation risks are not expected to be a significant factor of public concern. In fact this option would require less transport of hazardous materials in the short run than some processing approaches. If the breeder reactors are not located in close proximity to the DUF6 storage, and DUF6 were transported in large quantities for

the first time for processing, the number of vehicle trips and potential for accidents will be increased.

Other socioeconomic factors. The land use implications for this option are minimal, unless and until the breeder reactor is implemented. The site has been in this use for several decades and is consistent with the general industrial character of most surrounding uses. To the extent that the cumulative effect and acceptability of such uses is a concern to local residents, this use will also be scrutinized. Similarly, the ongoing operation of the storage facility, assuming no routine or accidental releases of hazardous materials, poses no new threats to cultural, historical or archaeological resources.

Nuclear power generation has significant problems with public acceptance at this time. With other conventional sources of electric power readily available at attractive prices, and the prospect of stable or lower electric prices in most areas in the near future, there will be little economic or resource pressure to further develop existing or new nuclear technologies. Public concern about environmental, health, safety and waste disposal issues is likely to retard future efforts to expand nuclear energy unless extraordinary needs exist.

7.1.9.5.3 Evaluation by Reviewer X

The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Improvements to the current storage practices will be necessary to address these concerns, including the addition of earthquake resistant buildings to provide a second level of confinement, and that will assure containment of any releases from leaking cylinders.

The only employment impact will be during the construction of confinement facilities. The current work force should be able to handle the continuing storage practices.

Public acceptance of a breeder reactor program is not likely to occur in the short-term future. However, as the need for additional economical electricity sources develops, and as the success of breeder programs in other countries become apparent, a new public and political perspective should emerge.

7.1.9.5.4 Evaluation by Reviewer Y

The near-term deployment, maintenance of UF₆ tanks will have no marked impact on employment. Public acceptance could be enhanced by making the tanks less visible.

The long-term usages of depleted Uranium to make fissile fuel in a breeder (or near breeder not part of this proposal) will be energy legacy for future generations as fossil fuel costs will rise with decreasing availability. Nuclear electricity generation has fewer environmental problems and should lead to cleaner air, particularly as electricity powered vehicles will be introduced into the economy.

7.1.9.5.5 Evaluation by Reviewer Z

Concerns about the long term storage of the depleted uranium cylinders is the factor which prompted the DOE to initiate this action. Continued long-term storage does not address the present concern.

Concerns about international proliferation of plutonium production and potential diversion of it into nuclear weapons has resulted in a U.S. government policy prohibiting spent fuel reprocessing and recovery of plutonium. This federal policy would have to be reversed in order to be viable.

7.1.9.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.9.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. According to this recommendation there is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of use--one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.9.6.2 Evaluation by Reviewer V

No additional factors.

7.1.9.6.3 Evaluation by Reviewer X

None.

7.1.9.6.4 Evaluation by Reviewer Y

The DU, as well as still abundant Thorium, will be the raw material of choice for energy generation in the future. It may well be that fly ash containing natural Uranium and Thorium, along with DU and natural Uranium, will power the economies of the future; this is the essence of the option.

7.1.9.6.5 Evaluation by Reviewer Z

The continued long-term storage of the cylinders preserves the investment associated with the purification of the uranium and conversion to UF_6 .

7.1.9.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.9.7.1 Conclusion by Reviewer U

Recovery of ^{238}U for use in breeder reactor blankets appears to be a reasonable and an appropriate application for DU. The timing of doing so is indeterminate at this point but is expected to be needed within the next one to two hundred years. The potential energy value of DU is very large and it should be considered as a future energy resource similar to the oil shales and tar sands of the North American continent.

Storage of DUF_6 has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF_6 for a long term period.

The organization providing the comments in Document #10 has considerable knowledge in the potential use of depleted uranium as an energy resource.

7.1.9.7.2 Conclusion by Reviewer V

Continued storage of DUF_6 appears to be a reasonable option for consideration by DOE. It can be implemented immediately and would handle all of the existing inventory. It creates no significant new environmental issues except the need to improve maintenance of the aging cylinders to avoid accidental releases. The costs would be well within program goals and is consistent with DOE and other Federal activities. As product or other applications become economically attractive to the government relative to storage, they can be implemented using this material. Preservation of the material solely for use in breeder reactors does not appear to be justified given the uncertainty of the future of that technology. Should the breeder program become active in the future, it would need only a portion of the stockpiles and natural and other sources could be substituted at the appropriate time.

7.1.9.7.3 Conclusion by Reviewer X

The choice to continue current storage practices is based on the assumption that a future use such as breeder reactor fuel will develop. Conversion of dUF_6 to any other form is an extremely expensive alternative relative to continued storage. To use the uranium after conversion may require converting it back to UF_6 , thus significantly increasing the cost of the end use. Thus, a recommendation to continue storage seems reasonable at this time, but additional uses for the dUF_6 will still need to be found.

The current storage practice in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. To meet this requirement, construction of earthquake resistant buildings into which the cylinders could be moved has been estimated to cost \$360 million. This cost, plus the maximum estimated cost of the present inspection and maintenance program brings the total cost of maintaining the dUF_6 in its present form to slightly less than \$500 million through the year 2020. This is 10% of the cost considered reasonable for a conversion and disposal program. Of course, after expending this amount, one is still left with the original material. Thus, faith that a beneficial use will develop is critical to this recommendation.

It isn't likely that a breeder reactor economy capable of using a major part of the current supply will develop by 2020. Thus, the total cost of storage will exceed the current projections. While the initial load of fuel in a breeder reactor will require about 90 tonnes of dU , reloads will require significantly less. Even with 100 breeders being built, less than 1% of the current inventory of dUF_6 will be used. Thus, continuing production of fuel for current LWR operation will provide more than adequate amounts of ^{238}U , and use of the dUF_6 in other applications will still need to be considered to utilize any significant amounts of what is available.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should this option be selected. This analysis should result in bases for deciding whether to build confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be prudent, what storage configuration would be safest, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

Construction of secondary confinement facilities and transferring dUF_6 from degraded cylinders to new cylinders will be necessary to achieve public acceptance.

7.1.9.7.4 Conclusion by Reviewer Y

The option is reasonable if not mandatory. It is consistent with the intent of the original Atoms for Peace Program developed under the Eisenhower Administration during the 1950s. This was the intent of the early developers who looked upon water reactors as an

interim step in the development on the use of nuclear fission to generate electricity. The final paragraph in Tom Clancy's book, *The Sum of All Fears*, is a modern statement of the original intent of the Atoms for Peace Program.

All of the factors for "reasonable" are consistent with the option. Beneficial economies can be achieved if the DUF6 disposal program is coordinated with related DOE and industry activities.

7.1.9.7.5 Conclusion by Reviewer Z

There is some merit in this option in that it preserves the significant investment which has been made in the purification and conversion of the uranium. However, as stated in Mr. Walter's response, the amount of uranium presently in storage, if used in a breeder reactor program would provide fuel for several hundred years of power plant operation. This does not address the primary concern which prompted the current action to provide for alternate disposition of the stored uranium hexafluoride. Therefore, this option does not address the long-term storage problem.

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7.1.10 Evaluation of Document No. 18 (Independent Technical Reviewers' No. 11)

Respondent:

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Description of Response:

This response consists of three recommendations. The first two consist of recommendations on use and include refeeding the stored depleted uranium cylinders back into the Gaseous Diffusion Plant cascades or utilizing the AVLIS process, perhaps doing demonstration studies using the existing AVLIS demonstration facility at Lawrence Livermore National Laboratory. The responders' third recommendation is to limit construction of any new manufacturing process designed to convert or utilize the depleted uranium to the affected site.

7.1.10.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.10.1.1 Evaluation by Reviewer U

Using depleted uranium (DU) as feed stock for additional uranium enrichment to recover more of the uranium isotope 235 (^{235}U) with either the gaseous diffusion or AVLIS processes is recommended in Document #11.

Congress, in legislation during 1992, designated that a Government Corporation be established to perform all future uranium enrichment activities by the Federal Government and the legislation provided the framework for the corporation to be privatized in the future and to operate as a profit making organization independent of federal subsidies. The existing depleted uranium hexafluoride (DUF_6) was retained as DOE material and not

allocated to the new corporation. However, DOE could contract with the new corporation, or with any other enriching organization to perform further separation of the ^{235}U from the DU.

Gaseous diffusion uranium enrichment has been performed in the U.S. and in other countries for several decades. It is the only process used for uranium enrichment in the U.S. and the enriching function has been performed by the Federal government for the production of commercial nuclear fuel. Other means of uranium enrichment have been developed. A centrifuge separation process is used by a consortium in Europe and a small production plant using the process is planned for construction in Louisiana. Both the gaseous diffusion and centrifuge processes use UF_6 as the feed material form. A unique AVLIS uranium enrichment process, using uranium metal as the feed stock, has been under development at Lawrence Livermore National Laboratory for nearly three decades. However, further development of the process is required to determine if it can be deployed commercially. The newly formed U.S. Uranium Enrichment Corporation is studying the AVLIS process for possible use in a new enrichment facility in the future.

The determination of the amount of enrichment function performed, that is the level of ^{235}U separated into commercial fuel, and the amount remaining in the depleted uranium, has been made on the basis of process limitations and overall economic assessment that includes factors of uranium cost, cost of electricity for the enrichment process and the other cost factors associated with uranium enrichment. Nominally, about seventy percent of the ^{235}U is recovered within the low enriched uranium fuels produced for use in nuclear energy plants. The remaining thirty percent is retained in the DUF_6 . The ^{235}U content of most of the DUF_6 is in the range of 0.2 to 0.3 percent. A decision on whether or not to recover more of the ^{235}U should be based on the economics of recovery. If the recovery cost is lower than the cost of producing enriched uranium from natural uranium then it should be pursued and sold on the commercial market. Economic recovery of more of the ^{235}U from DUF_6 may not be practical in the near term.

While the AVLIS process may turn out to be a dependable low cost means for enriching uranium, a significant pilot plant operation would be required to prove out the technology on a commercial scale. Input to the AVLIS process is uranium metal, not UF_6 . To deploy the AVLIS process, two new facilities would be required; 1- conversion of DUF_6 to metal and 2- AVLIS enrichment plant. The process limits on the degree of extraction of U_{235} from DUF_6 are undefined for the AVLIS process.

The present gaseous diffusion facilities do have a practical process limit on how much of the U_{235} can be extracted from DUF_6 . That limit is somewhere below 0.2 percent. However, if stripping is practical with gaseous diffusion the present facilities could be used since their capacity is greater than the customer backlog of enriching service. Contracted enrichment using the centrifuge process could be done at the Louisiana location at some future date, if that plant is built. However, the capacity planned for the centrifuge plant is considerably less than would be required for processing DUF_6 . The facilities needed for use of the AVLIS process could be built at the location of one of the present enrichment plants and the capacity for processing DUF_6 would be much larger than that being considered for enriching natural uranium.

Relatively large quantities of good grade uranium ore have been defined in Canada and Australia that can be developed to provide low cost natural uranium feed stock for uranium enrichment, equivalent to projected needs for many decades. Stripping ^{235}U from the DU appears to be higher in cost than the enrichment of natural uranium. However, high grade ores are finite and when they have been depleted, recovery of ^{235}U from DU may be economical. Such an economical basis may not be experienced for many decades.

Overall Federal regulation for safety of uranium enrichment operations is evolving. Temporarily, the new Uranium Enrichment Corporation is operating under DOE regulations that will be coordinated with the Nuclear Regulatory Commission (NRC). The private centrifuge facility is being licensed by the NRC. The unique nature of the AVLIS process will require substantial regulatory evaluation by the NRC.

7.1.10.1.2 Evaluation by Reviewer V

Option 1 - This option suggests refeeding DUF_6 through the GDP cascades for re-enrichment to fuel. The use of the GDP process is unlikely at this time due to its high energy cost (50 times as much) relative to the improved gas centrifuge process currently in permitting with the NRC. For this analysis, the newer process will be used to assess the feasibility of re-enrichment. The enrichment process does generate radiological and hazardous material risks to workers and the surrounding community, however, the NRC has judged these exposures and risks to be well within acceptable levels. All emissions and effluents would be carefully regulated and monitored, as would worker safety. None of these is expected to present unique problems. Siting a new processing facility of this type would cause resistance in some communities, while others will decide to accept the risks.

Option 2 & 3 - This option suggests the use of the AVLIS process for re-enrichment using DUF_6 . This would require that the DUF_6 be converted to uranium metal first in order to use it in the AVLIS process. This is a significant additional processing step. There are a number of different processes for doing this conversion with varying environmental impacts. The AVLIS process itself has some environmental, health and safety concerns. Prevention of accidental criticality at the plant and protection of workers from airborne uranium oxide particulates are the chief ones noted. In addition, typical operational risks associated with any large industrial facility must be considered as potential risks. None of these is expected to present unique problems. Use of DU tailings would reduce the amount of natural uranium mining required and depletion of that resource.

7.1.10.1.3 Evaluation by Reviewer X

Option 1 - This recommendation proposes to use the dUF_6 inventory in the same manner it has been used in the past resulting in its production. No additional effects would result from this process.

New plant would not be required. However, current Gaseous Diffusion Plant (GDP) technology may be supplanted by centrifuge technology having lower operational and

maintenance costs. The lower maintenance requirements of the centrifuge equipment should have lower worker health and safety impacts.

Refeed dUF_6 will not require transporting cylinders to other sites.

Option 2 & 3 - An AVLIS plant requires uranium metal as feedstock. Thus for this option to work, the dUF_6 would first have to be converted to metal.

Conversion of dUF_6 to metal currently results in a mixed waste effluent. Various methods to reduce this waste or alternatively to use new processes have been proposed.

Operational concerns are similar to those in Gaseous Diffusion Plants for the health and safety of workers, accidents resulting in releases of radioactive material to the public, and prevention of accidental criticality.

If a dUF_6 /metal conversion plant with a contiguous AVLIS plant were built at current GDP sites, then transportation among the plants would not be an issue.

7.1.10.1.4 Evaluation by Reviewer Y

The potential use of gaseous diffusion plant cascades is liable to open old environmental wounds. The potential for AVLIS technology is good for environment, safety, and health questions.

7.1.10.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. Steven Carter, provides two options for use of the depleted uranium hexafluoride, and also provides a recommendation that any new manufacturing facilities be located on existing sites in order to stabilize regional employment.

The first option proposed is to refeed the tails back through the Gaseous Diffusion Plant cascades in order to remove additional U^{235} from the UF_6 . Feeding UF_6 through the cascades is a normal practice which would not represent any new environmental, safety or health concerns.

The second option proposed is that the tails could be further depleted utilizing the Atomic Vapor Laser Isotope Separation Process (AVLIS) that has been developed by DOE. The environmental, safety, and health issues for this option are expected to be similar to those at other fuel cycle facilities, and would likely be subject to NRC regulation and licensing requirements.

The third issue of this proposal is an administrative recommendation which doesn't provide technical information. Any environmental, safety, or health issues would be dependent upon what manufacturing processes were selected, and therefore no evaluation is provided by this reviewer.

7.1.10.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.10.2.1 Evaluation by Reviewer U

Waste generation associated with further enrichment using either the gaseous diffusion or centrifuge process would be minimal.

Assuming recovery of one half of the U_{235} in the form of 4 percent enriched product, the reduction in DUF_6 would be about 15,000 MT. Thus, the amount of DUF_6 that would need eventual disposition would be reduced by about 2-3 percent--not a significant reduction.

Disposal of DU metal after further stripping of ^{235}U with the AVLIS process would entail the same disposal issues as imposed for disposal of DU metal without stripping. While it may be acceptable to eventually dispose of metal, safety regulations may require disposal to be in the form of uranium oxide. This will not be resolved until disposal decisions are made.

7.1.10.2.2 Evaluation by Reviewer V

Option 1 - The waste streams associated with this option would be low-level wastes requiring disposal in a licensed facility and meeting all applicable waste acceptance criteria. The largest waste stream would be the depleted DUF_6 , which would constitute 95% of the output and have the same general characteristics of the input. This is to say, you would still need to find some process to convert, store or dispose of the DUF_6 , which is corrosive, toxic and radioactive.

Option 2 & 3 - The conversion of DUF_6 to metals will have waste streams associated with the particular process chose. Some processes generate fairly significant amounts of low-level wastes. In addition, when the metal is used in the AVLIS process, only 10% will actually be incorporated into the enriched uranium, the remaining 90% in tailings will need disposal. There will also be other low-level wastes from operations and maintenance. There will be small amounts of ethanol which is a hazardous waste and non-hazardous waste streams from routine operations, e.g. cooling tower blow-down.

7.1.10.2.3 Evaluation by Reviewer X

Option 1 - The waste stream from a refeed process would be the same as the waste stream from a primary feed process using natural uranium rather than depleted uranium. The primary difference is that UF_6 does not need to be made.

The down side of this recommendation is that it will not significantly deplete the current inventory of dUF_6 . With a ^{235}U content of 0.2 to 0.3 percent, removal of the remaining ^{235}U inventory would use about 900 MTU metal as U^{235} plus additional metal as U^{238} for a total consumption of about 30,000 MT. A solution for the remaining dUF_6 would still have to be found.

Option 2 & 3 - The primary concern for the waste stream would come from the dUF_6 /metal conversion process. The specific wastes depend on the conversion selected process.

The AVLIS process will deplete less than 10 percent of the current dUF_6 supply. Thus, the remaining metal will either need to be disposed of or provided to a commercial market. The advantage of further depleted uranium to a commercial is that it will be less radioactive than uranium having a 0.2% or more ^{235}U content. However, this is probably less of a concern than the chemical toxicity of the uranium.

The AVLIS process is reported to have no significant radioactive liquid waste streams or mixed radioactive/hazardous waste streams.

7.1.10.2.4 Evaluation by Reviewer Y

Depending on process(es) location, the need for transport of waste may be considered a variable.

Reinserting into the cascade is a form of recycle.

7.1.10.2.5 Evaluation by Reviewer Z

The first option of this proposal is to refeed the material back into the diffusion plant cascades. This is a normal practice, and would not present any new waste management concerns.

The second option proposed is to further deplete the UF_6 utilizing the AVLIS process. The radioactive waste streams associated with this process are similar to other fuel cycle facilities. The principal hazardous waste stream generated by the plant is degraded optical dye dissolved in ethanol, which is removed from the dye laser system and disposed after recovery of about 90% of the ethanol content via distillation. This process utilizes uranium in a metallic form, alloyed with iron. The final product is metallic uranium. The selection of this option would therefore produce large amounts of metallic uranium alloy. The iron content in the depleted uranium could be a detriment to the use of the uranium

for other applications, or may require an additional process to separate the iron from the uranium before the uranium could be used.

7.1.10.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.10.3.1 Evaluation by Reviewer U

Assuming recovery of one half of the ^{235}U in the form of 4 percent enriched product, the enriched product would be about 15,000 MT. This is a significant amount of nuclear fuel material, equivalent to about seven years of fuel supply for the nuclear energy plants operating in the U.S.--a value of several billions of dollars. However, the cost of the further enrichment function is probably greater than the value of the recovered low enriched material.

Relatively low cost estimates for uranium enrichment have been provided by the research organization developing the AVLIS process. However, the overall cost of obtaining low enriched uranium from DU through the use of AVLIS is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

7.1.10.3.2 Evaluation by Reviewer V

Option 1 - The costs of re-enrichment with DUF_6 are not known, but the uranium content in the feed would be one third lower. It would appear from this general information that there may be some question whether this process would make sense economically. The large capital investment required to process the inventory would probably not be justified given that, after the processing, 95% of the inventory would still remain requiring treatment and/or disposal.

Option 2 & 3 - The costs of the conversion processes to metal vary significantly. The life-cycle cost of one process, plasma reduction, is estimated at \$1.2 billion for example. The estimated cost for an AVLIS plant is \$1.2 billion, with operations costing \$147 million annually to produce \$600 million in revenues (lower if depleted uranium is used). It would take two plants 20 years to convert the entire DU inventory to enriched uranium and tailings. This would produce the equivalent of 1,000 reactor-years of fuel supply. The availability of markets for these fuels and the effect on the markets is not known. Some gas diffusion plants with higher costs might be forced to close. Total system cost for this option is a concern.

7.1.10.3.3 Evaluation by Reviewer X

Option 1 - The affordability of this option depends on market pricing and process efficiency. Specific cost information was not available. However, an economic decision was previously made to declare the current dUF_6 inventory as tails with 0.2 to 0.3 percent ^{235}U remaining. Thus, it was considered uneconomical to continue with this material in the cascades. The question now is whether current market conditions provide a different economical environment.

If it is economical to use dUF_6 as feedstock, then the profits from SWU sales could be used to partially fund costs for converting the remaining dUF_6 to U_3O_8 or metal for disposal or other applications.

Option 2 & 3 - The viability of this recommendation depends on two ratios: (1) the ratio between the cost of making the depleted metal available from conversion of dUF_6 and the cost of producing the metal from natural uranium, and (2) the cost ratio of obtaining enriched uranium from depleted rather than natural uranium metal used as feedstock.

7.1.10.3.4 Evaluation by Reviewer Y

Reinsertion into cascades is likely to be very expensive even if there are no capital costs. Refurbishment for environmental acceptance is a potential big ticket item.

AVLIS R&D seems like a good R&D bet for a versatile future technology that has economic promise. Presumably, decommissioning costs for the cascades are born elsewhere, regardless of whether they are used for DUF_6 or not.

7.1.10.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of refeeding the depleted UF_6 through the gaseous diffusion plant. It is anticipated that as the residual U^{235} decreases, the incremental cost of removing it will increase.

Regarding the option for refeeding the material through the AVLIS system, if the presence of iron in the depleted material after feeding through the AVLIS system does not affect the use in other applications, or if the iron can be removed economically, then the AVLIS option should be considered for any material which will be used in metallic form. The recovery of the residual U^{235} would help to offset the costs of processing.

The recommendation that new facilities at existing sites is an administrative issue. No costs estimations are made for this option.

7.1.10.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.10.4.1 Evaluation by Reviewer U

The gaseous diffusion process is well developed and has been used for decades. There is sufficient excess capacity in the current facilities to perform further enrichment of DUF_6 if it turns out to be economical to do so. The centrifuge process is well developed and commercially mature, although capacity is not available to perform the DUF_6 stripping.

While considerable development has been completed for the AVLIS uranium enrichment process, practicality is yet to be determined. Obtaining enriched uranium from DU should be considered as a long term possibility, not a near term use. Conversion of the DUF_6 to AVLIS metal feedstock requires substantial development and the construction of a large conversion facility.

7.1.10.4.2 Evaluation by Reviewer V

Option 1 - The conversion processes are already in commercial use. After permitting, it takes about six years to put a plant into operation.

Option 2 & 3 - The conversion processes to metal are in various stages of development, however, some are already in commercial use. The AVLIS process is close to commercial with full specific scale tests completed.

7.1.10.4.3 Evaluation by Reviewer X

Option 1 - Gaseous diffusion is a mature process in the U.S., and centrifuge enrichment is a mature process in other countries.

Option 2 & 3 - AVLIS technology hasn't been commercially deployed. It is reported to have been successfully tested at full specific scale and in the final stages of engineering.

7.1.10.4.4 Evaluation by Reviewer Y

This proposal does not provide for any insight on two processes. Feeding into the cascades leaves further depleted DUF₆; does not solve basic problem. Feeding into cascades and then into AVLIS is "overkill."

7.1.10.4.5 Evaluation by Reviewer Z

Feeding UF₆ through the gaseous diffusion plant is a mature technology. No new problems would be anticipated to refeed the current depleted material through the plant.

The AVLIS technology has not been commercially deployed. The U-AVLIS technology is in the final stages of engineering and has been successfully tested at full specific scale.

The third part of the proposal is an administrative recommendation that involves no technology.

7.1.10.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.10.5.1 Evaluation by Reviewer U

Employment at the present uranium enrichment facilities would be expanded for the task of stripping of ²³⁵U from the DUF₆. The stripping function would entail several decades to process all of the 560,000 MT of DUF₆.

Performing the uranium stripping at one or all three of the existing sites where DUF₆ is stored should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

7.1.10.5.2 Evaluation by Reviewer V

Option 1 - The conversion plant would constitute a minor industrial construction and operation project with some direct and indirect impacts. Public acceptance of this type of facility might vary between communities, but it is likely a site could be found.

Option 2 & 3 - The conversion plant and the AVLIS plant together would constitute a major industrial construction and operation project with significant direct and indirect

impacts. If the combined plant were located in rural rather than developed areas for safety reasons, the magnitude of the impact would be greater. It may be necessary to co-locate other industrial facilities including a powerplant, thereby expanding the economic impact and regional development effects. Spin-off industries will be a function of the location of the conversion plant, its products, its supply needs and the underlying economic base of the region. The AVLIS plant would have a significant economic effect on its own in most areas. The \$1.2 billion in construction, the \$147 million in annual operating costs and the estimated 1100 new jobs created would be a stimulus to the regional economy. Siting may be an issue for either or both of the facilities. Co-locating them on existing DOE sites might ease some zoning and land use questions. On the other hand, the addition of these large facilities to already developed areas could have adverse effects in terms of traffic, pressure on public services and rapid growth in housing and service industries. The AVLIS plant is likely to meet some resistance in siting due to public concerns regarding nuclear power production.

7.1.10.5.3 Evaluation by Reviewer X

Option 1 - Using the dUF₆ as refeed would continue employment for workers at the current sites.

If new centrifuge plants, such as Claiborne, were to be built, local employment would increase with a corresponding improvement in the local economy.

Option 2 & 3 - The recommendation requests that DOE consider locating any new conversion or manufacturing facilities on the current plant sites to enhance local employment opportunities and stability for current employees and/or regional residents. This option would provide a currently experienced work force.

Local acceptance is indicated in the recommendation.

7.1.10.5.4 Evaluation by Reviewer Y

The heart of the submittal is a plea for deployment at or near the DUF₆ storage sites. This makes some sense unless there are compromises to such deployment that would exacerbate costs. This is not envisaged.

A plea for public comment on DOE plans for DUF₆ handling and processing is made and must be considered in today's world.

Public acceptance can be anticipated to be better if local employment is significantly enhanced.

7.1.10.5.5 Evaluation by Reviewer Z

Refeeding the depleted uranium through the gaseous diffusion plant would have some positive impact on employment at the existing facility, however, specific employment

figures are not available to this reviewer. There are no other socioeconomic impacts anticipated from this option.

This reviewer has no specific information on the socioeconomic impacts for the option of feeding the depleted uranium through the AVLIS process. One effect which should be considered is that the additional U^{235} removed from the depleted tails will reduce the need for natural UF_6 feedstock, which might impact companies on the front end of the fuel cycle, such as mining, milling and uranium conversion.

The recommendation of locating any new manufacturing processes at existing sites is specifically aimed at the socioeconomic impact which such action will have. This impact cannot be evaluated without knowing the kind of facility which would be needed and the schedule that it might have.

7.1.10.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.10.6.1 Evaluation by Reviewer U

The depleted uranium does contain potentially recoverable energy values in the form of ^{235}U . While the economic value of the energy resource is insufficient to recover the values in the near term, economic recovery may be achieved at some future date when high grade uranium ores are depleted. Thus, an important factor may be an assessment of potential energy values recoverable through isotope separation either in the near term or at some point several decades in the future.

7.1.10.6.2 Evaluation by Reviewer V

See General Comments.

7.1.10.6.3 Evaluation by Reviewer X

None.

7.1.10.6.4 Evaluation by Reviewer Y

This is really a plea for local deployment. Someone should look at reinserting into cascades for shared costs by the world (other people also have DU that they cannot soon use!).

7.1.10.6.5 Evaluation by Reviewer Z

None.

7.1.10.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.10.7.1 Conclusion by Reviewer U

An assessment should be made of the cost for recovery of ^{235}U from the DUF_6 using the gaseous diffusion process. The cost is anticipated to be considerably greater than the value of recovered ^{235}U for most of the DUF_6 . However, since a quantity of about 96,000 MT of DUF_6 contains above 0.3 percent ^{235}U , it may be cost effective to recover material from that portion of the DUF_6 . If it does become economically attractive to perform the stripping it should be done. However, in the near term this does not appear to be practical. Nor, does the stripping of ^{235}U reduce significantly the amount of DUF_6 .

Using DU as feed stock for AVLIS enrichment may be appropriate within a longer time period--several decades. It can not be viewed as a near term practical activity.

Stripping does not resolve the problem of what to do with the DUF_6 . At best, such an activity would reduce the amount of DUF_6 by an amount of 1-3 percent.

The organization making the recommendation in Document #11 is a business development organization that is interested in providing favorable business activity within the locality. Since one of the current enrichment plants is located within the area of interest of this organization, it is familiar with such facilities and finds them to be attractive for the local community. Expanding the ongoing activity is favored by the organization as well as encouraging the building of new such facilities in their area.

7.1.10.7.2 Conclusion by Reviewer V

Option 1 - Based on DOE criteria, this option would not be considered reasonable due to the small volume resolved using this approach and the potentially high costs.

Option 2 & 3 - Based on DOE criteria, this option would be considered reasonable. Costs would need to be verified based on the conversion technology chosen to provide the metal feedstock. The AVLIS process is nearly technically ready but is not limited to DU metal to begin operations. The U. S. Enrichment Corporation is proceeding with commercialization of AVLIS technology.

7.1.10.7.3 Conclusion by Reviewer X

Option 1 - Using the dUF_6 as refeed for a GDP or as feed for a centrifuge plant will be cost effective only if the cost for enrichment alone is less than the cost of the entire front end of the fuel cycle plus enrichment using natural uranium.

Using dUF_6 as refeed will utilize less than 10 percent of the current dUF_6 inventory. Thus, a solution will still have to found for the remaining dUF_6 . However, if use of the dUF_6 as refeed is economically justifiable, then the profits from a refeed process could be used to offset the cost dUF_6 disposal.

Option 2 & 3 - The viability of this recommendation depends on two ratios: (1) the ratio between the cost of making the depleted metal available from conversion of dUF_6 and the cost of producing the metal from natural uranium, and (2) the cost ratio of obtaining enriched uranium from depleted rather than natural uranium metal used as feedstock in the AVLIS process.

This option will use less than 10% of the current stock of dUF_6 (though requiring a throughput of 100% of the inventory). Thus, it will not have the necessary programmatic impact as an option by itself. However, the value of the resultant enriched uranium relative to the value of other metal products must be considered.

AVLIS has not been tested on a commercial basis. No information was provided to enable an estimate of how long it would take to be implemented. However, it is said to be in final engineering, and to have been successfully tested "at full specific scale."

7.1.10.7.4 Conclusion by Reviewer Y

It is reasonable to have an early look at the "affected plant sites" to look for program economies. The people are there and may have experience in requisite skills and technologies.

7.1.10.7.5 Conclusion by Reviewer Z

This reviewer is unable to evaluate the merit of refeeding the depleted uranium through the gaseous diffusion plant cascades. It is anticipated that the incremental cost of recovery of U^{235} will make this option cost prohibitive.

There appears to be merit in the second option which proposes that the depleted tails be fed through the AVLIS process. Although this reviewer does not have information related to the efficiency and cost of operation of the AVLIS process, based on the available information, it appears that the efficiency of the AVLIS process is adequate to recover additional U^{235} to sufficient make the process cost effective.

The reviewer is not able to make an assessment of the merit of locating new processes at existing sites.

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7.1.11 Evaluation of Document No. 19 (Independent Technical Reviewers' No. 12)

Respondent:

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Department of Energy
Washington, DC 20585

202/586-9620

Description of Response:

This response recommends use of depleted uranium metal in support of both the Multi-Purpose Canister subsystem and the General Atomics truck subcask system. The responder states that for the MPC subsystem, the depleted uranium metal can be used as the gamma shielding material for the lid or shield plug in the fabrication of a standardized sealable metal canister that is capable of holding multiple spent fuel assemblies and in fabrication of two transportation casks into which the canister will be placed. For the truck cask subsystem design, the responder states that the depleted uranium metal can also be used as shielding material for the cask.

7.1.11.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.11.1.1 Evaluation by Reviewer U

An estimate is provided for the amount of depleted uranium (DU) metal that could be envisioned for use as shield plugs for spent fuel canisters and as gamma shielding in the construction of Multi-Purpose Canister (MPC) transportation and storage casks. Under the maximum scenario, the program may utilize 25,000 to 45,000 metric tonnes (MT) of DU metal. The memorandum indicates a quantity of 4,200 MT as currently available in DOE's inventories that may be allocated for this application. If adopted for this application, a quantity of 20,000 to 40,000 MT of new uranium metal would need to be produced from the depleted uranium hexafluoride (DUF₆) stockpile. Existing capabilities within the private sector, with reasonable expansion, should be able to produce the quantity of DU

metal within the time period of need for this application. Uranium metal processing facilities at Oak Ridge could fabricate the components for these shielding applications.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. DU metal has been fabricated into components both internally within DOE and in the private sector for several decades. Large induction and arc melting furnaces, a large rolling mill and extensive machining capability presently in the Y-12 complex of Oak Ridge could be used to fabricate DU shield plugs and components for transportation casks. Containment of the uranium within a stainless steel outer skin would be needed to prevent excessive oxidation and surface sloughing.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF recovered during the defluorination of DUF_6 . HF is a very active acid that will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, uranium metal processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Transportation of DUF_6 to the defluorination plant for the quantities required probable would be via truck. Truck transport of natural and low enriched UF_6 are a regular part of current nuclear fuel supply. With DU metal production over a ten year period, the number of trucks required to transport the DUF_6 for this application would be about two trucks each day.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal processing could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities.

7.1.11.1.2 Evaluation by Reviewer V

This response suggests the conversion of DUF_6 to metal, or the use of existing DU metal inventories, for use in fabrication of Multi-Purpose Canisters (MPC) for the storage and disposition of spent nuclear fuel (SNF). DOE is sponsoring research on these concepts in which DU metal would be used for shielding material in the lid's shield plug and the transportation cask body. The environmental health and safety impacts of various

techniques for converting DUF_6 to DU metal are discussed in Documents 4-3, 8, 27 and 30.

The fabrication of MPC's is not expected to present significant environmental issues. Control of the exposure of workers to airborne particles will be a key concern. Environmental, health and safety standards would be enforced and provide mitigation of most risks. Siting could be a concern, however, use of existing facilities could ease some permitting issues. The use of MPC's in the handling of LEU wastes may attract more attention to their fabrication techniques, however, no unusual issues are expected. If environmental concerns limit the use of LEU in nuclear powerplants, it is unclear how the demand for these canisters will be effected. Transportation of the materials is not expected to cause any significant public health concerns.

7.1.11.1.3 Evaluation by Reviewer X

Once dUF_6 has been converted to uranium metal, fabrication of parts is a process with which the industry has had considerable experience. Depleted uranium has been used for shielding material in transportation casks for a number of years.

Fabrication methods and facilities account for the hazards of working with uranium. No new hazards are anticipated.

Depleted uranium used in MPCs or the multi purpose units (MPUs) would be clad to keep the uranium from oxidizing. This would provide personnel protection as well.

Any MPC or MPU would need to be designed to meet NRC and DOT requirements for transportation of radioactive materials.

7.1.11.1.4 Evaluation by Reviewer Y

The concept of using SNM as a container or shield for other SNM needs to be tested in the regulatory arena; principally, NRC and EPA purview, but DOT may also be involved. No substantive issues beyond worker safety and public exposure during mishap (e.g., transportation) are anticipated. Any mishap is likely to be overshadowed by container contents which will be really radioactive with penetrating rays and particles.

7.1.11.1.5 Evaluation by Reviewer Z

Mr. Williams provided the comment regarding the possible future use of depleted uranium metal in the construction of the Office of Civilian Radioactive Waste Management (OCRWM) Multi-Purpose Canister (MPC) subsystem and the General Atomics (GA 4/9) truck cask subsystem. The proposal suggests that up to 25,000 to 45,000 MT of DU metal might be utilized. While the proposed suggestion is viable and certainly a good application of the depleted uranium, the application does not meet the Assessment of Reasonableness criteria for Programmatic Impact for utilizing at least 15% of the depleted UF_6 inventory. Therefore, a detailed evaluation was not performed.

7.1.11.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.11.2.1 Evaluation by Reviewer U

For each MT of uranium metal produced by the conventional Ames process, approximately 0.5 to 1 MT of solid waste is produced, mostly in the form of MgF_2 . This solid waste must be allocated to low level waste (LLW) disposal or processed to remove essentially all of the uranium to permit it to be disposed in a sanitary land fill.

Disposal of empty UF_6 cylinders will be required. Input to the defluorination process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal of the depleted uranium remaining as heels. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites.

7.1.11.2.2 Evaluation by Reviewer V

The waste issues associated with conversion to DU metal are discussed in the documents listed above. The fabrication of the MPC's will generate only minor amounts of wastes from machining, casting and/or cutting fluid residues. The use of the DU metal in the MPC's itself is a significant recycling of material that is otherwise a disposal problem. Should the canisters not be needed at some future time, they would need to be disposed of in a facility appropriate to their risk level.

7.1.11.2.3 Evaluation by Reviewer X

A major advantage of using depleted uranium in MPUs is that it will be disposed of along with the high level wastes or spent fuel contained within the MPUs. Thus, it won't add to the waste stream. In fact, this use will reduce the total waste stream from conversion of dUF_6 .

Wastes generated in the machining and fabrication process (cuttings) can be recycled into the casting stream.

An estimated 10,000 MPCs will be needed over the next 20 years if the MPC concept is adopted. Each shield plug is estimated to require two MT of depleted uranium, and the transportation cask is estimated to require up to 20 MTUs. The Office of Civilian Radioactive Waste Management (OCRWM) thus estimates that up to 45,000 MTU could be required for this program alone. This represents about 12 percent of the DUF_6 inventory that would be permanently removed from the waste cycle. Because of uranium's effectiveness as a gamma shield, the size of the MPCs would be significantly reduced over the size from using other materials such as DUCRETE, thus reducing the size of a permanent or retrievable high-level waste facility.

7.1.11.2.4 Evaluation by Reviewer Y

Proposal seeks to utilize DU metal. Waste from process to obtain metal not considered in proposal. Ultimate disposal of this material could be to breeder or converter reactor blankets.

7.1.11.2.5 Evaluation by Reviewer Z

See Section 7.1.11.7.5.

7.1.11.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.11.3.1 Evaluation by Reviewer U

The cost of converting DUF_6 to uranium metal with the Ames process is well defined. The processing cost, metal fabrication costs and waste disposal costs would be included in the value of the metal components. This overall cost may result in a high value that cannot be justified for the application. Since the DUF_6 has a liability cost associated with eventual disposal, it may be desirable for the processing costs for metal production to be offset in the amount of the future liability cost for disposal of DUF_6 . Doing so would maintain a neutral position of overall cost to DOE.

7.1.11.3.2 Evaluation by Reviewer V

The costs associated with the use of DU metal are not identified. It is not clear how much of the fabrication costs might be attributable to the DUF management programs or how the cost savings from recycling the DU metal would be incorporated. The market for these

MPC's over time is not well documented. The costs are early estimates and need further clarification.

7.1.11.3.3 Evaluation by Reviewer X

Cost avoidance is the primary concern of this criterion. The total cost of DOE's MPC/MPU program is estimated to be \$5 to \$12.6 billion. However, this is not associated with the cost of the DUF_6 disposal program. More importantly, this program would avoid the cost of ever having to dispose of the depleted uranium. At least \$32 million would be saved in disposal costs using estimates from Hertzler (1994) for shallow land burial at NTS. More reasonable cost avoidance would be for deep geological burial. This would probably be at least triple the shallow land burial cost.

7.1.11.3.4 Evaluation by Reviewer Y

The proposal sheds no light on either total or incremental costs. In fact, the proposal states the costs cannot be evaluated. It seems important to ascertain realistic cost differentials between high-density material shields and those with SNM.

7.1.11.3.5 Evaluation by Reviewer Z

See Section 7.1.11.7.5.

7.1.11.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.11.4.1 Evaluation by Reviewer U

Production of DU metal from DUF_6 has been achieved for decades. The process and parameters are well understood. Metal casting and fabrication of large depleted uranium components have been accomplished for an extended period. Overall, the maturity of the approach is sufficient to provide high confidence of success. Some research effort appears appropriate to develop the most effective means to remove essentially all uranium from the slag produced during metal reduction.

7.1.11.4.2 Evaluation by Reviewer V

Some technologies for producing DU metal are commercial while others are within reasonable development range. The use of DU metal in the MPC's should not cause any significant issues. The MPC's themselves are currently undergoing feasibility evaluations, but environmental analyses are already underway. The technology for fabricating the containers is commercial.

7.1.11.4.3 Evaluation by Reviewer X

The technology for fabrication of uranium using both casting and wrought techniques is well established.

Uranium metal has been used for several years in the U.S. for shielding casks.

Dry storage systems for spent nuclear fuel have recently been licensed by the NRC.

7.1.11.4.4 Evaluation by Reviewer Y

DU metal in these applications makes sense if regulatory obstacles can be effectively handled. If not, alternate materials would have to be used. The proposal is very "iffy" with frequent reference to "If one were to assume..."

The form of DU metal might be of interest. Uranium is non-isotropic. Presumably, isotropy can be attained by alloying or rolling. The long-term behavior of unalloyed, alloyed, or rolled Uranium in these applications with mild temperature gradients may not be sufficiently known for confident long-term use.

7.1.11.4.5 Evaluation by Reviewer Z

See Section 7.1.11.7.5.

7.1.11.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.11.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a fairly steady rate for a decade or two to provide the needed material. Performing uranium processing operations at a location where uranium is presently being processed, should be

viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achieved as long as the operations are carried out at a location performing similar operations, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

7.1.11.5.2 Evaluation by Reviewer V

The facilities associated with this option are unlikely to create a significant economic impact. If existing plants are used or only a small portion of the inventory is used, impacts would be negated. Traffic impacts should be minimal. The fabrication activities should not cause significant public concern.

7.1.11.5.3 Evaluation by Reviewer X

Fabrication facilities are currently available at Oak Ridge, the Army's Kinetic Energy Penetrator Production Base, and in several private companies. Cask construction would provide additional work for these facilities.

Public resistance to transportation of any nuclear material is likely to be resisted. However, the potential for the synergistic permanent disposal of depleted uranium should receive a positive response.

7.1.11.5.4 Evaluation by Reviewer Y

Modest positive employment impacts anticipated for fabricating MPC and transport systems. The public concern will be focused on the contained materials. The fabrication of such containers could be highly desirable in a locally depressed area with requisite skills (e.g., Oak Ridge).

7.1.11.5.5 Evaluation by Reviewer Z

See Section 7.1.11.7.5.

7.1.11.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.11.6.1 Evaluation by Reviewer U

A primary factor is the question of whether a demand for uranium metal radiation shielding components will be forthcoming. The universal containment system for nuclear spent fuel is being considered by those responsible for nuclear waste disposal. The shielding material requirements will be defined by the lowest cost approach to achieve shielding. Materials other than depleted uranium metal are available and may be used for the shielding. Further development of the shielding requirements and a better definition for the cost of producing depleted uranium metal components are required before a determination can be forthcoming on the practical use of uranium metal in this application.

7.1.11.6.2 Evaluation by Reviewer V

See General Comments.

7.1.11.6.3 Evaluation by Reviewer X

None.

7.1.11.6.4 Evaluation by Reviewer Y

This is a good use for existing DU metal. Whether it is justified to convert DUF₆ for this use will ultimately be determined by the process to make DU metal and what other uses the process will have (e.g., blankets for breeders or high converters). This option could be the deciding factor on whether to convert DUF₆ to UO₂ or metal.

7.1.11.6.5 Evaluation by Reviewer Z

None.

7.1.11.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.11.7.1 Conclusion by Reviewer U

Conversion of DUF₆ to metal could readily be achieved within existing facilities, or reasonable expansion of these facilities, to provide the quantity of material needed for the recommended shielding applications. The quantity of 20,000 to 40,000 MT is less than the guideline amount to be considered reasonable (i.e., 84,000 MT). However, since this amount should be obtainable with modification of existing capabilities within the DOE and private industry, this application should be viewed as a responsible potential application. The technology is developed to a point where it could provide quality production of uranium metal components in the near term with existing technology and with modification

of existing facilities. These shielding applications should be pursued only if they provide an economically attractive approach for the OCRWM program.

The organization providing the comments in Document #12 has the best available information and understanding about the potential use of DU for shielding material and the quantity that could be employed by the OCRWM program. Shielding plug and transportation casks designers will define the economics of these applications.

7.1.11.7.2 Conclusion by Reviewer V

The idea of using DU metal for MPC's is consistent with DOE program goals in several program areas. There do not appear to be any major environmental, safety, health or siting concerns that would rule out this option. The major issues of concern are better definition of costs and the amount of DUF_6 which would be converted through this option. The requirements are likely to be too small to be significant in terms of responding to the inventory disposal issues, but may still be a worthwhile use of the DU metal on hand.

7.1.11.7.3 Conclusion by Reviewer X

This option would remove about 12% of the dUF_6 from the waste stream by enabling depleted uranium to be disposed of along with SNF and high level wastes while serving a beneficial purpose.

A disposal cost savings of as much as \$100 million will be incurred over the 20 year projected time schedule of the MPC program.

7.1.11.7.4 Conclusion by Reviewer Y

The option of using DU metal in some form for MPC and related container shields is reasonable on all counts except inability to use at least 15% of the DOE inventory. However, the numbers are uncertain and this factor is probably insignificant in the prospect of benign usage of a large quantity of DU metal.

7.1.11.7.5 Conclusion by Reviewer Z

See Section 7.1.11.7.5.

7.1.12 Evaluation of Document No. 22 (Independent Technical Reviewers' No. 13)

Respondent:

Mr. Charles R. Schmitt
110 Adelphi Road
Oak Ridge, TN 37830

615/483-6922

Description of Response:

This response recommends conversion of the uranium hexafluoride (UF_6) to uranium trioxide (UO_3), which the responder states is stable and non-corrosive, using a process where water is reacted with the depleted UF_6 to produce uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF) and the resultant UO_2F_2 is mixed with lime (CaO) to produce the UO_3 . According to the responder, this second process step will also produce calcium fluoride (CaF_2).

7.1.12.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.12.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium trioxide (UO_3) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities. The basic chemical steps described in Document #13 are well defined and appear to be doable. The process steps would require very little additional development. Considerable concern is expressed about the integrity of long term storage of DUF_6 and early conversion to an oxide is recommended.

UO_3 is a relatively inert chemical form of uranium (dry black powder or compressed cake) with low reactivity and low solubility. Long term storage of UO_3 should be acceptable in stainless steel containers. However, compacting of the UO_3 should be assessed to achieve a

lower volume for long term storage. A weather protecting building would probably be required for container storage.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The recommendation offers two options, recovery of HF and disposal of the fluorine as calcium fluoride (CaF_2). There is a limited market for aqueous HF in the U.S. and for HF to be marketable it needs to be recovered as anhydrous HF. Disposal of the fluorine as CaF_2 has limited if any market value and may be an unacceptable waste form.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of UF_6 has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is an on-going step of the nuclear fuel supply industry. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the UO_3 could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.1.12.1.2 Evaluation by Reviewer V

Although no specific process information is provided, this recommendation to convert DUF_6 to uranium trioxide (UO_3) via precipitation with lime is likely to have environmental, safety and health issues similar to those for the conversion to U_3O_8 , as discussed in Document 5. The use of lime in the second step would produce CaF_2 which would need further disposal, possibly as a low level waste depending on the carryover of uranium. Decontamination may be possible if this is necessary, but it does not appear to present any insurmountable issues. The AHF produced as a byproduct, being hazardous and corrosive, will have its own set of handling, storage and transportation issues that again should not present unique or new technical issues.

The permitting for environmental, health and safety issues is not expected to present problems, but should be carefully thought through and checked in the material licensing process. Siting this large an industrial facility with hazardous materials should be careful planned to protect environment, health and safety in the surrounding community.

The processed UO_3 will require transportation and storage or disposal in large quantities creating the risk of accidental releases. However, it is not likely to present a large hazard due to the stability of this chemical form. Disposal would not present a problem technically, however, the availability of sites might be an issue requiring further development or design to make sites more acceptable in new locations. If the option proposed by the NRC for deep mine disposal is adopted, special precautions to protect groundwater will be needed. Storage of UO_3 would not present significant environmental, health or safety risks if designed in a manner similar to those in Europe where metal containers are housed in above-ground buildings. Accidental releases could adversely effect workers if they came in contact with the material, but its largely inert chemical form makes the hazard minimal. Releases to surrounding areas are unlikely.

7.1.12.1.3 Evaluation by Reviewer X

The most widely used process for conversion of dUF_6 is to convert it to U_3O_8 . Conversion to UO_3 is expected to follow similar chemical treatment. The first part of the conversion, to uranyl fluoride, is the same as the process for conversion to U_3O_8 . No information is provided on the thermodynamics of separating the uranium from the UO_2F_2 using CaO (lime). As with the conversion of dUF_6 to metal using magnesium resulting in MgF_2 contaminated with uranium, the proposed process would probably result in contaminated CaF_2 .

The process would need to be bench and pilot tested to determine the economics of building a commercial sized plant to handle the necessary throughput of dUF_6 to meet DOE's goals. Any new plant would need to be licensed in accordance with NRC, OSHA, and EPA regulations.

7.1.12.1.4 Evaluation by Reviewer Y

Assertion that UF₆ is "very corrosive" with UF₆ leakage "causing safety, health, and environmental problems" needs testing. The opportunity for extensive corrosion has not manifested itself. No major releases have been observed. The DUF₆ is a solid in the tanks under most credible conditions. These are the proposer's egregious statements that are gratuitous to the process. Without more details on the process, it is difficult to evaluate this option.

7.1.12.1.5 Evaluation by Reviewer Z

This option, submitted by Mr. Charles Schmitt, proposes that the depleted uranium hexafluoride be converted to UO₃ and aqueous HF. Although this specific chemical process is not currently used on a commercial scale, it is a process similar in nature to those which occur at other fuel cycle facilities. Specific issues related to operations, transportation, and handling are well understood. Current incentives to contain material, to minimize effluents, to recover and recycle waste, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

7.1.12.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.12.2.1 Evaluation by Reviewer U

The DUF₆ conversion to UO₃ should be achievable, but it may involve some liquid effluents. Off gas streams could be fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the uranium contamination from liquids and solids or the solids may be disposed of in low level radioactive waste disposal facilities.

There is no current use for depleted UO₃. With no practical use for the UO₃ at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Disposal of UO₃ in underground repositories may be required for effective long term disposition with an indeterminate cost at this time. The task should be much easier and less contentious than the current problems associated with high level waste disposal.

Disposal of the HF by neutralizing with lime, as one option recommended, would entail the production of large quantities of CaF_2 that would probably have trace amounts of uranium at a level requiring disposal at low level radioactive waste disposal sites. This would be a substantial increase in the total low level waste volume produced in the U.S.

A special effort will be required for emptying, cleaning and disposing of the DUF_6 storage cylinders. The recommended process removes nearly all of the DUF_6 from the cylinders. However, a small amount will remain in the cylinder as a heel that must be removed by washing the cylinders. Conversion of material recovered this way may be achieved as a slip stream into the main process at some point or it may require a separate side stream process. Cylinder cleaning should be sufficient to allow the metal to be recycled, melted and used for other metal applications. If cleaning is insufficient to permit recycle, the cylinders may need to be disposed of at low level radioactive waste sites. Alternately, the cylinders may be modified and used as storage containers for UO_3 .

7.1.12.2.2 Evaluation by Reviewer V

The UO_3 waste stream may be capable of being handled at low level disposal sites using shallow burial. However, the NRC has recommended deep geologic disposal because of the waste volume involved, so the disposal of this material must be carefully considered. Additional uses for this material could be sought. The CaF_2 will also need disposal in quantities not identified, possibly requiring low level waste facilities. The hydrogen fluoride may be recycled. Empty DUF_6 cylinders will need to be recycled or disposed of in an acceptable manner. UO_3 storage is not expected to generate any additional wastes except those associated with construction of the containers and buildings used to store it.

7.1.12.2.3 Evaluation by Reviewer X

Insufficient information is available to evaluate the waste stream from this process. A new process design should incorporate steps that would insure that all waste streams are recycled and minimized.

Advanced Recovery Systems, Inc. (ARS), the operating division of NFS Technologies, Inc., has operated a plant since 1991 that decontaminates CaF_2 and recovers the uranium. Reagent chemicals are recovered and recycled. The uranium and fluoride are both recovered, and the final product is available for industrial use. The disposable waste from the process is on the order of 10% of the feed.

7.1.12.2.4 Evaluation by Reviewer Y

Without more detail, it is unclear whether that waste product's, CaF_2 , volumes are difficult to estimate. The potential for marketing HF was not considered in this submittal.

7.1.12.2.5 Evaluation by Reviewer Z

This option would produce UO_3 , aqueous HF and CaF_2 . The market for aqueous HF in the United States is limited. This could lead to a waste disposal problem with aqueous HF

in excess of the amount required to fulfill market demands. The CaF_2 also has a market value if the amount of uranium contamination is below the specified values. While it is possible to reduce the uranium concentrations, depending on market demands it may become cost prohibitive. If this occurs, then the CaF_2 becomes a radioactive waste which must be disposed.

7.1.12.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.12.3.1 Evaluation by Reviewer U

Since this process steps recommended are well understood, the costs can be reasonably well defined for both the processing plant and the operation.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of UO_3 would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total UO_3 would be about twenty percent less than the DUF_6 , although the volumetric space may be less depending upon the amount of compacting that is achieved. Rectangular containers of UO_3 would pack and stack in a space more efficient than the cylindrical containers of DUF_6 . However, the cost of new metal containers for the UO_3 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be called for at an added cost for storing containers of UO_3 , while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. The present worth value of continued storage as DUF_6 for one hundred years and delayed conversion to UO_3 for disposal may be considerably less than performing the conversion within the next few decades. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes. However, the cost for final disposal of DU is indeterminate at this time.

7.1.12.3.2 Evaluation by Reviewer V

No cost estimates are provided with this recommendation. It could be speculated that they would be the same order of magnitude as the U_3O_8 conversion facilities although the cost of handling the CaF_2 would be in addition to those costs. Storage and/or disposal costs would be likely to be in the same realm, as discussed in Document 5.

7.1.12.3.3 Evaluation by Reviewer X

No information is available to evaluate the costs associated with this option. However, by projection from other processes, a development and piloting program could cost up to \$10 million. Operating costs should be expected to be comparable to operating costs in similar chemical process plants.

7.1.12.3.4 Evaluation by Reviewer Y

There is not one shred of insight in the proposal. If the process works, it is very likely a low-cost option. This may have to be augmented by costs to generate UO_2 from the UO_3 .

7.1.12.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Since the market of aqueous HF in the United States is limited, consideration must be given to the fact that the aqueous HF produced may become a hazardous waste rather than a marketable commodity. Also, depending on the market demands, the CaF_2 could become a low level radioactive waste.

7.1.12.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.12.4.1 Evaluation by Reviewer U

The chemical process requirements for the conversion process are well defined and should be considered mature. Technical maturity is sufficient to permit its use with minimal research and development. Additional development is needed to recover the fluorine as a salable AHF.

Safe disposal of the large quantities of CaF_2 with some uranium contamination, if permitted, would require research and development efforts.

7.1.12.4.2 Evaluation by Reviewer V

This option seems to be well developed technically, but no specific information is given on time to implement. Some uncertainty regarding storage or disposal techniques still exists.

7.1.12.4.3 Evaluation by Reviewer X

Conversion of dUF_6 to UO_2F_2 is standard industry practice. Decontamination of CaF_2 has been practiced commercially for several years.

The thermodynamics of converting the UO_2F_2 to UO_3 and CaF_2 will require investigation. Based on the time needed to bench and pilot test similar processes, a two to five year development period should be anticipated.

7.1.12.4.4 Evaluation by Reviewer Y

This is clearly a conceptual proposal for R&D to define the or a solution. Nothing suggests extensive experience. However, the chemistry seems sound and merits some laboratory scale investigation.

7.1.12.4.5 Evaluation by Reviewer Z

The conversion of depleted UF_6 by this method, while not currently carried out on a commercial scale, is similar to other chemical methods presently in use. As such, this is considered to be a mature technology.

7.1.12.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.12.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to UO_3 would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure and the process inventory would be relatively low. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a new locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.12.5.2 Evaluation by Reviewer V

Developing a conversion facility to produce uranium trioxide in the volumes needed for the Deplete Uranium Program would have positive economic benefits for the local economy around the site. To the extent that labor and materials are purchased in the local economy, a major effect could be seen in a rural location. During operation, the creation of a large number of highly skilled jobs would have a positive effect on disposable income in the immediate area and would create secondary service jobs. Ongoing purchases of materials and services for operation would also improve the local economy. Construction of storage or disposal facilities could also have positive economic impacts, but the impact of their operation would be minimal.

Siting could be a significant public acceptance issue. Even in locations where processing, storage or disposal facilities are already in operation, growing concerns about the project specific and cumulative effects of such facilities could prolong or endanger the permitting process. The NRC permitting process as well as state and local reviews that would be necessary for this option must be seen as potential barriers to implementation. If a new low-level disposal facility were required, additional siting time and effort would be

required. Where possible, existing sites should be used to minimize the costs required to permit, including Federally-owned sites.

Transportation risks might also be a significant factor inducing public concern. If DUF_6 is to be transported in large quantities for the first time, and the AHF and UO_3 then trans-shipped to other locations, the number of vehicle trips and potential for accidents will be increased. Questions are already being raised about radioactive shipments in certain areas and at certain times because of high traffic volumes. Within the immediate vicinity of the processing activities, the communities may have serious concerns regarding transportation safety and impacts on roads.

The land use implications for this option could be significant. The processing facility would be a large industrial site. Even if it is located on an existing site, the increased intensity of use could present problems. Similarly, the cumulative effect of the additional land required for disposal somewhere in the country must be evaluated in light of other demands for disposal capacity.

7.1.12.5.3 Evaluation by Reviewer X

Siting conversion plants at the two sites where the bulk of UF_6 is currently stored would minimize the transportation concerns, and would provide continuing employment for the already trained work forces available from reduced enrichment activities, thus increasing local job stability.

Since the purpose of the plant is to convert dUF_6 to a more stable state, it is likely to receive public acceptance. However, disposition of the UO_3 product may receive public resistance in the local area where disposal is to occur if it is moved from the present sites.

7.1.12.5.4 Evaluation by Reviewer Y

Modest employment for the process. Both UO_3 and CaF_2 are insoluble; this may be very attractive for public acceptance.

7.1.12.5.5 Evaluation by Reviewer Z

This reviewer has no specific information regarding the impact of this option on employment, public acceptance or local/regional development.

7.1.12.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.12.6.1 Evaluation by Reviewer U

Volume of additional waste products is an important factor. The large volume of CaF_2 appears to be unsatisfactory.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, UO_3 , is greater than the cost of converting the DUF_6 to UO_3 in the near future, with associated impacts.

7.1.12.6.2 Evaluation by Reviewer V

See General Comments.

7.1.12.6.3 Evaluation by Reviewer X

None.

7.1.12.6.4 Evaluation by Reviewer Y

This looks like a good opportunity for some innovative research. Starting with this proposal could lead to an inert low waste volume. This is not assured.

7.1.12.6.5 Evaluation by Reviewer Z

None.

7.1.12.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.12.7.1 Conclusion by Reviewer U

This option recommended in Document #13, of converting DUF_6 to UO_3 may be chemically feasible, but does not appear to be an attractive option compared to other recommendations for the conversion of DUF_6 to stable oxides. Disposal of the fluorine in the form of CaF_2 with a small uranium content, would result in a large volume of contaminated solid waste. This disposal of CaF_2 does not appear to be an acceptable approach as a waste stream for the disposal of fluorine from the production of uranium oxides.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to uranium oxides. Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. Uranium oxide powder compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued.

The person submitting the recommendation in Document #13 appears to be knowledgeable on the processing of uranium and the handling of UF_6 .

7.1.12.7.2 Conclusion by Reviewer V

This option seems reasonable with regard to DOE guidelines, but little specific information is given. If the costs and technology can be verified, it should be given consideration.

7.1.12.7.3 Conclusion by Reviewer X

The proposed process must be proven in the laboratory and on a pilot scale before construction of a commercial plant. As with other proposed conversion methods, this process should be capable of depleting the current dUF_6 in less than 30 years.

Processes for conversion of dUF_6 to U_3O_8 are better known and in commercial use. UO_3 decomposes to U_3O_8 when it is heated. Also, U_3O_8 has a higher crystalline density, although the bulk densities of the two materials are essentially the same. If conversion to an oxide form is selected, U_3O_8 would be a better oxide choice.

However, conversion to an oxide form may not be the most prudent option. Oxides may be used for long-term storage, disposal, and possibly as an aggregate substitute in concrete to form Ducrete. Only U_3O_8 and UO_2 have been investigated for use in Ducrete.

A more viable option might be conversion of dUF_6 to uranium metal. The metal would then be available for direct use in other applications, such as counterweights, flywheels, ballast, or feedstock for the AVLIS process. Metal not required for immediate application would require less storage space for later use. Once available as metal (or ideally, before conversion occurs), uses will need to be developed so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

If the dUF_6 is converted to UO_3 , the only waste stream should be the UO_3 . Disposal options haven't yet been determined. It would not be able to be disposed as LLRW. Deep burial would be necessary. If instead it is stored in the same manner as dUF_6 is currently

stored, the main advantage of the process is that UO_3 is considerably more stable than dUF_6 .

7.1.12.7.4 Conclusion by Reviewer Y

The option is not reasonable as it is proposed. There is no assurance that any of the criteria can be met without further investigation. The promise of a low-cost option suggests some investigative R&D.

7.1.12.7.5 Conclusion by Reviewer Z

This option has some merit in that it will reduce the current inventory of UF_6 to the more stable form of UO_3 . The primary limitations of this process are the production of large amounts of aqueous HF, which has a limited market in the United States, and large amounts of CaF_2 , which has a market value, but which could exceed the market demand when produced in large quantities.

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7.1.13 Evaluation of Document No. 23 (Independent Technical Reviewers' No. 14)

Respondent:

Mr. Robert Bernero, Director
Office of Nuclear Material Safety and Safeguards
United States Nuclear Regulatory Commission
Washington, D.C. 20555-0001

301-415-7298 (POC, Michael Weber)

Description of Response:

This response recommends a long-term management option of converting the depleted uranium hexafluoride to triuranium octaoxide (U_3O_8) and placement of the material in a mined cavity, possibly an exhausted uranium mine.

7.1.13.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.13.1.1 Evaluation by Reviewer U

The Nuclear Regulatory Commission (NRC) believes that, because of the current excess world-wide inventory of depleted uranium hexafluoride (DUF_6), DOE should assume that a significant portion of both DOE and commercial DUF_6 will require disposal as waste. Further, the recommendation assumes the preferred disposal form would be triuranium octoxide (U_3O_8) that would require disposal in a unique underground disposal facility.

To perform large scale conversion of DUF_6 to U_3O_8 will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities. The processes used for the conversion are well understood technology that has been in operation for several decades in the U.S. Basic concepts have been developed and used in conjunction with the conversion of natural uranium to uranium hexafluoride (UF_6) and the conversion of UF_6 to uranium dioxide (UO_2) at commercial nuclear fuel production plants.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder or compressed cake) with low reactivity and low solubility. Long term storage of U_3O_8 should be acceptable within stainless steel containers. The U_3O_8 powder should be compacted to achieve a lower overall volume. A weather protection building would probably be required for storage of the containers. Disposal of DU as U_3O_8 is a concept at this point that has not been vetted through the a full environmental assessment and approved as a safe means of disposal.

Operational issues include for the conversion steps entail well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The processes used in the U.S. in the past have not attempted to recover HF. Undoubtedly, if large scale conversion is performed, the recovery of HF in the form of anhydrous HF (AHF) to the maximum extent practical will be developed and applied. Recover of AHF, a material with considerable demand in the U.S., will require research and development and the building of pilot plant demonstration. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades. and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system with minimal liquid steps or a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be stored on the surface at the present locations of the DUF_6 for an extended period prior to disposal.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of existing regulations for large scale conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, a major regulatory effort would be required to define the disposal requirements for DU if it is declared to be a waste material, both in material form and site requirements.

7.1.13.1.2 Evaluation by Reviewer V

Conversion of DUF_6 to U_3O_8 does not raise any unique environmental health or safety issues. However, as discussed in Documents 5 and 6, these industrial processes also involve handling large quantities of hazardous materials, so detailed facility-specific safety procedures and monitoring will be required. This will apply to the transport of DUF_6 and U_3O_8 as necessary to carry out conversion and disposal. In this option, it is suggested that U_3O_8 be disposed of in a deep geological facility such as an exhausted uranium mine or other mined cavity for better containment. The NRC feels that U_3O_8 is the most appropriate form in which to store DUF_6 because of its stability although its powder form makes it low density and dispersible, if spilled.

Although some sites have been evaluated, none is developed at this time. Finding a suitable site might be difficult. Any geological site would need to be carefully analyzed to determine risks to groundwater and other potential environmental issues. Careful design of the cavity or the storage containers may be required. No unique worker safety issues are foreseen.

7.1.13.1.3 Evaluation by Reviewer X

U_3O_8 is the most non-reactive and least-soluble form of uranium, thus making it the most desirable form for long-term storage and/or disposal. No further stabilization would be necessary for a deep disposal option. The primary radiological and environmental concerns should be addressed in a consideration of the conversion processes.

Without compacting, U_3O_8 has a density of about 3 gm/cm^3 . At this density, if the entire inventory of dUF_6 is converted to U_3O_8 , the total volume will be about five million ft^3 .

The key element of NRC's recommendation is that a retrievable storage option be selected if possible. Thus, storage in a mined cavity, one of which is not currently available, would

require packaging that would increase the total volume. Rectangular packaging rather than barrels would minimize this volume. Any packaging would require venting to protect against the buildup of decay gases. Also, any facility will require air filtering to protect the workers.

Assuming that deep mine cavities can handle storage of a 20-foot wide by 10-foot high continuous stack of storage boxes, approximately five miles of shaft length would be required. Shafts must allow for inspection space, sufficient air flow to maintain environmental safety for the work force, space for equipment to place and remove storage boxes, and systems to remove water seeping into the facility.

While external radiation exposure from ^{238}U is not a concern, external exposures may become a concern over time as daughter products build up.

7.1.13.1.4 Evaluation by Reviewer Y

The submittal states that existing DUF6 storage methods "have demonstrated insignificant impacts from a health and safety standpoint for about fifty years. However, conversions of the DUF6 to U308 could provide even safer intermediate storage..." It appears the USNRC does not have a basis for "How safe is safe enough?" The specious assertion of need is less than comforting. The assertion that some of the DUF6 must be disposed of as U308 with no future use will obviate the use of this material in favor of CO₂ emitting fossil fuels burners. The bag houses may be scrutinized for natural Uranium in the fly ash at that time.

7.1.13.1.5 Evaluation by Reviewer Z

This option, submitted by Mr. Robert Bernero, proposes that the depleted uranium hexafluoride be converted to U₃O₈ for disposal. No specific method of conversion is recommended. The recommendation is made that the disposal be made in a mined cavity such as an exhausted uranium mine, although some limited quantities could be disposed in conventional near-surface disposal facilities. Burial in an exhausted uranium mine would be similar in nature to that in any deep geological formation.

7.1.13.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor,, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.13.2.1 Evaluation by Reviewer U

The DUF_6 conversion to U_3O_8 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

Disposal of the U_3O_8 at a planned activity for DU at this time will entail a major effort to define the acceptable form and an acceptable site for disposal. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes. However, the challenges associated with acceptability of a disposal site are expected to be significant.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

In addition to the disposal of DU, the current storage cylinders will need to be cleaned and disposition defined. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites, at a high cost. Another use may be to cut the cylinders in half and weld flat end caps over the open end to provide disposal containers for U_3O_8 .

7.1.13.2.2 Evaluation by Reviewer V

The waste management issues for this option are similar to those for Documents 5 and 6. It is unlikely that use of deep geological disposal would create a great deal of additional waste that would need additional disposal.

7.1.13.2.3 Evaluation by Reviewer X

No additional waste stream will be developed as a result of storage or disposal of U_3O_8 .

7.1.13.2.4 Evaluation by Reviewer Y

Potential for recycling becomes difficult for U308 stored in a mine or mine cavity. No unique problems are envisaged though NRC will be a hurdle and EPA will be a problem if part of the DU inventory is classified as waste. Such an action would be foolhardy for future generations.

7.1.13.2.5 Evaluation by Reviewer Z

This option would convert the depleted uranium hexafluoride to U_3O_8 for disposal by burial in either near-surface or deep burial such as in an exhausted uranium mine. No specific method of conversion was recommended in this response, therefore, no assessment

is being made regarding potential waste management issues regarding the conversion process. No additional hazardous or radioactive wastes are produced as a result of disposal of the U_3O_8 .

7.1.13.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.13.3.1 Evaluation by Reviewer U

Since many elements of this conversion processes are currently in use within the U.S., the costs are reasonably well defined for both the processing plant and the operation. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Since uranium enrichment activities are continuing in the U.S., there is a continuing buildup in the quantity of DUF_6 . Thus, after the DOE material has been converted, the facility may be used for conversion of DUF_6 generated by others. The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of DU disposal as U_3O_8 is indeterminate at this time because of the undefined challenges that are anticipated for the selection of a site and the required containment of the U_3O_8 at the disposal site.

7.1.13.3.2 Evaluation by Reviewer V

The costs for conversion to U_3O_8 are estimated in the \$1.2 to \$1.7 billion range for the entire inventory. The additional costs for deep storage are unknown and could vary significantly depending on the specific site. If safe cavities can be found, the cost of disposal might be reduced as special packaging and handling becomes less critical.

However, construction and/or monitoring costs could be quite high. Transport costs would probably not be excessive but could increase the cost incrementally depending on the location.

7.1.13.3.3 Evaluation by Reviewer X

The most significant cost element of this option is in the conversion of dUF_6 to U_3O_8 . Estimates are in the range of \$3 billion. A deep mine facility is not available and would have to be constructed. Costs for near surface burial are estimated to be \$10/ft³ at NTS and \$58/ft³ at Hanford. Deep burial will be more expensive. If it is \$200/ft³, a pure guess for estimating purposes only, the disposal cost would be about \$1 billion. If deep storage is selected, then monitoring costs would add to this. Thus, the total cost for retrievable deep disposal of U_3O_8 would be about \$4 billion, approximately eight times greater than storing and monitoring dUF_6 in the current cylinders placed inside engineered confinement buildings.

7.1.13.3.4 Evaluation by Reviewer Y

Submittal is silent but costs for producing DU308 from DUF6 are estimated at a few dollars per pound, probably less than for natural U308. The sale of HF will impact overall costs, but probably within current overall uncertainty.

7.1.13.3.5 Evaluation by Reviewer Z

This reviewer has no specific numeric data on costs associated with this option.

7.1.13.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.13.4.1 Evaluation by Reviewer U

The chemical process requirements are reasonably well defined for the defluorination steps since many steps of the process have been in operation in the U.S. on a relatively large scale for several decades. Research and development efforts need to be performed to define the appropriate steps to recover the HF as AHF, including the construction and operation of a pilot plant to prove out details of converting aqueous HF to AHF. Technical

maturity is sufficient to permit a commitment to the conversion of DUF_6 to U_3O_8 on a large scale with relatively high degree of success.

Disposal of the large volume of DU as U_3O_8 has not been vetted through the environmental assessment process and must be viewed as immature and speculative at this point.

7.1.13.4.2 Evaluation by Reviewer V

The conversion processes are nearly or completely commercial. The deep geological storage is not a new concept but will require some additional analysis and site specific reviews to assure feasibility, and extensive environmental and safety analyses to prove no adverse environmental effects.

7.1.13.4.3 Evaluation by Reviewer X

No deep retrievable storage facility currently exists. Currently in the conceptual stages, deep retrievable storage of U_3O_8 would require full development prior to implementation.

7.1.13.4.4 Evaluation by Reviewer Y

The process of converting DUF_6 to DU308 is technically mature having been done in France at large scale. Containers for disposal are within reach though lifetime integrity may be a continuing issue.

The assertion that a portion of the DUF_6 be classified as waste is a technical immaturity. Is it surprising that the submittal did not specify a seismically inactive site?

7.1.13.4.5 Evaluation by Reviewer Z

Near-surface disposal is a standard industrial practice, and as such, it is considered to be a mature technology. Deep disposal, such as in an abandoned uranium mine or geological structure is still in the conceptual stage and would require full development before being put into practice.

7.1.13.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.13.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low temperature and low pressure and the process inventory relatively small. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

Siting of an acceptable location for the disposal of DU as U_3O_8 is an unknown at this stage. Recent experience in the siting of low level radioactive wastes sites and the major challenges encountered in the siting of a high level radioactive waste site suggests that the difficulty of site selection will be substantial.

7.1.13.5.2 Evaluation by Reviewer V

The economic regional development, employment, public acceptance and other socioeconomic aspects of conversion are highlighted in the responses to Documents 5 and 6. The addition of deep storage would have minimal effect. Some economic effect could come from new mining activities in sparsely populated areas. The effects would be small,

however. Land use would be minimal. but some additional traffic to and from the site would be generated. Some relatively small number of permanent jobs would be created.

7.1.13.5.3 Evaluation by Reviewer X

If deep disposal in a facility such as an abandoned uranium mine is selected, actual siting will need to be known to assess public acceptance and regional development issues.

7.1.13.5.4 Evaluation by Reviewer Y

Process and mined cavity will require people. Regional development will be dictated by mine site. Public acceptance will be mild unless credibly sought.

7.1.13.5.5 Evaluation by Reviewer Z

This reviewer has no specific information regarding the impact of this option on employment, public acceptance or local/regional development.

7.1.13.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.13.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.13.6.2 Evaluation by Reviewer V

See General Comments.

7.1.13.6.3 Evaluation by Reviewer X

None.

7.1.13.6.4 Evaluation by Reviewer Y

This submittal directs without supporting details on costs, technology, etc.

7.1.13.6.5 Evaluation by Reviewer Z

None.

7.1.13.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.13.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to U_3O_8 and AHF is reasonable, acceptable and the Federal regulatory requirements are understood. Most of the process steps are well defined. Operation of a pilot plant would confirm the operation and provide the final information needed to assure an effective commercial plant operation for the recovery of AHF. Since the value of the marketable AHF is less than the overall cost of recovering it from UF_6 , there is a net added cost over the current storage mode cost base.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued.

Proceeding with an approach of declaring DU to be waste material requiring disposal as U_3O_8 does not appear to be appropriate, practical or reasonable at this stage. The environmental considerations have not been defined and the specific regulations for disposal are not in place. The potential energy resource value at some time in the future appears to be very significant and to proceed with disposal at this time appears to be premature by several decades.

The organization submitting the recommendation in Document #14 is the federal regulatory body that will have the responsibility for approval of waste form and siting requirements when and if the DU is designated as a waste for permanent disposal.

7.1.13.7.2 Conclusion by Reviewer V

It appears that this option would meet DOE's criteria for reasonableness for the most part. The major uncertainty lies in the identification of a suitable site, its certification and licensure for this use, and the cost of preparing it. This option deserves further consideration as long term retrievable disposal is consistent with DOE's programs.

7.1.13.7.3 Conclusion by Reviewer X

Long-term retrievable storage methods for depleted uranium should be evaluated relative to the costs and risks involved.

The cost for converting dUF_6 to U_3O_8 and then placing it in a deep retrievable storage or disposal facility is about eight times the cost of storing the dUF_6 cylinders in engineered surface facilities at the three current storage sites.

The current open storage method has resulted in "insignificant impacts" (NRC, RFR#14) on the health and safety of workers and the public over the last 50 years.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should the long-term storage option be selected. The risk analyses should consider that the toxic hazards of dUF_6 are significantly greater than those of U_3O_8 , and that U_3O_8 is chemically and physically more stable than UF_6 . This analysis should result in bases for deciding whether to build a deep mine storage facility or confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be prudent, what storage configuration would be safest, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

7.1.13.7.4 Conclusion by Reviewer Y

The process defined is reasonable, but not on the basis of the submittal. The process to develop DU308 from DUF6 is well defined elsewhere and reasonably costed out. The process to store U308 is reasonable. What is not reasonable is to classify DUF6 or DU308 as waste! This is, in a sense, the ultimate travesty in the energy picture.

7.1.13.7.5 Conclusion by Reviewer Z

This option has a great deal of merit. It addresses the primary issue of reducing the volume of uranium hexafluoride and converting it into U_3O_8 , which is one of the most

inert chemical forms of uranium. The primary limitation is that only a limited quantity of the material can be buried in the current near-surface disposal areas, and disposal costs in these areas is substantial. Burial in deep structures will require additional time and expense for full development.

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7.1.14 Evaluation of Document No. 25 (Independent Technical Reviewers' No. 15)**Respondent:**

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(submittal by Aerojet Ordnance Tennessee (AOT) and Babcock & Wilcox (B&W))

615-753-1200

Description of Response:

This response recommends reducing the depleted uranium hexafluoride (UF_6) to depleted uranium tetrafluoride (UF_4) and then to metal for further processing into products and/or for long-term storage or disposal. The following is a list of existing or potential products and markets: armor and anti-armor munitions, bomb door reinforcement, shape charge devices and drill collars for the petroleum industry, storage or shipping devices for radioactive/hazardous waste, and Navy ballast and kinetic energy storage devices.

The responder further states that uranium metal is currently used as starting material for the Atomic Vapor Laser Isotopic Separation (AVLIS) process and that when the metal is vaporized in the process, uranium enriched in uranium-235 is separated and solidified as depleted uranium alloy. It is stated that these tails can be reduced to metal, prepared as starting material for AVLIS, and utilized to produce an enriched product at less cost for enrichment than the current gaseous diffusion process.

7.1.14.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.14.1.1 Evaluation by Reviewer U

The recommendation in Document #15 entails conversion of depleted uranium hexafluoride (UF_6) to uranium metal for further processing into products and/or storage.

Potential uses of depleted uranium metal were indicated, including; munitions, bomb door reinforcement, shape charge devices, drill collars, storage and shipping devices, ballast and kinetic storage devices. The total potential market for uranium metal is indicated to be 818 million pounds—equivalent to about 550,000 MT of DUF_6 . The two large uses indicated are bomb door reinforcement and shape charge devices for the petroleum industry.

Further, the recommendation indicates considerable potential hazards associated with continued storage of DUF_6 and states that the preferred form for long term storage or disposal is uranium metal because it is relatively stable in air and the volume is less than other material forms. Also, by converting the DUF_6 to metal, it could be processed through the AVLIS enrichment process to recover significant quantities of uranium isotope-235 (^{235}U) for use as commercial nuclear fuel to produce electricity. This could be performed as an interim step prior to allocation of the further depleted uranium to other uses.

Using DU as feed stock for additional uranium enrichment with the AVLIS process appears possible, but may not be economically practical within a time frame of several decades. The AVLIS process has been under development for approximately thirty years without achieving necessary results to permit the process to be deployed commercially. The only new uranium enrichment plant that has been proposed in the U.S. during the past fifteen years, employs the developed centrifuge process. While the AVLIS process may turn out to be a dependable low cost means for enriching uranium, a significant pilot plant operation would be required to prove out the technology on a commercial scale. Relatively large quantities of good grade uranium ore have been defined in Canada and Australia that can be developed to provide low cost natural uranium feedstock for uranium enrichment, equivalent to projected needs for many decades. Stripping U_{235} from the DU would be higher in cost than from natural uranium. To deploy this use, two new facilities would be required; 1- conversion of DUF_6 to metal and 2- AVLIS enrichment plant.

Energy storage flywheels is a novel concept that has received renewed interest in the past few years. Generally, the application of flywheel storage is associated with mobile devices, cars, trucks and buses. Using depleted uranium metal in a large number of mobile energy storage flywheels presents several areas of concern; material control to assure proper eventual disposition, recovery of depleted uranium components from accident scenes and when a vehicle is no longer in use, and maintenance control for flywheel components.

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal will require the design, construction, operation and eventual decommissioning of at least one new facility. Defluorination and metal production steps have been used to produce uranium metal for several decades. DUF_6 is reduced with hydrogen at a continuous rate in a tower reactor vessel and the resulting uranium tetrafluoride (UF_4) is further reacted with magnesium metal in a batch metallothermic reduction to produce "derbys" of uranium metal.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will

readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium derbys may be stored in sealed containers for long term storage or processed further into a desired uranium metal product.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched uranium is an ongoing part of the commercial supply of nuclear fuel. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium metal could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety could be under the existing DOE regulations for uranium metal production when performed at DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for the production and processing of uranium metal. However, regulations for the use of uranium metal in commercial applications in the petroleum industry and for kinetic energy storage devices or regulation for the operation of an AVLIS facility would need to be developed.

7.1.14.1.2 Evaluation by Reviewer V

Option 1 - This recommendation supports the conversion of depleted uranium to metal for use in dense materials application products including munitions, bomb door reinforcement,

shape charge devices, drilling collars for the petroleum industry, storage or shipping devices for radioactive/hazardous wastes, naval and other ballast and kinetic energy storage devices (flywheels). The environmental, health and safety concerns for DU metal production and use in flywheel applications is addressed in detail in Document 4-2. The risks are considered manageable and the effects within allowable limits. Final disposal of flywheels and other devices after they have served their useful life will need to be handled within the requirements of applicable NRC, DOE and EPA regulations. There are certain special concerns associated with some of the applications listed. With regard to munitions, bomb door reinforcements and shape charge devices, there is concern that use of uranium could result in spread of radioactive or hazardous debris over a broad area creating a situation that would be difficult to remediate and which could contaminate the land and water. Similarly, in normal use, other products such as drilling collars, flywheels and ballast could be handled in a manner causing DU metal to be released to the surrounding environment where it could be inhaled or contaminate resources. Shipping the metal products could also create concern for environmental or health risks. The siting of fabricating facilities is unlikely to present sensitive issues regarding public acceptance.

Option 2 - This recommendation supports the conversion of depleted uranium to metal for use in the AVLIS process for uranium enrichment discussed in detail in Document 4-3. This option for the production of U metal would have greater environmental, health and safety risks than processes currently in use. Shipping the metal would have minimal impact, but its use in the AVLIS process could present some environmental, health and safety issues. Prevention of accidental criticality at the plant and protection of workers from airborne uranium oxide particulates are the chief ones noted. In addition, typical operational risks associated with any large industrial facility must be considered as potential risks. Use of DU tailings would reduce the amount of natural uranium mining required and depletion of that resource. The use of enriched uranium in nuclear power plants has its own set of environmental concerns. The siting of these facilities will present environmental issues that will need careful resolution to meet public acceptance.

Option 3 - This recommendation suggests that DUF_6 be converted to metals or U_3O_8 if long term storage or disposal is required. Conversion of DUF_6 to depleted uranium metals is the preferred course and does not raise any unique environmental health or safety issues. Document 14 discusses the NRC's recommendation for storage as U_3O_8 . The effects of these conversion processes for metals are discussed in Documents 2-4, 3-2, 4-3, 8, 21-3, 27 and 30. The storage or disposal of the depleted uranium metal does present some environmental issues. The most important is the reactivity of DU metal to air and water. Without appropriate control, this could lead to worker exposures or releases to groundwater at the sites. When DU metal reacts with water at ambient temperatures, UO_2 and UH_3 are formed, both of which are highly toxic, spontaneously flammable and radioactive. This can be controlled through the use of special coatings or containers designed to be very corrosion resistant. Transportation of the DU metal would need to follow existing regulations, but is not expected to create any new problems.

DU metal is a low-level waste and will need appropriate storage and disposal facilities. Storage would require double containment, e.g. containers and a building, while disposal would require a licensed site. Storage sites would need to be identified but are not likely

to encounter major environmental or siting issues. Deep mined or shallow burial disposal sites may be more problematic as discussed below. Development of these disposal sites will have to ensure that groundwater and other resources are protected in perpetuity. Careful design of the cavity or the storage containers may be required. No unique worker safety issues are foreseen.

7.1.14.1.3 Evaluation by Reviewer X

Option 1 - AOT currently operates a plant to convert dUF_6 to dUF_4 . This plant would need to be increased in size to deplete the current inventory of dUF_6 . Their experience in handling these materials should preclude any increased risk to the environment or to public health and safety.

They state in their recommendation they are committed to the nuclear industry, compliance issues, maintaining their facilities, investing to meet new requirements, and striving to reduce production costs. However, they don't detail any of their upgrade plans or efforts. Another source (IP#3) states they are installing a leaching process to decontaminate the MgF_2 slag for disposal in a sanitary landfill. Assuming this and other process improvements are made, environmental issues will be addressed.

Option 2 - AOT currently operates a plant to convert dUF_6 to dUF_4 . This plant would need to be increased in size to deplete the current inventory of dUF_6 . Their experience in handling these materials should preclude any increased risk to the environment or to public health and safety.

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Option 3 - AOT currently operates a plant to convert dUF_6 to dUF_4 . This plant would need to be increased in size to deplete the current inventory of dUF_6 . Their experience in handling these materials should preclude any increased risk to the environment or to public health and safety.

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7.1.14.1.4 Evaluation by Reviewer Y

Argument for storage of metal because of high density, low volume, and strength seems reasonable for minimizing concerns. Provisions to keep Uranium from interacting with other materials needed, but not severe requirements as for DUF6. Proposal provides for conversion of non-product DUF6 to DU3O8 for permanent inert storage.

The products will generally require environmental and related safety considerations, particularly those in the civilian sector (drill collars, storage or shipping devices, etc.). AVLIS will need a special review for potential impacts and upsets.

7.1.14.1.5 Evaluation by Reviewer Z

Mr. Charles Montford proposes two options for use of the depleted uranium hexafluoride. The first option proposes to use the depleted uranium in the production of various products, including munitions, bomb door reinforcement, shape charge devices and drill collars for the petroleum industry, storage or shipping devices for radioactive/hazardous waste, ballast for ships, and kinetic energy storage devices. Potential environmental, safety and health effects associated with applications of depleted uranium as a dense material include the health effects of inhalation or ingestion of uranium dust. Uranium metal is pyrophoric, especially when divided into small fragments such as machine shavings or filings. This causes additional concerns regarding potential for fires as well as dispersment of uranium oxides into the atmosphere.

Uses of uranium in applications such as drill collars or kinetic energy storage devices would require that the material be clad in order to prevent exposure of the material to the atmosphere whereby it could become airborne. Each application of depleted uranium would require an evaluation of the potential for exposing the uranium due to damage to the cladding.

A final factor which must be considered is the final disposal of the device or product which used depleted uranium. This material would have to be recycled or disposed of as low-level waste, and it is not evident at this time what the long term disposal options will be. If disposed improperly, the uranium could present health or environmental concerns.

The second option proposed is that the tails could be further depleted utilizing the Atomic Vapor Laser Isotope Separation Process (AVLIS) that has been developed by DOE. The primary safety issue for this option, as with any enrichment process, is an unplanned criticality, which can be addressed using standard industry practices.

7.1.14.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.14.2.1 Evaluation by Reviewer U

The DUF_6 conversion to uranium metal is well known. However, this Document #15 does not indicate the recovery of fluorine in any form, nor does it discuss the process waste products. HF should be recovered from the UF_6 to UF_4 processing. The process steps should result in minimal liquid effluents and gaseous streams fully scrubbed to eliminate the discharge of contaminated or noxious components. The reduction from UF_4 to metal uranium produces a large volume of magnesium fluoride slag that contains a considerable amount of uranium. This slag does not appear to be an appropriate waste for disposal. Some means needs to be developed for the uranium to be removed from the slag. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low-level radioactive waste, requiring disposal at dedicated low-level waste disposal sites.

The disposal of the empty DUF_6 cylinders is a waste issue. Removal of UF_6 heels from cylinders, cleaning of the cylinders and their eventual disposition will be required. Washing of empty cylinders may be sufficient to permit them to be scrapped, melted and recycled for other uses of the recovered metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.14.2.2 Evaluation by Reviewer V

Option 1 - Waste management issues for conversion to DU metal is discussed in Document 4-3. The waste streams from fabrication are unlikely to present significant concern. All these products will need to be carefully accounted for at the end of their service life as a product. It may be possible to recycle the uranium metal into other products. If not, disposal in an acceptable facility will be needed.

Option 2 - The waste streams from conversion are discussed in Document 4-3. While this option will not have any major waste streams, it will have secondary wastes from air pollution control and other support activities, e.g. cylinder washing. The metal itself could become a waste stream unless acceptable uses can be found for the quantities that will be produced. The metal form will be a more efficient form for disposal, however, it would need to be placed in a specially designed facility for this type of waste. If it is used

in the AVLIS process, only 10% will actually be incorporated into the enriched uranium, the remaining 90% in tailings will need disposal. There will also be other low-level wastes from operations and maintenance. There will be small amounts of ethanol which is a hazardous waste and non-hazardous waste streams from routine operations, .e.g. cooling tower blow-down.

Option 3 - The volumes of DU metal for disposal will be significant in comparison to historic generation rates. Current low-level disposal sites have limited capacity and may not be willing to accept these wastes. If a low-level disposal site could be found, the material would need to be encapsulated at a minimum, and it is not clear if shallow burial will be acceptable. The NRC has recommended deep geologic disposal because of the volumes involved, in a specially designed facility. The density of this material would mean a much smaller cavity would be required than for U_3O_8 . Although some disposal sites have been evaluated, none is developed at this time. Finding a suitable site might be difficult. Any geological site would need to be carefully analyzed to determine risks to groundwater and other potential environmental issues. It is unlikely that use of deep geological disposal would create a great deal of additional waste that would need additional disposal.

7.1.14.2.3 Evaluation by Reviewer X

Option 1 - As stated above, AOT states a commitment to meet new requirements. IP#3 states they are installing a leaching process to decontaminate the MgF_2 slag for disposal in a sanitary landfill. This and additional improvements to their processes will be necessary to minimize the waste stream from the increased throughput necessary to deplete the current dUF_6 inventory.

Further consideration also should be given to recovery of the Mg and/or F_2 for commercial sale, or for recycling the MgF_2 into the conversion process.

Option 2 - As stated above, AOT states a commitment to meet new requirements. IP#3 states they are installing a leaching process to decontaminate the MgF_2 slag for disposal in a sanitary landfill. This and additional improvements to their processes will be necessary to minimize the waste stream from the increased throughput necessary to deplete the current dUF_6 inventory.

The ultimate lifetime of any uranium product produced will need to be considered. Controls will need to be implemented to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices. It will be necessary to assure that DU products are not discarded into the non-radioactive material waste streams.

Option 3 - As stated above, AOT states a commitment to meet new requirements. IP#3 states they are installing a leaching process to decontaminate the MgF_2 slag for disposal in a sanitary landfill. This and additional improvements to their processes will be necessary to minimize the waste stream from the increased throughput necessary to deplete the current dUF_6 inventory.

The ultimate lifetime of any uranium product produced will need to be considered. Controls will need to be implemented to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices.

Being a uranium metal producer, AOT is biased toward the production of the metal rather than an oxide form for disposal. This is clear in their recommendation. While uranium metal will result in the smallest volume for disposal, the volume of the oxide forms, even after being diluted for disposal in near-surface facilities, is not so great that it cannot be handled in existing facilities if it is permitted. For example, a total diluted oxide volume on the order of five million cubic feet represents a nominal 20-day capacity for Envirocare.

7.1.14.2.4 Evaluation by Reviewer Y

The products for waste, provided DU is not declared waste, are principally Fluorine, Mg, and perhaps Ca based.

The proposal does not cite a specific commercial path for processing the DUF₆. The proposal is therefore not specific on what the waste products are and how they will be treated. It is anticipated there will be a small amount of scrap Uranium metal from fabrication processes. Most of this could be recycled back into the process; this is an advantage if the overall process makes sense.

7.1.14.2.5 Evaluation by Reviewer Z

The first option of this proposal is to use the depleted uranium in the production of various products. Each of the products would have to be evaluated regarding fabrication methods in order to determine whether any product specific waste streams would be generated. It would be anticipated that any waste generated would be similar in composition to those currently seen in the industry. A more specific waste management consideration for this option is the final disposition of the products after their normal lifetime. This application would require the licensing and tracking of each product item in order to ensure proper disposal at the end of life. An additional consideration would be the method of disposal. This is an uncertainty at this point due to the lack of licensed burial sites, and a questionable schedule for the completion of the interstate compact sites.

The second option proposed is to further deplete the UF₆ utilizing the AVLIS process. This process utilizes uranium in a metallic form, alloyed with iron. The final product is metallic uranium. The selection of this option would therefore produce large amounts of metallic uranium alloy. The iron content in the depleted uranium could be a detriment to the use of the uranium for other applications, or may require an additional process to separate the iron from the uranium before the uranium could be used. If this did not occur, the metallic uranium alloy could have to be dispositioned as a waste stream.

7.1.14.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.14.3.1 Evaluation by Reviewer U

The cost of converting DUF_6 to uranium metal has been indicated by others to be in the range of \$10 per kilogram. However, the actual cost of uranium metal production in large quantities that would require new production facilities licensed by the NRC is not well defined and could be significantly higher than \$10 per kilogram. The conversion cost would be much greater than the value of any recovered usable HF. Eventually, this conversion cost may be required for disposal of DU if it is determined that DU is a waste material and that uranium metal is the proper form for disposal.

Cost of fabricating uranium metal munitions and ballast are reasonable well known since they have been fabricated for some time. Fabrication costs of other commercial components such as energy storage components are unknown. Until such applications are better defined, cost estimates are speculative.

Relatively low cost estimates for uranium enrichment have been made by the research organization developing the AVLIS process. However, the overall cost of obtaining enriched uranium from DU through the use of AVLIS is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

7.1.14.3.2 Evaluation by Reviewer V

Option 1 - Costs for production of DU metal and initial casting into a shape are estimated at \$11/kg of uranium. Depending on the useful products that are fabricated, the net cost for this option could be reduced. No revenue estimates are provided. The potential markets for the dense materials applications as identified in the response are about 818 million pounds, or 370,000 MT, over the next 10 years. If this were extrapolated to 30 years, the total potential market would be 1.1 million MT. Estimates provided in Information Package J1 vary somewhat but come to the same general conclusion that potential markets exist for these applications for a significant portion of the depleted uranium inventory. The viability of these potential markets needs to be carefully reviewed. For instance, some of the products identified involve munitions and drilling collars, which may meet environmental obstacles in their implementation. To the extent new facilities are needed to fabricate these products, capital and permitting costs will be

encountered. Costs for disposing of these products at the end of their service life could be significant if recycling is not possible.

Option 2 - According to the engineering estimates, the life-cycle cost of conversion to metals could be \$1.2 billion. These costs need to be verified as the process undergoes development. The market value of U metal is sensitive to demand, so potential revenues deserve further assessment. The estimated cost for an AVLIS plant is \$1.2 billion, with operations costing \$147 million annually to produce \$600 million in revenues. It would take two plants 20 years to convert the entire DU inventory to enriched uranium and tailings. This would produce the equivalent of 1,000 reactor-year of fuel supply. The availability of markets for these fuels and the effect on the markets is not known. Some gas diffusion plants with higher costs might be forced to close.

Option 3 - The costs for shallow land burial of DU metal at the Nevada Test Site are estimated in Information Package A2 at \$.35/ kg U or \$127 million for the entire inventory. It is noted that these costs could increase significantly as disposal requirements, cost recovery and litigation increase. Other regional sites would be much higher in cost. This additional demand would also have the effect of driving up the price of the limited disposal resources available.

The additional costs for deep storage are unknown and could vary significantly depending on the specific site. One respondent to the Request for Recommendations suggests that such a facility could be built for as little as \$50 million. If safe cavities can be found, the cost of disposal might be reduced as special packaging and handling becomes less critical. However, monitoring costs could be quite high.

Siting for either type of disposal facility could be costly depending on public acceptance. Transport costs would probably not be excessive but could increase the cost incrementally depending on the location. These costs would all be in addition to the cost of conversion to DU metal depending on the method selected.

7.1.14.3.3 Evaluation by Reviewer X

Option 1 - AOT provides no cost projections. Their current cost structure is likely to increase due to requirements to install equipment and/or new processes to reduce the waste stream. However, a greater throughput should enable cost recovery and a reduction in the overall average cost of the product.

Option 2 - AOT provides no cost projections. Their current cost structure is likely to increase due to requirements to install equipment and/or new processes to reduce the waste stream. However, a greater throughput should enable cost recovery and a reduction in the overall average cost of the product.

Conversion of dUF_6 to metal using the AOT process is projected to be the most expensive conversion alternative. However, if there is a demand for the metal, these costs should all be recoverable. Further, the cost of disposing of the uranium will be postponed to the time that the product is no longer required.

No information was provided on the availability of facilities to meet the projected fabrication demand. However, facilities at Oak Ridge (Y-12) are currently underutilized and may be available to meet a large part of the demand. Also, another submittal (RFR#18) mentioned the availability of the Kinetic Energy Penetrator Production Base. Except for contamination control and worker health considerations, cost for new facilities should be approximately the same as facilities for handling other materials.

Option 3 - AOT provides no cost projections. Their current cost structure is likely to increase due to requirements to install equipment and/or new processes to reduce the contaminated waste stream. However, a greater throughput should enable cost recovery and a reduction in the overall average cost of the product.

Production of uranium metal using the AOT technology currently is estimated to be three to five times higher than the cost of oxide production.

7.1.14.3.4 Evaluation by Reviewer Y

The AVLIS costs are largely speculation at this time. Metal production costs can be estimated, though they are not defined in the proposal. It is likely that DU metal, DU_3O_8 production costs will be on the order of several dollars per Kg each if two facilities are capitalized for the two products. If the decision can be made for only one highly utilized facility, capital costs might actually be attractive for the DU metal option with the AVLIS value added. If the DU_3O_8 is declared as "waste," the DU metal and AVLIS process cost could be exacerbated by 50-100% because of regulatory uncertainties (schedule and provisions). The proposal is silent on schedules, timing, and optimum facility operations.

7.1.14.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, operating or maintaining facilities necessary to execute the options outlined in this alternative.

If the presence of iron in the depleted material after feeding through the AVLIS system does not affect the use in other applications, or if the iron can be removed economically, then the AVLIS option should be considered for any material which will be used in metallic form. The recovery of the residual U^{235} would help to offset the costs of processing.

7.1.14.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.14.4.1 Evaluation by Reviewer U

The process requirements for the recommended production of uranium metal are well defined. New approaches for the recovery of fluorine as a useful by-product form and slag cleaning will need further R&D and pilot demonstration before proceeding with a commercial facility.

The storage of recovered uranium metal is well defined and could be implemented with known techniques. Disposal of depleted uranium metal may not satisfy the desired material stability for long term disposal and considerable R&D would be required to define whether metal is an acceptable form for disposal.

Fabrication of uranium metal components has been performed for decades. Thus, such fabrication is considered to be mature. However, using uranium in an application where material strength is important to allow high rotation speeds for storage of kinetic energy will undoubtedly require the development of composite structures, such as carbon fiber wheel rims, to retain structural integrity. Considerable development would be required to achieve the desired structure.

While considerable development has been completed for the AVLIS uranium enrichment process, practicality is yet to be determined. Obtaining enriched uranium from DU should be considered as a long term possibility, not a near term use.

7.1.14.4.2 Evaluation by Reviewer V

Option 1 - This conversion process to DU metal is available now. Fabricating techniques likely to be used are for the most part commercial. Specific applications may require some additional product or process engineering but it is unlikely this would significantly delay adoption.

Option 2 - This conversion process proposed by INEL process is still in very early development. The AVLIS process is close to commercial with full specific scale tests completed. Other DU metal production processes are commercial and could be used with AVLIS.

Option 3 - The storage and disposal options are fairly well known. The deep geological storage is not a new concept but will require some additional analysis and site specific reviews to assure feasibility, and extensive environmental and safety analyses to prove no adverse environmental effects. Shallow land burial may also need some additional development work if regulations are tightened, or to meet specific waste acceptance criteria of a selected site.

7.1.14.4.3 Evaluation by Reviewer X

Option 1 - The current process for converting dUF_6 to dUF_4 and the UF_4 to metal are mature processes. However, requirements for reducing the waste stream of contaminated MgF_2 add uncertainties to the maturity of the process. Further, alternate processes that haven't been fully tested may be necessary to meet regulatory and environmental concerns.

Option 2 - The AOT (Ames) process for converting dUF_6 to dUF_4 is a mature process. However, the successes of improvements for reducing the waste stream haven't been tested in a production environment and add some uncertainty to both cost and waste volumes. Further, alternate processes that haven't been fully tested may be more effective in meeting regulatory and environmental concerns, and also may be less expensive. The AOT conversion process is currently in place, and given sufficient plant capacity can be used immediately to deplete the current dUF_6 inventory.

Considerable experience exists with founding, casting, and milling processes.

Option 3 - The current process for converting dUF_6 to dUF_4 is a mature process. However, requirements for reducing the contaminated waste stream will add to uncertainties in the maturity of the process. Further, alternate processes that haven't been fully tested may be necessary to meet regulatory and environmental concerns.

7.1.14.4.4 Evaluation by Reviewer Y

The production of depleted Uranium metal from DUF_6 is state of the art based on extensive past experience. It is state of the art, but not industrial state of the art. The AVLIS process is clearly a conceptual system with considerable related small-scale experience. This process that could provide a "value-added" use for the tails will require considerable R&D before confidence in both small- and large-scale sets in; such R&D does show potential for technical promise even if value added becomes elusive to overall economics.

7.1.14.4.5 Evaluation by Reviewer Z

Processes for founding and milling uranium metal are well established industry practices.

The AVLIS technology has not been commercially deployed. The U-AVLIS technology is in the final stages of engineering and has been successfully tested at full specific scale.

7.1.14.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.14.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium metal would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. However, if the operation is dependent on the use of metal in various applications, up and down employment cycles would occur depending upon demand for the metal or changing customer desires. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility.

Use of uranium metal in kinetic energy storage devices for mobile application in vehicles such as cars, trucks or buses would raise the specter of safety with the public. Whether the public concerns in this regard could be satisfied is an open question.

Performing uranium processing operations at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment. A major hurdle to overcome is the history of the Fernald uranium metal production plant. Considerable uranium contamination was experienced with this plant, operated for the federal government for several decades. Much better material control technology would be employed at a new plant. However, the extensive challenges at Fernald establish a difficult threshold to overcome.

7.1.14.5.2 Evaluation by Reviewer V

Option 1 - If new facilities were required to convert the entire DU inventory to DU metal, this option would constitute a major industrial construction and operation project with significant direct and indirect impacts. The plants might meet some resistance but are likely to be able to locate an acceptable site. Fabrication plants are not likely to be opposed on the basis of local environmental concerns, however, significant political

resistance may come from members of the public concerned about the potential for widespread contamination from some uses, especially munitions.

Option 2 - The plants proposed would constitute a major industrial construction and operation project with significant direct and indirect impacts. If the plants were located in rural rather than developed areas for safety reasons, the magnitude of the impact would be greater. Spin-off industries will be a function of the location of the conversion plant, its products, its supply needs and the underlying economic base of the region. The plants are likely to meet some resistance in locating an acceptable site due to public concern regarding nuclear fuel and power plants.

Option 3 - The effects on regional economic development and employment from storage and/or disposal are likely to be relatively minor for DU metal. The smaller volumes would mean smaller facilities with proportional construction effects. The addition of deep storage would have minimal effect. Some economic effect could come from new mining activities in sparsely populated areas. The effects would be small, however. Land use would be minimal, but some additional traffic to and from the site would be generated. Some relatively small number of permanent jobs would be created. Public acceptance will be a significant issue that is difficult to predict. New low-level disposal facilities are now being developed or proposed but their success is not known.

7.1.14.5.3 Evaluation by Reviewer X

Option 1 - The existing plant will require considerable expansion to deplete the current inventory of dUF_6 . This will result in a short term increase in local employment to build the plant. Operation of the existing and new plant will require a larger work force that will at least double the current work force.

No information was provided on the availability of facilities to meet the projected demand for uranium metal. However, facilities at Oak Ridge (Y-12) are currently underutilized and may be available to meet a large part of the demand. Also, another submittal (RFR#18) mentioned the availability of the Kinetic Energy Penetrator Production Base. Except for contamination control and worker health considerations, cost for new facilities if required should be approximately the same as facilities for handling other materials.

If existing facilities are used or expanded, a trained work force should be available, and the impact on communities should be minimal. Demand for product will need to be carefully evaluated to assure that plant is not over built.

Option 2 - If existing facilities are used or expanded, a trained local work force should be available, and the impact on communities should be minimal. Demand for product will need to be carefully evaluated to assure that plant is not over built.

Option 3 - If existing facilities are used or expanded, a trained work force should be available, and the impact on communities should be minimal. Demand for product will need to be carefully evaluated to assure that plant is not over built.

7.1.14.5.4 Evaluation by Reviewer Y

The use of DU metal in military applications may be expected to come under more pressure from concerns over military staff exposure to SNM in routine and training operations.

Civilian uses of SNM have and probably will have public concern until regulatory organizations earn public confidence. This will not be soon for uses which the public has access.

Civilian uses without public access to material (e.g., flywheels) can be expected to get more public scrutiny.

The necessary facilities will support local and regional development, particularly in economically depressed areas. Employment will be modest, but for relatively high skills in depressed communities.

7.1.14.5.5 Evaluation by Reviewer Z

This reviewer has no specific information on the socioeconomic impacts of the use of depleted uranium in the production of various products. Each application would require individual review.

This reviewer has no specific information on the socioeconomic impacts for the option of feeding the depleted uranium through the AVLIS process. One effect which should be considered is that the additional U^{235} removed from the depleted tails will reduce the need for natural UF_6 feedstock, which might impact companies on the front end of the fuel cycle, such as mining, milling and uranium conversion. It would correspondingly reduce the environmental impacts of the front end of the fuel cycle and would conserve natural uranium resources.

7.1.14.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.14.6.1 Evaluation by Reviewer U

The depleted uranium does contain potentially recoverable energy values. While the economic value of the energy resources is insufficient to recover the values in the near term; economic recovery may be achieved at some future date—possibly one hundred years or more hence. Thus, an important factor may be an assessment of potential energy values recoverable through isotope separation or as fertile material in future energy programs.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be

achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, uranium metal, is greater than the cost of converting the DUF_6 to metal in the near future, with associated impacts.

7.1.14.6.2 Evaluation by Reviewer V

See General Comments.

7.1.14.6.3 Evaluation by Reviewer X

None.

7.1.14.6.4 Evaluation by Reviewer Y

The argument that metal density favors long-term storage volume rings true, particularly if near- and long-term metal product uses are anticipated. The argument that a significant fraction ($\sim 1/2$) of the inventory be considered as DU3O8 "waste" would complicate the overall program schedules and costs.

7.1.14.6.5 Evaluation by Reviewer Z

The option of using depleted uranium for the production of various products would have to be evaluated on a case-by-case basis. A factor to consider is the regulation under 10 CFR 40.22 which grants a general license to commercial and industrial firms for the possession of 15 pounds of uranium for research, development education, commercial operational purposes. Amounts of uranium in excess of 15 pounds require licensing by the Nuclear Regulatory Commission. Regulatory changes may be required for specific applications which would allow the possession of amounts of uranium in excess of 15 pounds for specific purposes.

7.1.14.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.14.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to uranium metal appears to be reasonable from a technical standpoint. However, the conversion to metal probably should be done only when a useful metal product is determined. Converting DUF_6 to metal for long term storage or disposal does achieve a much smaller volume of material (about one fourth that of DUF_6), but does not appear to be as attractive as converting the DUF_6 to uranium oxide for storage or disposal. If large quantities of uranium metal are to be produced, the

conversion processes used in the past may not be the more economical. Evaluation of plasma metal conversion and continuous casting technologies need to be considered.

Two potential uses, bomb door reinforcements and shape charge devices for petroleum industry, account for 94% of the indicated potential uses. The military will decide on the first and the second may entail regulatory constraints of the NRC—both unknown. Other potential applications indicated in the Document use small amounts of material and are speculative.

Kinetic energy storage technology is in early phases of development. The high density of uranium metal provides an attractive attribute. However, composite material containment of the uranium and the potential perceived safety aspects with the use of uranium in vehicles are difficult hurdles to overcome. Only applications for stationary energy storage devices should be considered and the timing for such applications is unknown.

Using DU as feedstock for AVLIS enrichment steps may be appropriate within a time span of one to two hundred years when the available low cost natural uranium ore resources are depleted. Such use does not appear appropriate within the next few decades.

The organization making the recommendation in Document #15 has considerable experience with the production of depleted uranium metal and the production of uranium metal components.

7.1.14.7.2 Conclusion by Reviewer V

Option 1 - Based on DOE criteria, it appears that this is a reasonable option for further evaluation. While most of the products could be fabricated at this time, it is not clear at what cost and how large or viable markets for them would be. In addition, concern about the environmental, health and safety effects of the use of these products would need further evaluation. Given these concerns, further definition of specific products, markets and costs should be made. The role for private industry in identifying and nurturing these opportunities could be investigated.

Option 2 - Based on DOE criteria, this option would be considered reasonable if the metal conversion process were more technically mature. Further development may be warranted under the auspices of this or other DOE programs, and it may be included in the implementation program at a later date. More solid information is needed on the technology operating at the pilot scale and its characteristics in commercial operation. Cost data needs verification. The AVLIS process is more technically ready but is not limited to this DU metal conversion process to begin operations. The U. S. Enrichment Corporation is proceeding with commercialization of AVLIS technology.

Option 3 - It appears that this option would meet DOE's criteria for reasonableness for the most part. The major uncertainty lies in the identification of a suitable site, its certification and licensing for this use, and the cost of preparing it. This option deserves further consideration as consistent with DOE's programs.

7.1.14.7.3 Conclusion by Reviewer X

Option 1 - The AOT/B&W recommendation places considerable emphasis on the companies' experience in the field and their ability and plan to first convert the dUF_6 inventory to dUF_4 using their existing plant. They state they are able to provide unbiased advice to DOE. However, they don't consider alternative conversion techniques in their recommendation. Also, they state that "dU metal is relatively stable in air (slowly forms an oxide layer) . . ." while others state that uranium metal requires cladding to preclude dispersion of the oxide forming on the surface (IP#J1). Their only case for producing the metal instead of the oxide (U_3O_8) is that it will require less storage space. This assumes the metal will be stored for future use rather than disposed of.

Considerable expansion of existing facilities will be necessary to handle the additional throughput required to deplete the current inventory of dUF_6 . This will require an investment of greater than \$300 million according to other sources.

Option 2 - The AOT/B&W recommendation places considerable emphasis on the companies' experience in the field and their ability and plan to first convert the dUF_6 inventory to dUF_4 using their existing plant. They state they can provide unbiased advice to DOE. However, they don't consider alternative conversion techniques in their recommendation. Also, they state that "dU metal is relatively stable in air (slowly forms an oxide layer) ..." while others state that uranium metal requires cladding to preclude dispersion of the oxide forming on the surface (IP#J1). Their only case for producing the metal instead of the oxide (U_3O_8) is that it will require less storage space if disposed of.

Their recommendation is to use the metal from conversion of dUF_6 as feed for the AVLIS process before its use in other products. AOT/B&W state "Studies performed at LLNL indicate that the existing depleted tails (.2 and .3 ^{235}U) can be reduced to metal, prepared as starting material for the AVLIS process, and utilized to produce an enriched product at substantially less than the cost for enrichment using the current gaseous diffusion process." The tails from AVLIS would then be available for use in other proposed metal products. Removal of the remaining ^{235}U inventory would use about 900 MTU metal as U^{235} plus additional metal as U^{238} for a total consumption of about 30,000 MT. This may be a good recommendation if it can be shown to be cost effective relative to the use of natural uranium metal feed stock, or relative to the use of dUF_6 as the feedstock in a gaseous diffusion or centrifuge system as proposed for Claiborne, thus saving the high cost of converting the dUF_6 to metal.

Their list of potential uses, whether pre- or post-use in AVLIS, will deplete the current inventory in less than 10 years. Thus, if all are implemented, part of the current production of depleted uranium also will be needed to support the projected activities. However, before committing to production of significant amounts of metal product, the demand for these products should be verified relative to the use of other materials having less of a potential environmental impact.

The ultimate lifetime of any uranium metal product produced also will need to be considered. Many of the proposed uses for the metal are in the civilian community. Thus,

controls currently in place for military applications won't be appropriate in the new environment. Controls will be required to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices and regulations. This is a problem today with some materials. Since the proposed uranium metal applications require large masses of uranium, a requirement for stamping or engraving the disposal requirements into the finished product might be established.

Option 3 - The AOT/B&W recommendation places considerable emphasis on the companies' experience in the field and their ability and plan to first convert the dUF_6 inventory to dUF_4 using their existing plant. They state they can provide unbiased advice to DOE. However, they don't consider alternative conversion techniques in their recommendation. Also, they state that "dU metal is relatively stable in air (slowly forms an oxide layer) . . . " while others state that uranium metal requires cladding to preclude dispersion of the oxide forming on the surface (IP#J1). Their only case for producing the metal instead of the oxide (U_3O_8) is that it will require less storage space.

Production of uranium metal closes the door on the possibility of near-surface disposal and necessitates deep burial. While only a 100x100x100 foot cube would be necessary for stacking metal bricks, the option of disposing of the oxide requires only a 20-day capacity at a facility such as Envirocare. Note that while IP#A2 implies that NTS or Hanford could accept the metal, a closer reading of the Waste Acceptance Criteria (WAC) for these sites indicates that the maximum concentration for uranium is about the same as for Envirocare (See EGG-MS-11297, page 33, WAC 3). The Midwest Compact site (legislation is currently in the Ohio House Committee stage) is not projected (by limitations of the legislation) to be large enough to accept the quantity of waste in the oxide form. The metal form would be one-third of the Compact's total capacity. It's fair to say it would never be accepted even if it did meet the WAC!

Long-term retrievable storage is a reasonable alternative if the surface of the metal can be stabilized and a future need for the element exists. The most reasonable shape would be square or rectangular to minimize the required storage volume and water infiltration. Surface treatment would need to be thick and strong enough to withstand handling damage. If the storage facility is designed to be monitored, repair of damaged surfaces could be done until the uranium is removed for use in a product. Monitored retrievable storage options are only in a conceptual stage at the present time.

Production of uranium metal using the AOT technology currently is estimated to be three to five times higher than the cost of oxide production. Thus, unless the cost decreases due to performing an improved Ames process less expensively or through development of another less expensive process, this option seems prohibitive.

The need for preserving this resource is dependent on future decisions to use the metal in breeder type reactors. It is an invaluable resource for future energy needs. It may have too many drawbacks for extensive use in other applications. As long as enrichment of uranium for power generation purposes is required, there will be a sufficient supply of DU for current applications.

7.1.14.7.4 Conclusion by Reviewer Y

Insofar as details can be inferred, the metal option with or without the AVLIS process seems reasonable on all counts. With a significant fraction of the DUF6 going to DU3O8 classified as waste, the overall option could well become unreasonable based on two major capital facility expenditures plus more operations costs including those for enhanced regulation and scheduled stretchouts.

7.1.14.7.5 Conclusion by Reviewer Z

There is merit in the option of using the depleted uranium for the production of various products. Each application would have to be evaluated on its own merit, with consideration given to the changes in regulations, control of licensed material, and ultimate disposal of the product after its useful life.

There also appears to be merit in the second option which proposes that the depleted tails be fed through the AVLIS process. Although this reviewer does not have information related to the efficiency and cost of operation of the AVLIS process, it appears that the efficiency of the AVLIS process is adequate to recover additional U²³⁵ sufficient to make the process cost effective.

7.1.15 Evaluation of Document No. 26 (Independent Technical Reviewers' No. 16)**Respondent:**

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502-527-1217

Description of Response:

This response recommends on-site aboveground storage of the radioactive wastes located at the Paducah Gaseous Diffusion Plant in earthquake proof concrete structures to allow for monitoring of surface leaks and radiation releases. The responder further recommends that residents living near the site be relocated and compensated for damages done to their property by DOE.

7.1.15.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.15.1.1 Evaluation by Reviewer U

The recommendation in Document #16 calls for the storage of the depleted uranium hexafluoride (DUF₆) at the current locations in above ground earthquake proof concrete structures. The DU is viewed as a radioactive waste and the stated reason for on-site storage is to not adversely affect a new community with this radioactive waste. However, if the DU is declared to be a waste, siting requirements for long term waste storage and disposal may preclude the current sites. Also, the recommendation calls for stabilizing and cleaning of the current storage sites with permanent isolation of contaminated areas along with relocating and compensating residents adjacent to the DOE facility.

Operational issues include well understood controls for storing and handling of DUF₆. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. The potential health

concerns associate with long term storage of DUF_6 are well known and when properly implemented, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage.

While this recommendation implies that the current sites are a danger to human and animal life, the DU contributes very little to overall community danger. Site stabilization and clean up as much as possible is urged. Isolation of the contaminated plant site is recommended with further restrictions. These recommended actions are appropriate to some extent at this time and of greater significance when the plant site is determined to be a surplus site.

Overall Federal regulation for safety of DUF_6 storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF_6 is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC. A modification in the regulations would be required for NRC licensing for long term storage of DUF_6 . However, if the DU is declared a radioactive waste, it would trigger a new set of regulatory and siting requirements for waste disposal.

7.1.15.1.2 Evaluation by Reviewer V

The option of storing DUF_6 in its present chemical form does not appear to present any major environmental, safety or health issues. The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air, DUF_6 can react to moisture producing HF acid and UO_2F_2 , both hazardous. The HF is an acid that could cause skin burning and damage to the lungs on contact and the fluorides and uranium can have toxic effects if ingested. In addition, the alpha particle emissions from inhaled or ingested uranium could be a health risk. Releases to the environment are most likely to be limited to the storage facility itself. If a large release occurred, however, the potential exists to effect the surrounding area effecting the public, the land, vegetation and domesticated and wild animals.

The handling of the storage cylinders and routine operations at the storage facility raise the possibility of minor environmental risks from accidental releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. Past experience has shown very few incidents of releases, virtually all of which had insignificant health effects. With the aging of the cylinders, however, the potential for increased numbers and severity of accidental releases must be seriously addressed.

The transport of DUF_6 required under this option would be very limited and, therefore, minimize potential exposure of the public. Use of the current sites is probably the least

risk approach from an environmental, health and safety perspective. While the public is located in proximity to the facilities, there are no major population centers in the immediate vicinity. Selection of different sites would require licensing, delay and transport of aging cylinders which might pose a greater environmental risk than current storage. Within the existing sites, there may be potential for relocating storage areas to improve storage conditions and minimize hazards of accidental release.

Continued storage at existing sites again would not present a problem technically, however the management of the sites and perhaps the storage techniques may need to be modified. Handling the cylinders for inspection and routine stacking and unstacking can cause leakage, although in many cases any breaches are self-sealing. The steel cylinders have been stored out-of-doors, some for as long as thirty years which is the estimated useful life expectancy. While high risk cylinders with identified risk potential (about 15,000) are inspected annually, only one fourth of the remaining inventory is inspected annually. Current storage conditions may make it difficult to inspect some cylinders.

Current management programs include cylinder inspections for integrity with repairs and replacements performed as necessary. Some technical assessments of the condition of the cylinders and techniques for maintaining them are underway. In addition, some improvements in cylinder storage facilities are underway including saddle replacement, new cylinder yards at Paducah and Portsmouth, cylinder replacements and a cylinder refurbishment facility. The latter would have the capacity to handle about 1/20th of the existing cylinders per year. The current outdoor storage system is not in compliance with DOE regulations requiring two levels of confinement for all radioactive materials, e.g. use of a container that is protected within a building.

Given the advancing age of the cylinders, increased inspections and refurbishments as well as improved storage systems should be considered. Nearly a third of the cylinders are described as "high risk" and inspected annually due to poor drainage, heavy scale or pitting, suspected leaking valves, etc. The risks of accidental releases should be evaluated given these conditions and additional improvements in storage and handling considered. Additional measures might include a more rigorous and frequent inspections program, an accelerated program for refurbishing and replacing cylinders on a preventive basis and improved yards, saddles and containment systems for all cylinders at an early date. Additional measures for reducing risks in handling the cylinders are discussed in Document #20.

It is suggested in this response that covered storage in above ground, earthquake-proof concrete structures be considered. This is certainly technically feasible and would provide the second level of confinement called for in DOE regulations which would increase the level of environmental protection. While it is unlikely that "earth-quake proof" structures can be provided at any reasonable cost, a higher level of quake resistance could be requested. Indoor storage of the cylinders would slow the deterioration of the steel and would limit the exposure of cracks to water vapors. Monitoring of the air in an enclosed building might allow earlier detection of leaks, however if a leak were to occur it would not allow the poisonous gases to dissipate, thus creating greater danger to workers.

Containment within a building would limit the potential for a plume caused by a leak to impact the surrounding community.

It would appear that the likelihood of an accident impacting the surrounding community is relatively small. Further serious analysis of accident scenarios may be appropriate to determine if relocation and compensation of nearby residents is justified and to see if any additional emergency response contingency measures are required.

7.1.15.1.3 Evaluation by Reviewer X

Since the current dUF₆ storage program began, six cylinders have been identified to have experienced leaks. All of the leaks were identified long after they occurred because of the early absence of a periodic inspection program. Each leak self-sealed. Four of these leaks were determined to have been caused by cylinders weakened by handling. The remaining two leaks were in cylinders that had corroded. Programs are currently in place to (1) replace cylinders that are at risk, (2) improve cylinders that are weak, (3) inspect all cylinders on a rotating basis, revisiting those at greater risk more often. Apparently, no new leaks have been observed since these programs were implemented. (See EGG-MS-11416, pg. 9.)

The real question relative to risk to workers or the general public is "How rapidly does the dUF₆ react with moisture in the air to cause a cloud with dangerous levels of HF or uranium?" No data was provided to answer this question. However, it was stated that the above-mentioned leaks self-sealed prior to being identified "because the material loss and reaction with atmospheric moisture were so slow." Apparently, no injuries resulted from the leaks. (See EGG-MS-11416, pg. 9.)

Measures to reduce or eliminate leaks during handling include (1) administrative procedures prohibiting transport of liquid-filled cylinders, and (2) modifications of the specifications for the metal used in cylinder construction, including steel with favorable low-temperature impact response and low sulfur content, which improves ductility and impact strength.

Additional programs are in place to provide new stands for some cylinders to improve safety, and to further protect cylinders from contact with standing water. Information provided doesn't indicate whether seismic concerns are addressed in the designs for the new stands. However, the combined weight of the cylinders, their content, and the stands, and the low center of gravity of the combination should preclude damage during most low intensity earthquakes. However, if cylinders are stacked to reduce the acreage required for storage, the cylinders on top might face greater damage probabilities in a seismic event. Seismic analysis for more severe earthquakes should probably be done, and horizontal and vertical acceleration estimates should be used in the design of concrete pads for holding the cylinders, and any buildings that may be built to enclose the cylinders.

The present storage method in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. Thus, it is reasonable to expect that construction of new storage facilities could be required. The question is whether the cost is

justified by the reduction in risk. Risk should be evaluated based on vaporization rates, dispersion rates, reseal rates, and detection probabilities. If earthquake resistant buildings are built for the cylinders, the second confinement level should preclude release of materials if one or more cylinders become cracked.

Whether an enclosed facility is built or not, it is apparent that many cylinders will need to be moved due to (1) being stored too close together to facilitate inspection, (2) needing to be placed on new moisture resistant cradles, or (3) requiring transfer of the DUF₆ to new cylinders because of cylinder deterioration. This movement also causes a risk of further cracking. Handling practices can minimize serious damage which would produce large releases.

7.1.15.1.4 Evaluation by Reviewer Y

A seismically secure for "no additional exposure" of DUF₆ can be argued to be an environmental "overkill" in terms of an honest cost/benefit evaluation. A location that is roughly at the midpoint between the New Madrid quake of ~1830 and the Charleston quake of ~1870 is likely to be a good bet for significant seismic activity during the next 100 years (e.g., high probability ~0.3 g). Funds to make earthquake-proof pads could be more beneficially applied to strengthening bridges, commercial buildings, roadways, and even residences for greater public good than some small puffs of DUF₆ with a high likelihood of solid material under high probability conditions.

7.1.15.1.5 Evaluation by Reviewer Z

This option, submitted by Ms. Corinne Whitehead, proposes that the radioactive waste be stored above ground in earthquake proof concrete structures. The structures should be high enough off the ground to be monitored for surface leaks and radioactive releases, and be stored in a manner to cause no additional exposure during seismic activity. It is further recommends that the site be stabilized and that restrictions and isolation be in perpetuity. Due to the lack of merit of this option, a detailed evaluation was not performed. See Section 7.1.15.7.5.

7.1.15.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.15.2.1 Evaluation by Reviewer U

Storage cylinder monitoring and maintenance would be required for the DUF_6 . Occasionally, it will be necessary to remove the DUF_6 from defective or degrading cylinders and transfer the DUF_6 to new storage cylinders. During such activity, a limited amount of contaminated waste will be encountered. These wastes could be allocated to disposal at low-level radioactive disposal sites.

Disposal of defective and empty DUF_6 cylinders will be required. A small amount of UF_6 must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for recovery of the material and disposal or storage. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites.

Above ground perpetual storage of DUF_6 may be an appropriate way to manage and dispose of DU. However, federal regulations may preclude using DUF_6 as an acceptable waste form and they may preclude the current sites from being acceptable locations for disposal.

7.1.15.2.2 Evaluation by Reviewer V

The waste streams associated with this option are minimal. There would be minor amounts of waste generated from normal maintenance activities including replacing or repairing cylinders, valves and other equipment. The replacement of wood saddles with concrete or other supports will generate quantities of waste that is likely to be disposable in a regular landfill. The cleaning and recoating of canisters will also generate some waste, but there would be limited potential for recycling or waste minimization in any of the operations. If indoor storage is used these activities would be minimized.

7.1.15.2.3 Evaluation by Reviewer X

No additional wastes are expected to be generated from the continued storage of dUF_6 .

Cleanup and stabilization of the rest of the site are not part of the considerations for the disposition of the dUF_6 .

7.1.15.2.4 Evaluation by Reviewer Y

This proposal maintains the DUF_6 under some levels of monitoring with no solution for any emissions. Waste process is minimal for DUF_6 but monstrous for suggestion of relocation of large populations near storage sites. The potential for asbestos management is significant and costly.

7.1.15.2.5 Evaluation by Reviewer Z

See Section 7.1.15.7.5.

7.1.15.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.15.3.1 Evaluation by Reviewer U

Long term storage of DUF_6 can be achieved based on the extensive knowledge gained from storage over the past several decades. Such costs are expected to be significantly less than all alternatives of converting DUF_6 to another form for storage and/or disposal.

Building above ground earthquake proof concrete structures for the perpetual storage of DUF_6 would add significantly to the cost of storage compared to the present mode of outside storage on support bases. The high density of the DU in cylinders provides a reasonable earthquake proof containment since it takes considerable effort to move the containers. The cylinders will not roll around because of the heavy cylinder bottom of solid DUF_6 and void space at the top of each cylinder. Even if jostled with an earthquake, they could become jumbled and wrenched askew without serious danger of material loss or a health risk to residents in the vicinity.

7.1.15.3.2 Evaluation by Reviewer V

The costs of outdoor storage as estimated by contractors to DOE are low, in the range of \$.22/kgU to \$.34/kgU assuming a storage inventory of only 375,000 MTU, corresponding to life cycle costs of \$83 million to \$129 million. This estimate is based on current storage practices to be used through the year 2020 including planned upgrades of cylinders and yards, new cleaning/coating facilities and current inspection and maintenance.

The capital costs for an additional confinement level using indoor storage was estimated at \$360 million for all three sites, with some additional maintenance costs ongoing associated with those facilities. If these estimates are accurate, this would increase the cost of this option by four fold or more. It is not clear what the costs would be for earthquake proof concrete structures. The costs of various containment options should be reviewed with the potential safety and health benefits reviewed in the context of the proportionate increase in costs. The use of outside contractors to operate and maintain such facilities could be considered if it offered a cost savings. It appears that increased costs will need to be

incurred to bring any storage option to a higher level of safety as requested by the community and suggested by some familiar with the current system.

There would be no additional revenue streams associated with storage unless it were provided with another alternative immediate or future use. The later sale or use of DUF6, its products and byproducts could produce some revenues.

7.1.15.3.3 Evaluation by Reviewer X

Costs to maintain current storage practices through the year 2020 are estimated range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional will be required.

Insufficient information was provided to determine whether the capital costs for an enclosure included the cost of seismic analysis and appropriate seismic-proof construction. Seismic concerns were not stated to have been considered in the assumptions used for long-term storage cost estimates in EGG-MS-11416.

7.1.15.3.4 Evaluation by Reviewer Y

These are significant for erecting structures to seek to identify leaking tanks. It is likely that tank monitoring by ultrasonic and chemical means would be reasonable without significant civil (pad) construction. The costs of relocation would be significant without significant improvement in safety. Costs for residential monitoring of effluents in schools, fire stations, etc., could be a viable solution to this issue. Seismic protection costs could be more beneficially applied elsewhere.

7.1.15.3.5 Evaluation by Reviewer Z

See Section 7.1.15.7.5.

7.1.15.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.15.4.1 Evaluation by Reviewer U

Storage of DUF_6 has been the practice for several decades. Augmenting the current practices to assure the safety of long term storage—a century or two—appears to be reasonable by transferring the material to new cylinders whenever degradation of the cylinders is encountered. The rate and frequency of degradation is indeterminate, but expected to be easily accommodated.

Arriving at a decision of declaring the DU to be a waste would require considerable research and development to define the acceptable material form for waste disposal. A major program would be involved to establish the requirements of an acceptable disposal site, including the characterization of one or more sites and the acquiescence of the locality for such a site.

7.1.15.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. Some additional work on the potential for increased failure of aging canisters may be appropriate. Management can be on the lookout routinely for safer or more economical ways of managing the storage of these materials.

7.1.15.4.3 Evaluation by Reviewer X

DOE has stored dUF_6 using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

7.1.15.4.4 Evaluation by Reviewer Y

All aspects of the specifics and implied actions are state of the art without obvious benefit. Total activities can be accomplished without strategic solution resulting if one is deemed necessary.

7.1.15.4.5 Evaluation by Reviewer Z

See Section 7.1.15.7.5.

7.1.15.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.15.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining perpetual storage of DUF₆ would be fairly constant forever. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Since the storage activity would be a continuation of current practices, public acceptance should be achieved. However, a major public information program is needed to provide responsible information of the potential health impacts and perceived dangers associated with the storage of DU. As indicated in the comment letter, there is a perception of considerable risk that needs to be addressed.

If the DU is defined as a waste to be stored in perpetuity at the current storage sites, major public involvement and interface activities will be necessary to provide factual information for public review, reaction and understanding. It is doubtful that the current form, DUF₆ will be acceptable as a waste form and the current sites may not be acceptable for long term disposal as a waste material.

7.1.15.5.2 Evaluation by Reviewer V

Economics: Storage of DUF₆ using the existing management scheme would not have a significant effect on employment or income in the vicinity of the sites. Maintenance operations as currently planned would require no major increases in labor to handle the monitoring and refurbishing activities.

If major improvements were made in the facilities or maintenance operations were expanded there could be some effects on the local economies surrounding the site. Economic impacts from the construction of a covered storage building(s) at each site could be in the following ranges, based on the RIMS II regional economic multipliers (U.S. Department of Commerce, 1992):

Total estimated capital costs: \$ 360 million

Paducah (62%)	\$232.2 million
Portsmouth (28%)	\$100.8 million
Oak Ridge (10%)	\$ 36.0 million

Net effect on local economy in terms of:

	Total increase <u>direct demand</u>	New earnings <u>to employees</u>	Jobs created <u>(temporary)</u>
Paducah	\$527 million	\$158 million	8,437
Portsmouth	\$255 million	\$ 77 million	3,699
Oak Ridge	\$ 88 million	\$ 28 million	1,300

The impacts actually experienced could vary considerably, however. The economic effects of the operation and maintenance of covered storage on overall storage costs should be neutral in that protection from the elements could slow the degradation of the cylinders and reduce ongoing refurbishment costs.

Siting. Siting could be a significant public acceptance issue. It has been raised in this and other responses to program notices as a concern for some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the condition and management of the cylinders needs to be addressed. A request is made in this response to relocate residents closest to the site for their safety. Proposed legislation in Congress requiring Federal compensation to private property owners for actions that constitute "taking" of the economic value of their property as a result of government actions deserves monitoring with regard to this issue. Relocations should be carefully evaluated in terms of real safety issues, cost and continued community acceptance of the DUF6 facilities. The difficulties in obtaining storage sites makes the current location valuable.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities under current management practices. This response reflects the discontent with the situation as it currently exists, requesting a concrete facility for future storage. In response to this discomfort, additional analysis of the potential risk and education of the public may be beneficial. It may also be useful to involve concerned members of the local community in advisory committees to the storage sites to provide the community with an on-going source of information and a ready mechanism for quickly addressing any current or new concerns. Through these actions DOE may also gain additional information that will be useful in evaluating its on-going safety and maintenance standards with regard to handling and storing DUF6. In general, the community acceptability of this material will be higher at an existing site than at a new location where there is less experience with these kinds of operations and materials.

Other socioeconomic factors. Transportation risks are not expected to be a significant factor of public concern. This option would require little transport of hazardous materials.

The land use implications are also minimal. The site has been in this use for several decades and is consistent with the general industrial character of most surrounding uses. To the extent that the cumulative effect and acceptability of such uses is a concern to local residents, this use will also be scrutinized. Similarly, the ongoing operation of the storage facility, assuming no routine or accidental releases of hazardous materials, poses no new threats to cultural, historical or archaeological resources.

7.1.15.5.3 Evaluation by Reviewer X

The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Improvements to the current practices will be necessary to address these concerns.

The only employment impact will be during the construction of confinement facilities. The current work force should be able to handle the continuing storage practices.

Future use of parts of the sites not impacted by storage of dUF_6 cylinders is beyond the scope of this review.

7.1.15.5.4 Evaluation by Reviewer Y

Employment for pad construction and relocation would be significant in depressed areas. Public acceptance could be easily obtained for this non-solution. The construction industry could benefit substantially.

7.1.15.5.5 Evaluation by Reviewer Z

See Section 7.1.15.7.5.

7.1.15.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.15.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of eventual use—one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.15.6.2 Evaluation by Reviewer V

No additional factors.

7.1.15.6.3 Evaluation by Reviewer X

None.

7.1.15.6.4 Evaluation by Reviewer Y

It is possible that relocation could earn much good-will for other activities related to DUF_6 . Some motion in this regard could prove to be ultimately beneficial since it removes the specter of a "Love Canal."

7.1.15.6.5 Evaluation by Reviewer Z

None.

7.1.15.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.15.7.1 Conclusion by Reviewer U

Storage of DUF_6 has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF_6 for a long term period. Providing above ground earthquake structures for long term storage of DUF_6 does not appear to be warranted.

It does not appear to be appropriate to define the DU as a waste at this time. If a decision is made that the DU is a waste material it will trigger a major program to provide appropriate regulations, defining an acceptable waste form and the selection of a waste disposal site.

There does not appear to be a real health threat to nearby residents with the storage of DUF_6 and there is no justification for the relocation and compensation of such residents.

The organization providing the comments in Document #16 appears to represent some portion of the residents adjacent to one of the current DU storage locations. The recommendations do not include specific technical or cost details that would be involved for implementation of the recommendations.

7.1.15.7.2 Conclusion by Reviewer V

Continued storage of DUF₆ appears to be a reasonable option for consideration by DOE. It can be implemented immediately and would handle all of the existing inventory. It creates no significant new environmental issues except the need to improve maintenance of the aging cylinders to avoid accidental releases. It does maintain a large inventory of a very hazardous material that will require closer attention, however. The costs would be within program goals and is consistent with DOE and other Federal activities. A major drawback is the temporary nature of the solution. Eventually this material may require a more final disposition. In the meantime, the material is not being used to produce useful products. On the other hand, it is being preserved as a resource for future uses that may have higher value. This option may be best used in combination with other options. As product or other applications become economically attractive to the government relative to storage, they can be implemented using this material.

7.1.15.7.3 Conclusion by Reviewer X

The choice to continue current storage practices is based on the assumption that a future use such as breeder reactor fuel will develop. Conversion of dUF₆ to any other form is an extremely expensive alternative relative to continued storage. To use the uranium after conversion may require converting it back to UF₆, thus significantly increasing the cost of the end use. Thus, a recommendation to continue storage seems reasonable at this time.

The current storage practice in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. To meet this requirement, construction of buildings into which the cylinders could be moved has been estimated to cost \$360 million. (Specifications for building design were not provided.) This cost, plus the maximum estimated cost of the present inspection and maintenance program brings the total cost of maintaining the dUF₆ in its present form to slightly less than \$500 million through the year 2020. This is 10% of the cost considered reasonable for a conversion and disposal program. Of course, after expending this amount, one is still left with the original material. Thus, faith that a beneficial use will develop is critical to this recommendation.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should this option be selected. This analysis should result in bases for deciding whether to build confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be prudent, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

Construction of secondary confinement facilities and transferring dUF₆ from degraded cylinders to new cylinders will be necessary to achieve public acceptance. Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

7.1.15.7.4 Conclusion by Reviewer Y

Measures to monitor possible effluents in nearby communities are reasonable to earn goodwill by the nearby population. Ultrasonic monitoring of tank integrity may be a good investment. Pad construction would be difficult to assure seismic integrity, particularly for "Charleston Earthquake" magnitudes. The seismic protection monies can be more effectively applied to other civilian population services and facilities.

7.1.15.7.5 Conclusion by Reviewer Z

This option has no merit. It does not specify the chemical form for final disposal, and would require perpetual controls for the stored material. Permanent above ground storage in seismically qualified structures does not resolve the current problem. A detailed evaluation of this option is not warranted.

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7.1.16 Evaluation of Document No. 27 (Independent Technical Reviewers' No. 17)**Respondent:**

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913-532-5624

Description of Response:

This response recommends converting ^{238}U to $^{239}(94)\text{Pu}$ for use as reactor fuel to produce electricity. Since this is described as a long-term prospect, it is recommended that the depleted UF_6 be converted to a more stable chemical form such as an oxide and stored for use as an energy source.

7.1.16.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.16.1.1 Evaluation by Reviewer U

The recommendation in Document #17 calls for conversion of the depleted uranium hexafluoride (DUF_6) to uranium oxide and continued storage until the time of future application as fuel for reactors for the production of electricity. The recommendation incorporates the anticipated future need of nuclear reactors to convert the ^{238}U to ^{239}Pu and subsequently used to produce electricity. The potential energy value of the depleted uranium when used in this manner is indicated as an amount equivalent to the electricity needs for the U.S. of approximately 1200 years. There is no indication of when such an application would be economical or could be implemented.

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium oxides will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities at several sites.

Uranium oxides are relatively inert chemical forms of uranium with the probable oxide being U_3O_8 (dry black powder or compressed cake) with low reactivity and low solubility. Long term storage of U_3O_8 should be acceptable in stainless steel containers. A weather protecting building would probably be required for container storage.

Operational issues include well understood controls for handling DUF_6 and storage of uranium oxide until the time for use to produce electricity. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled. The potential health concerns associate with long term storage of DU are well known and when properly implemented, effectively controlled. The production, separation and recycle of plutonium fuels would entail significant controls for health protection and to prevent criticality during fuel fabrication.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage. Future activities of converting the DU to commercial nuclear reactor fuel are not defined and plans for this activity would occur many decades in the future.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of UF_6 has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is an on-going step of the nuclear fuel supply industry. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

Overall Federal regulation for safety of the conversion of DUF_6 to uranium oxide and the storage of the oxide could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DU is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. A modification in the regulations would be required for NRC licensing of long term storage of DU at private facilities.

7.1.16.1.2 Evaluation by Reviewer V

The option of converting DUF_6 from its present form to uranium oxides such as U_3O_8 to preserve it for later use does not appear to present any major environmental, safety or health issues. Two options for doing so are discussed in some detail in Documents 5 and 6. There are significant environmental benefits to storing uranium in this more stable form. There are also some potential environmental risks in the conversion processes and

in the handling and transport, as discussed. Siting of the conversion and storage facilities is expected to be possible, although they may meet some resistance. Co-locating the facilities would be advantageous.

The proposed use of DUF_6 as a fuel for reactors for the production of electricity in the future presents more environmental, health and safety issues. The processing of fuels and the use of reactors would require handling large quantities of radioactive materials and low and high level wastes that require special processing and disposal facilities. The siting of the reactors and related fuel processing facilities would require many years of advance planning and permitting procedures. Given the current public disaffection with nuclear power it is unlikely the planning process would begin in the next decade. Further, as the author notes, the current stock pile of DUF_6 would last 1,200 years, so that significant amounts would need to remain stored for a long period of time. If a new generation of reactors is developed, some environmental, health and safety issues may be resolved, but that is not anticipated soon.

7.1.16.1.3 Evaluation by Reviewer X

Converting the dUF_6 to an oxide form, such as U_3O_8 , would produce a more stable form for long-term storage. Storing this material for possible future uses rather than disposing of it would preserve a resource that may become more valuable with time as the earth's fossil energy resources become less available.

No specific conversion technology is recommended and so none are evaluated here. Several that have been proposed are stated to produce little or no additional waste streams, and so no additional hazards should be anticipated.

7.1.16.1.4 Evaluation by Reviewer Y

This proposal for an end use without a process defines the issue of fossil fuel emissions (near term) against near term very low nuclear reactor emissions. The safety issues are those of safe nuclear reactor performance versus fossil emissions that have long-term ozone layer and global warming effects. The safety of a nuclear reactor can be assured by reactor design and fuel cycle. The quantification of the proposal draws very beneficial conclusions on the health and well-being (e.g., available electricity) for a fantastic length of time based on current electricity needs. Electric transportation enhancement in the next two decades adds further emphasis to the proposal.

7.1.16.1.5 Evaluation by Reviewer Z

Implementation of this proposal would require a chemical processing facility to convert UF_6 to a stable form such as an oxide. In the event it is converted into plutonium in the future, fabricating the breeder blanket or the fuel and recovering plutonium from the spent fuel or the blanket for reuse would be done as part of the plutonium fuel cycle. In this evaluation, UF_6 conversion to a stable form for storage is considered.

Processes to convert UF_6 to stable forms such as oxide or metal have been used commercially and environmental impacts are reasonably well known. Current incentives to contain material, to minimize effluents, to recover and recycle wastes, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

Siting a conversion facility would influence transportation issues. Siting a conversion and oxide storage facility adjacent the existing UF_6 storage yards would presumably eliminate a transportation step in the foreseeable future. When transportation is necessary, e.g., to a blanket or fuel fabrication facility, the more stable form would be transported from the site.

Existing UF_6 to oxide processes may be expected to produce a powder or cake form of the oxide. Since the powder or cake may be expected to be dispersible, for long term storage, its containers would need to maintain long term integrity to prevent leakage and potential dispersion. Health and safety provisions will need to be similar to practices currently authorized for concentrate (yellowcake) to UF_6 conversion facilities or UF_6 to oxide fuel fabrication facilities. Containment requirements for dispersible powder form or uranium would need to be about the same as for UF_6 .

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 or oxide powder from its storage vessel and subsequent atmospheric dispersion.

The current technology for converting U^{238} to Pu^{239} would be irradiation in a fast breeder nuclear reactor and recovery of the plutonium in a spent fuel reprocessing plant. As Professor Eckhoff anticipates, that will be a long term prospect, the environmental, health, and safety issues of the plutonium fuel cycle would not be encountered until the distant future.

7.1.16.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.16.2.1 Evaluation by Reviewer U

The DUF_6 conversion to U_3O_8 should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may

contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

Conversion to oxides will result in the generation of fluoride compounds that will need to be purified and converted to a useful chemical compound. Cleaning of waste streams from the conversion process will be required.

A special effort will be required for emptying, cleaning and disposing of the DUF_6 storage cylinders. The recommended process removes nearly all of the DUF_6 from the cylinders. However, a small amount will remain in the cylinder as a heel that must be removed by washing the cylinders. Collection and conversion of material recovered as heels may be achieved as a slip stream into the main process at some point or it may require a separate side stream process. Cylinder cleaning should be sufficient to allow the metal to be recycled, melted and used for other metal applications. If cleaning is insufficient to permit recycle, the cylinders may need to be disposed of at low-level radioactive waste sites. Alternately, the cylinders may be modified and used as storage containers for U_3O_8 .

7.1.16.2.2 Evaluation by Reviewer V

The waste streams associated with the conversion to U_3O_8 are discussed in Documents 5 & 6. In general, it would appear that most byproducts could be recycled and wastes would be minimized.

The waste management issues associated with use of U_3O_8 for reactor fuels would be much more complicated. If the breeder reactor were implemented, the waste issues associated with use of U_3O_8 , would be no greater than those associated with the use of natural uranium. However, significant levels of low and high level waste would need to be processed and placed in appropriate repositories. Many of these issues are still being resolved with regard to current nuclear activities. Additional radioactive wastes would simply expand the scope of the situation.

7.1.16.2.3 Evaluation by Reviewer X

The waste stream from a selected conversion process will need to be evaluated. Processes proposed elsewhere state that little or no additional wastes will be produced, but that all byproduct material can be sold commercially or recycled.

Converting the dUF_6 to U_3O_8 prior to using it in a reactor fuel application means that it will need to be converted to a metal in the future. This process will result in another waste stream that will require evaluation. For storage purposes, it would be more reasonable to convert the dUF_6 directly to metal and to stabilize the metal, possible with a plastic coating, to prevent oxidation. This would save costs in the long run, and would eliminate the source of another waste stream.

By the time a breeder economy becomes accepted by the public, new methods for handling the waste streams from reactor operation will have been developed. If a concept such as

the Integrated Fast Reactor (IFR) is found to be economically feasible, problems with actinide production, plutonium proliferation, and long-term high-level reactor waste disposal will be minimized.

7.1.16.2.4 Evaluation by Reviewer Y

When this proposal is implemented, long-term storage facilities should be available. Short-term wastes for the process to produce oxide (as cited) or metal for advanced breeders (not cited) are within reach and meet criteria for reasonableness.

7.1.16.2.5 Evaluation by Reviewer Z

A UF_6 conversion (to oxide or metal) facility would produce some radioactive effluent and radioactive waste. The solid radwaste would be expected to be transported to a regional low-level radioactive waste burial facility.

Conversion of UF_6 to an oxide or metal form would release the fluorine, a toxic chemical. During the conversion process, the fluorine would need to be captured. It seems more likely that the fluorine would be captured as HF, a commercially valuable chemical, and unlikely to become a waste form. Solid wastes would be mainly contaminated equipment, effluent scrubber sludge, clothing, process maintenance materials and such other materials that become contaminated incidental to processing UF_6 to a more stable form. The heel, or residue, in a UF_6 cylinder that does not vaporize along with the UF_6 contains radioactive progeny of U^{238} and U^{234} , especially protactinium-234. It has much higher radioactive concentration than U^{238} or U^{234} and must be dealt with as a radioactive waste. Storage to allow radioactive decay is usually a waste management practice for the cylinder heels.

In the long term, conversion of the stable form to Pu^{239} would involve irradiation in a nuclear power reactor and reprocessing steps in the nuclear fuel cycle.

High waste burial costs, state and federal regulation, high costs of disposing of radioactive waste, health hazards of UF_6 and HF that is not contained, high costs of decontaminating and decommissioning facilities and surrounding land that has been contaminated, and recovery of commercially valuable HF are incentives to minimize creation of radioactive waste during the conversion of UF_6 to a more stable form or to breeder reactor fuel or blanket.

7.1.16.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.16.3.1 Evaluation by Reviewer U

Since process steps for converting DUF_6 to uranium oxide are well understood, the costs can be reasonably well defined for both the processing plant and the operation. Recovery of HF as anhydrous HF is the only means to achieve a salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

The operational and use period for the facility for the conversion of DOE material of about two decades may be a normal life of such chemical facilities. However, since uranium enrichment operations are continuing in the U.S., additional DUF_6 is being generated. Extended use of the plant may be achieved for additional conversion of this added material. After the facility has reached full economic life, it would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the DUF_6 , although the volumetric space would be similar. Rectangular containers of U_3O_8 would pack and stack in a space more efficient than the cylindrical containers of DUF_6 . However, the cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be called for at an added cost for storing containers of U_3O_8 , while outdoor storage of DUF_6 cylinders appears to be adequate.

7.1.16.3.2 Evaluation by Reviewer V

The costs of converting DUF_6 to uranium oxides for storage could be significant. As discussed in Documents 5 and 6, the existing commercial process costs \$3.00/kgU with credit for recycling. The proposed process that has not been demonstrated at commercial scale is estimated at \$2.20/kgU before byproduct sales. These would result in total conversion costs for the inventory of \$1.2 to \$1.7 billion. In addition, storage costs are likely to equal or exceed those for DUF_6 , although volumes will be reduced.

The costs of using DU as fuel in reactors of the future are not well known at this time. Until a better understanding of the technology and the role uranium oxides would play can be developed, little can be determined with regard to the cost to the Government of using stockpiled DU in this way. However, it is difficult to estimate the opportunity cost of not having the material available for such uses in the future, should they become needed. In some cases, however, less expensive substitute fuels may be available.

7.1.16.3.3 Evaluation by Reviewer X

Long-term storage of an oxide form for future use in a breeder reactor economy is likely to be nominally more expensive than disposal. Whether all this material would ever be used, however, may be questionable but should be investigated. Eventual sale of the oxide for fuel should cover the increased costs for storage.

If the projected long-term use is for a uranium metal, then conversion to metal rather an oxide would be more cost effective.

The cost of converting the dUF_6 to an oxide form rather than continuing storage in the present form will be significantly greater than a long-term dUF_6 storage and monitoring program.

7.1.16.3.4 Evaluation by Reviewer Y

For the specifics of the proposal, the reactor capital and operating costs plus the recycle costs need estimating. The target should be current fossil fuel costs as escalated in time due to reduced availability. The process costs to generate either DUO_2 or DU metal can certainly be on the order of a few dollars per pound, with alternate availabilities being a significant lever. These include coal, oil, gas, and environmental control costs.

7.1.16.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Presuming fluorine or HF were recovered, it would be commercially valuable. In the event the uranium is eventually bred into fissile plutonium, Professor Eckhoff's estimate of potential energy reserves provide an indication of the potential value as a nuclear reactor fuel and source of energy. Eventual utilization of the uranium by conversion to plutonium cannot be assessed by this reviewer.

7.1.16.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.16.4.1 Evaluation by Reviewer U

The chemical process requirements to convert DUF_6 to uranium oxide are well defined and considered mature. Technical maturity is sufficient to permit the conversion with minimal research and development. Some effort will be required to refine an approach to produce anhydrous HF as a salable product.

Storage of uranium oxide is considered to be a low risk activity, readily achieved. Special efforts of monitoring and maintenance would be required to assure the safety of long term storage—a century or two.

Using the DU at some future date for the production of electricity entails technology that has been well defined. Commercial demonstration will require many decades and large financial commitments. Future economic viability is an unknown at this time.

7.1.16.4.2 Evaluation by Reviewer V

Conversion of uranium to oxides is commercialized and the storage technology has been proven in Europe. Reactor technology currently in commercial use in Europe, however, has not been adopted in the U.S. Current focus on next generation reactors makes it unlikely that the breeder or other reactors will be adopted in this country in the near future for electricity production.

7.1.16.4.3 Evaluation by Reviewer X

Several technologies for converting the dUF_6 to an oxide form or to metal have been proposed. Several of these use current technology. Some propose new technologies that reduce the waste streams. The selected technology will need to be assessed independently.

Breeder reactor technical aspects have already been demonstrated in the U.S. and abroad, and are in commercial use abroad. The IFR concept is being demonstrated on a pilot scale in the EBR-2 in Idaho with some fuel operating for 30 years without experiencing cladding leaks. EBR-2 is currently fully fueled with pyroprocessed and electrorefined fuel (U-Pu-Zr

with contained actinides). Since a pure plutonium product isn't possible with this process, the fuel is self-protecting from a nuclear proliferation perspective.

7.1.16.4.4 Evaluation by Reviewer Y

Most aspects of the proposal are technically mature short of "standard industrial practice." The technology of building a safe, fast neutron breeder is understood with significant experience and demonstration. The option to further enhance at least the perception of safety with two fuel cycles (U233-Th and Pu239-U238) is understood but has not been demonstrated under power operating conditions. Decisions on oxide fueled breeders or the Integral Fast Reactor (IFR) would be helpful early on to optimize DUO2 or DU metal production (not in this proposal).

7.1.16.4.5 Evaluation by Reviewer Z

UF₆ conversion to a stable form such as an oxide is a mature chemical process. UF₆ conversion to U₃O₈, UO₃, and UO₂ has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel. Large scale uranium-to-plutonium breeder reactors have been constructed and operated in other nations. Spent fuel has been reprocessed to recover plutonium in the United States and in other nations on a commercial scale and by the U.S. Government installations. Fuel reprocessing and fabrication of plutonium mixed oxide fuel should be considered a developed, perhaps, mature technology.

7.1.16.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.16.5.1 Evaluation by Reviewer U

Employment for converting DUF₆ to uranium oxide and the monitoring and maintaining storage of DU as uranium oxide would be fairly constant for many decades. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the conversion and storage are carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Also, there will be strong objection

by some members of the public to a storage mode that would anticipate the use of breeder reactors in the future.

7.1.16.5.2 Evaluation by Reviewer V

Economics: As discussed in Document 5, a conversion facility to process DUF_6 to U_3O_8 could cost \$80 to \$100 million and would be a significant economic stimulant during construction and operations in many communities. Similarly, construction of a storage facility would have significant short-term effects and some residual employment. Production would be a further economic stimulus and could support or sustain the economic health or growth of the surrounding area.

Siting. Siting could be a significant public acceptance issue. Concern about nuclear facilities has been expressed by at least some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the operations need to be addressed. Requests have been made in some cases to relocate residents closest to the site for their safety. Proposed legislation in Congress requiring Federal compensation to private property owners for actions that constitute "taking" of the economic value of their property as a result of government actions deserves monitoring with regard to this issue.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities. Although U_3O_8 is a much more stable and safe form of storage, it may also be useful to involve concerned members of the local community in advisory committees to provide the community with an on-going source of information and a ready mechanism for quickly addressing any current or new concerns. Careful work with the public regarding new reactors will be a key part of obtaining acceptance.

Transportation. Transportation risks are not expected to be a significant factor of public concern. If materials were transported in large quantities for the first time for processing, the number of vehicle trips and potential for accidents will be increased.

Other socioeconomic factors. The land use implications for this option are significant. Land would be required for conversion facilities, storage and reprocessing as well as for the use of the uranium in reactors as fuel.

Nuclear power generation has significant problems with public acceptance at this time. With other conventional sources of electric power readily available at attractive prices, and the prospect of stable or lower electric prices in most areas in the near future, there will be little economic or resource pressure to further develop existing or new nuclear technologies. Public concern about environmental, health, safety and waste disposal issues is likely to retard future efforts to expand nuclear energy unless extraordinary needs exist.

7.1.16.5.3 Evaluation by Reviewer X

Conversion of dUF_6 to an oxide or metal form should receive greater public acceptance than continued storage of the dUF_6 because of the greater chemical stability of the product.

Public acceptance of a breeder reactor program is not likely to occur in the short-term future. However, as the need for additional economical electricity sources develops, and as the success of breeder programs in other countries become apparent, a new public and political perspective should emerge.

7.1.16.5.4 Evaluation by Reviewer Y

As fossil fuels become less available and no large-scale alternatives come into being (~50-100 years), this option will not only be desirable, but necessary. The risk/benefit and cost/benefit are the guiding numbers. Obviously, process and generation employment are significant. At today's rate of electricity use, ~500 nuclear reactors will be needed in the USA for an all-electric economy; this may be too ambitious, but France seems to be operating well with significant environmental benefits at ~75% nuclear (including one large breeder reactor). Employment is often a precursor to public acceptance, particularly in small communities.

7.1.16.5.5 Evaluation by Reviewer Z

Concerns about international proliferation of plutonium production and potential diversion of it into nuclear weapons has resulted in a U. S. Government policy prohibiting spent fuel reprocessing and recovery of plutonium. This federal policy would have to be reversed in order to be viable.

7.1.16.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.16.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. According to this recommendation there is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of eventual use—one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.16.6.2 Evaluation by Reviewer V

See General Comments.

7.1.16.6.3 Evaluation by Reviewer X

None.

7.1.16.6.4 Evaluation by Reviewer Y

While very brief, the proposal is a mature statement of an option for beneficial use of DUF₆. This is what the Atoms for Peace Program envisaged during the 1950s and that vision is unchanged!

7.1.16.6.5 Evaluation by Reviewer Z

None.

7.1.16.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.16.7.1 Conclusion by Reviewer U

Conversion of DUF₆ to uranium oxide and storage of the oxide until a need is defined for using the DU as fuel for the production of electricity is a reasonable approach. A determination of whether the advantages of storage in the oxide form are sufficient to justify the cost of conversion at this point should be undertaken. It does appear reasonable to be able to monitor and maintain safe storage of DU as uranium oxide for a long term period and keep open the option of using the material as an energy resource at some time in the future.

The organization providing the comments in Document #17 has considerable knowledge on the potential energy values of depleted uranium when used as an energy resource for the production of electricity.

7.1.16.7.2 Conclusion by Reviewer V

Conversion and storage of DUF₆ as uranium oxide solely for later use in reactors may not be a reasonable option for consideration by DOE at this time. It can not be implemented immediately and would not result in a final disposition of the existing inventory in the required 30 year time frame. It creates no significant new environmental issues that need to be addressed at this time. The costs for conversion and storage would be within program goals, but the costs for reuse as fuel are poorly defined. This option is consistent

with DOE and other Federal activities. A major drawback is that the material is not being used to produce useful products within 30 years. On the other hand, it is being preserved as a resource for future uses that may have higher value. Preservation of the material solely for use in reactors must be questioned given the uncertainty of the future of that technology. Should the reactor program become more active in the future, only a portion of the stockpiles would be needed, or natural and other sources could be substituted at the appropriate time.

7.1.16.7.3 Conclusion by Reviewer X

Conversion of dUF_6 to oxides for long-term storage rather than disposal would preserve the option to use the uranium in future reactor applications while rendering the material safer than in its present form. However, conversion to uranium metal that is surface stabilized to prevent oxidation would provide a directly usable form that requires less storage space. Production of HF and HFC products during the conversion process would alleviate the costs.

Use of the ^{238}U in an FBR economy will require only 2% of the current inventory for the initial fuel loads in a 100-FBR economy, something not likely to occur for more than 100 years from now. Reloads will require only about 2% of this amount (0.05% of the current inventory). Thus, continuing production of fuel for current LWR operation will provide more than adequate amounts of ^{238}U , and use of the dUF_6 in other applications will still need to be considered to utilize any significant amounts of what is currently available.

7.1.16.7.4 Conclusion by Reviewer Y

The proposal very simply states the vast benefits inherent in the DUF_6 . If a reasonably economic process for making DUO_2 or DU metal can be developed (not in this proposal), this is a major benefit product that meets a need. The potential for using U233-Th with this cycle may markedly enhance safety perceptions. Startup for U233 operations could beneficially use some surplus highly enriched Uranium.

7.1.16.7.5 Conclusion by Reviewer Z

This option has a great deal of merit. It is based on proven technology, and offers at least two useful products from the depleted uranium. The energy potential which could be derived from the depleted uranium is enormous. The primary limitation is political rather than technical, and would require a reversal of current U.S. policy in order to be a viable option.

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7.1.17 Evaluation of Document No. 31 (Independent Technical Reviewers' No. 18)**Respondent:**

Mr. Thomas McWilliams
Chief, Life Cycle Readiness Division
Department of the Army
U.S. Army Production Base Modernization Activity
Picatinny Arsenal, New Jersey 07801-5000

201-724-3049 (POC, George O'Brien)

Description of Response:

This response recommends using the depleted uranium stockpile in the production of drill collars, well penetrators, and well shape charge perforators for use in the US oil well drilling industry. The responder further states that DOE should consider liability issues in its decisions on the use of depleted uranium since it could be considered government furnished property and that the level of radioactivity of the depleted uranium stockpile will be a factor in the usability of this material.

7.1.17.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.17.1.1 Evaluation by Reviewer U

The recommendations in Document #18 entail the use of depleted uranium metal for drill collars, well penetrators and shape charge perforators. No indication is provided for the process of converting depleted uranium hexafluoride (DUF₆) to uranium metal or for the quantity of material that may be applicable to each of the recommended uses. The total potential quantity of uranium metal that may be used for these applications has been indicated by others as about 220 million pounds over ten years—equivalent to about 150,000 MT of DUF₆.

Further, the recommendation indicates concern about the Government's potential liability associated with the use of government furnished material in the commercial sector.

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal will require the design, construction, operation and eventual decommissioning of at least one new facility. The defluorination and metal production steps have been used to produce uranium metal for several decades. DUF_6 is reduced with hydrogen at a continuous rate in a tower reactor vessel and the resulting uranium tetrafluoride (UF_4) is further reacted with magnesium metal in a batch metallothermic reduction to produce "derbys" of uranium metal.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium metal may be forged and machined into specific shapes to satisfy the needs of the indicated applications.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched uranium is an ongoing part of the commercial supply of nuclear fuel. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for disposal of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Uranium metal processing and machining must be done in a facility qualified for the working of uranium.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation. Conventional metal processing and machining operations must be supplemented with specific procedures for uranium metals.

Overall Federal regulation for safety could be under the existing DOE regulations for uranium metal production when performed at DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for the production and processing of uranium metal. However, regulations for the use of uranium metal in commercial applications in the petroleum industry need to be developed.

7.1.17.1.2 Evaluation by Reviewer V

This recommendation supports the conversion of depleted uranium to metal for use in dense materials application products including well shape charge perforators, drilling collars and well penetrators for the oil well drilling industry. The environmental, health and safety concerns for DU metal production and use in these applications is addressed in detail in Document 15-1. The risks are considered manageable and the effects within allowable limits. Final disposal of these devices after they have served their useful life will need to be handled within the requirements of applicable NRC, DOE and EPA regulations. There are certain special concerns associated with some of the applications listed. With regard to these devices, there is concern that use of uranium could result in spread of radioactive or hazardous material into the earth or groundwater contaminating it. In normal use and abrasion, these products could be handled in a manner causing DU metal to be released to the surrounding environment where it could be inhaled or contaminate resources. Shipping the metal products could also create concern for environmental or health risks. The siting of fabricating facilities is unlikely to present sensitive issues regarding public acceptance.

7.1.17.1.3 Evaluation by Reviewer X

The Army recommends the use of DU in three oil field applications:

- Drill Collars
- Well Penetrators
- Well Shape Charge Perforators.

Worker safety during handling of the materials must be considered. The application doesn't lend itself to protecting the uranium effectively with cladding as do other applications having little or no abrasion associated with the process.

A potential for contamination of the environment also exists during drilling processes, or should an accident occur. The uranium may be dispersed or lost in the well and certainly will be if it's used for shaped charge applications. During drilling, the well and the outside of inserted casing will become contaminated due to abrasion.

Controls for disposal or preferably recycling of damaged or worn components will need implementation.

7.1.17.1.4 Evaluation by Reviewer Y

The proposal is silent on these issues. It does raise the related issue of liability of government furnished material, possibly in perpetuity! Does regulation by NRC and/or EPA obviate this question?

It is not likely that the oil well equipment will pose unusual environmental problems or significant health and safety issues. The Army's DU specifications could or should be scrutinized to ascertain a wider basis of confident use for regulation.

7.1.17.1.5 Evaluation by Reviewer Z

Mr. Thomas McWilliams proposal is that material be used in the manufacture of oil industry equipment such as drill collars, well penetrators, and well shape charge perforators.

If properly clad with other metals, the application of depleted uranium (DU) for drill collars should not present any undue risks. The use of DU in applications which would result in the material being left in the geologic formations surrounding the well, such as well penetrators, presents the risk of uranium contamination of the formation and any oil which might come from the well in the event the clad is damaged during the perforation process.

7.1.17.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.17.2.1 Evaluation by Reviewer U

The DUF_6 conversion to uranium metal should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. The reduction to metal uranium produces a large volume of magnesium fluoride slag that contains a considerable amount of uranium. The uranium must be removed from the slag to achieve a usable magnesium by-product. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low-level radioactive waste, requiring disposal at dedicated low-level waste disposal sites.

Small uranium metal pieces are pyrophoric and must be handled with care. Machining chips may be converted to an oxide in a controlled manner to render them safe. Disposal of this material may entail disposal at low-level radioactive waste disposal sites.

7.1.17.2.2 Evaluation by Reviewer V

Waste management issues for these options are discussed in Document 15-1. All these products will need to be carefully accounted for at the end of their service life as a product. It may be possible to recycle the uranium metal into other products, or, if not, disposal in an acceptable facility will be needed.

7.1.17.2.3 Evaluation by Reviewer X

The ultimate lifetime of any uranium drill product produced will need to be considered. Controls will need to be implemented to assure that when the drill product is no longer needed, disposal will occur according to appropriate safety practices.

Since wells will become contaminated during drilling operations and shaped charge use, installed casing also will become contaminated. If the casing is removed, it will need to be decontaminated before disposal or reuse. Otherwise, it will need to be disposed of in an LLRW facility, thus adding to the radioactive material waste stream.

7.1.17.2.4 Evaluation by Reviewer Y

The proposal is silent, though it can reasonably be anticipated that process to metal wastes including Fluorine and Magnesium can be anticipated short of a new exotic process.

7.1.17.2.5 Evaluation by Reviewer Z

It is anticipated that any waste generated in production of oil industry equipment would be similar in composition to those currently seen in the industry. A more specific waste management consideration for this option is the final disposition of the equipment after their normal lifetime. This application would require the licensing and tracking of each item in order to ensure that it was properly disposed at the end of life. An additional consideration would be the method of disposal. This is an uncertainty at this point due to the lack of licensed burial sites, and a questionable schedule for the completion of the interstate compact sites.

7.1.17.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.17.3.1 Evaluation by Reviewer U

The cost of converting DUF_6 to uranium metal has been indicated by others to be in the range of \$10 per kilogram. However, the actual cost of uranium metal production in large quantities that would require new production facilities licensed by the NRC is not well defined and could be significantly higher than \$10 per kilogram. The conversion cost would be much greater than the value of recoverable HF. Eventually, this conversion cost may be required for disposal of DU if it is determined that DU is a waste material and that uranium metal is the proper form for disposal.

Cost of fabricating uranium metal components are reasonable well known since they have been fabricated for some time.

7.1.17.3.2 Evaluation by Reviewer V

Costs for production of DU metal and initial casting into a shape are estimated at \$11/kg of uranium. Depending on the useful products that are fabricated, the net cost for this option could be reduced. No revenue estimates are provided, and potential markets are not quantified. Costs for disposing of these products at the end of their service life could be significant if recycling is not possible.

7.1.17.3.3 Evaluation by Reviewer X

No information was provided on cost for this option. However, the potential for environmental contamination will need to be considered if DU is used in the proposed well applications.

7.1.17.3.4 Evaluation by Reviewer Y

The proposal is silent on this. The potential liability of product use in the civilian sector could double or triple production costs. Would this lead to less expensive exploration and extraction (of oil) costs?

7.1.17.3.5 Evaluation by Reviewer Z

This reviewer has no specific data regarding the costs associated with founding and fabricating uranium metal. In addition to the fabrication costs, additional operational costs might be associated with handling and tracking oil field equipment which contains uranium metal in order to ensure that it is properly dispositioned at the end of its service life. Data related to such tracking is not available to this reviewer.

7.1.17.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.17.4.1 Evaluation by Reviewer U

The process requirements for the production of uranium metal are well defined. Forming and machining of uranium metal has been done for decades. Thus, the production of uranium metal components should be considered a mature technology.

The use of uranium metal as drill collars, well penetrators and shaped charge perforators would need to be demonstrated. Standard techniques for the use of other materials in these applications are well developed. Applying similar techniques with the use of uranium may achieve improvements over other materials, but demonstration is necessary to confirm the applications.

7.1.17.4.2 Evaluation by Reviewer V

This conversion process to DU metal is available now. Fabricating techniques likely to be used are for the most part commercial. Specific applications may require some additional product or process engineering but it is unlikely this would significantly delay adoption.

7.1.17.4.3 Evaluation by Reviewer X

Considerable experience exists with founding, casting, and milling processes. Also, considerable drilling experience exists. However, the use of uranium in drilling operations hasn't been done. An evaluation will be required concerning the environmental effects of this application.

7.1.17.4.4 Evaluation by Reviewer Y

The technology to produce DU metal from DUF₆ is not in the proposal but is reasonably well established, probably short of standard industrial practice. While the use of strong high-density material is attractive, it is not clear that this is the only technical option for such application. Do these applications require unique NRC, EPA, and OSHA actions? If so, the benefit may be elusive, and, without knowing more, may be contrived?

7.1.17.4.5 Evaluation by Reviewer Z

Uranium metal founding and milling processes are well established, and this is considered a mature technology.

7.1.17.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.17.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF₆ to uranium metal and the manufacturing of uranium metal components for the petroleum industry should be at a relatively steady level. However, since the need will be dependent on the use of metal in various applications, up and down employment cycles would occur depending upon demand for the metal or changing customer desires. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility.

Performing uranium processing operations at one or all three of the existing sites where DUF₆ is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since the DU becomes a disposed item under ground were used as penetrators or perforators, the question of dispersed contamination and possible contamination of the biosphere at some future date will need to be addressed.

7.1.17.5.2 Evaluation by Reviewer V

If new facilities were required to convert the entire DU inventory to DU metal, this option would constitute a major industrial construction and operation project with significant direct and indirect impacts. The plants might meet some resistance but are likely to be able to locate an acceptable site. Fabrication plants are not likely to be opposed on the basis of local environmental concerns.

7.1.17.5.3 Evaluation by Reviewer X

The recommendation mentioned the Kinetic Energy Penetrator Production Base as a potential facility to manufacture the products. It stated the manufacture of drilling products would provide significant work to retain that base.

If existing facilities are used or expanded, a trained work force should be available, and the impact on communities should be minimal.

7.1.17.5.4 Evaluation by Reviewer Y

This proposal is not likely to feature strong considerations except perhaps where the material may be in use. Modest employment and regional development are anticipated. Probably no significant regional enhancement except for the process to produce DU metal (not part of this proposal).

7.1.17.5.5 Evaluation by Reviewer Z

Employment

This reviewer has no information related to the effects this application may have on employment.

Public Acceptance

Some limited public resistance might be anticipated from any application which would leave uranium material in the geologic formations, such as well perforation.

Regional Development

This reviewer has no information regarding the impacts of this option on regional development.

7.1.17.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.17.6.1 Evaluation by Reviewer U

Controlled and safe disposal of the DU is an appropriate factor. Drill collars could be catalogued and properly disposed of after their use has been completed. However, well penetrators and perforators would be dispersed at the point of use. This may or may not be an acceptable practice from a long term safety standpoint.

7.1.17.6.2 Evaluation by Reviewer V

See General Comments.

7.1.17.6.3 Evaluation by Reviewer X

The RFR expressed a concern for the "overriding issue of the government's liability for the use of the dUF_6 " asking "does the government retain liability for the life cycle of any and all of its uses?"

The RFR also stated that the Army's specification for the use of depleted uranium is that the ^{235}U be $<0.2\%$ per five pounds of dUF_6 . This specification needs to be interpreted.

7.1.17.6.4 Evaluation by Reviewer Y

None.

7.1.17.6.5 Evaluation by Reviewer Z

The option of using depleted uranium for the production of oil industry equipment would have to be evaluated on a case-by-case basis. A factor to consider is the regulation under 10 CFR 40.22 which grants a general license to commercial and industrial firms for the possession of 15 pounds of uranium for research, development education, commercial operational purposes. Amounts of uranium in excess of 15 pounds require licensing by the Nuclear Regulatory Commission. Regulatory changes may be required for specific applications which would allow the possession of amounts of uranium in excess of 15 pounds for specific purposes.

7.1.17.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.17.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to uranium metal appears to be reasonable from a technical standpoint. The potential quantity of 100,000 MT of uranium metal over a ten year period was indicated by one source (not Document #18) for petroleum uses in drill

collars, well penetrators and shaped charge perforators. This quantity may or may not be realistic. If it is, and the safety concerns associated with metal dispersal are satisfied, then the use and quantity fall within the reasonableness guidelines provided for the use of DU. A careful assessment of the relative cost of the DU components, compared to other materials that may satisfy the needs of the applications, must be made to define whether the applications are economically attractive.

The organization making the recommendation in Document #18 has considerable experience with the use of depleted uranium metal components.

7.1.17.7.2 Conclusion by Reviewer V

Based on DOE criteria, it is hard to evaluate this option. While technically most of the products could be made at this time, it is not clear at what cost and how large or viable markets for them would be. In addition, concern about the environmental, health and safety effects of the use of these products would need further evaluation. Given these concerns, further definition of specific products, markets and costs should be made before they are included in the program. The role for private industry in identifying and nurturing these opportunities could be investigated.

7.1.17.7.3 Conclusion by Reviewer X

The ultimate lifetime of any uranium metal product produced will need to be considered. The proposed use for the metal is in the civilian community. Thus, controls currently in place for military applications won't be appropriate in the new environment. Controls will be required to assure that when the product is no longer needed, disposal will occur in accordance with appropriate safety practices and regulations. This is a problem today with some materials.

Since the proposed uranium metal application will result in loss of material through abrasion or chemical explosion, concern for environmental contamination and equipment contamination and cleanup also must be considered.

Though no projection was provided for the total amount of dUF_6 to be consumed by this application, another source (RFR# 15) estimated a demand over a 10-year period of 110,000 tons for shaped charge devices and 1,000 tons for drill collars. Thus, the application has the potential to significantly deplete (about one-third) the existing inventory and also cut into the inventory from ongoing enrichment activities during the next 30 years.

However, the application also has the potential to disperse depleted uranium into well holes where drilling occurs and especially where shaped charges are used. This dispersion should be evaluated relative to contamination of both the rock strata and groundwater.

7.1.17.7.4 Conclusion by Reviewer Y

The process is not "reasonable" since it is unlikely to utilize 15% or more of the existing DUF6. However, in concert with other metal uses, the oil well applications may be highly beneficial provided the liability issues are clarified.

7.1.17.7.5 Conclusion by Reviewer Z

This option has merit. There are benefits to be gained due to the density of the depleted uranium metal, the technology is well established, and the potential risks associated with this application are small.

7.1.18 Evaluation of Document No. 32 (Independent Technical Reviewers' No. 19)

Respondent:

Dr. Velma Shearer
124 Chestnut Street, #210
Englewood, Ohio 45322

phone number not provided

Description of Response:

This response recommends against the no action alternative of maintaining current storage and management practices based on health and safety concerns and against the use as shielding for other nuclear materials or in the production of armaments. The responder recommends conversion of the depleted uranium at plants built at either Portsmouth, Ohio, or Paducah, Kentucky, as a solution that would produce fluorides, which could be sold for other industrial uses, or metal to be mixed with concrete slurry or sand and returned for deposit in abandoned uranium mines.

7.1.18.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.18.1.1 Evaluation by Reviewer U

The recommendation in Document #19 specifically states that continued storage of depleted uranium hexafluoride (DUF_6) is not satisfactory for several listed reasons and that DU should not be used for shielding or in armaments. The recommendation calls for the conversion of DUF_6 into metal for diluted disposal in a concrete or sand slurry and the recovery of fluorides for industrial uses. Conversion of large quantities of DUF_6 to metal will require the design, construction, operation and eventual decommissioning of at least one new facility. The recommendation call for at least two conversion facilities.

The defluorination and metal production steps have been used to produce uranium metal for several decades. DUF_6 is reduced with hydrogen at a continuous rate in a tower reactor vessel and the resulting uranium tetrafluoride (UF_4) is further reacted with

magnesium metal in a batch metallothermic reduction to produce "derbys" of uranium metal.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal, that might be appropriate for dilution with concrete or sand as recommended in this proposal, are pyrophoric and will readily burn in air. Eventual disposal of DU may require the chemical form of U_3O_8 , requiring a conversion from the metal to the oxide if a disposal decision is forthcoming in the future.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched uranium is an ongoing part of the commercial supply of nuclear fuel. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for disposal of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill. Conventional processes for the production of uranium metal result in the generation of large quantities of MgF_2 as a slag that would require removal of uranium and controlled disposal.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Defining an acceptable site for disposal of diluted DU in concrete or sand would be a major undertaking to achieve acquiescence of a locality for the disposal. Such dilution steps should be performed at the disposal location because of the large quantity of cement and sand required for dilution.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal production could be either under the existing DOE regulations or under

10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, if the operation entails disposal of the DU metal diluted with concrete or sand in an underground disposal facility, regulations are not in place and the ability to obtain safety regulatory approval from the NRC is problematic and indeterminate.

7.1.18.1.2 Evaluation by Reviewer V

This recommendation suggests that DUF_6 be converted to metals and mixed with concrete slurry or sand to natural background levels of radioactivity for disposal in abandoned uranium mines. Conversion of DUF_6 to depleted uranium metals does not raise any unique environmental health or safety issues. The effects of these conversion processes for metals are discussed in Documents 2-4, 3-2, 4-3, 8, 21-3, 27 and 30. The disposal of the depleted uranium metal does present some environmental issues. The most important is the reactivity of DU metal to air and water. Without appropriate control, this could lead to worker exposures or releases to groundwater at the sites. When DU metal reacts with water at ambient temperatures, UO_2 and UH_3 are formed, both of which are highly toxic, spontaneously flammable and radioactive. This can be controlled through the use of special coatings or containers designed to be very corrosion resistant. It is not clear if mixing the metal with sand and/or concrete to natural levels would control these reactions effectively protecting groundwater. Use of exhausted uranium mines may require special construction measures to prevent infiltration or migration to groundwater. Transportation of the DU metal would need to follow existing regulations, but is not expected to create any new problems.

7.1.18.1.3 Evaluation by Reviewer X

The recommendation is to use existing sites for conversion of the dUF_6 to metal. This has the advantage of minimizing transportation concerns for the dUF_6 . The recommendation also states to construct the conversion facilities at the Paducah and Portsmouth sites where the largest amounts of material are stored. Thus, only 11 percent of the dUF_6 cylinders would need to be transported to a conversion facility.

7.1.18.1.4 Evaluation by Reviewer Y

Proposal suggests early action before "a very pressing accident situation or weighted clean-up occurs." Any but the very nearest exposure of workers is likely to be a "non-accident" in the context of injury to nose, throat, and lungs of material that is largely solid. The potential for cylinder rupture when moving them suggests at least an investigation into transferring material to another cylinder for transport. This would probably require heating

of the solid DUF₆ in the "high risk" tank. The potential for declaring the material as "waste" will profoundly impact regulatory procedures. Such procedures are intended to safeguard the environment, and provide for safety and health of public and workers. Blind application of existing regulatory procedures would nominally exacerbate "paper" without providing thoughtful procedures and cost-effective benign results. Not clear why no "center" at Oak Ridge!

7.1.18.1.5 Evaluation by Reviewer Z

Dr. Velma Shearer's proposal is that at least two centers (Paducah and Portsmouth) be constructed for depleted UF₆ conversion. A detailed evaluation was not performed of this option. See response to Section 7.1.18.7.5, Conclusion.

7.1.18.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.18.2.1 Evaluation by Reviewer U

The DUF₆ conversion to uranium metal and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. The reduction to metal uranium produces a large volume of magnesium fluoride slag that contains a considerable amount of uranium. The uranium must be removed from the slag to achieve a usable magnesium by-product. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low-level radioactive waste, requiring disposal at dedicated low-level waste disposal sites.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

The disposal of the empty DUF₆ cylinders is a waste issue. Removal of UF₆ heels from cylinders, cleaning of the cylinders and their eventual disposition will be required. Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the recovered metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.18.2.2 Evaluation by Reviewer V

The volumes of DU metal for disposal will be significant in comparison to historic generation rates. The NRC has recommended deep geologic disposal because of the volumes involved, in a specially designed facility. Although some disposal sites have been evaluated, none is developed at this time. Finding a suitable site might be difficult. Any geological site would need to be carefully analyzed to determine risks to groundwater and other potential environmental issues. It is unlikely that use of deep geological disposal would create a great deal of additional waste that would need additional disposal.

7.1.18.2.3 Evaluation by Reviewer X

The recommendation is consistent with the NRC's assessment in the Claiborne EIS that deep burial will be necessary. However, it recommends that the dUF_6 be converted to metal which is potentially the most expensive conversion alternative. Also, this conversion alternative has the potential for producing the largest secondary waste stream requiring disposal at non-radioactive waste sites.

No deep disposal sites currently exist.

If the metal is mixed with other materials to background levels, it will qualify for near-surface disposal, a less expensive alternative.

A large amount of "product" for disposal (the mixture of uranium metal and concrete or sand) would pose a huge and expensive transportation task. The only practical way to transport this large material would be by rail car, necessitating the installation of rail links at both the processing and disposal ends. Envirocare of Utah is already set up to handle delivery by rail and disposes of all materials unpackaged.

7.1.18.2.4 Evaluation by Reviewer Y

The extraction of the Fluoride from DU metal production would be a source of modest funds. The waste from metal production, principally Mg and Ca, would be significant. However, much more significant is the proposed mixture of DU metal with concrete or sand to a "natural" background level. Fantastic volumes of this material would be needed for disposal as waste. The material (the mixture of DU metal with concrete or sand) would have to exhibit some stability in time. Therefore, DU loadings in these materials would, without demonstration of multicentury lifetime, be quite low to extrapolate current experiences.

7.1.18.2.5 Evaluation by Reviewer Z

See Section 7.1.18.7.5, Conclusion.

7.1.18.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.18.3.1 Evaluation by Reviewer U

Since the conversion of DUF_6 to metal has been performed for several decades, the cost of scaled up facilities and the operation of the facilities can be reasonably well defined. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities and performing the conversion operations.

Slag cleaning and disposal will be a major cost factor for this recommendation. Research and development efforts appear to be needed to define the preferred means of slag cleaning and disposal. The added cost and time required for R&D and pilot plant demonstration of slag cleaning appear to be reasonable with high probability of success.

The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility could be torn down with all contamination removed from the site. The site could be returned to uncontrolled use. Decontamination and decommissioning costs for a DUF_6 to metal conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

Dilution of DU metal in concrete or sand to achieve natural background levels would entail a very, very large dilution factor, much beyond what would be considered reasonable for public health and safety reasons. Marginally economic uranium ores contain more than five pounds of uranium per ton of ore. Even these ores have a radiation level higher than generally considered background radiation. If the dilution step as recommended were to provide a disposal product of one pound of uranium per ton, the total quantity of material required for disposal would be in the range of one billion tons. The cost of disposal for such a magnitude of material is well beyond what could be justified for health or safety reasons.

If a decision is made at a future date to dispose of the DU in an underground disposal facility, U_3O_8 would probably be the material form of choice for disposal. Converting

DUF₆ to metal as the first step for disposal would add an extra unnecessarily costly step and does not appear to be appropriate.

7.1.18.3.2 Evaluation by Reviewer V

The costs for deep storage are unknown and could vary significantly depending on the specific site. One respondent to the Request for Recommendations suggests that such a facility could be built for as little as \$50 million. If safe cavities can be found, the cost of disposal might be reduced as special packaging and handling becomes less critical. However, monitoring costs could be quite high. These costs could increase significantly as disposal requirements and litigation increase. This demand could also have the effect of driving up the price of the disposal resources.

Siting for a disposal facility could be costly depending on public acceptance. Transport costs would probably not be excessive but could increase the cost incrementally depending on the location. These costs would all be in addition to the cost of conversion to DU metal depending on the method selected.

7.1.18.3.3 Evaluation by Reviewer X

Conversion processes proposed by others would produce anhydrous HF which could be sold in the commercial sector or recycled in the uranium fuel cycle. This would result in a credit to the conversion process to decrease overall costs.

The conversion cost depends on the method selected and the success of development efforts for new conversion methods. Existing conversion methods would cost close to \$10/kgU. Recommendations for new conversion methods estimate costs as low as \$1/kgU, but these are now only in the laboratory testing phase.

If the metal is mixed with cement or sand to background levels, transportation costs will increase due to the large volume of material needing transport.

7.1.18.3.4 Evaluation by Reviewer Y

DU metal production costs (not part of the proposal) with an offset for Fluorine sales are likely to be on the order of a few dollars per pound, less than the cost of natural Uranium; probably about half the cost at the present time. Land costs are likely to be significant if the concrete slurry or sand mixture are used. The grout experience with Hanford Tank Waste would be a good basis for early estimates. Cylinder overpacks are a reasonable consideration if potentially weak containers are transported on public highways. These latter costs are quite modest and probably commensurate with regulatory costs.

7.1.18.3.5 Evaluation by Reviewer Z

See Section 7.1.18.7.5, Conclusion.

7.1.18.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.18.4.1 Evaluation by Reviewer U

The process requirements for the recommended production of uranium metal are well defined. New approaches for recovery of the fluorides as AHF and slag cleaning will need further R&D and pilot demonstration before proceeding with a commercial facility.

Disposal of depleted uranium metal diluted with concrete or sand may not satisfy the desired material stability for long term disposal and considerable R&D would be required to define whether metal is an acceptable form for disposal.

7.1.18.4.2 Evaluation by Reviewer V

Deep geological storage is not a new concept but will require some additional analysis and site specific reviews to assure feasibility, and extensive environmental and safety analyses to prove no adverse environmental effects.

7.1.18.4.3 Evaluation by Reviewer X

Conversion of dUF_6 to metal can be done using existing and mature technologies. However, several improvements to these technologies as well as new technologies to reduce the waste streams have been proposed. None of these proposals has been tested on a large scale. Thus the potential for reducing the waste streams or reducing the costs cannot be projected.

7.1.18.4.4 Evaluation by Reviewer Y

The technical maturity of the proposal may be lacking in the relationship between chemical and nuclear toxicities and the real effects due to released material. For example, the nuclear toxicities are quite different at low-levels between surface exposures and inhalation (remember the Uranium watch dial workers during the 1920s!).

The technical maturity of processes described or inferred range from developed but untested at large scale to almost standard industrial practices.

The suggestion that the work be coordinated with that of the U.S. Enrichment Corporation merits consideration for programmatic and potential beneficial hardware economies.

7.1.18.4.5 Evaluation by Reviewer Z

See Section 7.1.18.7.5, Conclusion.

7.1.18.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.18.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the chemical components of the process entail relatively low pressure and temperature. The batch metallothermic reduction process is a high temperature step that is limited by batch size to achieve controllability. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment. A major hurdle to overcome is the history of the Fernald uranium metal production plant. Considerable uranium contamination was experienced with this plant, operated for the Federal Government for several decades. Much better material control technology would be employed at a new plant. However, the extensive challenges at Fernald establish a difficult threshold to overcome.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not

outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the metal production at one of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. Such an operation may be helpful for encouraging related locality development of processing uranium metal to finished products.

Disposal of DU as a diluted component of concrete or sand may be a publicly supported approach. However, attempting to perform dilution to a level equating to natural background levels appears to be unnecessary for public health or safety. Using abandoned uranium mines may be inappropriate because such mines are generally located in high water content soils with considerable permeability. Disposal of DU will very likely require a site that is dry or one that has very slow moving ground water. Neither of these criteria appear to be compatible with abandoned uranium mines.

7.1.18.5.2 Evaluation by Reviewer V

The effects on regional economic development and employment from this type of disposal are likely to be relatively minor for DU metal. The smaller volumes would mean smaller facilities with proportional construction effects. The addition of deep storage would have minimal effect. Some economic effect could come from new mining activities in sparsely populated areas. The effects would be small, however. Land use would be minimal, but some additional traffic to and from the site would be generated. Some relatively small number of permanent jobs would be created. Public acceptance will be a significant issue that is difficult to predict. The effects of the conversion processes could be more significant and are discussed in the documents referenced above.

7.1.18.5.3 Evaluation by Reviewer X

Building a conversion facility on or near a current production facility would provide employment for a local and experienced work force currently being cut back due to less demand for enriched uranium.

Conversion of the dUF_6 to uranium metal would likely have greater public acceptance than continued storage in the current form due to the greater chemical stability of the product.

If a current disposal facility, such as NTS, Hanford, or Envirocare, is used, there should be no change in regional development or public acceptance at the disposal end. If deep disposal in a facility such as an abandoned uranium mine is selected, actual siting will need to be known to assess public acceptance and regional development issues.

7.1.18.5.4 Evaluation by Reviewer Y

Public acceptance is not assured for creating mildly accessible mines; this is not a strategic petroleum reserve, but it could be (not the intent of this proposal). Land requirements in the absence of mine disposal could become staggering. Employment and local development would be significant in economically depressed areas cited by the proposal.

7.1.18.5.5 Evaluation by Reviewer Z

See Section 7.1.18.7.5, Conclusion.

7.1.18.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.18.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years as DUF_6 .

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in some other form of uranium is greater than the cost of converting the DUF_6 to that form at an early stage.

7.1.18.6.2 Evaluation by Reviewer V

See General Comments.

7.1.18.6.3 Evaluation by Reviewer X

None.

7.1.18.6.4 Evaluation by Reviewer Y

A serious moral question is raised because the proposal suggests that "the converted depleted UF_6 should not be used in armaments...which limits post-war use of the land." This rings like the recent soundings of "We shouldn't have used the atomic bombs at the end of WW-II." This reviewer finds very little credibility here since he was being trained to invade Japan in 1945 with expected very high casualties. This reviewer has also visited both Hiroshima and Nagasaki. There is little evidence that the areas devastated by the bombs are not being used beneficially.

7.1.18.6.5 Evaluation by Reviewer Z

None.

7.1.18.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.18.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to uranium metal and to dilute the uranium with concrete or sand to a natural background level of radiation for disposal in abandoned uranium mines does not appear to be practical or reasonable. The likely waste form, if DU is declared to be a waste, is uranium oxide, not metal. Converting DUF_6 to an oxide for disposal appears to be a better approach than converting DU to metal as the first step. Dilution to a natural background level of radiation does not appear to be necessary for public health or safety. Disposal in abandoned uranium mines, which generally contain high water content permeable soils, does not appear to be appropriate.

The stated concerns with regard to storage of DUF_6 are not supported. The potential for cylinder rupture is relatively low and controllable. Serious exposure of workers and nearby residents is overstated. The one step where exposure is of concern is when the cylinders are heated for removal of the DUF_6 . Appropriate precautions must and will be taken for this activity.

The person making the recommendation in Document #19 appears to be concerned about the integrity of the present storage approach as DUF_6 . However, the recommendation does not provide a supportable basis for early disposal of DU or any cost basis for the recommended approach.

7.1.18.7.2 Conclusion by Reviewer V

It appears that this option might not meet DOE's criteria for reasonableness, unless the disposal in mines were developed further. From the information provided, DU metal will require more processing and control for environmentally acceptable disposal than that proposed. A major uncertainty lies in the identification of a suitable site, its certification and licensure for this use, and the cost of preparing it. This option deserves further consideration as part of the discussion of Document 14 from the NRC.

7.1.18.7.3 Conclusion by Reviewer X

The recommendation for siting conversion facilities at current storage sites would have a beneficial local impact, and would minimize or eliminate the hazards associated with moving the dUF_6 cylinders to other sites.

Conversion of the dUF_6 to U_3O_8 or to UO_2 would be a less expensive and more compatible alternative for the recommended disposal method.

Even though dilution for disposal will result in large volumes of material, it is only about 20 days capacity at a facility such as Envirocare.

7.1.18.7.4 Conclusion by Reviewer Y

The guidelines for "Reasonableness" are generally met from explicit in the proposal plus costs inferred by actions in the proposal. However, the totality of declaring the DUF_6 as waste with only Fluorine commercial sales would be an unfortunate legacy for future generations that could ultimately result in a "Uranium Rush" in about 150 years.

The idea of coordinating this activity with those of the U.S. Enrichment Corporation cited in the proposal plus similar activities in other countries (not cited in the proposal) merits consideration at an early date.

7.1.18.7.5 Conclusion by Reviewer Z

This option has little merit. The construction of two centers for UF_6 conversion (reduction) would be an unnecessary expense. If an option for reduction of UF_6 is selected, only one location would be required. The transportation of UF_6 cylinders from one location to another is not a great expense, and the risks associated with transportation are minimal and are well understood. The remainder of the proposed option is that the uranium "metal" be mixed with concrete slurry or sand to a natural background level and returned to or deposited in abandoned uranium mines. If a burial option is selected, the chemical form should be an oxide rather than a metal. Due to the low specific activity of uranium (both natural and depleted) it is not necessary to dilute it to natural background levels prior to deposition in underground locations. There would be a very minimal increase in risk by leaving the uranium in an oxide form.

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7.1.19 Evaluation of Document No. 33 (Independent Technical Reviewers' No. 20)

Respondent:

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502-462-3495

Description of Response:

This response recommends that the depleted uranium located at the Paducah Gaseous Diffusion Plant be maintained at that site in above ground earthquake proof non-corrosive concrete storage structures so that monitoring for surface leaks and radiation releases can be performed. The responder also recommends that DOE stabilize and clean the affected site area and adjacent lands to the extent required by law and offer relocation or compensation to landowners for damages to their land and homes.

7.1.19.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.19.1.1 Evaluation by Reviewer U

The recommendations in Document #20 call for continued storage of the depleted uranium hexafluoride (DUF₆) at the current locations in above ground earthquake proof concrete structures. The DU is viewed as a radioactive waste and the stated reason for on-site storage is that transportation of the waste to other sites is unacceptable. However, if the DU is declared to be a waste, siting requirements for long term waste storage and disposal may preclude the use of the current sites. Also, the recommendation calls for stabilization and clean up of the sites and permanent isolation of the contaminated areas along with relocating and compensating residents adjacent to the DOE facility.

Operational issues include well understood controls for storing and handling of DUF₆. Since the material is depleted uranium, there is no concern related to criticality. The

primary uranium health concern is the heavy metal toxicity potential. The potential health concerns associated with long term storage of DUF_6 are well known and when properly implemented, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage.

While this recommendation implies that the current sites are heavily contaminated and dangerous, the DU contributes very little to overall community danger. Site stabilization and clean up as much as possible is urged. Eternal isolation of the contaminated plant site is recommended. Some cleanup activities are appropriate at this time and of greater significance when the plant site is determined to be a surplus site.

Overall Federal regulation for safety of DUF_6 storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF_6 is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC. A modification in the regulations would be required for NRC licensing for long term storage of DUF_6 . However, if the DU is declared a radioactive waste, it would trigger a new set of regulatory and siting requirements as well as a determination of acceptable waste form for disposal.

7.1.19.1.2 Evaluation by Reviewer V

The option of storing DUF_6 in its present chemical form does not appear to present any major environmental, safety or health issues. The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air, DUF_6 can react to moisture producing HF acid and UO_2F_2 , both hazardous. The HF is an acid that could cause skin burning and damage to the lungs on contact and the fluorides and uranium can have toxic effects if ingested. In addition, the alpha particle emissions from inhaled or ingested uranium could be a health risk. Releases to the environment are most likely to be limited to the storage facility itself. If a large release occurred, however, the potential exists to affect the surrounding area affecting the public, the land, vegetation and domesticated and wild animals.

The handling of the storage cylinders and routine operations at the storage facility raise the possibility of minor environmental risks from accidental releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. Past experience has shown very few incidents of releases, virtually all of which had insignificant health effects. With the aging of the cylinders, however, the potential for increased numbers and severity of accidental releases must be seriously addressed.

The transport of DUF_6 required under this option would be very limited and, therefore, minimize potential exposure of the public. Use of the current sites is probably the least

risk approach from an environmental, health and safety perspective. While the public is located in proximity to the facilities, there are no major population centers in the immediate vicinity. Selection of different sites would require licensing, delay and transport of aging cylinders which might pose a greater environmental risk than current storage. Within the existing sites, there may be potential for relocating storage areas to improve storage conditions and minimize hazards of accidental release.

Continued storage at existing sites again would not present a problem technically, however the management of the sites and perhaps the storage techniques may need to be modified. Handling the cylinders for inspection and routine stacking and unstacking can cause leakage, although in many cases any breaches are self-sealing. The steel cylinders have been stored out-of-doors, some for as long as thirty years which is the estimated useful life expectancy. While high risk cylinders with identified risk potential (about 15,000) are inspected annually, only one fourth of the remaining inventory is inspected annually. Current storage conditions may make it difficult to inspect some cylinders.

Current management programs include cylinder inspections for integrity with repairs and replacements performed as necessary. Some technical assessments of the condition of the cylinders and techniques for maintaining them are underway. In addition, some improvements in cylinder storage facilities are underway including saddle replacement, new cylinder yards at Paducah and Portsmouth, cylinder replacements and a cylinder refurbishment facility. The latter would have the capacity to handle about 1/20th of the existing cylinders per year. The current outdoor storage system is not in compliance with DOE regulations requiring two levels of confinement for all radioactive materials, e.g. use of a container that is protected within a building.

Given the advancing age of the cylinders, increased inspections and refurbishments as well as improved storage systems should be considered. Nearly a third of the cylinders are described as "high risk" and inspected annually due to poor drainage, heavy scale or pitting, suspected leaking valves, etc. The risks of accidental releases should be evaluated given these conditions and additional improvements in storage and handling considered. Additional measures might include a more rigorous and frequent inspections program, an accelerated program for refurbishing and replacing cylinders on a preventive basis and improved yards, saddles and containment systems for all cylinders at an early date. Additional measures for reducing risks in handling the cylinders are discussed in Document #20.

It is suggested in this response that covered storage in above ground, earthquake-proof concrete structures be considered. This is certainly technically feasible and would provide the second level of confinement called for in DOE regulations which would increase the level of environmental protection. While it is unlikely that "earth-quake proof" structures can be provided at any reasonable cost, a higher level of quake resistance could be requested. Indoor storage of the cylinders would slow the deterioration of the steel and would limit the exposure of cracks to water vapors. Monitoring of the air in an enclosed building might allow earlier detection of leaks, however if a leak were to occur it would not allow the poisonous gases to dissipate, thus creating greater danger to workers.

Containment within a building would limit the potential for a plume caused by a leak to impact the surrounding community.

It would appear that the likelihood of an accident impacting the surrounding community is relatively small. Further serious analysis of accident scenarios may be appropriate to determine if relocation and compensation of nearby residents is justified and to see if any additional emergency response contingency measures are required.

7.1.19.1.3 Evaluation by Reviewer X

Since the current dUF₆ storage program began, six cylinders have been identified to have experienced leaks. All of the leaks were identified long after they occurred because of the early absence of a periodic inspection program. Each leak self-sealed. Four of these leaks were determined to have been caused by cylinders weakened by handling. The remaining two leaks were in cylinders that had corroded. Programs are currently in place to (1) replace cylinders that are at risk, (2) improve cylinders that are weak, (3) inspect all cylinders on a rotating basis, revisiting those at greater risk more often. Apparently, no new leaks have been observed since these programs were implemented. (See EGG-MS-11416, pg. 9.)

The real question relative to risk to workers or the general public is "How rapidly does the dUF₆ react with moisture in the air to cause a cloud with dangerous levels of HF or uranium?" No data was provided to answer this question. However, it was stated that the above-mentioned leaks self-sealed prior to being identified "because the material loss and reaction with atmospheric moisture were so slow." Apparently, no injuries resulted from the leaks. (See EGG-MS-11416, pg. 9.)

Measures to reduce or eliminate leaks during handling include (1) administrative procedures prohibiting transport of liquid-filled cylinders, and (2) modifications of the specifications for the metal used in cylinder construction, including steel with favorable low-temperature impact response and low sulfur content, which improves ductility and impact strength.

Additional programs are in place to provide new stands for some cylinders to improve safety, and to further protect cylinders from contact with standing water. Information provided doesn't indicate whether seismic concerns are addressed in the designs for the new stands. However, the combined weight of the cylinders, their content, and the stands, and the low center of gravity of the combination should preclude damage during most low intensity earthquakes. Seismic analysis for more severe earthquakes should probably be done, and horizontal and vertical acceleration estimates should be used in the design of concrete pads for holding the cylinders, and any buildings that may be built to enclose the cylinders.

The present storage method in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. Thus, it is reasonable to expect that construction of new storage facilities could be required. The question is whether the cost is

justified by the reduction in risk. Risk should be evaluated based on vaporization rates, dispersion rates, reseal rates, and detection probabilities.

Whether an enclosed facility is built or not, it is apparent that many cylinders will need to be moved due to (1) being stored too close together to facilitate inspection, (2) needing to be placed on new moisture resistant cradles, or (3) requiring transfer of the DUF_6 to new cylinders because of cylinder deterioration. This movement also causes a risk of further cracking. Handling practices can minimize serious damage which would produce large releases.

Concrete storage structures are recommended. While concrete may be the best choice for shielding considerations, it may not be the most cost-effective choice for seismic considerations. Direct radiation shielding is not an issue for the contained uranium. Rather the primary concern is confinement to protect workers and the public from ingestion and internal exposure from both the uranium and any HF that may be formed. Thus, confinement building design should follow from engineering analyses that include cost considerations, isolation capabilities, and seismic response.

7.1.19.1.4 Evaluation by Reviewer Y

Seismic concerns because of New Madrid fault and experience in the 1830s are the basis for suggesting above-ground, earthquake-proof, non-corrosive concrete structures. The latter will require development for assurances. Such expenditures would have a much higher benefit/cost ratio if expanded on normal civil seismic protection (e.g., roads, bridges, electric and water systems). Declaration of DUF_6 as waste is inconsistent with facts and would exacerbate any subsequent activities with material (e.g., recycle for beneficial use). Recovery of Kentucky Wildlife Preserve seems appropriate if found to be necessary per existing regulations.

7.1.19.1.5 Evaluation by Reviewer Z

Mr. Ronald Lamb proposes that the radioactive waste be stored above ground in earthquake proof concrete structures. The structures should be high enough off the ground to be monitored for surface leaks and radioactive releases, and be stored in a manner to cause no additional exposure during seismic activity. It also states that adequate public warning systems should be in place if a release should occur. Due to the lack of merit of this option, a detailed evaluation was not performed. See Section 7.19.7.5.

7.1.19.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.19.2.1 Evaluation by Reviewer U

Storage cylinder monitoring and maintenance would be required for the DUF_6 . Occasionally, it will be necessary to remove the DUF_6 from defective or degrading cylinders and transfer the DUF_6 to new storage cylinders. During such activity, a limited amount of contaminated waste will be encountered. These wastes could be allocated to disposal at low-level radioactive disposal sites.

Disposal of defective and empty DUF_6 cylinders will be required. A small amount of UF_6 must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal or storage of the recovered material. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites.

Above ground perpetual storage of DUF_6 does not appear to be an appropriate way to manage and dispose of DU. Federal regulations will probably preclude using DUF_6 as an acceptable waste form and they may preclude the current sites from being acceptable locations for disposal.

7.1.19.2.2 Evaluation by Reviewer V

The waste streams associated with this option are minimal. There would be minor amounts of waste generated from normal maintenance activities including replacing or repairing cylinders, valves and other equipment. The replacement of wood saddles with concrete or other supports will generate quantities of waste that is likely to be disposable in a regular landfill. The cleaning and recoating of canisters will also generate some waste, but there would be limited potential for recycling or waste minimization in any of the operations. If indoor storage is used these activities would be minimized.

7.1.19.2.3 Evaluation by Reviewer X

No additional wastes are expected to be generated from the continued storage of dUF_6 .

Cleanup and stabilization of the rest of the site are not part of the considerations for the disposition of the dUF_6 .

7.1.19.2.4 Evaluation by Reviewer Y

The proposal is silent other than protection of tanks as waste. Basically, there is no reduction in volume of the material.

7.1.19.2.5 Evaluation by Reviewer Z

See Section 7.1.19.7.5.

7.1.19.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.19.3.1 Evaluation by Reviewer U

Long term storage of DUF_6 can be achieved based on the extensive knowledge gained from storage over the past several decades. Such costs are expected to be significantly less than all alternatives of converting DUF_6 to another form for storage and/or disposal.

Building above ground earthquake proof concrete structures for the perpetual storage of DUF_6 would add significantly to the cost of storage compared to the present mode of outside storage on support bases. The high density of the DU in cylinders provides a reasonable earthquake proof containment since it takes considerable effort to move the containers. The cylinders will not roll around because of the solid material in the bottom of the cylinders and the void space at the top of each cylinder. Even if jostled with an earthquake, they could become jumbled and wrenched askew without serious danger of material loss or a health risk to residents in the vicinity. The added cost of an above ground earthquake concrete structure would provide little if any added safety for containment of DUF_6 in the event of an earthquake.

7.1.19.3.2 Evaluation by Reviewer V

The costs of outdoor storage as estimated by contractors to DOE are low, in the range of \$.22/kgU to \$.34/kgU assuming a storage inventory of only 375,000 MTU, corresponding to life cycle costs of \$83 million to \$129 million. This estimate is based on current storage practices to be used through the year 2020 including planned upgrades of cylinders and yards, new cleaning/coating facilities and current inspection and maintenance.

The capital costs for an additional confinement level using indoor storage was estimated at \$360 million for all three sites, with some additional maintenance costs ongoing associated with those facilities. If these estimates are accurate, this would increase the cost of this option by four fold or more. It is not clear what the costs would be for earthquake proof concrete structures. The costs of various containment options should be reviewed with the potential safety and health benefits reviewed in the context of the proportionate increase in costs. The use of outside contractors to operate and maintain such facilities could be considered if it offered a cost savings. It appears that increased costs will need to be incurred to bring any storage option to a higher level of safety as requested by the community and suggested by some familiar with the current system.

There would be no additional revenue streams associated with storage unless it were provided with another alternative immediate or future use. The later sale or use of DUF6, its products and byproducts could produce some revenues.

7.1.19.3.3 Evaluation by Reviewer X

Costs to maintain current storage practices through the year 2020 are estimated to range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional is estimated to be required.

Insufficient information was provided to determine whether the capital costs for an enclosure included the cost of seismic analysis and appropriate seismic-proof construction. Seismic concerns were not stated to have been considered in the assumptions used for long-term storage cost estimates in EGG-MS-11416.

7.1.19.3.4 Evaluation by Reviewer Y

Building seismic resistant tanks supports (on or above ground) may be a least-cost option that is no long-term solution to anything. Wildlife restoration costs, if needed, should be reasonable in the context of overall costs for any realistic option (not necessarily this one).

Offers for relocation costs should be considered only for those land and home ownerships that were in place before knowledge about the tanks became public and only if relocation or compensation are warranted by independent evaluation.

Some form of public monitoring system seems like a small investment to generate local good-will even if not really necessary.

7.1.19.3.5 Evaluation by Reviewer Z

See Section 7.1.19.7.5.

7.1.19.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.19.4.1 Evaluation by Reviewer U

Storage of DUF_6 has been the practice for several decades. Augmenting the current practices to assure the safety of long term storage—a century or two—appears to be reasonable by transferring the material to new cylinders whenever degradation of the cylinders is encountered. The rate and frequency of degradation is indeterminate, but expected to be easily accommodated.

Arriving at a decision of declaring the DU to be a waste would require considerable research and development to define the acceptable material form for waste disposal. A major program would be involved to establish the requirements of an acceptable disposal site, including the characterization of one or more sites and the acquiescence of the locality for such a site.

7.1.19.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. Some additional work on the potential for increased failure of aging canisters may be appropriate. Management can be on the lookout routinely for safer or more economical ways of managing the storage of these materials.

7.1.19.4.3 Evaluation by Reviewer X

DOE has stored dUF_6 using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

7.1.19.4.4 Evaluation by Reviewer Y

These are low-technology non-solutions. The tanks could be monitored in place. Seismic protection of tanks is ill-advised when other civilian seismic protection needs are so much more effective. A demonstration of what happens when a tank or two split open under normal and carefully monitored ambient conditions could do much to demonstrate that the concerns of subliming DUF₆ are not the disasters cited in this (and other) proposals.

7.1.19.4.5 Evaluation by Reviewer Z

See Section 7.1.19.7.5

7.1.19.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.19.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining perpetual storage of DUF₆ would be fairly constant forever. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Long term storage, a century, may be viewed as a continuation of current practices and acceptable with reasonable public education and public involvement in the associated decisions. However, a major public information program is needed to provide responsible information of the potential health impacts and perceived dangers associated with the storage of DU. As indicated in the comment letter, there is a perception of considerable risk that needs to be addressed.

If the DU is declared to be a waste to be stored in perpetuity at the current storage sites, major public involvement and interface activities will be necessary to provide factual

information for public review, reaction and understanding. It is doubtful that DUF₆ will be an acceptable form for permanent disposal and the current storage sites may not be acceptable for permanent disposal.

7.1.19.5.2 Evaluation by Reviewer V

Economics: Storage of DUF₆ using the existing management scheme would not have a significant effect on employment or income in the vicinity of the sites. Maintenance operations as currently planned would require no major increases in labor to handle the monitoring and refurbishing activities.

If major improvements were made in the facilities or maintenance operations were expanded there could be some effects on the local economies surrounding the site. Economic impacts from the construction of a covered storage building(s) at each site could be in the following ranges, based on the RIMS II regional economic multipliers (U.S. Department of Commerce, 1992):

Total estimated capital costs:	\$ 360 million
Paducah (62%)	\$232.2 million
Portsmouth (28%)	\$100.8 million
Oak Ridge (10%)	\$ 36.0 million

Net effect on local economy in terms of:

	Total increase <u>direct demand</u>	New earnings <u>to employees</u>	Jobs created <u>(temporary)</u>
Paducah	\$527 million	\$158 million	8,437
Portsmouth	\$255 million	\$ 77 million	3,699
Oak Ridge	\$ 88 million	\$ 28 million	1,300

The impacts actually experienced could vary considerably, however. The economic effects of the operation and maintenance of covered storage on overall storage costs should be neutral in that protection from the elements could slow the degradation of the cylinders and reduce ongoing refurbishment costs.

Siting. Siting could be a significant public acceptance issue. It has been raised in this and other responses to program notices as a concern for some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the condition and management of the cylinders needs to be addressed. A request is made in this response to relocate residents closest to the site for their safety. Proposed legislation in Congress requiring Federal compensation to private property owners for actions that constitute "taking" of the economic value of their property as a result of government actions deserves monitoring with regard to this issue. Relocations should be carefully evaluated in terms of real safety issues, cost and continued

community acceptance of the DUF6 facilities. The difficulties in obtaining storage sites makes the current location valuable.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities under current management practices. This response reflects the discontent with the situation as it currently exists, requesting a concrete facility for future storage. In response to this discomfort, additional analysis of the potential risk and education of the public may be beneficial. It may also be useful to involve concerned members of the local community in advisory committees to the storage sites to provide the community with an on-going source of information and a ready mechanism for quickly addressing any current or new concerns. Through these actions DOE may also gain additional information that will be useful in evaluating its on-going safety and maintenance standards with regard to handling and storing DUF6. In general, the community acceptability of this material will be higher at an existing site than at a new location where there is less experience with these kinds of operations and materials.

Other socioeconomic factors. Transportation risks are not expected to be a significant factor of public concern. This option would require little transport of hazardous materials. The land use implications are also minimal. The site has been in this use for several decades and is consistent with the general industrial character of most surrounding uses. To the extent that the cumulative effect and acceptability of such uses is a concern to local residents, this use will also be scrutinized. Similarly, the ongoing operation of the storage facility, assuming no routine or accidental releases of hazardous materials, poses no new threats to cultural, historical or archaeological resources.

7.1.19.5.3 Evaluation by Reviewer X

The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Improvements to the current practices will be necessary to address these concerns.

The only employment impact will be during the construction of confinement facilities. The current work force should be able to handle the continuing storage practices.

Future use of parts of the sites not impacted by storage of dUF₆ cylinders is beyond the scope of this review.

7.1.19.5.4 Evaluation by Reviewer Y

The option would provide considerable local employment and short-term development without any long-term solution. Definition of material as waste exacerbates problem(s). Necessary clean-up of the Wildlife Refuge and civil release warning systems would be positive in earning public interest if not enthusiastic acceptance.

7.1.19.5.5 Evaluation by Reviewer Z

See Section 7.1.19.7.5.

7.1.19.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.19.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of eventual use--one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.19.6.2 Evaluation by Reviewer V

No additional factors.

7.1.19.6.3 Evaluation by Reviewer X

None.

7.1.19.6.4 Evaluation by Reviewer Y

Definition of whether land clean-up and relocation are justified need standards for actions otherwise this will become a lawyers' playpen.

7.1.19.6.5 Evaluation by Reviewer Z

None.

7.1.19.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.19.7.1 Conclusion by Reviewer U

Storage of DUF₆ has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF₆ for a long term period. However, it does not appear necessary to provide above ground earthquake structures for the storage of DUF₆.

It does not appear to be appropriate to declare the DU as a waste at this time. If a decision is made that the DU is a waste material it will trigger a major program to provide different safety regulations, to define an acceptable waste form and to select a waste disposal site.

There does not appear to be a real health threat to nearby residents with the storage of DUF₆ and there is no justification for the relocation and compensation of such residents.

The person providing the comments in Document #20 appears to be a resident within the general area of one of the current DU storage locations. The recommendations do not include specific technical or cost details that would be involved for implementation of the recommendations.

7.1.19.7.2 Conclusion by Reviewer V

Continued storage of DUF₆ appears to be a reasonable option for consideration by DOE. It can be implemented immediately and would handle all of the existing inventory. It creates no significant new environmental issues except the need to improve maintenance of the aging cylinders to avoid accidental releases. It does maintain a large inventory of a very hazardous material that will require closer attention, however. The costs would be within program goals and is consistent with DOE and other Federal activities. A major drawback is the temporary nature of the solution. Eventually this material may require a more final disposition. In the meantime, the material is not being used to produce useful products. On the other hand, it is being preserved as a resource for future uses that may have higher value. This option may be best used in combination with other options. As product or other applications become economically attractive to the government relative to storage, they can be implemented using this material.

7.1.19.7.3 Conclusion by Reviewer X

The choice to continue current storage practices is based on the assumption that a future use such as breeder reactor fuel will develop. Conversion of dUF₆ to any other form is an extremely expensive alternative relative to continued storage. To use the uranium after

conversion may require converting it back to UF_6 , thus significantly increasing the cost of the end use. Thus, a recommendation to continue storage seems reasonable at this time.

The current storage practice in uncovered areas doesn't meet current DOE regulations for containing uranium by two levels of confinement. To meet this requirement, construction of buildings into which the cylinders could be moved has been estimated to cost \$360 million. This cost, plus the maximum estimated cost of the present inspection and maintenance program brings the total cost of maintaining the dUF_6 in its present form to slightly less than \$500 million through the year 2020. This is 10% of the cost considered reasonable for a conversion and disposal program. Of course, after expending this amount, one is still left with the original material. Thus, faith that a beneficial use will develop is critical to this recommendation.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should this option be selected. This analysis should result in bases for deciding whether to build confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be prudent, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

Construction of secondary confinement facilities and transferring dUF_6 from degraded cylinders to new cylinders will be necessary to achieve public acceptance. Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known. Whether the buildings should be of concrete construction or other materials should be determined by engineering analyses that consider cost effectiveness and seismic response. Since concrete shielding isn't necessary to protect workers and the public from direct radiation exposure, concrete may not be the best material choice.

7.1.19.7.4 Conclusion by Reviewer Y

While some actions in the proposal may be justified, this proposal is not a solution. It is expensive without providing substantive forward steps. Any compensations should be determined by calendar dates (e.g., was the house there before the waste tank "intrusion"?).

7.1.19.7.5 Conclusion by Reviewer Z

This option has no merit. It does not specify the chemical form for final disposal, and would require perpetual controls for the stored material. Permanent, above ground storage in seismically qualified structures does not resolve the current problem. A detailed evaluation is not warranted.

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7.1.20 Evaluation of Document No. 35 (Independent Technical Reviewers' No. 21)**Respondent:**

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306-956-6287

Description of Response:

This response recommends use of a defluorination process to recover anhydrous hydrogen hexafluoride (AHF) and depleted uranium oxide, preferably depleted triuranium octaoxide (DU_3O_8) in powder form for storage or use in the production of various products. The respondent states that depleted U_3O_8 could be used in the fabrication of shielding components, production of high density concrete products, or conditioned with or without additives for disposal in either an underground facility or an engineered surface disposal of shallow depth. Another future use recommended by responder is the conversion of the depleted uranium hexafluoride (UF_6) to uranium metal, along with recovery of AHF and other useful by-products, for use as feed material for the Atomic Vapor Laser Isotopic Separation (AVLIS) process or as high density material for shielding (e.g., spent fuel casks and high level nuclear waste disposal facilities). The respondent recommends three defluorination process options for conversion of the depleted UF_6 which includes use of a multi-stage pyrohydrolysis process with steam and hydrogen or ammonia to produce triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2); use of respondent's process that uses H_2SO_4 to convert UF_6 into a uranyl sulfate complex which is subsequently subjected to a thermal decomposition process producing U_3O_8 and an off-gas; and use of a U-Metal/ MgSO_4 process to recover uranium metal, with further conversion of the resulting magnesium fluoride to AHF and crystallized magnesium sulfate.

7.1.20.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.20.1.1 Evaluation by Reviewer U

Option 1 - Processing of large quantities of depleted uranium hexafluoride (DUF_6) into triuranium octoxide (U_3O_8) will require the design, construction, operation and eventual decommissioning of at least one new facility. The defluorination process described in Document 21 is a reasonable expansion of technology that has been in operation for several decades in the U.S. and Canada. Basic processing techniques have been developed and used in conjunction with the conversion of natural uranium to uranium hexafluoride (UF_6) and the conversion of UF_6 to uranium dioxide (UO_2) at commercial nuclear fuel production plants. The recommendation anticipates the upgrading of aqueous hydrofluoric acid (HF) to anhydrous hydrofluoric acid (AHF) using distillation/rectification or other thermo-chemical and crystallization techniques. However, the addition of underground disposal of a conditioned U_3O_8 material brings into play a host of new considerations and considerable uncertainty.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder) with low reactivity and low solubility. This recommendation calls for the U_3O_8 to be conditioned and to include the sludge recovered from the neutralization activity to provide a blended paste rather than a dry powder or cake. Addition of cement is suggested if solidification of the material is desired. Research would be required to determine if the conditioned U_3O_8 is a satisfactory material for long term storage or an appropriate material for underground disposal.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid, will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers AHF, a material with considerable demand in the U.S. Pilot plant demonstration of the conversion steps from aqueous HF to AHF would be required. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Considerable attention is devoted to disposal of the U_3O_8 after defluorination. With the focus on disposal, the recommended location for the activity is close to the selected disposal site. This location would facilitate the conditioning of the U_3O_8 and associated neutralization products and solidification with cement for deep underground disposal. For a stand alone defluorination facility, the recommendation calls for a location in the vicinity of the DUF_6 storage sites.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from other sites could be transported via rail or truck to the new facility. Rail transportation of

uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is readily achieved. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites. If the decision of site location is predicated on the location of the final disposal site location, considerable time delay undoubtedly would be involved. Rail transport is preferred and rail access would be required for the disposal/defluorination site to permit efficient transportation of the DUF_6 .

The conversion process is amenable to a closed system with a negative water balance, eliminating a requirement for disposal of liquid effluents. All residues could be in the form of solid wastes that may be disposed of as a component of the U_3O_8 paste or in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone defluorination facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be retained in long term storage on the surface at the present locations of the DUF_6 , prior to a decision on final disposition.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, if the operation included preparation of the U_3O_8 for disposal along with the underground disposal facility, regulations are not in place and the ability to obtain safety regulatory approval from the NRC is problematic and indeterminate.

Option 2 - Processing of large quantities of depleted uranium hexafluoride (DUF_6) into triuranium octoxide (U_3O_8) will require the design, construction, operation and eventual decommissioning of at least one new facility. One defluorination process described in Document 21 is a proposed new process (patent pending) that differs from the approach being pursued by others. The recommendation anticipates direct capture of anhydrous hydrofluoric acid (AHF). The uranium from defluorination would be captured as an insoluble uranyl sulfate complex in an acidic solution and subsequently thermally decomposed to produce U_3O_8 . Otherwise, this recommendation follows the same path as

the Multi-Stage Pyrohydrolysis recommendation evaluated as Document #21a. The addition of underground disposal of the recovered U_3O_8 brings into play a host of new considerations and considerable uncertainty.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder) with low reactivity and low solubility. This recommendation calls for the U_3O_8 to be conditioned and to include the sludge recovered from the neutralization activity to provide a blended paste rather than a dry powder or cake. Addition of cement is suggested if solidification of the material is desired. Research would be required to determine if the conditioned U_3O_8 is a satisfactory material for long term storage or an appropriate material for underground disposal.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers AHF, a material with considerable demand in the U.S. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Considerable attention is devoted to disposal of the U_3O_8 after defluorination. With the focus on disposal, the recommended location for the activity is close to the selected disposal site. This location would facilitate the conditioning of the U_3O_8 and associated neutralization products and solidification with cement for deep underground disposal. For a stand alone defluorination facility, the recommendation calls for a location in the vicinity of the DUF_6 storage sites.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of natural and enriched UF_6 is a continuing mode of transport. A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites. If the decision of site location is predicated on the location of the final disposal site location, considerable time delay undoubtedly would be involved. Rail transport would be the preferred mode and rail access would be required to the disposal/defluorination site to permit efficient transportation of the DUF_6 .

The conversion process is amenable to a closed system with a negative water balance, eliminating a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of as a component of the U_3O_8 or in conventional

low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone defluorination facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF , are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, if the operation included preparation of the U_3O_8 for disposal along with the underground disposal facility, regulations are not in place and the ability to obtain safety regulatory approval from the NRC is problematic and indeterminate.

Option 3 - Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal will require the design, construction, operation and eventual decommissioning of at least one new facility. The first two steps of the process described in Document 21 for uranium metal production are basic steps that have been used to produce uranium metal for several decades. DUF_6 is reduced with hydrogen at a continuous rate in a tower reactor vessel and the resulting uranium tetrafluoride (UF_4) is further reacted with magnesium metal in a batch metallothermic reduction to produce "derbys" of uranium metal. The recommendation anticipates direct capture of anhydrous hydrofluoric acid (AHF) from the first stage of the process. The unique feature of the recommendation is the recovery of AHF from magnesium fluoride slag, complete uranium removal from the slag and the recovery of magnesium as epsom salt.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium derbys may be stored in sealed containers for long term storage or processed further into a desired uranium metal product.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary

uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers AHF, a material with considerable demand in the U.S. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step. The magnesium is to be recovered as epsom salt and sold to the chemical or fertilizer industries.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades. Truck transport of UF_6 is an ongoing element of the nuclear fuel supply. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium metal could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal processing could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations. However, if the operation includes disposal of uranium metal in an

underground disposal facility, regulations are not in place and the ability to obtain safety regulatory approval from the NRC is problematic and indeterminate.

7.1.20.1.2 Evaluation by Reviewer V

Option 1 - The MSP process suggested in this option is much like the process described in Document 5 and, therefore, would have very similar impacts on environment, safety and health. This option includes an extra step that "conditions" the U_3O_8 for disposal using residuals from the processing that would have required another kind of disposal otherwise. This option also calls for deep disposal of U_3O_8 . Neither of these additional activities are expected to cause significant environmental, health or safety effects if managed properly. As the respondent states, several environmental issues will need to be carefully managed, however. These include careful review of worker and public safety in routine and accidental situations and establishing appropriate safeguards in design and operations. Transportation of inputs and products must be managed to reduce potential for accidents. The respondent anticipates that long term deep disposal will generate the most regulatory and public concern with regard to environmental risks. They suggest that DOE develop a site selection strategy that can be widely supported. Safeguards for waste infiltration and migration of stored material to groundwater would be needed. However, with design and siting meeting all licensing and other regulatory requirements, the facilities in this option should be acceptable.

Option 2 - The process proposed this option will have many of the same environmental issues as Document 21-2 regarding the handling of DUF_6 and U_3O_8 , and their safety and public health risk. No major new issues are anticipated, however, the Cameco process has less commercial experience and they may need to develop new operational procedures to assure safe operations. This process does require large quantities of sulfuric acid, but they are recycled within the process and industry standards for its handling can be applied. Siting and design considerations are very similar to those for the option in Document 21-1.

Option 3 - The process, while producing uranium metal rather than U_3O_8 , will have many of the same environmental issues as Document 5 regarding the handling of DUF_6 and AHF, and the operation of a large conversion facility handling hazardous and radioactive materials. The major difference is the use of an improved Ames process to convert the DUF_6 to metal using magnesium. No major new issues are anticipated because the first two steps of the proposed process are now in commercial use. Only the MgF_2 conversion will constitute a new process. This latter process is typical of others in the industry, but appropriate operational procedures will be needed to assure safe operations. This process does require large quantities of sulfuric acid, but they will be handled according to industry standards. Siting and design considerations are very similar to those for the options in Document 21-1 and 21-2.

The environmental, health and safety concerns regarding this option will parallel those experienced in the uranium metals industry and the nuclear fuels industry, in general. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also

presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen. This is particularly true for the slag processing options. Careful siting and design taking into account public concerns about these facilities will be needed.

7.1.20.1.3 Evaluation by Reviewer X

Option 1 & 2 - Siting and transportation are related by three concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site,
2. Transportation of the U_3O_8 to the ultimate disposal site, and
3. Transportation of the AHF product to the end user.

These three concerns need to be evaluated from both cost and safety aspects. Since U_3O_8 is the most stable of the three products (dUF_6 , U_3O_8 , and AHF), closeness of the disposal site to the processing site should be the least concern. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport) or to transfer them into overpacks prior to shipping might be required. However, special measures need to be developed for handling cylinders in overpacks. The third concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So the first and third concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

Option 3 - Siting and transportation are related by two concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site, and
2. Transportation of the AHF product to the end user.

These two concerns need to be evaluated from both cost and safety aspects. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport) or to transfer them into overpacks prior to shipping might be required. However, special measures need to be developed for handling cylinders in overpacks. The second concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So the preferred location for a plant converting the dUF_6 to uranium metal would be near a current storage site if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

7.1.20.1.4 Evaluation by Reviewer Y

This experience-based proposal for three options touches these issues in a substantive manner. The long-term issues associated with storage of the metal (Option 3) was not pursued in depth, possibly because it is beyond their direct experience. One feels comfortable generally with their experience-based application of safety, health, and environmental science. They favor U308 production (Options 1 and 2) because this is the "natural" state of the raw material. Favoring this in the absence of need for DU metal or DUO2, the energy supply required to make these materials is not evaluated and might lead to reconsideration of Options.

7.1.20.1.5 Evaluation by Reviewer Z

Mr. Peter Lenny submitted a three part proposal. Option 1 proposes the conversion of depleted UF_6 to either U_3O_8 or UO_2 using multi-stage Pyrohydrolysis (MSP) process with steam and hydrogen or ammonia.

Option 2 proposes the conversion of depleted UF_6 to U_3O_8 using sulfuric acid in the Cameco defluorination process.

Option 3 proposes to convert the depleted UF_6 to metal using U-metal/ MgSO_4 -process.

The powdered product from these processes would be either stored or used. No specific applications are proposed in this proposal.

The options proposed in this proposal would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated.

7.1.20.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.20.2.1 Evaluation by Reviewer U

Option 1 - The DUF_6 conversion to U_3O_8 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

The recommendation emphasizes the disposal of U_3O_8 in a deep underground repository. The disposed material would include a conditioned product of U_3O_8 that is a paste including waste from neutralization steps of the facility and possible addition of cement for solidification. While this may eventually turn out to be an acceptable form for disposal, extensive time is anticipated to resolve the many questions that will be raised about the acceptable form for disposal and the requirements for disposal siting.

As an alternative, the recommendation considers long term storage of dry U_3O_8 powder in drums and the possibility of using the U_3O_8 as a component of concrete where shielding is needed. No consideration is provided for eventual disposition of the concrete with contained depleted uranium.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

The recommendation discusses the removal of UF_6 heels from cylinders, cleaning of the cylinders and their eventual disposition. The main process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to U_3O_8 . Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost. Another use may be to modify them for use as storage containers for U_3O_8 .

Option 2 - The DUF_6 conversion to U_3O_8 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

The recommendation emphasizes the disposal of U_3O_8 in a deep underground repository. Disposal would include a conditioned product of U_3O_8 that is a paste including waste from neutralization steps of the facility and possible addition of cement for solidification. While this may eventually turn out to be an acceptable form for disposal, extensive time is

anticipated to resolve the many questions that will be raised about the acceptable form for disposal.

As alternatives the recommendation considers long term storage of dry U_3O_8 powder in drums and the possibility of using the U_3O_8 as a component of concrete where shielding is needed. However, no indication is provided on the eventual disposition of concrete containing depleted uranium.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

The recommendation discusses the removal of UF_6 heels from cylinders, cleaning of the cylinders and their eventual disposition. The main process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to U_3O_8 . Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost. Another use may be to modify them for use as storage containers for U_3O_8 .

Option 3 - The DUF_6 conversion to uranium metal and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. The reduction to metal uranium produces a magnesium fluoride slag that contains a considerable amount of uranium. The recommendation entails removal of all uranium from the slag to achieve a usable magnesium by-product. If the removal steps do not achieve essentially complete removal of the uranium, the disposition of slag may require handling the material as a low-level radioactive waste, requiring disposal at dedicated low-level waste disposal sites.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers. Clean epsom salt has several uses and the amount recovered would not significantly affect the existing commercial market.

Uranium metal properties may preclude the approval of metal as an acceptable form for uranium disposal. This will be determined when the disposal decisions are reviewed by the safety regulatory body.

The recommendation discusses the removal of UF_6 heels from cylinders, cleaning of the cylinders and their eventual disposition. The main process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to UF_4 . Washing of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the

recovered metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.20.2.2 Evaluation by Reviewer V

Option 1 - As in the option described in Document 5, U_3O_8 storage or disposal will require special attention. This option would condition the already chemically stable U_3O_8 into a paste form that would make handling for storage somewhat easier. Over 30,000 tons per year would need to be disposed of, requiring over 10,000 m³ annually. This would be the equivalent of recreating a "very small" mine that would hold a major uranium deposit. This is probably the safest waste disposal option. Some risks from transporting U_3O_8 to the mine could exist if the processing and disposal cannot be co-located. As in Document 5, the sale of AHF for commercial uses will recycle some of the materials and the potential exists to recycle U_3O_8 into products. Storage for later use is also possible.

Option 2 - This option would produce the same materials, U_3O_8 and AHF, as Document 21-1. The resulting wastes would not create unique problems as discussed in Document 5 and 21-1, however, the reuse or disposal of both products in most cases is expected to need further development work. An additional waste stream from this process includes small amounts of uranium precipitates and calcium fluoride, and water insoluble "daughter products" from cylinder washing. This will be used in the U_3O_8 conditioning to produce a paste product.

Option 3 - The process suggested by the Cameco Corp. is described as having only a very small stream of insoluble low-level waste. The earlier Ames process produces large amounts of MgF_2 . For waste reduction, as well as cost considerations, alternative processing of wastes is needed. The processes for leaching discussed would decrease the volume of low-level wastes needing special handling. The potential to recycle more anhydrous HF and uranium need better definition and markets need to be identified, but the potential reduction in volume and ability to dispose of decontaminated MgF_2 in a sanitary landfill are important cost factors. Some $MgSO_4$ (epsom salt) would be produced and recycled to the chemical or fertilizer industry. Other wastes would include the empty and decontaminated cylinders from the DUF_6 which would be recycled or disposed.

7.1.20.2.3 Evaluation by Reviewer X

Option 1 & 2 - Cameco states that a water deficit will occur in the process and no liquid waste will be produced. Their proposed design would recycle all materials and produce no waste products. They emphasize their experience with waste minimization by stating that their plant in Canada has operated since 1988 without the need for access to an LLRW disposal facility.

Cameco also proposes to ship the U_3O_8 product to a disposal site for conditioning and permanent disposal. Conditioning at the disposal site would reduce transportation costs. Several options are proposed, but ultimate deep disposal is anticipated, thus alleviating the concern for reducing the activity of the uranium to levels acceptable for near-surface

disposal. Their experience with deep mining technology also is emphasized to demonstrate their ability to handle the entire process stream.

Option 3 - Cameco states that a water deficit will occur in the process and no liquid waste will be produced. Their proposed design would recycle all materials and produce a waste stream of less than 200 tons/year of insoluble acid. They emphasize their experience with waste minimization by stating that their plant in Canada has operated since 1988 without the need for access to a LLRW disposal facility.

7.1.20.2.4 Evaluation by Reviewer Y

Obviously, as waste, the U308 is a much lower density (higher volume) material than DU metal. The proposal adequately describes the Fluorine streams, their potential for conversion, and sale. Cameco's experience stands out in the context of effective waste management.

7.1.20.2.5 Evaluation by Reviewer Z

The processes proposed in these three options are not anticipated to generate waste streams which are different in characteristics than what is currently seen at operating fuel cycle facilities. The general proposal that the powder produced would be either stored or used leaves an open ended question regarding what the ultimate disposition of the material would be. This would therefore require that any of these three options be a part of an overall program to disposition the depleted UF_6 in order to ensure that a method for use, storage or disposal is in place when the material is produced.

Options 1 and 2 of this proposal produce aqueous HF as an intermediate process. The aqueous HF is then upgraded to anhydrous HF using distillation/rectification or other thermo-chemical and crystallization techniques. It is the understanding of this reviewer that these techniques have not been fully implemented on a commercial scale, and therefore there exists the potential of generating large amounts of aqueous HF which might have to be disposed as waste.

There will be two primary waste streams associated with Option 3. The first is the decontaminated MgF_2 , which should be suitable for disposal in a sanitary landfill, and the second is the grouted mixture of $U_3O_8/MgF_2/MgO$, which will require disposal as a low-level waste.

7.1.20.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.20.3.1 Evaluation by Reviewer U

Option 1 - Since many elements of this process are currently in use within the U.S. and Canada, the costs are reasonably well defined for both the processing plant and its operation.

AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Since uranium enrichment activities are continuing in the U.S., there is a continuing buildup in the quantity of DUF_6 . Thus, after the DOE material has been converted, the facility may be used for conversion of DUF_6 generated by others. The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Cleanup residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the DUF_6 , although the volumetric space would be somewhat less depending on the compacting of the U_3O_8 powder. Rectangular containers of U_3O_8 would pack and stack in a space more efficiently than the cylindrical containers of DUF_6 . However, the cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of U_3O_8 , while outdoor storage of DUF_6 appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of retaining the DU as DUF₆, with conversion to U_3O_8 one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades and storing the U_3O_8 for several decades prior to disposal.

If immediate disposal of U_3O_8 as a waste is the selected path, considerable time would be required for the determination of the acceptable waste form and for selection of a disposal site. The cost included for disposal in the recommendation is an optimistic assessment of costs associated with an already approved site. Overall cost of an approach of early disposal, including site characterization, public acceptability and regulatory approval, probably would be several times that of the estimate provided.

Option 2 - Except for the new defluorination approach, the technology recommended is reasonably well known and reasonable cost considerations defined for both the processing plant and its operation. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

The unique defluorination step will require research and development efforts to provide information for the design of a large commercial facility. A reasonable size pilot plant demonstration appears to be necessary to confirm the parameters of the process. The added cost and time required for R&D and pilot plant demonstration, with a risk of the process not achieving the desired result places a premium on the front end program costs.

Additional revenue may be obtained from the plant operation through contract services provided to others now generating DUF₆ from ongoing uranium enrichment activities. Thus, after the DOE material has been converted, the facility could be used for conversion of DUF₆ generated by others. The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a DUF₆ conversion facility would be typical of those for commercial UF₆ conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Cleanup residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing DUF₆ over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the DUF₆, although the volumetric space would be somewhat less depending on the amount of U_3O_8 powder compacting that is achieved. Rectangular containers of U_3O_8 would pack and stack in a space more efficient than the cylindrical containers of DUF₆. However, the cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the DUF₆ in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would

probably be added at additional cost for storing containers of U_3O_8 , while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of retaining the DU as DUF_6 , with conversion to U_3O_8 one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades.

If immediate disposal of U_3O_8 as a waste is the selected path, considerable time would be required for the selection of a disposal site. The cost for waste disposal included in the recommendation is an optimistic assessment of costs associated with an already approved disposal site. Overall cost of an approach of early disposal, including site characterization, public acceptability and regulatory approval, probably would be several times that of the estimate provided.

Option 3 - Except for the process of cleaning and recycling the magnesium fluoride slag, the technology recommended is reasonably well known and cost estimates should be quite accurate for both the processing plant and its operation. AHF and possibly epsom salt, are salable products from the operation. The market value of the recovered materials would be only a fraction of the overall cost of building facilities and performing the conversion operations.

The slag cleaning steps will require research and development efforts to provide information for the design of a large commercial facility. A reasonable size pilot plant demonstration appears to be necessary to confirm the parameters of the slag treatment process. The added cost and time required for R&D and pilot plant demonstration appear to be reasonable with high probability of success and low risk.

The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility could be torn down with all contamination removed from the site. The site could be returned to uncontrolled use. Decontamination and decommissioning costs for a DUF_6 to metal conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of uranium metal would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. Removal of the fluorine component will result in an overall weight reduction of about one third. Since the density of uranium metal is very high, the volumetric reduction would be on the order of a factor of six. To minimize oxidization and prevent the sloughing of the oxide film, it appears necessary to place the uranium metal in stainless steel containers for long term storage. The cost of new metal containers for the uranium metal would be a significant added cost over that of continuing to keep the DUF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost

for storing containers of uranium metal while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. Converting DUF_6 to metal in the near term may require a further processing to uranium oxide at a later date, if a decision is made to dispose of depleted uranium in underground disposal facilities. The present worth value of retaining the DU as DUF_6 , with conversion to uranium oxide in the future for disposal, would be considerably less than performing the conversion to metal in the near term and subsequently converting it to the oxide later.

7.1.20.3.2 Evaluation by Reviewer V

Option 1 - The costs for this option appear to be fairly high. The proposed plant with only slightly more than 50% of the capacity of the plant proposed in Document 5 would cost \$280 million. The capacity would need to be increased by nearly 50% to meet DOE's timetable for disposition of the entire inventory if this method were used alone. This would increase costs, probably somewhat proportionately. Disposal would require an additional \$45 million. Operating expenses would include 160 full-time personnel for normal conversion operations; storage operating costs would be additional. No clear figures are made available on the cost per kgU for direct comparison with other options. Because some process development is still to be done, the costs may still vary, but if comparable processes are available for less, they should be adopted. The costs do include conditioning the material for disposal. The AHF would bring some revenue when recycled. As is noted in Document 5, the costs and cost-sharing should be carefully evaluated by DOE.

Option 2 - This option is expected to have capital and operating costs in the same general range as the options in Document 21-1. Similar issues arise from these costs.

Option 3 - Although the conventional Ames process is commercial, no costs are presented for this variation. Information must be collected on the real cost to DOE of this alternative before any serious evaluation can be made. Similarly, the current market production seems to be 7,000 tons per year. Conversion of even a part of the inventory at the assumed 20,000 tons per year scale presented, would more than double the supply to a market where prices are very sensitive to demand. It is not clear that markets exist for this material. A better analysis of potential users needs to be made. Another cost item of concern for this option remains the cost of disposal. Even with reduced quantities, the cost of packaging, transport and disposal can be significant. Other by-products such as HF and epsom salts may help offset some costs, but markets and prices need to be clarified.

7.1.20.3.3 Evaluation by Reviewer X

Option 1 - Capital costs are estimated by Cameco to be on the order of \$300 million. Operating costs were not estimated.

Option 2 - The amount of electricity and/or natural required have not been estimated.

Capital costs are estimated by Cameco to be on the order of \$300 million. Operating costs were not estimated.

Option 3 - Cameco estimates that 13,520 t/yr of U metal will be produced from this process. This is nearly double the annual capacity of U metal produced by the two U.S. producers Nuclear Metals Inc. (NMI) and Aerojet Ordinance Tennessee (AOT) from depleted UF₄. Thus, the product will either need to be stored long-term, or the demand for it will need to be increased. This may have a negative impact on the pricing of U metal from NMI and AOT, and thus the economic impact on these producers should be examined in light of current demand. (Note that AOT and B&W in a separate submittal (See RFR # 15) suggest that as much as 40,000 tons/year could be consumed. But if this is so, why haven't they increased their own capacity?)

The production of salable epsom salt has the potential to decrease the overall cost of the process. Again, the quantity to be produced should be compared to the overall market to evaluate the market effect.

The amount of electricity and/or natural required have not been estimated.

Capital and operating costs were not estimated.

7.1.20.3.4 Evaluation by Reviewer Y

The estimated capital costs for both process and disposal facilities are developed and are estimated to be low, particularly if the DUF6 is declared as waste. Capital costs are also believed to be low for two reasons. First, inflationary factors for a major facility that is nominally 5-10 years away from startup. Second, the "Other Capital" costs could well be off by a factor of two that would feed back to increase the plant facilities by about 30-40%. In round numbers, Capital Costs could easily be 150-200% of those stated.

Operating costs are not detailed, but staffing requirements seem on the low side. Are 12-hour shifts state-of-the-art in this industry? These costs are probably on the order of \$20-25 million/year!

7.1.20.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute any of the three options proposed in this alternative.

7.1.20.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.20.4.1 Evaluation by Reviewer U

Option 1 - The chemical process requirements for defluorination are reasonably well defined since many steps of the process have been in operation in the U.S. and Canada on a relatively large scale for several decades. Technical maturity is sufficient to permit its use after the operation of a pilot plant to prove out the details of conversion of aqueous HF to AHF.. A relatively small amount of research and development appears needed to finalize process design for defluorination.

If the early disposal approach is selected for U_3O_8 , waste form development, site suitability and acceptability would be extensive and indeterminate. Whether an acceptable program could be achieved within a reasonable time period is problematic.

Option 2 - The chemical process requirements for the recommended defluorination process are defined conceptually, but the approach is unique and unproven. Technical maturity is not sufficient to permit immediate commercial use. Both R&D and the operation of a pilot plant to prove out many details of defluorination would be required.

The collection of AHF and the storage of recovered U_3O_8 are well defined and could be implemented with known techniques.

If the early disposal approach is selected for U_3O_8 , waste form development, site suitability and acceptability would be extensive and indeterminate. Whether an acceptable program could be achieved in a reasonable period of time is problematic.

Option 3 - The process requirements for the recommended production of uranium metal are well defined. The approach for slag cleaning and the recovery of clean epsom salt will need further R&D and pilot demonstration before proceeding with a commercial facility.

The collection of AHF and the storage of recovered uranium metal are well defined and could be implemented with known techniques. Disposal of depleted uranium metal may not satisfy the desired material stability for long term disposal and considerable R&D would be required to define whether metal is an acceptable form for disposal.

7.1.20.4.2 Evaluation by Reviewer V

Option 1 - This option seems to be at an advanced stage of development with some further development and piloting of U_3O_8 conditioning and the HF upgrading to AHF before full commercial scale construction. This is expected to be completed within 24 months, with full commercial operation within 6 to 9 years. As most of the technology has already been used in similar applications, it seems likely that it will be viable for its proposed use. The conditioning is a new process and the site-specific requirements for mined storage are yet to be determined.

Option 2 - This option includes a conversion process that has only recently been submitted for patents and is state of the art. The process has been optimized at bench scale, but not piloted. It is expected to be 24 months before small scale piloting is completed, however, it is claimed that it can be commercially operational in 8 to 9 years. It seems likely that more uncertainty exists with this option, as it has not been in commercial use prior to this application.

Option 3 - While individual processes are mature, according to the information provided, the new combination requires piloting before a 20,000 MT/yr facility could be built. Also, process work to ensure the epsom salts are not contaminated is needed. Substituting existing commercial technologies could shorten development now estimated at 12-24 months. One domestic uranium producer is now installing a leaching facility to handle MgF_2 slag, but there is no data on operations at this time. It seems likely that these processes could be defined quickly when addressed. The respondent estimates that any plant will take up to six years to start operations due to design, permitting, construction and testing.

7.1.20.4.3 Evaluation by Reviewer X

Option 1 - The conversion of dUF_6 to U_3O_8 is a standard process with a commercial plant in operation in France. However, the product being aqueous HF, further processing is required for AHF to be available for use in the U.S. Cameco states "There are numerous processes available which have been used in the chemical industry." However, no information has been provided on the scale of these processes or on their cost. Further test work is apparently required to select and implement a method.

Option 2 - The proposed process is new and requires pilot scale testing prior to production implementation. Cameco states "the technology used . . . except for the defluorination stage, is mostly state-of-the-art for the chemical industry." Only bench-scale testing has been performed. Thus, the key stage in the proposed process requires additional development. Small-scale piloting is estimated to require 18-24 months.

Option 3 - The proposed process for converting dUF_6 to uranium metal is a mature technology. However, the process of decontaminating the resultant MgF_2 requires further research and piloting. Cameco estimates this to require up to 24 months, although they claim that state-of-the-art precipitation techniques may be used. An advantage of their

process is that the resultant end product is epsom salt that can be sold as a commercial product.

7.1.20.4.4 Evaluation by Reviewer Y

Virtually all aspects of the process proposals are within the state-of-the-art (e.g., current industrial practice or nearly so). The storage of depleted U308 is a new issue that needs to be considered but should not be a serious technical obstacle in the USA since it has been accomplished elsewhere. The technology contained in the proposal is refreshing and seems realistic on the state of development for each of the three options.

The use of DU or DUO2 as an energy source is conspicuous by its absence. This could be because of Canadian policy or practice.

7.1.20.4.5 Evaluation by Reviewer Z

The technology proposed for the implementation of Option 1 is a new technology which has not been tested. This reviewer is not aware of testing of this technology on a laboratory scale.

The technology proposed for the implementation of Option 2 is also a new technology for which research and demonstration work has not been completed.

The technology required for the implementation of Option 3 is well developed, and is considered a mature technology.

7.1.20.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.20.5.1 Evaluation by Reviewer U

Option 1 - Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires. Operation may continue for several decades after the DOE material is processed since the generation of DUF_6 is being continued by others.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and only one step is at a high temperature (750C) and the amount of material within the process inventory is relatively small. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small. A special effort would be required for handling the aged cylinders to compensate for any deterioration.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the costs and risks for a locality, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the defluorination operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

However, if a decision to proceed is based on obtaining an acceptable site for disposal of the U_3O_8 , with the defluorination step performed near the disposal site, the challenges associated with the location of a disposal site are indeterminate.

Option 2 - Employment at a facility to convert DUF_6 to U_3O_8 and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires. Operation may continue for several decades after the DOE material is processed since the generation of DUF_6 is ongoing by others.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and temperature and the quantity of material in process inventory is relatively small. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small. Special handling procedures may be needed for the aged cylinders to compensate for any deterioration that may have occurred over time.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the defluorination operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

However, if a decision to proceed is based on obtaining an acceptable site for disposal of the U_3O_8 , with the defluorination step performed near the disposal site, the challenges associated with the location of a disposal site are indeterminate.

Option 3 - Employment at a facility to convert DUF_6 to uranium metal and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the chemical components of the process entail relatively low pressure and temperature. The batch metallothermic reduction process is a high temperature step that is limited by batch size to achieve controllability. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment. A major hurdle to overcome is the history of the Fernald uranium metal production plant. Considerable uranium contamination was experienced with this plant, operated for the Federal Government for several decades. Much better material control technology would be employed at a new plant. However, the extensive challenges at Fernald establish a difficult threshold to overcome.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the metal production at one of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. Such an operation may be helpful for encouraging related locality development of processing uranium metal to finished products.

7.1.20.5.2 Evaluation by Reviewer V

Option 1 - As with all conversion options, the construction of a major industrial facility will have a significant short term effect economically on the locality or region especially in less populated areas. Mine construction could also have a minor effect. Operational economic impact will be less significant.

Public acceptance of the conversion and disposal facilities must be seen as a major consideration. As the respondent notes, "Based on our experience, the disposal site will be a major political, social and regulatory hurdle." They go on to recommend a siting process that will gain wide spread support. While deep permanent disposal may raise greater issues, it would not be unique among options in its need to put a greater emphasis on public acceptance. The issues here would include land use/site requirements, traffic safety, proximity to communities and other sensitive uses, and environmental safety. Public perceptions about the impacts of these types of facilities will be an important determining factor in siting, as has been seen in other low-level and high-level disposal facilities.

Option 2 - The effects of this option will be essentially the same as Document 21-1.

Option 3 - The construction of a facility capable of producing 20,000 tons of uranium metal annually would constitute an major industrial construction project. This would significantly impact communities in which it might be located. It is estimated that

operations could require on the order of 300 permanent employees. In a small community this would stimulate significant economic growth, two to three times the size of the direct impact.

The siting of such a facility may face problems with public acceptance. There is likely to be close scrutiny of the public health risks and environmental effects. Traffic, including uranium transport, to and from the site will be examined. While the proportion of low-level wastes generated by the proposed process would be reduced significantly, expanded production will increase the demand for disposal sites. The LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty associated with siting such facilities.

7.1.20.5.3 Evaluation by Reviewer X

Cameco estimates that a typical plant would employ about 40 management staff and 120 hourly workers. The plant would operate around the clock five days per week to meet the production requirements. No availability factors were provided.

If the plant is built near an existing production facility, a trained work force should be available, although if production is not cut back at these facilities, labor rates may increase.

Reduction of the dUF_6 inventory should result in a positive public acceptance of the proposed process if the new plant is constructed in the vicinity of current production facilities.

7.1.20.5.4 Evaluation by Reviewer Y

Semipermanent disposal of U308 should receive public acceptance until costs for converting this material to UO₂, UC, or metal become real and necessary. Future generations may well ask what this generation was trying to do!

A plant employing on the order of 200 people could have significant local impact, particularly in sparsely populated areas.

7.1.20.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of these proposed options on socioeconomics.

7.1.20.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.20.6.1 Evaluation by Reviewer U

Option 1 & 2 - Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 , with associated impacts.

A significant factor raised with this recommendation is whether it is appropriate to consider a defluorination step only for the DUF_6 or is it necessary to resolve the final disposition requirements before taking any action to change the material form. Undoubtedly this will be debated during the preparation of an EIS for any option of processing DUF_6 whether processed to achieve a specific useful product or for long term storage. Since there is a recognizable potential future use for the material, it appears reasonable to proceed with defluorination without a determination of final disposition.

Option 3 - Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years as DUF_6 . If and when a need for metallic uranium components is defined for shielding, enrichment, metallic fuels or other uses, then would be the proper time to decide on facilities to convert DUF_6 to metal. The size of the conversion facility should be appropriate to match the need for metal products and not sized to convert of the existing DUF_6 .

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in some other form of uranium is greater than the cost of converting the DUF_6 to that form at an early stage.

7.1.20.6.2 Evaluation by Reviewer V

This company is located in Canada with Canadian ownership. If materials were to be shipped out of the country for processing or disposal some issues may arise. Also, see General Comments.

7.1.20.6.3 Evaluation by Reviewer X

None.

7.1.20.6.4 Evaluation by Reviewer Y

This is a mature proposal with three viable options. One option can be selected. However, two can be accommodated in the overall disposal strategy. It is presumed that NAFTA preempts Buy American!

7.1.20.6.5 Evaluation by Reviewer Z

Each of these options proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form, either U_3O_8 or uranium metal. A decision to select one or more of these options should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.1.20.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.20.7.1 Conclusion by Reviewer U

Option 1 - This option of converting DUF_6 to U_3O_8 and AHF is reasonable, acceptable and the Federal regulatory requirements are understood. Most of the process steps are well defined. Operation of a pilot demonstration of the step to make AHF from aqueous HF should be performed to provide the final information needed to assure an effective commercial plant operation. Since the value of the marketable AHF is less than the overall cost of recovering it from UF_6 , there is a net added cost over the current storage mode cost base.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low-level radioactive waste disposal facility should be pursued.

The concept of final disposal of U_3O_8 in a underground repository does not appear to be resolvable within a reasonable time frame. This element of the recommendation is not practical for the near term.

The organization making the recommendation in Document #21 is well experienced and competent in the processing of uranium and UF_6 . Also, decades of mining experience provides a sound basis for the physical work and basic approach of underground disposal of U_3O_8 . However, no one has a reasonable handle on the overall requirements and approach to site and obtain approval for a deep underground waste disposal facility for large volumes of radioactive material within the U.S.

Option 2 - This option of converting DUF_6 to U_3O_8 and AHF appears to be reasonable. However, since the techniques employed are unique for the defluorination steps, additional R&D and demonstration efforts are required to determine whether the process will achieve the desired results with large scale operation. Process steps other than the unique defluorination appear to be well defined.

Since the value of the marketable AHF is less than the overall cost of recovering it from DUF_6 , there is a net added cost over the current storage mode cost base.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low-level radioactive waste disposal facility should be pursued.

The concept of final disposal of U_3O_8 in a underground repository does not appear to be resolvable within a reasonable time frame. This element of the recommendation is not practical for the near term.

The organization making the recommendation in Document #21b is well experienced and competent in the processing of uranium and UF_6 . Also, decades of mining experience provides a sound basis for the physical work and basic approach of underground disposal of U_3O_8 . However, no one has a reasonable handle on the overall requirements and approach to siting and obtaining approval for a deep underground waste disposal facility within the U.S.

Option 3 - This option of converting DUF_6 to uranium metal and AHF appears to be reasonable. However, the conversion to metal probably should be done only when a useful metal product is determined. Converting DUF_6 to metal for long term storage purposes does achieve a much lower volume of material. However, producing uranium metal for long term storage does not appear to be the more economical and attractive path to pursue. If there is a demand for large quantities of depleted uranium metal, alternate processes of plasma conversion and continuous metal production should be evaluated to determine the more economical process.

Since the market value of the marketable AHF, and epsom salt if sufficiently clean, is less than the overall cost of recovering them from DUF_6 , there is a net added cost over the current storage mode cost base.

The organization making the recommendation in Document #21c is well experienced and competent in the processing of uranium, UF_6 and AHF.

7.1.20.7.2 Conclusion by Reviewer V

Option 1 - This option deserves some further consideration as it appears to fall within most of DOE's criteria for reasonableness with regard to cost, timing, implementation and consistency with the program. It should be noted that this and other conversion options will require continued storage of DUF_6 during their development and implementation. In this case, processing would begin in six to nine years from now and would not be complete within the 30 year limit by itself, unless more process capacity is added. DUF_6 will need to be stored in decreasing volumes throughout this time. The costs of this option should be carefully compared to other similar options for producing U_3O_8 and AHF.

Option 2 - It appears that this option would fit within the reasonableness criteria established by DOE. The uncertainty about the technical maturity and the time to implement are areas of concern. Cost may also become a concern depending on the process development results and the recycling or disposal options chosen.

Option 3 - It appears that this option would fit within the reasonableness criteria established by DOE. The uncertainty about the technical maturity and the time to implement are areas of concern. Cost may also become a concern depending on the process development results and the success in recycling most of the products at attractive prices. Alternatively, if storage or disposal options are chosen, costs will rise. Public acceptance of siting a conversion plant and the disposal of waste materials may present problems.

7.1.20.7.3 Conclusion by Reviewer X

Option 1 - Cameco seems to be well positioned to implement the proposed option, having extensive experience in the nuclear fuel cycle from mining, UF_6 production, and UO_2 and uranium metal production. They state they have extensive experience in the handling of HF, and in the fabrication of depleted uranium metal products.

Their financial condition is reported as being stable with considerable backlog through 2003. Their current plant capacity is for ore conversion is 10500 tonne/year to UF_6 , and is operating under full utilization.

Cameco proposes to defluorinate the dUF_6 and produce anhydrous HF (AHF) for use in their own process or to be sold to other users. The option of producing aqueous HF is available at a lower cost in this proposal if a market can be identified.

Cameco provides an implementation schedule that includes up to one year development time, five to six years for construction, and full production within nine years (public hearings and legal challenges permitting), consuming 20,000 tonne of dUF_6 per year thereafter.

The MSP process uses conventional technology. It results in U_3O_8 and aqueous HF. Upgrading to AHF will require some research and testing, although standard process are recommended. All chemicals are recycled, and no waste stream is projected.

Capital costs are projected to be less than \$300 million. An operating crew of 160 is projected, but no operational costs are projected. However, others have projected a conversion cost of \$3.00/kg or less. Disposal costs for deep burial (100-150 m beneath the surface) would add about \$50 million to the total cost. With their experience in the industry, there is no reason to believe that Cameco's process would be more expensive than this.

This recommendation is consistent with DOE's guidelines for reasonableness, and should be implementable by Cameco.

Option 2 - Cameco seems to be well positioned to implement the proposed option, having extensive experience in the nuclear fuel cycle from mining, UF_6 production, and UO_2 and uranium metal production. They state they have extensive experience in the handling of HF, and in the fabrication of depleted uranium metal products.

Their financial condition is reported as being stable with considerable backlog through 2003. Their current plant capacity is for ore conversion is 10500 tonne/year to UF_6 , and is operating under full utilization.

Cameco proposes to defluorinate the dUF_6 and produce anhydrous HF (AHF) for use in their own process or to be sold to other users. The option of producing aqueous HF is available at a lower cost in this proposal if a market can be identified.

Cameco provides an implementation schedule that includes up to two years development time, five to six years for construction, and full production within nine years (public hearings and legal challenges permitting), consuming 20,000 tonne of dUF_6 per year thereafter.

The proposed defluorination, according to Cameco, has shown excellent results on a small scale. A patent has been applied for. The process produces U_3O_8 and AHF. All chemicals are recycled, and no waste stream is projected.

Capital costs are projected to be less than \$300 million. An operating crew of 160 is projected, but no operational costs are projected. However, others have projected a conversion cost of \$3.00/kg or less. Disposal costs for deep burial (100-150 m beneath the surface) would add about \$50 million to the total cost. With their experience in the industry, there is no reason to believe that Cameco's process would be more expensive than this.

This recommendation is consistent with DOE's guidelines for reasonableness, and should be implementable by Cameco.

Option 3 - Cameco seems to be well positioned to implement the proposed option, having extensive experience in the nuclear fuel cycle from mining, UF_6 production, and UO_2 and uranium metal production. They state they have extensive experience in the handling of HF, and in the fabrication of depleted uranium metal products.

Their financial condition is reported as being stable with considerable backlog through 2003. Their current plant capacity is for ore conversion is 10500 tonne/year to UF_6 , and is operating under full utilization.

Cameco proposes to defluorinate the dUF_6 and produce uranium metal, anhydrous HF (AHF) for use in their own process or to be sold to other users, and epsom salts for sale in the market place as a commercial product.

The conversion to uranium metal produces no LLRW waste stream. However, about 200 t/yr ($< 1\%$) of solid insoluble non-radioactive waste is projected. Further minimization and recycling of this waste requires additional research.

Cameco provides an implementation schedule that includes up to two years development time, five to six years for construction, and full production within nine years (public hearings and legal challenges permitting), consuming 20,000 tonne of dUF_6 per year thereafter. The annual production of depleted uranium metal is nearly double the capacity of the only two current U.S. producers. The impact of this amount of new capacity on the market, and the effect on the market price should be investigated. If the price falls too low due to a saturated market, one or more of the producers may be forced to close, displacing an entire work force in a community.

Capital costs are projected to be less than \$300 million. An operating crew of 160 is projected, but no operational costs are projected. However, others have projected a conversion cost of \$3.00/kg or less. With their experience in the industry, there is no reason to believe that Cameco's process would be more expensive than this.

This recommendation is consistent with DOE's guidelines for reasonableness, and should be implementable by Cameco.

7.1.20.7.4 Conclusion by Reviewer Y

One or more of the options in the proposal are reasonable. The potential contractor has experience in accomplishing similar work on large scale. The only real concern is the focus, principally disposal as U308, with less emphasis on DU metal and none on DUO_2 . This strategic call must come from within the Program rather than from the contractor. The latter can only propose versatile options; this he did very well.

7.1.20.7.5 Conclusion by Reviewer Z

All of these options have some merit, and should be considered. Any of these options have the potential for converting amounts of depleted UF_6 to a more stable form for use in other applications, for long-term storage, or for burial. These options include only the conversion of the material to a more stable, less chemically reactive form, and do not propose a final use or disposition for the product produced from the process. Therefore, the selection of any one or more of these options would be dependent upon what decision is made for final disposition of the depleted uranium.

7.1.21 Evaluation of Document No. 37 (Independent Technical Reviewers' No. 22)**Respondent:**

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Description of Response:

This response recommends that depleted uranium be converted into small borosilicate glass beads for use as a backfill material inside repository waste packages containing LWR spent nuclear fuel (SNF). The responder states that there are four benefits to this recommendation and use including lower radionuclide release rates from the waste packages over geological time; assured control of nuclear criticality for geological time frames; lower radiation levels from the waste package; and disposal of excess depleted uranium.

7.1.21.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.21.1.1 Evaluation by Reviewer U

The recommendation in Document #22 identifies a unique use for depleted uranium (DU) in the form of borosilicate glass beads as a filler material in light water reactor (LWR) spent fuel repository waste packages. The filler material may be used in waste packages assembled at the repository or in Multi-Purpose Canisters (MPC) with the loading occurring at nuclear energy plant sites. If adopted for this application, the recommendation indicates the potential use of 100,000 MT of DU. The four main benefits listed are; lower radionuclide release rates, control of nuclear criticality, lower radiation levels and disposal of DU. Other possible benefits indicated are added mechanical stability and increased thermal conductivity. No information is provided on the technology for producing the

borosilicate glass beads or an estimate of the costs of producing the filler material. A high uranium loading of 20-40% is indicated for the beads with very low solubility.

Borosilicate glass logs have been the anticipated waste form for high level radioactive wastes from both defense programs and for high level wastes separated during the reprocessing of LWR spent fuel. Considerable research has been performed on borosilicate glass to be used for this application. Large glass logs have been produced as a demonstration for waste disposal. Producing conventional glass beads in industry has been performed for a number of purposes, but not with borosilicate glass. Producing borosilicate glass beads with a heavy DU loading should be possible.

As a reviewer, I have no knowledge of the processes that may be used for the production of borosilicate glass beads or the problems encountered. There does not appear to be a process to produce glass beads directly from DUF_6 . The hexafluoride would first require conversion to an oxide or metal before being incorporated into glass beads. Thus, major conversion facilities would be required for DU conversion and for glass bead production. The total amount of glass beads applicable for this use would be in the range of 350,000 to 600,000 MT—a much larger quantity than the amount of glass beads produced for other commercial applications.

Operational issues for the production of glass beads with a high loading of DU are unknown. Processing of DUF_6 , DU oxide or metal include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF recovered during the defluorination of DUF_6 . HF is a very active acid that will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, uranium metal processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation. Special skills and technology would need to be defined and developed to produce large quantities of borosilicate glass beads with high uranium loading.

Transportation of DUF_6 to the defluorination plant and the transport of glass beads for the quantities required probable would be via truck. Truck transport of natural and low enriched UF_6 are a regular part of current nuclear fuel supply.

Overall Federal regulation for safety of system design and operation for the defluorination activity and production of borosilicate glass beads could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Since the application, backfilling of high level

waste canisters, entails an activity of disposal within a repository licensed by the NRC, the production of glass beads would probably be under NRC regulations, yet to be developed.

7.1.21.1.2 Evaluation by Reviewer V

The environmental, health and safety issues associated with this option are difficult to evaluate without information on the processes to create the DU borosilicate glass beads. Assuming that this is an existing process that would be modified to incorporate DU, the risks may be identified and characterized. The environmental advantages of using the beads as shielding material for SNF waste packages are identified in the response as 1) reduction of radionuclide release rates over geological time frames, 2) assured control of nuclear criticality over geological time frames, 3) lower radiation levels emitted to immediate surroundings of the waste package, and 4) the beneficial use of excess DU.

7.1.21.1.3 Evaluation by Reviewer X

A process for producing the glass is not described in the recommendation. Any plant built to produce the glass would have to be licensed by the appropriate agencies. The plant must be designed to minimize the waste stream.

7.1.21.1.4 Evaluation by Reviewer Y

The issues are primarily those of producing Borosilicate glass containing DU; probably DU_3O_8 . It is likely that the process of producing glass logs containing fission products might lend itself to this process; it has (or is) being demonstrated at SNL and eventually at WHC.

No new or insurmountable E,S&H issues are likely. The proposal of geologic criticality (e.g., Oklo) as proposed by C. Bowman of LANL would have to be evaluated vis-a-vis the chemical retardation of effects proposed by Bowman. "Bottom line" on this is not obvious.

7.1.21.1.5 Evaluation by Reviewer Z

Dr. Charles Forsberg proposes that some of the depleted uranium be made into borosilicate glass beads, and that the beads be used for backfill material inside repository waste packages containing Light Water Reactor (LWR) spent nuclear fuel (SNF).

Implementation of this option would require the processing of the UF_6 to form the borosilicate glass beads. This processing would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated.

Normal quality control requirements would be expected for the manufacture of the glass beads in order to ensure uniformity of size.

Criticality control measures would be required during the loading and storage of the multi purpose canisters (MPC). However, as noted in Dr. Forsberg's comment, the borosilicate glass would serve as both a radiation shield and a criticality control measure, thereby reducing the long-term risks in these areas.

7.1.21.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.21.2.1 Evaluation by Reviewer U

Assuming that DUF_6 conversion to oxides or metal are first steps required before making the glass beads, processing waste materials from these first conversion steps would be encountered. These solid wastes must be allocated to low-level waste (LLW) disposal or processed to remove essentially all of the uranium to permit it to be disposed in a sanitary land fill.

Waste materials resulting from the production of the glass beads are not known at this point. It is assumed that the wastes will be a solid material with uranium contamination that requires disposal in a LLW disposal facility.

Disposal of empty DUF_6 cylinders will be required. Input to the defluorination process will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the capture and disposal of the depleted uranium remaining as heels. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites.

7.1.21.2.2 Evaluation by Reviewer V

This option would recycle part of the DU inventory into a useful product. The waste streams from the glass bead manufacturing process are unknown.

7.1.21.2.3 Evaluation by Reviewer X

The waste stream from a depleted uranium borosilicate glass production facility hasn't been evaluated because no information is available describing the process.

7.1.21.2.4 Evaluation by Reviewer Y

Without specifics on the process, it is unlikely that specifics on waste management can be identified beyond those from changing UF_6 to the oxide. The presence of Fluorides in the borosilicate glass could accelerate the deterioration of cladding and structure in MPC. How to deal with failed fuel is not clear.

7.1.21.2.5 Evaluation by Reviewer Z

The formation of depleted uranium borosilicate glass beads would not generate waste forms which are different from those which have previously been evaluated. The borosilicate glass matrix would inhibit any leaching of uranium or toxic materials from the material.

7.1.21.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.21.3.1 Evaluation by Reviewer U

The cost of converting DUF_6 to uranium oxides or metal with the Ames process are reasonably well defined. The cost of producing glass beads is unknown. Since the DUF_6 has a liability cost associated with eventual disposal, it appears appropriate for the processing costs of glass beads to be offset in the amount of the future liability cost for disposal of DUF_6 . Doing so would maintain a neutral position of overall cost to DOE.

7.1.21.3.2 Evaluation by Reviewer V

No cost data is provided. It is not known if there are any commercial conversion processes of this type from which to draw comparable data. The total demand for this material needed is not identified.

7.1.21.3.3 Evaluation by Reviewer X

No cost information is available for this option.

7.1.21.3.4 Evaluation by Reviewer Y

The main byproduct for cost recovery is commercial fluorine. Capital costs are promisingly low if processes from fuel fabrication and fission product waste disposal can be adapted. The quality of Uranium and Fluorine products will be cost-sensitive and could affect commercial market interests.

It is conceivable that implementation of this option could be reasonably and cost effectively achieved with natural Uranium (metal or oxide).

Insertion into MPC or equivalent without attempts to assure dispersal within individual fuel channels seems potentially very cost-effective (e.g., use the material as "filler").

7.1.21.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute this alternative. One cost consideration which should be factored into the consideration of this option is the two-fold advantage which it serves. It provides for the effective use of a reasonable amount of the depleted uranium, and also serves as an effective shielding and stabilizing agent for the spent nuclear fuel.

7.1.21.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.21.4.1 Evaluation by Reviewer U

Production of DU oxides or metal from DUF_6 has been achieved for decades. The process and parameters are well understood. However, the production of borosilicate glass beads with a high uranium content is an undeveloped process that would require substantial research and development. Overall, the maturity of the application and the production processes are insufficient to provide high confidence of success.

Considerable research and development efforts would be required to determine whether there are benefits achieved with the backfilling of waste disposal containers with borosilicate glass beads having a high DU loading. The suggested benefits may not be realized. Specifically, the indication that dissolution of the uranium oxide and release of radionuclides would be slowed probably will not be achieved. The borosilicate glass will tightly bind the DU and the dissolution of the uranium oxide in the spent fuel rods will proceed earlier (probably by thousands of years) than dissolution of DU from the glass beads. As for a lower hydraulic conductivity within the package, it is doubtful that the glass beads will impede the very slow movement of water through the package at any time within the isolation period. Water flow through the package will be at a very slow rate--inches per year or less--and the packing of beads leaves significant void spaces that would not decrease the flow. Since the dissolution rate of the uranium oxide within the spent fuel will be substantially greater than the dissolution of DU from the glass beads it is unlikely that ion-exchange will occur to assure isotopic dilution. From a regulatory standpoint, no isolation credit is expected to be granted or advantage recognized for slower rates of radionuclide release, lower hydraulic conductivity or isotopic dilution.

The indicated potential benefits of lower radiation levels from the waste package, disposition of DU, and increase package thermal conductivity may be realized. However, extensive and lengthy research efforts would be required to define the actual advantages of these characteristics.

7.1.21.4.2 Evaluation by Reviewer V

The technical status of the glass bead option is not identified.

7.1.21.4.3 Evaluation by Reviewer X

Production of Depleted-Uranium Borosilicate Glass is likely to be similar to the production of leaded glass. Thus, the technology is mature. The uranium feedstock will probably be a metal.

7.1.21.4.4 Evaluation by Reviewer Y

The technology is conceptual supported by small-scale tests. It is likely that the technology could be rapidly brought to fruition. Small glass particle production almost suggests a coprecipitation process (which may be expensive). The LWR fuel bundle may not be easily filled since spent fuel rods may be warped and/or failed. Product quality before insertion into long-term storage will be difficult to assure as will be the uniformity of the inserted material. It is likely that insertion of borosilicate glass with DU outside the fuel bundles will be easier and almost as effective.

7.1.21.4.5 Evaluation by Reviewer Z

The manufacture and use of borosilicate glass is a well understood technology. In order to implement this option, a large scale facility would be required in order to implement this option on a commercial scale.

7.1.21.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.21.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium oxide or metal and at a facility to produce glass beads would be at a fairly steady rate for several decades to provide the needed material to fill waste packages as they are assembled. Performing uranium processing operations at a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the operations are carried out at a location performing similar operations, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

7.1.21.5.2 Evaluation by Reviewer V

The economic, public acceptance and other socioeconomic impacts of this option cannot be identified at this time.

7.1.21.5.3 Evaluation by Reviewer X

No information was provided to evaluate this factor.

7.1.21.5.4 Evaluation by Reviewer Y

This approach may be very socially acceptable since it virtually precludes an "Oklo" type event 10^8 years hence except for the recent "Bowman, *et al.* projections. These need to be clarified.

This would not solve the unemployment problem for large segments of the U.S. population.

The approach might also provide more confidence in "on-site dry storage." This may be necessary for providing permanent storage (or more time to consider recycling of spent fuel before it is inserted into long-term storage facilities).

7.1.21.5.5 Evaluation by Reviewer Z

Public acceptance of this option is related primarily to the aspect of storage or disposal of spent nuclear fuel.

7.1.21.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.21.6.1 Evaluation by Reviewer U

A primary factor is the question of whether the indicated application of using borosilicate glass beads with high DU content will be advantageous to the waste disposal program. The waste package design and filler material will be determined by cost, regulation requirements and practicality. Backfill materials other than depleted uranium in borosilicate glass beads may be more applicable for the disposal package.

7.1.21.6.2 Evaluation by Reviewer V

See General Comments.

7.1.21.6.3 Evaluation by Reviewer X

Four arguments are provided in support of this recommendation.

The first is that the presence of Depleted-Uranium Borosilicate Glass in the Multi Purpose Canisters (MPCs) would slow the dissolution of uranium oxide in the fuel over time, thus helping to contain fission products and other radionuclides within the fuel pellets. If gross leaks occur in the fuel cladding, this might be true. It is also stated that the silica content of the glass would assure that groundwater passing through the MPC would be saturated in silicon and thus not dissolve the uranium. For groundwater to pass through the MPC, it would have to develop leaks at both the top and bottom. MPCs are likely to exist at a slight vacuum over time as the fuel cools. Thus, if water is in the repository, and if the MPC has a leak, it could fill with water. More likely, the repository will be dry (by design) and the atmosphere in a leaking MPC will come to an equilibrium with its surroundings. However, the recommendation for a fill material is a good recommendation to minimize intrusion of any external substances.

The second recommendation is to use the Depleted-Uranium Borosilicate Glass as a neutron absorber to assure that a criticality will not occur over geologic time. This problem has been extensively researched. Recently, two scientists from New Mexico

published unreviewed material suggesting that a criticality might happen. Review of their material has suggested the possibility is extremely remote. In any event, if criticality is a concern, any type of borated material placed in the MPCs would be a less expensive option than Depleted-Uranium Borosilicate Glass.

The third benefit is that the use of Depleted-Uranium Borosilicate Glass would increase the shielding and make handling easier. This use might enable less shielding to be used in the MPC wall, further lightening the assembly, and enabling the MPC to be radially smaller. This would result in a net materials savings and a savings in required storage space.

The final benefit, and the reason for the recommendation, is the disposition of excess depleted uranium. This is a disposal option for a significant amount of depleted uranium that wouldn't require additional disposal site space, or the development of an additional deep burial facility. However, it is an option that could just as well be met by using unprocessed U_3O_8 , perhaps mixed with boron to satisfy criticality concerns if they exist.

On the negative side, any fill material must have a high enough thermal conductivity to allow the heat from the fuel elements to transfer to the MPC wall and be dissipated.

7.1.21.6.4 Evaluation by Reviewer Y

It is not likely that this technology will make a large dent in the existing inventory of DUF6. However, it is judged that the technology can be implemented in a finite length of time.

DU metal can probably be used here! It is more chemically mobile than the oxide.

7.1.21.6.5 Evaluation by Reviewer Z

None.

7.1.21.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.21.7.1 Conclusion by Reviewer U

The application of converting DU into a form for the production of glass beads and subsequently using the glass beads as a filler within waste disposal packages entails many unknowns. Substantial research and development would be required for both the production of the glass beads and the evaluation of the usefulness as backfill material. The probability of achieving the benefits indicated with the recommendation is very low within the regulatory regime that is to be followed for disposal of spent nuclear fuel. The low probability of overcoming all of the hurdles, unknowns and achieve final acceptance for

this application, suggests that it not be considered a dependable means for disposition of DU.

The organization providing the recommendation in Document #22 has extensive experience and capability to perform the research and development activity necessary to evaluate this application and the production of borosilicate glass beads with a high DU loading. Such efforts would probably extend over a period of several decades.

7.1.21.7.2 Conclusion by Reviewer V

It is difficult to assess the reasonableness of this option because of the lack of cost and other data. The option needs to be better defined. There do not appear to be any major environmental, safety, health or siting issues that are unique to this technology. The potential benefits of this shielding material deserve further consideration, but the option could not be considered reasonable without more supporting data.

7.1.21.7.3 Conclusion by Reviewer X

This option would dispose of as much as 25% of the dUF_6 inventory. However, though Depleted-Uranium Borosilicate Glass production costs are unknown at this time, it might be possible to implement this option less expensively using U_3O_8 rather than glass. While most thoroughly reviewed material has determined that criticality is not a concern in a long term disposal facility using MPCs, boron could be mixed with the U_3O_8 matrix to completely dispense with the concern.

If a fill material is needed in MPCs to help preclude water intrusion and to improve the structural integrity, then less expensive options might be available, including using relatively plain sand, again mixed homogeneously with boron only if criticality protection is determined to be prudent.

However, uranium disposal should be subjugated to beneficial uranium uses. The ultimate solution for the dUF_6 inventory is to develop commercial uses for depleted uranium, in particular the metal, so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

7.1.21.7.4 Conclusion by Reviewer Y

This option has very reasonable objectives with economic promise. It provides some assurances which, if necessary, are sound. It does not preclude ultimate recycle of spent fuel so treated. It does not represent a very large fraction of the DUF_6 . Combined with other such partial options, a significant dent in the DUF_6 program could be achieved.

7.1.21.7.5 Conclusion by Reviewer Z

This option has a great deal of merit. It provides an option for the use of substantial quantities of depleted uranium in an application which provides specific benefits of

radiation shielding and stabilization for high level radioactive waste in the form of spent nuclear fuel.

7.1.22 Evaluation of Document No. 42 (Independent Technical Reviewers' No. 23)**Respondent:**

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Description of Response:

This response recommends creation of a Kentucky Wastes and Energy Interim Storage and Transportation (KY WEST) Facility to centralize the depleted uranium stockpile for interim storage which would involve construction of Waste Staging and Shipping Areas at each of the three current storage sites and an upgrade of the responders Interim Storage and Transfer Facility for use as the interim centralized repository in order to meet near-term storage needs and in preparation for final disposition of this material. Responder states that development of this concept can be done in five phases, with private funding for phase I, Government funding for phase II which involves the detailed planning, and with possible funding by DOE and/or private sector firms for phases III through V (construction, operations, shipment).

7.1.22.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.22.1.1 Evaluation by Reviewer U

The recommendations in Document #23 identify a private business approach for the monitoring, storage and transport of depleted uranium (DU) as a service function for the DOE. While the recommendation recognizes that depleted uranium hexafluoride (DUF₆) may be converted to an oxide by others, it does not include any activity or process for converting the material to another form. Nor does it include recommended uses or a

preferred means for disposition of the DU. The basic premise for this recommendation is stated as; "The critical missing path involves the preparation, staging, interim storage, shipment, and tracking of radiological, hazardous, and mixed low-level waste for reprocessing, treatment, or long-term storage at the deep-mined geologic repository." In addition, the recommendation states that; "Clearly an interim waste storage facility is desperately needed in the United States ... especially for the temporary storage and transfer of DOE's UF_6 tailing cylinders." The recommendation seems to ignore that effective interim storage of DUF_6 is in existence and has been for several decades at the location of enrichment plants in Ohio, Kentucky and Tennessee.

Apparently the organization providing Document #23 has a misunderstanding of some existing legislated actions and associated disposal requirements. The Nuclear Waste Policy Act of 1982 specifically addresses the disposal of high level radioactive waste. It does not address low-level radioactive wastes, mixed hazardous wastes nor is it applicable to DU. There is no requirement at this time to provide long term storage or the disposal of DU in a deep-mined geologic repository as indicated in the recommendation. Also, the reference to past Monitored Retrieval Storage (MRS) concepts appears to be incorrect by indicating them to be underground and not monitored or inspected on a routine basis. Quite the contrary is provided with past and current MRS concepts. These differences from reality in regard to legislation and regulatory requirements tend to detract from the recommendations offered.

An integrated plan for staging and shipping of DUF_6 is appropriate after decisions are made on the management and disposition of the existing material. Providing storage and monitoring at a private storage facility may be an appropriate service at some point in the future. Such actions do not address the questions of appropriate material form, the proper time for making decisions and taking specific actions or the eventual disposition of the depleted uranium.

Since this recommendation is limited to functions of monitoring, storage, staging and transportation, there are few issues of significance from an environmental, safety and health standpoint. Site restrictions applicable to this recommendation are aligned with infrastructure for transportation rather than for material processing. Such a site should have reasonable accessibility to both major highways and rail lines. Appropriate precautions for handling and transporting DU must be undertaken and they are well defined and understood.

Overall Federal regulation for safety of DUF_6 storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF_6 is turned over to a separate Government Corporation or stored at a privately owned site it would be regulated by the NRC. Basic regulations have been in place for several decades and at least one license granted by the NRC for a storage facility. A modification in the regulations would be required for NRC licensing for the storage of large quantities of DUF_6 for an extended period of time.

7.1.22.1.2 Evaluation by Reviewer V

The option of temporarily storing DUF_6 in its present form at private licensed sites to preserve it for later use does not appear to present any unresolvable environmental, safety or health issues. The current storage of DUF_6 without processing has some potential for environmental risks. When exposed to ambient air, DUF_6 can react to moisture producing HF acid and UO_2F_2 , both hazardous. The HF is an acid that could cause skin burning and damage to the lungs on contact and the fluorides and uranium can have toxic effects if ingested. In addition, the alpha particle emissions from inhaled or ingested uranium could be a health risk. Releases to the environment are most likely to be limited to the storage facility itself. If a large release occurred, however, the potential exists to the surrounding area effecting the public, the land, vegetation and domesticated and wild animals.

The handling of the storage cylinders and routine operations at the storage facility raise the possibility of minor environmental risks from accidental releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. Past experience has shown very few incidents of releases, virtually all of which had insignificant health effects. With the aging of the cylinders, however, the potential for increased numbers and severity of accidental releases must be seriously addressed. Under the proposed option, the handling of the cylinders would be increased as they are inspected and prepared for transport, thus increasing the potential for releases.

The transport of all of the DUF_6 inventory to an alternative site, as required under this option, would significantly increase the potential exposure of the public. Use of the current sites is probably the least risk approach from an environmental, health and safety perspective. While the public is located in proximity to some of the facilities, there are no major population centers in the immediate vicinity. Within the existing sites, there may be potential for relocating storage areas to improve storage conditions and minimize hazards of accidental release.

Continued storage at existing sites again would not present a problem technically, however the management of the sites and perhaps the storage techniques may need to be modified. Handling the cylinders for inspection and routine stacking and unstacking can cause leakage, although in many cases any breaches are self-sealing. The steel cylinders have been stored out-of-doors, some for as long as thirty years which is the estimated useful life expectancy. While high risk cylinders with identified risk potential (about 15,000) are inspected annually, only one fourth of the remaining inventory is inspected annually. Current storage conditions may make it difficult to inspect some cylinders.

Current management programs include cylinder inspections for integrity with repairs and replacements performed as necessary. Some technical assessments of the condition of the cylinders and techniques for maintaining them are underway. In addition, some improvements in cylinder storage facilities are underway including saddle replacement, new cylinder yards at Paducah and Portsmouth, cylinder replacements and a cylinder refurbishment facility. The latter would have the capacity to handle about 1/20th of the existing cylinders per year. The current outdoor storage system is not in compliance with

DOE regulations requiring two levels of confinement for all radioactive materials, e.g. use of a container that is protected within a building.

Given the advancing age of the cylinders, increased inspections and refurbishments as well as improved storage systems should be considered. Nearly a third of the cylinders are described as "high risk" and inspected annually due to poor drainage, heavy scale or pitting, suspected leaking valves, etc. The risks of accidental releases should be evaluated given these conditions and additional improvements in storage and handling considered.

7.1.22.1.3 Evaluation by Reviewer X

No additional environmental, safety, or health concerns are raised by this proposal. However, it would require that dUF_6 be shipped from its current storage locations near its production sites in the currently used cylinders to an off-site location in Western Kentucky. This raises concerns for safety during transportation of the dUF_6 while the uranium is in its most reactive condition.

Several safety measures might be taken should this recommendation be embraced to assure safe transportation of the cylinders to the site. These include the use of straddle carriers with enclosed cabs, emergency communications, and off-hour movements. These recommendations would reduce the risks should an accident occur. However, they need to be evaluated relative to the actual risks involved.

Further, the transportation process could be coupled with the cylinder inspection program currently in place to replace either damaged or old and weakened cylinders. It is reasonable to plan shipments of the newer cylinders first, allowing transfer of dUF_6 in older cylinders into cylinders to take place in an orderly fashion.

7.1.22.1.4 Evaluation by Reviewer Y

The inclusion of low-level waste into the KY WEST facilities will exacerbate problems and costs under the aegis of safety, health, and environment beyond those for the largely chemical concerns of the DUF_6 . While there may be merit for interim storage of low-level wastes, the argument for moving DUF_6 to a new site with above-ground storage seems to provide marginal, if any, benefits. Classifying the DUF_6 as waste and commingling of it with low-level waste assures RCRA actions on DUF_6 .

7.1.22.1.5 Evaluation by Reviewer Z

Mr. Jerry Hutchinson proposes that a private sector company provide interim storage of the UF_6 cylinders until final disposition is determined. This option addresses only interim storage until long term disposal is available. Environmental, safety or health hazards due to this option would be similar to those currently posed by long term storage or transportation options.

7.1.22.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.22.2.1 Evaluation by Reviewer U

Since this recommendation does not entail processing of the DU, there are few if any waste management issues. Minor quantities of waste would be expected from monitoring and transport container surface clearing functions.

7.1.22.2.2 Evaluation by Reviewer V

The waste streams associated with this option are minimal. There would be minor amounts of waste generated from normal maintenance activities including replacing or repairing cylinders, valves and other equipment. The replacement of wood saddles with concrete or other supports will generate quantities of waste that is likely to be disposable in a sanitary landfill. The cleaning and recoating of canisters will also generate some waste, but there would be limited potential for recycling or waste minimization in any of the operations.

7.1.22.2.3 Evaluation by Reviewer X

As stated above, this recommendation adds nothing to the waste stream. It also doesn't lessen the amount of waste being stored now.

A new storage facility would need to meet licensing requirements of the NRC and the double confinement requirements of DOE.

7.1.22.2.4 Evaluation by Reviewer Y

This proposal is all about waste (storing, monitoring, inspection, transport, etc.). A new privately-owned facility might be a nicety that is not affordable when storage, monitoring, and inspection are possible at the three existing sites.

7.1.22.2.5 Evaluation by Reviewer Z

This option proposes that a private sector company provide interim storage and monitoring of the UF₆ cylinders. This option would not pose any waste management issues which are

different from those currently encountered during long term storage or transportation of cylinders.

7.1.22.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.22.3.1 Evaluation by Reviewer U

The operational costs associated with monitoring and storage of DUF_6 will be encountered at about the same magnitude whether performed at the present DOE sites or by a contracted service at a private storage location. However, the establishment of a private site, lease cost for storage space and the licensing of such a site entail additional costs over and above those associated with continued storage at present locations. Until there is a need to relocate the DU or a decision is made for the disposition of the DU, it does not appear to be economically desirable to establish new private storage capability or to relocate the DU.

7.1.22.3.2 Evaluation by Reviewer V

The costs of storage of DUF_6 at the existing sites as estimated by contractors to DOE are low, in the range of \$.22/kgU to \$.34/kgU assuming a storage inventory of only 375,000 MTU, corresponding to life cycle costs of \$83 million to \$129 million. This estimate is based on current storage practices to be used through the year 2020 including planned upgrades of cylinders and yards, new cleaning/coating facilities and current inspection and maintenance. No estimates are given for the costs to store DUF_6 at a new private site. Construction and transportation costs would probably higher than minor modifications of the existing site.

The capital costs for an additional confinement level using indoor storage was estimated at \$360 million for all three sites, with some additional maintenance costs ongoing associated with those facilities. If these estimates are accurate, this would increase the cost of this option by four fold or more. The costs of various containment options should be reviewed, including the use of outside contractors to operate and maintain such facilities. It is generally recognized that some increased costs may need to be incurred to bring the storage option to a higher level of safety.

There would be no additional revenue streams associated with storage unless it were provided with another alternative immediate or future use. The later sale or use of DUF_6 , its products and byproducts could produce some revenues.

7.1.22.3.3 Evaluation by Reviewer X

This recommendation for a staging area separate from the current sites would be more expensive than maintaining all storage at the current sites.

However, if it is selected in coordination with the recommendation from Allied Signal to provide a conversion plant nearby, then its cost might be reasonable.

However, since it doesn't provide a solution for disposal of dUF_6 , it cannot be considered on its own merits unless the selected option is to continue storage for the long term pending potential use of the dUF_6 for energy production.

Costs to maintain current storage practices through the year 2020 are estimated to range from \$83 million to \$129 million. If confinement facilities are built for the cylinders to meet current DOE regulations requiring double confinement of uranium, \$360 million additional will be required. This double confinement cost will need to be expended to receive public support for continued storage.

It isn't likely that a breeder economy will develop by 2020. Thus, longer term storage will be necessary, and this recommendation provides an alternative. The storage cost will be greater than the projected amounts due to the increased cost of transporting the cylinders from their current sites. However, it will still be much lower than the cost of converting the dUF_6 to U_3O_8 .

7.1.22.3.4 Evaluation by Reviewer Y

There are no costs given beyond the Phase II activities of $\$3 \times 10^6$ which is reasonable. However, constructing a new facility to avoid RCRA processes is likely to be non-cost-effective.

7.1.22.3.5 Evaluation by Reviewer Z

This reviewer has no specific numerical data regarding the cost of this option.

7.1.22.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.22.4.1 Evaluation by Reviewer U

Storage, monitoring and transportation techniques are well defined and have been practiced for several decades. These functions are fully mature. The development of an integrated plan for staging and shipping of large quantities of DUF₆ may be desirable after the decisions are made on material form for long term storage and eventual disposition of the material.

7.1.22.4.2 Evaluation by Reviewer V

This option seems to be well developed technically and leaves little significant concern regarding its feasibility. Some additional work on the potential for increased failure of aging canisters may be appropriate. Management can be on the lookout routinely for safer or more economical ways of managing the storage of these materials.

7.1.22.4.3 Evaluation by Reviewer X

DOE has stored dUF₆ using the present methods since the mid 1940s. Storage improvements have been implemented (primarily monitoring programs, use of improved cylinders, and cylinder repair programs).

Confinement buildings are widely used in industry and especially in the nuclear industry. Ventilation and filtering equipment are commonly used, and isolation systems are routinely employed. Detection of radiation leaks using monitors in ventilating systems is common.

Building designs similar to Secondary Containment Buildings for nuclear power plants would be appropriate for confinement structures. These are built to withstand earth velocities predicted for the local areas, including at least two sites in California. The design of such buildings and their behavior during actual earthquakes is well known.

7.1.22.4.4 Evaluation by Reviewer Y

There is no new technology proposed. The transport of aging cylinders will require consideration to provide safety on public highways. Provision for above-ground,

monitored, and inspected sites can be accomplished. Seismic concerns plus those from tornado-borne missiles are conspicuous by their absence.

7.1.22.4.5 Evaluation by Reviewer Z

Long term storage and monitoring is a mature technology.

7.1.22.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.22.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining storage of DUF₆ would be fairly constant for many decades. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. If the storage is performed at a new private site, there are very likely to be objections from the locality in regard to potential long term storage of nuclear waste material, the associated transportation of the material to the new locality and subsequent transportation of the material away from the site once a decision is made on disposition. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Since the storage activity would be a continuation of current practices there does not appear to be a need for seeking significant public involvement or initiating a major public information program at the current sites. Significant public concern will likely be raised if the DUF₆ is moved from the present storage sites to a new private site for lengthy storage periods.

7.1.22.5.2 Evaluation by Reviewer V

Economics: Storage of DUF₆ using the existing management scheme would not have a significant effect on employment or income in the vicinity of the sites. Maintenance operations as currently planned would require no major increases in labor to handle the monitoring and refurbishing activities.

If major improvements were made in the facilities or maintenance operations were expanded there could be some effects on the local economies surrounding the site.

Economic impacts from the construction of a covered storage building(s) at each site could be in the following ranges, based on the RIMS II regional economic multipliers (U.S. Department of Commerce, 1992):

Total estimated capital costs:	\$360.0 million
Paducah (62%)	\$232.2 million
Portsmouth (28%)	\$100.8 million
Oak Ridge (10%)	\$ 36.0 million

Net effect on local economy in terms of:

	<u>Total increase direct demand</u>	<u>New earnings to employees</u>	<u>Jobs created (temporary)</u>
Paducah	\$527 million	\$158 million	8,437
Portsmouth	\$255 million	\$ 77 million	3,699
Oak Ridge	\$ 88 million	\$ 28 million	1,300

The impacts actually experienced could vary considerably, however. The economic effects of the operation and maintenance of covered storage on overall storage costs should be neutral or slightly positive in that protection from the elements could slow the degradation of the cylinders and reduce ongoing refurbishment costs.

If other conversion facilities are located nearby, such as the Allied/Signal oxide plant mentioned in the response, the economic effects will be amplified.

Siting. Siting could be a significant public acceptance issue. It has been raised in a number of responses to program notices as a concern for at least some parties living in the vicinity of the existing sites. Even in locations where processing facilities are already in operation, growing concerns about the condition and management of the cylinders needs to be addressed. Related development of conversion facilities could increase public concern over cumulative impacts. Requests have been made in some cases to relocate residents closest to the existing sites for their safety.

Public Acceptance. The public has expressed concern regarding the safety of the storage facilities under current management practices. Several responses to the Request for Response reflect the discontent with the situation as it currently exists and request action. In response to this discomfort, or if public concern for safety increases, additional analysis of the potential risk and education of the public may be beneficial.

Transportation. Transportation risks would become a significant factor of public concern if the DU is transported off DOE sites. The number of vehicle trips and potential for accidents will be increased.

Other socioeconomic factors. The land use implications for this option deserve consideration. The proposed site has been in similar use for more than two decades. For this project it will need to be upgraded and the amount of material stored and handled will

obviously increase dramatically. To the extent that the cumulative effect and acceptability of such uses is a concern to local residents, this use will also be scrutinized. The ongoing operation of such a storage facility, assuming no routine or accidental releases of hazardous materials, poses no new threats to cultural, historical or archaeological resources.

7.1.22.5.3 Evaluation by Reviewer X

The primary reason for investigating alternatives to continued storage is the number of concerned citizens indicating opposition. Any move to a new site will require consideration of public concerns to gain acceptance. Improvements to the current storage practices will be necessary to address these concerns, including (1) the addition of earthquake resistant buildings to provide a second level of confinement, and that will assure containment of any releases from leaking cylinders, and (2) analysis of storage practices, such as stacking cylinders, to assure the safest configurations.

The recommendation states that co-locating a $\text{dUF}_6/\text{U}_3\text{O}_8$ conversion facility in proximity to the proposed storage facility would provide a large number of industrial and skilled labor jobs and economic stability for the McCracken area for years to come, independent of any change in operations at the Paducah GDP.

Location of a storage site will create a large job market during the construction of confinement facilities. A smaller work force can probably handle the continuing storage practices.

7.1.22.5.4 Evaluation by Reviewer Y

This proposal is primarily one for regional development on an "interim basis"!! Public acceptance is not likely to be a serious problem except for transport to and from the interim site. Employment for construction of the facility would be significant, pending rate of construction. Employment of the mature facility would be small but provide leverage for collocation with processing facility.

7.1.22.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the socioeconomics of this option.

7.1.22.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.22.6.1 Evaluation by Reviewer U

A determination on the potential energy value of DU in a realistic manner for public education and understanding appears to be needed. A reasonable time period for storage

should be defined in anticipation of eventual use—one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach or location of storage any time in the near term. Safe storage of DUF_6 at the present sites appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

7.1.22.6.2 Evaluation by Reviewer V

See General Comments.

7.1.22.6.3 Evaluation by Reviewer X

None.

7.1.22.6.4 Evaluation by Reviewer Y

If interim storage and monitoring can be negotiated at existing sites, the costs in this proposal can be obviated, particularly since existing sites are likely to be more fault-tolerant for aging vessels.

7.1.22.6.5 Evaluation by Reviewer Z

None.

7.1.22.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.22.7.1 Conclusion by Reviewer U

Storage of DUF_6 has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF_6 for a long term period. There is no apparent need or advantage to establishing a new private storage site for the material. Development of an integrated plan for staging and shipping should be delayed until after decisions are made on material form for storage and/or the eventual disposition of DU.

The organization providing the recommendations in Document #23 has considerable knowledge on storage, monitoring and transportation of nuclear materials. However, little knowledge or experience is provided for nuclear material processing or eventual disposition.

7.1.22.7.2 Conclusion by Reviewer V

Temporary private storage of DUF_6 appears to be a reasonable option for consideration by DOE. The question remains whether this option offers the best environmental protection. The proposal could be implemented immediately and would handle all of the existing inventory. It creates no significant new environmental issues except the need to improve maintenance of the aging cylinders to avoid accidental releases. The costs would be higher than on-site storage but probably well within program goals and are consistent with DOE and other Federal activities. A major drawback is the temporary nature of the solution. Eventually this material may require a more final disposition. This option may be best used in combination with other options.

7.1.22.7.3 Conclusion by Reviewer X

This recommendation is for a new site as a staging area that will simply receive dUF_6 cylinders and prepare them either for long-term storage or transfer to a processor. It presupposes the establishment of a $\text{dUF}_6/\text{U}_3\text{O}_8$ conversion plant nearby. It provides no additional value to the present storage method other than (1) a new area should the currently used areas become full, and (2) a level of expertise for handling hazardous materials.

Construction of a new storage area will need to go through the licensing process, including several series of public meetings. Even though it is proposed for a region with considerable experience with the enrichment and uranium product fabrication processes, the potential for public approval is difficult to predict.

If this option is looked at as part of the continued long-term strategy, then the potential market for uranium must be evaluated. It isn't likely that a breeder reactor economy capable of using a major part of the current supply will develop by 2020. Thus, the total cost of storage will exceed the current projections through that date. While the initial load of fuel in a breeder reactor will require about 90 tonnes of dU , reloads will require significantly less. Even with 100 breeders being built, less than 1% of the current inventory of dUF_6 will be used. Thus, continuing production of fuel for current LWR operation will provide more than adequate amounts of ^{238}U , and use of the dUF_6 in other applications will still need to be considered to utilize any significant amounts of what is available.

A risk analysis should be performed to clearly identify the risk to both workers and the general public should the long-term storage option be selected. This analysis should result in bases for deciding whether to build confinement facilities for the cylinders, what type of structures to build (including design requirements for withstanding seismic and other natural events), whether to replace specific cylinders and what replacement rates would be

prudent, what storage configuration would be safest, what monitoring instrumentation should be required for leak detection and measurement of releases, and what equipment might be necessary for isolating building ventilation should a leak be detected. It should also provide information to the public so they may understand the risk of continuing the current practices.

7.1.22.7.4 Conclusion by Reviewer Y

This proposal is not reasonable since it provides no solution for the future. It has merit only as a tank handling entity as a first step of a processing facility nearby.

7.1.22.7.5 Conclusion by Reviewer Z

This option little merit. It addresses only the interim storage of the material until long-term disposition is determined. It would require transportation of all cylinders currently stored at the three locations, and additional expense of constructing facilities for the storage. This expense is not warranted unless a permanent disposition cannot be determined in the foreseeable future. This option would be worth further consideration in the event that continued storage at current locations until final disposition is not an option.

7.1.23 Evaluation of Document No. 8 (Independent Technical Reviewers' No. 24)**Respondent:**

Mr. Dennis Wright
No address provided

phone number not provided

Description of Response:

This response is an oral recommendation via a telephone message, wherein the commentor recommended using a titan missile or the space shuttle to send the uranium hexafluoride (UF₆) to the sun and to refrain from placing more pollution from UF₆ on the Earth.

7.1.23.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.23.1.1 Evaluation by Reviewer U

The recommendation in Document #24 calls for sending the depleted uranium hexafluoride (DUF₆) to the sun with a titan rocket or into space on the space shuttle. Very little detail was provided and the evaluation is accordingly limited.

Operational issues include a large array of factors associated with the decision of what form may be applicable for DU in space, the very large number of rockets or space shuttles needed to carry out the mission, the potential for accidents upon launching the large number of vehicles and the practicality of sending DU into space.

While this recommendation implies that having UF₆ on earth is a major pollution problem, it does not recognize that both uranium and fluorine are materials that are on the earth in plentiful quantities. Removal of the DUF₆ from earth would not change significantly the overall amount of either element within the earth's environment.

Overall Federal regulation for safety of DUF₆ disposal in space is an uncharted arena. Undoubtedly, other nations would be concerned if the U.S. was to attempt to dispose of

large quantities of radioactive materials in space. All forms of International involvement would be forthcoming and the ability to obtain consensus for such an activity is highly circumspect.

7.1.23.1.2 Evaluation by Reviewer V

This option would present significant environmental, safety and health risks. In order to process the volume of DUF₆ currently in storage using this method, a large number of rocket launchings would be required. The failure on any of these would present significant potential for harm from DUF₆ released to the environment. A great deal of processing and packaging would be required to prepare the material for loading which would also generate waste and expose workers to safety risks.

7.1.23.1.3 Evaluation by Reviewer X

Data on failed launches is not available. However, if this recommendation is considered further, then the risk of failure should be considered. The space shuttle would not be available for this mission since it is a specialized vehicle devoted to space research, development, and applications. Thus, the Titan or a new advanced launch vehicle would have to be used. The payload mass for a Titan rocket is 29.5 MT/launch into orbit. However, for launch out of orbit, a lower mass would be required. Assuming that only one dUF₆ cylinder could be launched at a time, 47,000 launches would be necessary. At least some of these would fail based on prior experience.

The dUF₆ cylinders would have to be shipped from their current storage facilities to a launch site, presumably on one of the two coasts. This would entail the design and use of overpacks, or the transfer of dUF₆ to new and/or smaller cylinders, such as the 2.5 MT cylinders now in common use for transportation.

7.1.23.1.4 Evaluation by Reviewer Y

Sending DUF₆ to sun or outer space would be environmentally sound for the earth. However, the potential of not reaching the sun resulting in space garbage plus launch pad accidents could have very serious environmental implications due to dispersal. This suggests current storage under controlled conditions may be a lower risk enterprise. If there are environmental issues, they may be subsumed by health and safety issues in space on the way to the sun. If Chaos theory is credible, the potential for upset on the sun must be credibly evaluated.

The statement "no more pollution from UF₆ on earth" needs analysis for what the pollution is. Let us not forget that the DUF₆ triple point is 146°F. Even Death Valley does not reach this temperature.

7.1.23.1.5 Evaluation by Reviewer Z

This option, submitted by Mr. Dennis Wright, proposes that the UF₆ be put on a Titan rocket to the sun or sent off in a Space Shuttle so that there will be no more pollution

from UF₆ on the Earth. A detailed evaluation of this option is not warranted. See Section 7.1.23.7.5.

7.1.23.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.23.2.1 Evaluation by Reviewer U

Very large quantities of atmospheric dispersions would be involved from the burning of rocket fuels used to launch DUF₆ into space.

7.1.23.2.2 Evaluation by Reviewer V

This option could generate large amounts of wastes in the material handling and rocket production. These could include toxic and low-level radiological wastes.

7.1.23.2.3 Evaluation by Reviewer X

No radiological waste would result from this option. However, the effect of combustion products on the atmosphere from four or five launches per day to meet DOE's 30-year guideline should be assessed. Additionally, the waste stream from production of fuel for such a large program also should be assessed.

7.1.23.2.4 Evaluation by Reviewer Y

Presumably this material is classified as waste. This raises real problems and issues for both launch pad upsets and vehicle upsets in space. Neither area has been extensively evaluated in this context.

7.1.23.2.5 Evaluation by Reviewer Z

See Section 7.1.23.7.5.

7.1.23.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.23.3.1 Evaluation by Reviewer U

Very large costs would be involved to transport DUF₆ into space. The cost for this recommendation is anticipated to be several orders of magnitude higher than any other recommendation for eventual disposal of DU within a disposal facility, either near the surface or deep underground.

7.1.23.3.2 Evaluation by Reviewer V

The costs for this option would need to be carefully identified. It seems likely that with the relatively small tonnage that could be carried in any given rocket launch, the overall cost for this option would be quite high.

7.1.23.3.3 Evaluation by Reviewer X

Costs have not been evaluated.

7.1.23.3.4 Evaluation by Reviewer Y

This has got to be a very high cost option!

7.1.23.3.5 Evaluation by Reviewer Z

See Section 7.1.23.7.5.

7.1.23.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.23.4.1 Evaluation by Reviewer U

The number of vehicles and the cost of sending large quantities of material into space can be estimated using the experience of sending satellites into space and the cost of launching the space shuttle. The large amount of fuel for launching the vehicles and the large number of vehicles needed would overwhelm the ability of the U.S. space and aircraft industry manufacturing capability.

7.1.23.4.2 Evaluation by Reviewer V

This option is probably technically feasible using existing technology.

7.1.23.4.3 Evaluation by Reviewer X

Space launches have been common since the early sixties. The technology is mature. However, NASA is not prepared to launch four or five rockets per day and additional launch facilities would need to be built. Also, capacity for keeping up with rocket production would need to be installed.

7.1.23.4.4 Evaluation by Reviewer Y

The proposal can be accomplished at very high cost. This will be exacerbated by provisions to assure safety on earth (e.g., limited payload per rocket).

Chaos theory in the context of this proposal merits a look for broad consequences.

7.1.23.4.5 Evaluation by Reviewer Z

See Section 7.1.23.7.5.

7.1.23.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.23.5.1 Evaluation by Reviewer U

Employment for manufacturing space launch vehicles, the fuel and preparing the DUF₆ for launch would be well beyond the capability of the U.S. work force.

Arriving at a decision of declaring the DU to be a waste would require considerable research and development to define the acceptable material form for space disposal.

General public acquiescence for space disposal is believed to be unachievable.

7.1.23.5.2 Evaluation by Reviewer V

This option would be likely to have significant capital costs associated with rocket production and, therefore, would be a stimulant to the aerospace industry. The exact location of these effects would be hard to pinpoint. Operations and maintenance would also generate economic activity and jobs. The economic costs and environmental and health risks are likely to make this option unacceptable to the public.

7.1.23.5.3 Evaluation by Reviewer X

Employment for a launch vehicle production facility would impact the communities where a new plant is built. Other employment would be necessary for a rocket fuels program and for the launch facility.

Whether the population around the new plants would accept the production and transportation of highly dangerous rocket fuel needs to be assessed.

Likewise, the atmospheric effects of launching four or five Titans per day needs to be determined before acceptance of such a high launch frequency should be assessed.

7.1.23.5.4 Evaluation by Reviewer Y

This would provide lots of jobs for a currently reengineered and redirected space program.

The proposal would probably get initial public acceptance until costs and problems would become prominent.

7.1.23.5.5 Evaluation by Reviewer Z

See Section 7.1.23.7.5.

7.1.23.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.23.6.1 Evaluation by Reviewer U

Is DUF₆ of such a great hazard that it should be eliminated from earth? Clearly, the answer to this question is no. There is no need or justification for sending DUF₆ into space.

7.1.23.6.2 Evaluation by Reviewer V

No additional factors.

7.1.23.6.3 Evaluation by Reviewer X

Sending the dUF₆ into deep space or into the sun would certainly eliminate it from being a problem on earth. However, it also would deny humanity a valuable resource into which considerable investment already has been expended.

7.1.23.6.4 Evaluation by Reviewer Y

The generic issue of dumping garbage in space or on space bodies should be evaluated before such action is initiated.

7.1.23.6.5 Evaluation by Reviewer Z

None.

7.1.23.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.23.7.1 Conclusion by Reviewer U

It does not appear reasonable to consider sending DUF_6 to the sun or into space.

The person providing the recommendation in Document #24 does not appear to have a reasonable understanding of the contribution of DUF_6 in the overall scheme of environmental pollution or the relative impact of hazardous materials.

7.1.23.7.2 Conclusion by Reviewer V

This option does not seem reasonable based on the potential cost per unit disposed, the potential environmental, health and safety impacts and the public acceptability.

7.1.23.7.3 Conclusion by Reviewer X

The space shuttle is a specialized vehicle devoted to space research, development, and applications and would not be available for use as a "trash truck." The maximum payload for the Titan launch vehicle is 29.5 MT. Thus, to meet DOE's 30-year guideline, at least two launches per day would be required. However, to preclude having to design a new and larger, and potentially more dangerous, dUF_6 launch cylinder, it would be more reasonable to have a payload of one cylinder per launch. Thus, as many as five launches per day would be necessary for 30 years.

Environmental effects due to a launch vehicle production program, a fuels production program, and a long-term launch program need to be assessed. Also, the risk of launch failure needs to be determined. Finally, the potential damage to the oceans of a single failure distributing the contents of a dUF_6 cylinder to a local ocean ecosystem should be assessed.

Finally, this option would preclude the use of a valuable resource for beneficial purposes.

This is not a practical or wise alternative for the disposition of dUF_6 .

7.1.23.7.4 Conclusion by Reviewer Y

This option is not reasonable to today's world! Cost is the number one obstacle. The generic issue of dumping material away from this globe is not answered!

7.1.23.7.5 Conclusion by Reviewer Z

This option has no merit. It has no technical or scientific basis. Considering the large number of rocket vehicles necessary to transport the UF_6 or a derivative form such as uranium metal, potential health risks arising from rocket failure and air pollution from rocket fuel exhaust seem likely to exceed that of many other alternatives. A detailed evaluation is not warranted.

7.1.24 Evaluation of Document No. 40 (Independent Technical Reviewers' No. 25)**Respondent:**

Mr. Victor Ransom
Purdue University
1290 Nuclear Engineering Building
West Lafayette, IN 47907-1290

phone number not provided

Description of Response:

This response recommends that the ^{238}U in the depleted uranium be maintained so that it is available for potential use in the production of plutonium fuel in breeder reactors.

7.1.24.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.24.1.1 Evaluation by Reviewer U

The recommendation in Document #25 calls for recovery of ^{238}U in the future for producing plutonium fuels in breeder reactors. The uranium in uranium hexafluoride (DUF_6) should be retained in some form for potential use as a valuable resource. There is no indication of when such an application would be economical or could be implemented.

Operational issues include well understood controls for storing and handling DUF_6 and/or some other chemical form of depleted uranium until the time for use as breeder reactor fuel. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. The potential health concerns associated with long term storage of DUF_6 are well known and when properly implemented, effectively controlled.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, are appropriate for the recommended storage. Future activities of converting the

DUF₆ to breeder reactor fuel are not defined and plans for this activity would occur some time in the distant future.

Overall Federal regulation for safety of DUF₆ storage could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Continued storage at a DOE site operated by a contractor to DOE would generally be regulated by DOE. However, if the DUF₆ is turned over to a separate Government Corporation or stored at a privately owned site it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. A modification in the regulations would be required for NRC licensing long term storage of DUF₆.

7.1.24.1.2 Evaluation by Reviewer V

This option suggests that the ²³⁸U in DUF₆ is potentially useful for future production of plutonium fuel in breeder reactors and should be kept in retrievable storage or disposal for that purpose. The environmental, health and safety factors for commercial operation of breeder reactors are somewhat well known from European experience. This use would require high levels of care in the fabrication and handling of the output fuel elements and scrap materials. Worker safety procedures exist, but the potential hazard is greater with this type of use. Public health and safety should not be effected by routine operations of a licensed facility. Public concerns that have been expressed in the past regarding safety and health issues associated with breeder reactors will need to be carefully addressed.

7.1.24.1.3 Evaluation by Reviewer X

Retaining some amount of depleted uranium for use in a breeder reactor program would require continued storage as dUF₆ or conversion to either a metal or oxide form specifically for storage.

Converting the dUF₆ to a metal or an oxide form, such as U₃O₈, would produce a more stable form for long-term storage. Storing this material for possible future uses rather than disposing of it would preserve a resource that may become more valuable with time as the earth's fossil energy resources become less available.

No specific conversion technology is recommended and so none are evaluated here. Several that have been proposed are stated to produce little or no additional waste streams, and so no additional hazards should be anticipated.

When a need for breeder reactors becomes politically acceptable and a technology is selected, new methods for handling the waste from these facilities also will be available.

7.1.24.1.4 Evaluation by Reviewer Y

This very brief proposal clearly states that Depleted Uranium Hexafluoride contains U238 which will become a valuable resource. As such, its effective use will obviate the release of CO₂ and other effluents from burning fossil fuels. (A proposal like this could also

suggest retrieving natural Uranium from fly ash in burning of fossil fuels; equivalent ultimate energies may be involved with significant environmental benefits.)

The proposal is not specific on the process for "recoverable" U238. However, presuming oxide, metal, or carbide storage possibilities, the Fluoride will have to be handled along with the process. It is, of course, possible to argue that DUF6 has recoverable U238 and a prevailing status quo with enhanced safeguards is the appropriate option. No unusual health and safety issues arise for the possible processes. The use of U238 in the breeder will require revisiting past issues of safety and related subjects including the environmental impact of breeder operations versus the alternatives.

7.1.24.1.5 Evaluation by Reviewer Z

Mr. Victor Ransom's proposal is that the U²³⁸ is potentially useful for producing plutonium fuel in breeder reactors and thus will one day become a valuable resource. The ability to recover the U²³⁸ in the future should be an evaluation factor. No specifics are provided for the storage or disposal of the depleted uranium. This would offer the options of either continued storage practice, interim storage, or retrievable storage.

Although the near-term risks associated with continued storage of the material are small, the risks associated with storage and cylinder handling will increase with extended storage due to continued degradation of the cylinders due to corrosion.

The proposal is that the material be used to make blanket material for producing plutonium. Implementation of the second part of this proposal would require a chemical processing facility to convert UF₆ to a stable form such as an oxide. In the event it is converted into plutonium in the future, fabricating the breeder blanket or the fuel and recovering plutonium from spent fuel or the blanket for reuse would be done as part of the plutonium fuel cycle. In this evaluation, UF₆ conversion to a stable form for storage is considered.

Processes to convert UF₆ to stable forms such as oxide or metal have been used commercially and environmental impacts are reasonably well known. Current incentives to contain material, to minimize effluents, to recover and recycle wastes, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

Siting a conversion facility would influence transportation issues. Siting a conversion and oxide storage facility adjacent the existing UF₆ storage yards would presumably eliminate a transportation step in the foreseeable future. When transportation is necessary, e.g., to a blanket or fuel fabrication facility, the more stable form would be transported from the site.

Existing UF₆ to oxide processes may be expected to produce a powder or cake form of the oxide. Since the powder or cake may be expected to be dispersible, for long term storage, its containers would need to maintain long term integrity to prevent leakage and potential dispersion. Health and safety provisions will need to be similar to practices at currently

authorized concentrate (yellowcake) to UF_6 conversion facilities or UF_6 to oxide fuel fabrication facilities. Containment requirements for dispersible powder form of uranium would need to be about the same as for UF_6 .

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 or oxide powder from its storage vessel and subsequent atmospheric dispersion.

The current technology for converting U^{238} to Pu^{239} would be irradiation in a fast breeder nuclear reactor and recovery of the plutonium in a spent fuel reprocessing plant. That will be a long term prospect, and the environmental, health, and safety issues of the plutonium fuel cycle would not be encountered until the distant future.

7.1.24.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.24.2.1 Evaluation by Reviewer U

Storage cylinder monitoring and maintenance would be required for the DUF_6 . Occasionally, it will be necessary to remove the DUF_6 from defective or degrading cylinders and transfer the DUF_6 to new storage cylinders. During such activity, a limited amount of contaminated waste will be encountered. These wastes could be allocated to disposal at low-level radioactive disposal sites.

Disposal of defective and empty DUF_6 cylinders will be required. A small amount of UF_6 must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for the recovery of the material and disposal or storage. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.24.2.2 Evaluation by Reviewer V

The nuclear fuel produced by the breeder reactor will eventually need reprocessing or disposal. Also, residuals of low-level waste and some high level waste will require

disposal in repositories. Assuming these sites can be found, the wastes could be managed with other radioactive wastes.

7.1.24.2.3 Evaluation by Reviewer X

The waste stream from a selected conversion process will need to be evaluated. Processes proposed elsewhere state that little or no additional wastes will be produced, but that all byproduct material can be sold commercially or recycled.

Converting the dUF_6 to U_3O_8 prior to using it in a reactor fuel application means that it will need to be converted to a metal in the future. This process will result in another waste stream that will require evaluation. For storage purposes, it would be more reasonable to convert the dUF_6 directly to metal and to stabilize the metal, possibly with a plastic coating, to prevent oxidation. This would save costs in the long run, and would eliminate the source of another waste stream.

By the time a breeder economy becomes accepted by the public, new methods for handling the waste streams from reactor operation will have been developed. If a concept such as the Integrated Fast Reactor (IFR) is found to be economically feasible, problems with actinide production, plutonium proliferation, and long-term high-level reactor waste disposal will be minimized.

7.1.24.2.4 Evaluation by Reviewer Y

This very brief proposal is not explicit on waste. Unless the status quo is implemented, with no waste products, the waste products implied are those of generating a Fluorine market at competitive prices and impurity clean-up. There is nothing in the proposal here.

7.1.24.2.5 Evaluation by Reviewer Z

For extended storage periods, the degradation of the UF_6 cylinders would potentially create additional contamination, thereby creating additional low-level waste. This waste would be of the same type as currently present.

A UF_6 conversion (to oxide or metal) facility would produce some radioactive effluent and radioactive waste. The solid radwaste would be expected to be transported to a regional low-level radioactive waste burial facility.

Conversion of UF_6 to an oxide or metal form would release the fluorine, a toxic chemical. During the conversion process, the fluorine would need to be captured. It seems more likely that the fluorine would be captured as HF , a commercially valuable chemical, and unlikely to become a waste form. Solid wastes would be mainly contaminated equipment, effluent scrubber sludge, clothing, process maintenance materials and such other materials that become contaminated incidental to processing UF_6 to a more stable form. The heel, or residue, in a UF_6 cylinder that does not vaporize along with the UF_6 contains radioactive progeny of U^{238} and U^{234} , especially protactinium-234. It has much higher radioactive concentration than U^{238} or U^{234} and must be dealt with as a radioactive waste.

Storage to allow radioactive decay is usually a waste management practice for the cylinder heels.

In the long, term, conversion of the stable form to Pu^{239} would involve irradiation in a nuclear power reactor and reprocessing steps in the nuclear fuel cycle.

High waste burial costs, state and federal regulation, high costs of disposing of radioactive waste, health hazards of UF_6 and HF that is not contained, high costs of decontaminating and decommissioning facilities and surrounding land that has been contaminated, and recovery of commercially valuable HF are incentives to minimize creation of radioactive waste during the conversion of UF_6 to a more stable form or to breeder reactor fuel or blanket.

7.1.24.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.24.3.1 Evaluation by Reviewer U

Long term storage of DUF_6 can be achieved based on the extensive knowledge gained from storage over the past several decades. Such costs are expected to be significantly less than all alternatives of converting DUF_6 to another form for storage and/or underground disposal.

The future activities of using the DUF_6 for breeder reactor fuel are indeterminate with regard to either the time of need, the cost of conversion or the value of energy produced.

7.1.24.3.2 Evaluation by Reviewer V

Costs for breeders of the future are not well known. Also, the costs of competing fuels in the future cannot be predicted. DUF_6 would have to compete with natural uranium as an input to the breeder at lower cost. Also, relatively little DUF_6 would be needed for this use, so only a small portion of the inventory would be required.

7.1.24.3.3 Evaluation by Reviewer X

Long-term storage of an oxide form for future use in a breeder reactor economy is likely to be nominally more expensive than disposal. Whether all this material would ever be

used, however, may be questionable but should be investigated. Eventual sale of the oxide for fuel should cover the increased costs for storage.

If the projected long-term use is for a uranium metal, then conversion to metal rather than an oxide would be more cost effective.

The cost of converting the dUF_6 to an oxide form rather than continuing storage in the present form will be significantly greater than a long-term dUF_6 storage and monitoring program.

7.1.24.3.4 Evaluation by Reviewer Y

Maintenance of the status quo with enhanced site and off-site monitoring is probably the least cost option. Other preparations to provide recoverable U238 are on the order of several billion dollars unless some "piggyback" facilities can be utilized.

7.1.24.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Costs would be affected by the storage method, and would vary greatly between the extremes of continued storage in place and retrievable storage for retrieval at some future date. Presuming fluorine or HF were recovered, it would be commercially valuable. In the event the uranium is eventually bred to fissile plutonium, Whether eventual utilization of the uranium by conversion to plutonium cannot be assessed by this reviewer.

7.1.24.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.24.4.1 Evaluation by Reviewer U

Storage of DUF_6 has been the practice for several decades. Augmenting the current practices to assure the safety of long term storage—a century or two—appears to be reasonable by transferring the material to new cylinders whenever degradation of the cylinders is encountered. The rate and frequency of degradation is indeterminate, but expected to be easily accommodated.

Basic breeder reactor technology has been developed and research reactors operated that illustrate that the conversion of ^{238}U to plutonium is predictable and possible. The energy value of the plutonium has been defined. Large scale demonstration of breeder reactors will be necessary before they could be deployed commercially.

7.1.24.4.2 Evaluation by Reviewer V

Prototype first generation breeder reactors are currently in use outside the U. S. and could be used now in this country if licensing and permitting could be accomplished. New breeder concepts are currently being tested for future use.

7.1.24.4.3 Evaluation by Reviewer X

Several technologies for converting the dUF_6 to an oxide form or to metal have been proposed. Several of these use current technology. Some propose new technologies that reduce the waste streams. The selected technology will need to be assessed independently.

Breeder reactor technical aspects have already been demonstrated in the U.S. and abroad, and are in commercial use abroad. The IFR concept is being demonstrated on a pilot scale in the EBR-2 in Idaho with some fuel operating for 30 years without experiencing cladding leaks. EBR-2 is currently fully fueled with pyroprocessed and electrowinning fuel (U-Pu-Zr with contained actinides). Since a pure plutonium product isn't possible with this process, the fuel is self-protecting from a nuclear proliferation perspective.

7.1.24.4.4 Evaluation by Reviewer Y

Some process to provide for U238 recovery are well within the state-of-the-art. The proposal is not specific but can be interpreted to imply avoiding the U308 option since this provides for more difficult recovery. It is highly probable that Fluorine impurities in either oxide or metal will have to be very low to facilitate use in reactor fuel.

7.1.24.4.5 Evaluation by Reviewer Z

Storage of uranium hexafluoride is a mature technology. Long term storage or retrievable storage would require additional measures to protect the stored cylinders from corrosion, but no new technology would be required.

UF_6 conversion to a stable form such as an oxide is a mature chemical process. UF_6 conversion to U_3O_8 , UO_3 , and UO_2 has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel. Large scale uranium-to-plutonium breeder reactors have been constructed and operated in other nations. Spent fuel has been reprocessed to recover plutonium in the United States and in other nations on a commercial scale and by the U.S. government installations. Fuel reprocessing and fabrication of plutonium mixed oxide fuel should be considered a developed, and perhaps, mature technology.

7.1.24.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.24.5.1 Evaluation by Reviewer U

Employment for monitoring and maintaining storage of DUF_6 would be fairly constant for many decades. If the storage is performed at the present storage sites it should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable as long as the storage is carried out at the current storage sites. However, public concerns undoubtedly will be raised about long term storage of any nuclear material. Also, there will be strong objection by some members of the public to a storage mode that anticipates the use of breeder reactors in the future. Since the storage activity would be a continuation of current practices there does not appear to be a need for seeking significant public involvement or initiating a major public information program.

7.1.24.5.2 Evaluation by Reviewer V

The breeder reactor has had significant problems with public acceptance and will likely face difficulties in siting the reactors. The ongoing difficulties in finding sites for disposal of low and high level wastes will further complicate use of breeder reactors. At this time it seems unlikely that new nuclear plants can compete with conventional fuels given the costs associated with these concerns.

7.1.24.5.3 Evaluation by Reviewer X

Conversion of dUF_6 to an oxide or metal form should receive greater public acceptance than continued storage of the dUF_6 because of the greater chemical stability of the product.

Public acceptance of a breeder reactor program is not likely to occur in the short-term future. However, as the need for additional economical electricity sources develops, and as the success of breeder programs in other countries become apparent, a new public and political perspective should emerge.

7.1.24.5.4 Evaluation by Reviewer Y

When the U238 becomes a valuable resource, due to scarcity of fossil fuel or U235, public acceptance can be obtained. At this time, cost of breeder construction and operation does not lead to easy public acceptance. This is a question of social cost/benefit.

A full implementation of the explicit and implied factors in the proposal suggest local employment and development ranging from modest for nominal status quo to several billion dollars and several hundred employees for extensive defluorination into oxide, metal, or carbide storage facilities.

7.1.24.5.5 Evaluation by Reviewer Z

Concerns about the long term storage of the depleted uranium cylinders is the factor which prompted the DOE to initiate this action.

Concerns about international proliferation of plutonium production and potential diversion of it into nuclear weapons has resulted in a U.S. government policy prohibiting spent fuel reprocessing and recovery of plutonium. This federal policy would have to be reversed in order to be viable.

7.1.24.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.24.6.1 Evaluation by Reviewer U

Defining the potential energy value of depleted uranium is an important factor. According to this recommendation there is a large potential energy content and a possible need for depleted uranium at some future point as an energy resource. A prudent activity at this time may be to define the potential energy value in a realistic manner for public education and understanding. A reasonable time period for storage should be defined in anticipation of eventual use—one or two centuries. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the DUF_6 to U_3O_8 in the near future, with associated impacts.

This recommendation includes a suggestion that ability to recover the ^{238}U in the future should be an evaluating factor. Recovery from stored DUF_6 would be readily achieved. However, if the DU is declared to be a waste material and disposed of in deep underground repository, it would not be easily recovered. Also, using DU in shielding application for high level waste would preclude easy recovery.

7.1.24.6.2 Evaluation by Reviewer V

See General Comments.

7.1.24.6.3 Evaluation by Reviewer X

None.

7.1.24.6.4 Evaluation by Reviewer Y

None.

7.1.24.6.5 Evaluation by Reviewer Z

The potential future use of the depleted uranium for the production of breeder blankets for breeder reactors should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.1.24.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.24.7.1 Conclusion by Reviewer U

Recovery of ^{238}U for use in producing plutonium fuel for breeder reactors appears to be a reasonable and appropriate application for DU. The timing of doing so is indeterminate at this point. While not expected to be applicable within the next few decades, it may well be needed within the next one to two hundred years. The very large potential energy resource of DU and the ability to some day extract that energy should be a significant evaluation factor when considering the management of and disposition of depleted uranium.

Storage of DUF_6 has been accomplished for several decades. It does appear reasonable to be able to monitor and maintain safe storage of DUF_6 for a long term period. Recovery of ^{238}U from some other recommended uses for depleted uranium, such as DUCRETE or shielding for high level waste disposal, would not be achievable.

The organization providing the recommendation in Document #25 has considerable knowledge in the potential use of depleted uranium as an energy resource.

7.1.24.7.2 Conclusion by Reviewer V

Using DOE criteria for reasonableness, this option would not be considered viable for inclusion in the program. The quantities of DUF_6 used would be too small and the problems with public acceptance and siting would be significant. This is not to say that DUF_6 could not be used for this purpose in the future if the technology develops and the need arises.

7.1.24.7.3 Conclusion by Reviewer X

Conversion of dUF_6 to oxides for long-term storage rather than disposal would preserve the option to use the uranium in future reactor applications while rendering the material safer than in its present form. However, conversion to uranium metal that is surface stabilized to prevent oxidation would provide a directly usable form that requires less storage space. Production of HF and HFC products during the conversion process would alleviate the costs.

Use of the ^{238}U in an FBR economy will require only 2% of the current inventory for the initial fuel loads in a 100-FBR economy, something not likely to occur for more than 100 years from now. Reloads will require only about 2% of this amount (0.05% of the current inventory). Thus, continuing production of fuel for current LWR operation will provide more than adequate amounts of ^{238}U , and use of the dUF_6 in other applications will still need to be considered to utilize any significant amounts of what is currently available.

7.1.24.7.4 Conclusion by Reviewer Y

This very brief proposal implies a very reasonable situation; that of providing an energy resource (not unlike the strategic petroleum preserve!). All of the DUF_6 falls into this category. The decision to be made is the form of providing the resource (e.g., hard coal or soft coal). The proposal is consistent with the Atoms for Peace Program developed by the Federal Government (Eisenhower Administration) during the 1950s.

7.1.24.7.5 Conclusion by Reviewer Z

There is some merit in this option in that it recognizes the significant potential fuel source available from the Plutonium should the U^{238} be used in a breeder reactor.

7.1.25 Evaluation of Document No. 45 (Independent Technical Reviewers' No. 26)

Respondent:

Mr. Peter MacDowell
St. Helen's Trading, Ltd.
P.O. Box 911
Azusa, CA 91702-0911

818-969-0911

Description of Response:

This response indicates that responder may be interested in the depleted uranium stockpile if it can be converted into a solid form in order to recycle Naturally Occurring Radiation Material (NORM) material into shielding bricks to serve as bulk shielding medium in the construction of a second sarcophagus at Chernobyl Reactor 4.

7.1.25.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.25.1.1 Evaluation by Reviewer U

The recommendation in Document #26 entails the use of naturally occurring radioactive material (NORM) as shielding bricks in the construction of a second sarcophagus over Chernobyl Reactor #4 as well as protective barriers for debris and contaminated equipment storage facilities in the Ukraine. The effort is referred to as a commercial international joint brick manufacturing venture that is projected to be economically self-sufficient in less than eight years. Depleted uranium hexafluoride (DUF₆) is viewed within the recommendation as not meeting the requirement for solid NORM material, but if provided as a solid, could be a NORM material and potentially used for shielding brick construction. The projected quantity of NORM material that may be employed is in the range of 0.75 to 1.25 billion tons. No process details or material forms are disclosed with the recommendations. Thus, this evaluation extrapolates information from and extends the recommendation to identify a possible scenario.

DUF₆ could be converted to either an oxide or metal to provide the "solid" NORM material referenced in the recommendation. Uranium oxide, in the form of either powder or pellets could be used as aggregate within a concrete or other material matrix to produce shielding bricks. Uranium metal blocks could be used directly as shielding bricks. A large new conversion plant would be required to convert the DUF₆ to uranium oxide or to metal, including associated siting and Federal safety licensing steps for the facility. Obtaining federal approval for the transfer of DU to the Ukraine for shielding purposes is an open ended question that would be debated within a number of public forums, including the U.S. Congress. It is indeterminate whether such approval could be obtained and within what time period.

Transportation of DU in any form from the U.S. to the Ukraine would be a major undertaking that would entail export approvals in addition to domestic approval. The Nuclear Regulatory Commission would be a major player for such approvals.

Overall Federal regulation for safety could be under the existing DOE regulations for the conversion of DUF₆ to uranium oxide or to metal if it is performed at a DOE site for DOE using contractors to operate DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for the production of uranium oxides and uranium metal. Regulations governing the export of source material are defined. However, export of large quantities of DU for shielding material will be viewed as a new application that would entail detailed regulatory evaluation.

7.1.25.1.2 Evaluation by Reviewer V

This response suggests the conversion of DUF₆ to metal for transport to the Ukraine to be fabricated into bricks that would be used as shielding material around Chernobyl. The environmental health and safety impacts of various techniques for converting DUF₆ to DU metal are discussed in Documents 4-3, 8, 27 and 30. The level of impact can vary by process, however, each approach will have some effects. These hazards could include radiological and hazardous materials risks, as well as risks from potential industrial accidents (e.g. fire, explosion, injuries).

The fabrication of shielding bricks using DU metal could have some environmental effects. The preparing, blending and curing of the bricks would need careful emissions control. Control of the exposure of workers to airborne particles will be a key concern. Environmental, health and safety standards in that nation are not identified, nor are enforcement mechanisms.

Siting of a facility to convert DUF₆ to metal could be a concern. Transportation of the DUF₆ to the conversion site and the metal to the port of debarkation are not expected to cause any significant public health concerns. Risks associated with shipping are not identified. The use of the shielding material should also be carefully considered. While the environmental levels of radiation are quite high in that area, the potential for other contamination from use of the brick should be explored.

7.1.25.1.3 Evaluation by Reviewer X

The basic premise of the recommendation is that low-level radioactive material is the most efficient shielding for high-level radioactive material. So the proposal is that appropriately processed dUF_6 be provided to St. Helen's for export to the Ukraine.

In their letter, they mistakenly state that dUF_6 is a liquid. While this is not true, and is apparently a misunderstanding, dUF_6 would not be an appropriate form for their application. Conversion to either a metal or oxide form would be preferable before delivering it to them. Further information is necessary to determine whether one of these forms would be most desirable, or whether further processing into a form such as DUCRETE would be best.

For purposes of this review, it will be assumed that either U_3O_8 or UO_2 would be the best form for delivery. St. Helen's could then either export it directly for further processing in Kiev, or could manufacture DUCRETE bricks before export. Presumably, an oxide form would be most useful, having the potential for producing a larger volume of shielding material, and having a lower specific activity, approaching the limits established for low-level radioactive waste (LLRW). The most economical alternative would be to ship the oxide to Kiev for further processing.

The primary environmental, health, and safety considerations would be in the conversion of dUF_6 to an oxide form. No unusual additional concerns should be anticipated in the manufacture of DUCRETE, or if the oxide is to be shipped directly, in the packaging for shipment.

Any plant preparing material for shipment would have to be licensed by the NRC and would have to comply with NRC, OSHA, and DOT regulations. Further, any material prepared for export would also have to comply with international requirements, including those of each country through which it must travel.

Since external radiation hazards from U_3O_8 or UO_2 handling are generally not a major concern, packaging of the oxide product for safe shipping as a toxic chemical would be the primary concern. Toxic materials are routinely shipped on the oceans.

7.1.25.1.4 Evaluation by Reviewer Y

The proposal deals with administrative arrangements and end uses of NORM (naturally occurring radioactive material). The proposal does not deal with the process for reaching solid material NORM that is desired. The proposer concludes that the DUF_6 is liquid! The proposer concludes that the DUF_6 does not meet their criterion for acceptance. The proposal also includes a premise that "low-level radioactive material is the most efficient shielding for high level."

While the prospect of using domestic DUF_6 for a new shield for Chernobyl #4 is interesting, it would seem that overseas DUF_6 might be a more logical candidate.

Worker and public safety would have to be considered for the process of turning DUF₆ to NORM. Depending on where conversion takes place, Fluorine and other metal byproducts would have to be considered, particularly if DUF₆ is classified as waste domestically. Obviously, if domestic entities are involved in the shielding of overseas activities, the question of liability for safety and health needs clarification for transportation and end use.

7.1.25.1.5 Evaluation by Reviewer Z

Mr. MacDowell notes that St. Helen's Trading, Ltd. is interested in obtaining Naturally Occurring Radioactive Material (NORM) (solids only) for export and recycling at Natalka/Katrina for use as shielding material for Chernobyl Reactor #4. No additional specifications were provided for the form of the solid material.

Selection of this option would require conversion of the material to either an oxide or metal. Processes to convert UF₆ to stable forms such as oxide or metal have been used commercially and environmental impacts are reasonable well known. Current incentives to contain material, to minimize effluents, to recover and recycle wastes, and to plan for decommissioning would be expected to cause more containment and consequently fewer environmental, safety, and potential health impacts than experience to date.

Siting a conversion facility would influence transportation issues. Siting a conversion and oxide storage facility adjacent to the existing UF₆ storage yards would presumably eliminate a transportation step. When transportation is necessary, the more stable form would be transported from the site.

Any facility handling and processing UF₆ will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF₆ or oxide powder from its storage vessel and subsequent atmospheric dispersion.

7.1.25.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.25.2.1 Evaluation by Reviewer U

Waste streams would entail those associated with a conversion plant for the production of uranium oxides and/or uranium metal from DUF₆.

An assumption is made that AHF would be recovered during the conversion of DUF_6 to uranium oxide or to uranium metal. There is reasonable demand for AHF in the U.S., several times that of the recoverable AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Chemical cleaning of empty DUF_6 cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.25.2.2 Evaluation by Reviewer V

The waste issues associated with conversion to DU metal are discussed in the documents listed above. In most cases, significant recycling occurs and the wastes that are generated can be disposed of in low-level waste facilities. This disposal capacity may be a significant issue. The use of the DU metal in the bricks provides recycling of material that is otherwise a disposal problem.

7.1.25.2.3 Evaluation by Reviewer X

The wastes of concern would primarily be from the selected conversion process.

This recommendation offers a unique alternative to direct disposal of the material in a facility in the U.S. Establishing such a facility would entail an arduous licensing process involving extensive public hearings and likely opposition. Rather than converting the dUF_6 "problem" to a different problem, this recommendation offers a solution that would convert a waste product to a useful commodity. Further, the entire unneeded inventory of dUF_6 could be consumed by this application, and no wastes would be generated.

7.1.25.2.4 Evaluation by Reviewer Y

The use of NORM as a shield will minimize waste principally to conversion products and possibly Fluorine, pending market remuneration relative to byproduct production and purification costs.

If NORM is a metallic material, waste byproducts are minimal. If NORM is ceramic or something like DUCRETE, some unique wastes may be created but of significantly lesser magnitude than the DUF_6 . It is possible that the NORM material may be candidate for recycling for its U238 content.

7.1.25.2.5 Evaluation by Reviewer Z

A UF_6 conversion (to oxide or metal) facility would produce some radioactive effluent and radioactive waste. The solid radwaste would be expected to be transported to a regional low-level radioactive waste burial facility.

Conversion of UF_6 to an oxide or metal form would release the fluorine, a toxic chemical. During the conversion process, the fluorine would need to be captured. It seems more likely that the fluorine would be captured as HF, a commercially valuable chemical, and unlikely to become a waste form. Solid wastes would be mainly contaminated equipment, effluent scrubber sludge, clothing, process maintenance materials and such other materials that become contaminated incidental to processing UF_6 to a more stable form. The heel, or residue, in a UF_6 cylinder that does not vaporize along with the UF_6 contains radioactive progeny of U^{238} and U^{234} , especially protactinium-234. It has much higher radioactive concentration than U^{238} or U^{234} and must be dealt with as a radioactive waste. Storage to allow radioactive decay is usually a waste management practice for the cylinder heels.

7.1.25.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.25.3.1 Evaluation by Reviewer U

Conversion of DUF_6 to oxides or to metal would entail costs significantly greater than the value of recovered usable HF. However, this conversion cost may be required at some time in the future for eventual disposal of DU if it is determined that uranium oxide is the proper form for disposal. Using uranium oxide in the production of shielding bricks or the use of uranium metal blocks for shielding would then entail added cost of processes to provide the proper aggregate sizes and the cost of producing bricks. Special controls would be required to contain the uranium oxide aggregate during the construction of bricks. Conventional aggregate materials for the construction of concrete shielding structures are low cost sand and gravel with limited need for environmental containment control. Substituting uranium oxides for the conventional low cost aggregates will result in much higher cost. Thus, the only advantage of using DU is where applications that require shielding also are space or weight limited, this is not the case at Chernobyl.

Cost of fabricating uranium metal blocks for shielding can be estimated within reasonable limits based on existing technology. Undoubtedly, new lower cost processes would be developed for the production of very large quantities of uranium metal blocks. Such future technology costs are anticipated to be considerably less than associated conventional technology. However, the cost of producing uranium metal bricks will probably be higher than other shielding materials.

7.1.25.3.2 Evaluation by Reviewer V

The costs of converting the entire inventory to DU metal could be over \$3 billion depending on the conversion method selected. Beyond the conversion costs for DU metal, it is not clear how much the transportation might cost. The cost of fabrication would be covered by the Ukraine. The disposal costs that might be attributable to the disposal of DU metal, or products thereof, would not be incurred with this option. The costs are early estimates and need further clarification.

7.1.25.3.3 Evaluation by Reviewer X

The cost for this alternative would be in the conversion of dUF_6 to an oxide form. This has been estimated to range from about \$2 to \$4 per kg of uranium, or \$1.5 to \$3 billion. It's not clear whether some or all of this could be retrieved by selling the material to St. Helen's. The recommendation states that the Ukrainian agencies expect to receive the NORM at no cost. No information is provided on who pays for the processing or shipping. It's also not clear whether no cost would be for the dUF_6 or the oxide. It's suggested by the statement that dUF_6 "does not meet our basic criteria of acceptable material."

However, even if DOE must absorb the cost of conversion, the financial and emotional costs of disposal of the oxide as waste would be avoided.

7.1.25.3.4 Evaluation by Reviewer Y

Major costs (~several dollars per pound) may be anticipated for the process (not part of the proposal) to turn DUF_6 into a useful form of NORM for the intended application. Shipping requirements may be unique. Byproduct sales (Flourine) will be on the order of one or two dollars per pound. It is unlikely that the Ukraine would commit any financial support for the process to create NORM; the only source for such funds in this application would have to come from the U.S.A. government.

7.1.25.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities needed to execute this alternative. Presuming fluorine or HF were recovered, it would be commercially valuable.

If this option were selected, there would be no disposal costs associated with burial or long-term storage.

7.1.25.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.25.4.1 Evaluation by Reviewer U

Construction of shielding structures using DU appears to be an extrapolation of known technology. However, the production of large quantities of DU cement or metal blocks for shielding would require the development and demonstration of new processes that minimize both waste materials and achieve a lower cost of production.

Brick structures using conventional aggregate materials is fully mature. Substitution of uranium oxides as the aggregate requires the development of techniques to achieve the appropriate aggregate sizes, distribution within the matrix, consistent uniformity, defining structure strength and establishing controls during construction to assure containment of the uranium oxides. Brick construction is a rough and tumble type of activity that does not entail the need for highly skilled personnel. Using uranium oxide aggregates, where substantial contamination controls would be required, would entail a culture change of significant magnitude in the production of bricks and the construction of structures with uranium containing materials. This significant change in how materials must be controlled and structures constructed will be difficult to achieve.

7.1.25.4.2 Evaluation by Reviewer V

Some technologies for producing DU metal are commercial while others are within reasonable development range. The use of DU metal in bricks should not raise any significant technical issues.

7.1.25.4.3 Evaluation by Reviewer X

While the conversion of dUF_6 to oxide forms is considered a mature technology, production of DUCRETE is still undergoing preliminary testing.

7.1.25.4.4 Evaluation by Reviewer Y

Without specifics on NORM (e.g., metal, oxide), it is difficult to judge technical maturity. Violating the premise that low-level activity material is best for shielding high-level

material, the potential for using DUCRETE (other proposals) might make some sense in the NORM applications cited (e.g., Chernobyl 4).

The reason the Chernobyl 4 sarcophagus is deteriorating is the quality of its construction. Without quality control and R&D on new products in that construction, history might well repeat itself.

Adequate time for requisite R&D seems available since several years of converting DUF₆ to NORM, whatever its form, are anticipated.

7.1.25.4.5 Evaluation by Reviewer Z

UF₆ conversion to a stable form such as an oxide is a mature chemical process. UF₆ conversion to U₃O₈, UO₃, and UO₂ has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel. No specific technology is associated with the transfer of the stabilized material.

7.1.25.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.25.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF₆ to U₃O₈ or uranium metal and HF would be at a steady level for a couple of decades if all of the existing DUF₆ is converted. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility.

Production of bricks containing uranium oxide would likely be performed at the site where the bricks would be used. This would undoubtedly be near the Chernobyl site in the Ukraine.

Performing uranium processing operations at one or all three of the existing sites where DUF₆ is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is

obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

Shipping DU out of the U.S. as a means of effective disposal may be attractive to U.S. citizens. However, citizens in the Ukraine are likely to object to becoming the dumping ground for U.S. radioactive materials. International public interest organizations are expected to become actively involved in such a concept and vigorously oppose.

7.1.25.5.2 Evaluation by Reviewer V

A conversion plant could constitute a significant industrial construction and operation project with direct and indirect impacts, if most of the inventory is converted to DU metal. If existing plants are used or only a small portion of the inventory is used, impacts would be mitigated. The conversion facility may arouse public scrutiny, but is likely to be accepted. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities. Traffic from uranium transport to and from the various conversion sites and ports would increase.

7.1.25.5.3 Evaluation by Reviewer X

It might seem that giving the oxide material to another country would solve any domestic acceptance concerns. However, opposition to giving this material to the Ukraine could be significant. Opposition groups would site the low-level competence in the former Soviet Block countries, and in particular, the low-level of competence demonstrated with their power reactor program.

Since no disposal facilities would be required in the U.S., local public acceptance of this alternative would be expected to be high.

7.1.25.5.4 Evaluation by Reviewer Y

Even though the premise for NORM may not be sound (e.g., compare Pb, UO₂ as shielding material!), the potential for public acceptance is great; certainly in the Ukraine and the rest of the world. Process employment could involve 200-300 people plus those involved in construction of the shields from NORM (could be ~200 workers). Regional development would be significant in the Ukraine or small communities for process facilities and operations.

7.1.25.5.5 Evaluation by Reviewer Z

This reviewer has no specific information regarding the socioeconomic impact of this option. It is anticipated that there would be public support for this option since it addresses the concern of long-term storage of the UF₆ and also supports a technical solution to the shielding problem at the Chernobyl Reactor.

7.1.25.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.25.6.1 Evaluation by Reviewer U

The depleted uranium does contain potentially recoverable energy values. While the economic value of the energy resources is insufficient to recover the values in the near term, economic recovery may be achieved at some future date--possibly one hundred years or more hence. Thus, an important factor may be an assessment of potential energy values recoverable through isotope separation or as fertile material in future energy programs. Shipping the DU to the Ukraine for use as shielding material essentially precludes the possibility of ever being able to recover the potential energy value at some future date.

7.1.25.6.2 Evaluation by Reviewer V

See General Comments.

7.1.25.6.3 Evaluation by Reviewer X

The recommendation states that approximately one billion tons of NORM is produced annually by the oil/gas, mining, geothermal, coal-fired utilities, and fertilizer industries, and that approximately 60 billion tons of NORM contaminated material is already in the U.S. inventory. The proposed project would only consume approximately one billion tons. Thus, even though depleted uranium oxide would be an ideal shielding material, the projected amount to be available from a conversion process would be a small amount of the total material available to the Natalka Project. (534,000 MT of dUF_6 is equivalent to 361,000 MTU, yielding 426,000 MT of U_3O_8 , which at 3 gm/cm^3 (not compacted) yields 5 million ft^3 (From RFR#4 report, pg. 3)).

7.1.25.6.4 Evaluation by Reviewer Y

It is conceivable that this might be a low-risk activity that could preempt Ukrainian and Russian staff from supporting the Iranian nuclear power development program. This reviewer doubts whether Secretary of State, Warren Christopher, had this in mind but it could fit his stated criteria (circa April 1995). It is also conceivable that insertion of the AVLIS process would preclude potential for someone else to extract U^{235} from DUF_6 .

7.1.25.6.5 Evaluation by Reviewer Z

This option would require approval of international transfer of licensed material. This should not present any significant obstacles since the material is a low specific activity and has no strategic value.

7.1.25.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.25.7.1 Conclusion by Reviewer U

Using DU as shielding material is an appropriate application. However, the recommendation of using U.S. DU for shielding at the Chernobyl reactor appears inappropriate. There is an excess of DU within the FSU countries that could be considered and used for such an application. Also, the referenced multi-billions of tons of other NORM produced by the oil/gas, mining, geothermal, coal-fired utilities and fertilizer industries would appear to be lower cost for the proposed activity than the use of depleted uranium.

Unfortunately, the proposal and recommendation has the appearance of an intellectual scam perpetrated on the Ukraine. The approach appears to seek legitimacy through the establishment of a series of internationally related intellectual organizations with California State University involvement. While the underlying need to shore up the Chernobyl reactor is real, the recommended scheme appears to be a disturbing disservice.

Using DU for shielding material at the Chernobyl reactor may be technically attractive. However, the complicated arrangement provided with the recommendation should not be supported. With anticipation of considerable international public interest group involvement and opposition, the approach of using U.S. DU for shielding at Chernobyl should not be encouraged.

The organization making the proposal and recommendation in Document #26 does not appear to have been responsive to the request for management and disposition of DUF_6 .

7.1.25.7.2 Conclusion by Reviewer V

The idea of using DU metal for shielding bricks at Chernobyl is certainly technically feasible. The political implications of this option need careful consideration. The cost to convert the DU to metal would be significant, as would the environmental effects. There do not appear to be any major environmental, safety, health or siting concerns that would rule out this option, however. In general, it would appear that this option is reasonable enough to deserve further attention.

7.1.25.7.3 Conclusion by Reviewer X

This recommendation offers an attractive alternative to domestic disposal of uranium oxide. It could utilize the entire inventory of converted dUF_6 probably as fast as it could be converted. It also would preclude both the financial and emotional costs of disposal.

The primary question would be whether transfer to the Ukrainian agencies would assure safe and prudent handling of the material and whether such transfer would be acceptable to domestic opposition groups.

This option would not produce additional waste streams, but would actually help to solve a current environmental problem with a high-level waste site.

7.1.25.7.4 Conclusion by Reviewer Y

The Option meets all criteria for reasonableness except for the one on consistency with other DOE or Federal programs. If it turns out that NORM is metallic, oxide, or DUCRETE, the consistency criterion could be met. However, short of an international initiative through the State Department and IAEA or OECD, there would be strong incentives to spend much if not most of the process money in the USA.

7.1.25.7.5 Conclusion by Reviewer Z

This option has merit. It provides an option of disposing of a significant amount of stored, depleted uranium. The only costs associated with this option would be those associated with reduction of the UF_6 to a more stable form, since there would be no costs associated with long-term storage or burial. This option should be considered for material in excess of the amounts for which other commercial applications are identified.

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7.1.26 Evaluation of Document No. 49 (Independent Technical Reviewers' No. 27)

Respondent:

DOE Recommendation

Package 5

Continuous Metallothermal Reduction to Uranium Metal

Description of Response:

This response recommends replacing the batch reduction process with a continuous metallothermal reduction process. The depleted uranium hexafluoride (UF_6) would be reduced to uranium tetrafluoride (UF_4) which would then be reduced to uranium metal using a continuous process. This process is being developed to provide a uranium/iron (Fe) metal alloy for the Uranium-Atomic Vapor Laser Isotope Separation (U-AVLIS) process.

7.1.26.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.26.1.1 Evaluation by Reviewer U

Document #27 provides information on a unique process for the continuous production of an iron-uranium metal alloy from uranium tetrafluoride (UF_4), as an alternate to the batch process that has been used for several decades. The unique process is being developed to provide a uranium-iron metal alloy as feed stock for the Uranium-Atomic Vapor Laser Isotope Separation (U-AVLIS) process. No other recommendations are provided for the use of depleted uranium metal produced by the unique process. The primary advantage of the uranium-iron alloy is to provide a material with a lower melting temperature than pure uranium to permit a lower operation temperature for the U-AVLIS process. The five percent iron alloy is near the eutectic point for these two metals and provides a lower melting point than that of either metal alone. This makes the metal vaporization step of the U-AVLIS process easier to achieve, although the alloy is more brittle than pure iron or pure uranium.

Using depleted uranium (DU) as feed stock for additional uranium enrichment with the U-AVLIS process appears possible, but may not be practical within a time frame of several decades. The U-AVLIS process has been under development for over twenty years without achieving necessary results to permit the process to be deployed commercially. The only new uranium enrichment plant that has proceeded through licensing in the U.S. during the past fifteen years, employs the developed centrifuge process.

While the AVLIS process is currently being evaluated by the new U.S. Enrichment Corporation as a potential process for future enrichment activities, a decision to deploy the technology has not been made. U-AVLIS may achieve the goal of being a dependable low cost means for enriching uranium. However, a major pilot plant operation would be required to prove out the technology to be employed on a commercial scale. Relatively large quantities of good grade uranium ore have been discovered in Canada and Australia that can be developed to provide low cost natural uranium feedstock for uranium enrichment, equivalent to the projected needs for many decades. Stripping ^{235}U from the DU would be higher in cost than obtaining the low enriched uranium from natural uranium. To deploy this use, two new facilities would be required; 1- conversion of DUF_6 to metal and 2- AVLIS enrichment plant.

However, this unique process for the continuous production of uranium metal has several advantages over the prior AMES batch process and appears to be applicable to the production of uranium metal for applications other than feed stock for U-AVLIS. Lower production cost and a significant decrease in the quantity of associated waste materials appear to be advantages of this new process. The use of this technology is advantageous only if there is a significant demand for uranium metal products or if a determination is made that DU is a waste that should be disposed of in the form of uranium metal. A large material volume reduction is achieved with the conversion of DUF_6 into uranium metal.

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium metal will require the design, construction, operation and eventual decommissioning of at least one new facility. The continuous process should require less costly production facilities than the prior processes. The first step of converting DUF_6 to UF_4 would be the same as the original process. DUF_6 is reduced with hydrogen on a continuous basis in a tower reactor vessel to produce the UF_4 . The unique feature in this document is the second step performed within a calcium chloride salt bath to convert the UF_4 to a uranium metal alloy. This replaces the conventional production step of batch metallothermic reduction to produce "derbys" of uranium metal. The information package does not indicate the capture of fluorine from the first step and indicates the fluorine from the second step would be retained as magnesium fluoride (MgF_2) for disposal after uranium leaching.

Uranium metal when freshly cleaned has a silver appearance that oxidizes quite rapidly to form a black oxide surface. Chips and shavings of uranium metal are pyrophoric and will readily burn in air. Thus, small pieces must be protected with an inert atmosphere, or converted to an oxide for stability. The uranium blocks cast from the continuous process may be stored in sealed containers for long term storage or processed further into a desired uranium metal product.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

An assumption is made that the first step of converting UF_6 to UF_4 would include the recovery of HF as anhydrous HF (AHF). AHF, a material with considerable demand in the U.S. could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming the new facility is located on one of the sites where the DUF_6 is now stored. DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transport of UF_6 is an ongoing element of nuclear fuel supply. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

The conversion process is amenable to a closed system, eliminating a requirement for disposal of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a stand alone uranium metal production facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium metal could be stored on the surface at the present locations of the DUF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing, pyrometallurgy operations and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity and metal processing could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new

regulations. NRC regulations are in place for the licensing of uranium enrichment using the centrifuge process. Additional regulatory clarification appears to be needed for the operation of an U-AVLIS facility.

7.1.26.1.2 Evaluation by Reviewer V

The environmental, health and safety concerns regarding this option will parallel those experienced in the uranium metals industry and the nuclear fuels industry, in general. The higher operating temperatures of this process may increase the risk of this conversion process over the current Ames process. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen. This is particularly true for the alternative slag processing options. Careful siting and design taking into account public concerns about these facilities will be needed.

7.1.26.1.3 Evaluation by Reviewer X

Siting and transportation are related by two concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site, and
2. Transportation of the AHF product to the end user.

Even though a site is already licensed for handling some materials, license approval for handling large quantities of dUF_6 feedstock, metal product, and AHF would still be required. Thus, a comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations. The licensing process will be subject to public hearings and comment.

The above two concerns need to be evaluated from both cost and safety aspects. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to or on a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport), to insert them into overpacks prior to shipping, or to transfer the dUF_6 to 2½ ton cylinders as is currently done for transportation might be required. Special measures may need to be developed for handling cylinders in overpacks.

The second concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So both concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

Current development work on the CMR process is being done at Y-12. This would be a reasonable location for a production-scale conversion plant. Another potential location would be the current NMI site near the Barnwell LLRW disposal facility. This site has considerable experience converting dUF_6 to metal using the Ames process. NMI has been transporting dUF_6 from the GDPs to their site apparently without incident.

7.1.26.1.4 Evaluation by Reviewer Y

It is unlikely that any new or unreviewed E, S&H issues will emerge from the continuous versus batch (Ames) process. The higher temperature operation with Uranium vs. Uranium-Iron alloy will exacerbate some detailed concerns.

The major concern relates to ability to rapidly terminate the continuous operation when desired in the presence of a major exothermic reaction.

7.1.26.1.5 Evaluation by Reviewer Z

This proposal, Continuous Metallothermic Reduction (CMR) to Uranium Metal, was developed as Information Package 5. The process described uses UF_4 as feedstock for a continuous feed process for conversion to uranium metal. This would therefore require a separate process for the reduction of UF_6 to UF_4 . No information was provided regarding the process or location for the first phase reduction process.

Neither process would present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated. No site location was specified.

7.1.26.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.26.2.1 Evaluation by Reviewer U

Disposal of DU metal after being stripped of U_{235} with the U-AVLIS process would entail the same disposal issues as imposed for disposal of DU metal without stripping. The

difference in the total amount of material would be very small--less than three percent. While it may be acceptable to dispose of metal in a disposal facility, regulations may require disposal to be in the form of uranium oxide. This will not be resolved until disposal decision's are made.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Magnesium fluoride is generated as a by-product of the process and it will undoubtedly contain some uranium. This may be disposed of as a waste or receive further processing to recover both the fluorine and the magnesium in usable chemical forms.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The first step of the process, converting DUF_6 to UF_4 will result in the removal of nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost.

7.1.26.2.2 Evaluation by Reviewer V

The Ames process currently produces large amounts of MgF_2 . The continuous process promises to significantly reduce the leaching of wastes which will be required. This would make disposal of wastes much easier, safer and less expensive. For waste reduction, as well as cost considerations, alternative processing of wastes is needed. The two alternatives for leaching discussed would decrease the volume of low-level wastes needing special handling. The potential to recycle more anhydrous HF and uranium need better definition and markets need to be identified.

7.1.26.2.3 Evaluation by Reviewer X

Bench scale tests of the CMR process have resulted in MgF_2 slag having lower levels of contamination than the Ames process. If the contamination levels are low enough (less than 100 to 200 ppm), the slag can be dealt with as non-radioactive material, thus saving the cost of LLRW disposal. Other materials would be recycled into the process.

The current bench tests have been done at temperatures that result in the uranium being contaminated or mixed with iron. This product is the appropriate feedstock for the AVLIS process. To produce uranium for the commercial marketplace, the iron would have to be removed. This has the potential for an additional waste stream, or the process could be refined to operate at a higher temperature that would result in higher purity uranium.

A significant advantage of this process is the elimination of the contaminated magnesium fluoride slag, currently being disposed of in LLRW disposal facilities. Elimination of this waste stream would make room in these facilities for waste from other generators such as hospitals, universities, and small industry.

The uranium metal will be available for sale to commercial industries or may be disposed of in a deep burial facility.

7.1.26.2.4 Evaluation by Reviewer Y

This looks like a low waste option with low Uranium contamination of MgF_2 . While not detailed in the package, there must be some gaseous or vapor release that needs treatment or condensation. This will be true if unalloyed Uranium is used at higher temperatures.

7.1.26.2.5 Evaluation by Reviewer Z

The reduction of UF_6 to UF_4 is a dry process that produces very little waste other than low-level waste from routine plant decontamination activities and equipment maintenance and replacement. Anhydrous HF is produced during the reduction process, which has a ready market in the United States. Some small amount of "off spec" material may be generated that does not meet the feedstock requirements for the next phase of the process. This material must be either re-processed in order to bring it up to specification or disposed of as low-level waste.

The CMR process produces contaminated MgF_2 slag, which must be either disposed of as low-level radwaste or decontaminated to below release levels and disposed of in a sanitary landfill.

7.1.26.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.26.3.1 Evaluation by Reviewer U

Relatively low cost estimates for uranium enrichment have been made by the research organization developing the U-AVLIS process. However, the overall cost of obtaining enriched uranium from DU through the use of U-AVLIS is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

The cost of converting DUF_6 to uranium metal should be significantly lower with the continuous metallothermic reduction process than the present process and it should provide a cleaner slag for disposal. However, the actual cost of such an operation can not be defined until considerable development work has been completed. Also, the current development is for the production of a uranium-iron alloy. If a pure uranium metal is required the operation probably could be achieved by using a higher operating temperature.

7.1.26.3.2 Evaluation by Reviewer V

No costs are presented for the continuous process. It is hypothesized that the continuous process will reduce capital and operating costs and require less land, but no estimates of the cost to process per kgU are offered. Information must be collected on the real cost to DOE of this alternative before any serious evaluation can be made. Similarly, the current market production seems to be 7,000 tons per year. Conversion of even a part of the inventory would greatly expand the supply to a market where prices are very sensitive to demand. It is not clear that markets exist for this material. A better analysis of potential users needs to be made. Another cost item of concern for this option remains the cost of disposal. Even with reduced quantities, the cost of packaging, transport and disposal can be significant. Other by-products such as HF may help offset some costs, but markets and prices need to be clarified.

7.1.26.3.3 Evaluation by Reviewer X

Costs for conversion are not provided directly. However, derivation using numbers from other sources suggests that conversion costs, excluding disposal of the uranium which would presumably be entirely consumed in the marketplace, could be as low as \$1.50/kgU. Thus, the total would be less than \$1.5 billion, and possibly less than \$800,000.

This leaves some 361,000 MT of depleted uranium to either dispose of or sell. If a market can be developed, the whole process could turn profitable at a sale price as low as \$3.00/kgU.

7.1.26.3.4 Evaluation by Reviewer Y

The experience gained from the Uranium/Iron alloy process for AVLIS would be a valuable benchmark for extrapolations. In its absence, Ames process data would suggest ~\$10/Kg (~\$5/lb). Any emerging quality issues would raise costs somewhat. However, limited experience suggests such add-ons might be obviated, particularly for alloyed Uranium; this may be a favored option!

7.1.26.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. The anhydrous hydrofluoric acid recovered it has commercial value. As noted in the Information Package, the CMR

process would have a lower capital investment and lower operating cost than the current technology, and would therefore result in lower cost per unit converted. Also, the uranium metal is assumed to have a commercial value for use as shielding material, etc.

It is also assumed that the magnesium fluoride produced from the reduction process could be processed to produce AHF and magnesium sulfate, which would also have commercial value.

7.1.26.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.26.4.1 Evaluation by Reviewer U

Conversion of DUF_6 to uranium metal with the continuous metallothermic reduction process will require considerable development to determine whether it is practical and to define operating characteristics and conditions needed for large scale operation. While considerable development has been completed for the production of uranium-iron alloy as feed stock for the U-AVLIS uranium enrichment process; practicality is yet to be determined. Obtaining enriched uranium from DU should be considered as a long term possibility, not a near term use.

If DU is declared to be a waste and the metal form determined to be the form for disposal, then the unique process of this document may be an appropriate step in the conversion to the metal form. The uranium-iron alloy should be as acceptable as pure uranium metal for disposal. However, if DU is converted to metal for other specific applications, it may be necessary to produce a pure uranium metal rather than the uranium-iron alloy. Considerable development efforts will be required to determine if the process can produce pure uranium metal because it will require operation at a higher temperature.

Development of processes to recover uranium, fluorine and magnesium from the process slag appear to be needed to minimize the waste.

7.1.26.4.2 Evaluation by Reviewer V

This process is in the early stages of development with two to three years needed to reach pilot scale. No projection of commercial readiness is given.

7.1.26.4.3 Evaluation by Reviewer X

Conversion of dUF_6 to dUF_4 is a standard industrial practice, as is the use of magnesium to produce uranium metal and magnesium fluoride. Conversion to dUF_4 is the first step in the CMR process.

An R&D effort examining the CMR process relative to AVLIS is apparently currently under way. However, several technical questions remain to be investigated, and are estimated to require 12 to 24 months and \$2 million to be answered. The CMR process has only been bench tested. The technology to convert magnesium fluoride to AHF and magnesium sulfate has never been practiced commercially.

Current conversion plants would probably have to be enlarged to handle DOE's long term goal for timeliness.

7.1.26.4.4 Evaluation by Reviewer Y

The behavior of unalloyed Uranium is, at best, uncertain. The Uranium lattice is complex. The behavior under irradiation is extreme; the behavior due to thermal cycling is non-uniform. It is not obvious that the preferred form of DU metal is unalloyed. The AVLIS process features Uranium/Iron alloy. One form of nuclear breeder reactor requires core and blanket material to stabilize/minimize irradiation growth with diluent metals. The presumption that the metal form be unalloyed from the continuous process may not be as sound as stated. While high density desirability for some applications (e.g., shielding, ballast) is apparent, the arbiter of lower cost for somewhat lower densities can well rule. Usually, lower cost can be the result of lower temperature operations.

The AVLIS feedstock development is at small-scale status and looks promising.

Outstanding issues focus around crucible (graphite) lifetime in the high-temperature environment. This could be GO/NO GO on economics.

Impurity control has not been demonstrated at either high or low temperature; requirements should be dictated by potential use.

While this process is largely exothermic, valuable insights of crucible performance, effluent control, and hydraulic controls might be obtained from the IFR (at ANL) and the waste treatment furnace (at SNL).

Prudent system startup is not a "given" as is not the ability to rapidly shut the system down! The operation must be demonstrated to be stable.

7.1.26.4.5 Evaluation by Reviewer Z

UF_6 conversion to UF_4 is a mature process that has been practiced commercially in the United States for many years. The CMR process is still in the pre-prototype testing phase, and is expected to take an additional 2 to 3 years before pilot system testing is ready.

7.1.26.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.26.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium metal, HF and magnesium fluoride would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. There would be a temporary increase in skilled construction employment over two to five years for construction of the facility.

Performing uranium processing operations at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

7.1.26.5.2 Evaluation by Reviewer V

The construction of a commercial scale facility capable of producing 28,000 tons of uranium metal annually would constitute an major industrial construction project. This would significantly impact communities in which it might be located. Operations would require fewer permanent employees than the conventional Ames process. In a small community there could be a significant economic stimulus to growth, especially if processes to use the metal are co-located.

The siting of such a facility may face problems with public acceptance. There is likely to be close scrutiny of the public health risks and environmental effects. Traffic, including uranium transport, to and from the site will be examined. While the proportion of low-level wastes generated by a continuous process would be reduced, the overall quantity could increase with expanded production. The LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.26.5.3 Evaluation by Reviewer X

Other sources estimate that a long term program will create over 100 jobs in a conversion plant, and additional jobs at other customer processing sites, such as at the Martin-Marietta Y-12 facility.

Construction of a larger plant would have to obtain regulatory and community approvals.

7.1.26.5.4 Evaluation by Reviewer Y

Public acceptance should not be a problem unless there is an issue of airborne effluents.

No major regional development or major increase in employment is anticipated. Collocation of this process with other related facilities (e.g., AVLIS, shield and ballast fabrication) could provide some significant employment and local development, albeit at the expense of somewhere else.

7.1.26.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.1.26.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.26.6.1 Evaluation by Reviewer U

The depleted uranium does contain potentially recoverable energy values. While the economic value of the energy resources is insufficient to recover the values in the near term, economic recovery may be achieved at some future date—possibly one hundred years or more hence. Thus, an important factor may be an assessment of potential energy values recoverable through isotope separation or as fertile material in future energy programs.

7.1.26.6.2 Evaluation by Reviewer V

See General Comments.

7.1.26.6.3 Evaluation by Reviewer X

If the CMR and slag decontamination processes are successful, they will also reduce the inventory of LLRW going to commercial/compact LLRW disposal facilities. This has nationwide implications.

The Barnwell LLRW disposal facility was the last disposal facility open to the nation's LLRW generators. It closed to non-Southeast Compact members permanently in June 1994. In late April 1995, the Governor of South Carolina suggested the facility reopen for compacts making progress toward establishing their own facilities. (His rationale is that the per cubic foot surcharge would provide significant funds for the State's schools.) This would be a temporary measure until the new sites could open.

Only the Ward Valley site in California is closer than ten years from opening, and it's currently being held up in court, the U.S. Department of Interior, and Congress. Thus, a successful significant reduction in the wastes going to Barnwell from within the Southeast Compact could help solve the LLRW problem for the rest of the country.

7.1.26.6.4 Evaluation by Reviewer Y

Without a decision on use, it may be premature to conclude that DU metal must be produced. DU/Fe is being investigated for AVLIS. It may be easier to remove iron from DU/Fe alloy and make the DU directly. These considerations should precede a decision on technology use.

7.1.26.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to uranium metal. A decision to select this option should be based on the need for the uranium metal produced. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a metallic state, including consideration of costs of future processes which may utilize the material.

7.1.26.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.26.7.1 Conclusion by Reviewer U

Using DU as feedstock for U-AVLIS enrichment steps may be appropriate within a time span of one to two hundred years when the available low cost natural uranium ore resources are depleted. Such use does not appear appropriate within the next few decades.

Development of continuous metallothermic reduction of UF_4 to uranium metal should be pursued if a demand for uranium metal is identified or if a determination is made that DU is a waste and should be disposed of as a metal. The technology probably could be developed to a point where it could be relied upon as a commercial process within a decade. If this process is to be used, additional effort should be applied to process the MgF_2 slag into a useful fluorine compound and magnesium salt.

The organization providing Document #27 is devoted to research and the development of nuclear technology.

7.1.26.7.2 Conclusion by Reviewer V

The proposal appears technically feasible in terms of process development. However, the timing, the costs of constructing and operating a plant and the markets for the uranium are unclear. The public acceptance of siting a conversion plant and the disposal of waste materials may be very problematic. Given the time uncertainty for commercial operations, this option does not seem reasonable for this program at this time. If further development of the process occurs, it could be considered for inclusion at that time.

7.1.26.7.3 Conclusion by Reviewer X

The process for converting dUF_6 to dUF_4 is a standard industrial process. But the CMR process for separating the uranium and fluoride and producing metal has only been bench tested, and the process for decontaminating the magnesium fluoride and producing salable AHF must still be demonstrated.

Capital and operating costs were not stated, but a stated goal of applying these processes is to reduce the cost of producing depleted uranium metal to make it more attractive for use in other applications. Even without sale of the depleted uranium, the total cost for conversion should be less than \$1.0 billion, well within DOE's definition of reasonable.

The ultimate solution for the metal is to develop end product uses so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

Of primary concern in the sale of the metal will be the controls necessary to assure the depleted uranium isn't randomly disposed as industrial waste when it is no longer needed. Companies currently selling uranium to private industry should be contacted to obtain information on licensing practices. It would seem that selling metal for large scale applications would provide for easier license maintenance than small scale applications. For instance, large quantities of uranium used for counterweights would be easier to track than small quantities used for wheel balancing.

Elimination of the contaminated slag waste stream from current conversion processes would free up space in various compact LLRW disposal facilities, in particular the Barnwell facility. This might enable Barnwell to receive wastes from other LLRW Compacts throughout the U.S. This facility closed to all non-Southeast Compact states in June 1994. However, the Governor of South Carolina has proposed the facility reopen to some compacts on a temporary basis. This would have a significant impact on the country's LLRW problem.

7.1.26.7.4 Conclusion by Reviewer Y

This technology is reasonable on all counts. Unfortunately, the lack of use (other than AVLIS) leaves the review in limbo. However, the prospects are good even with uncertainty on product, use, and quality.

7.1.26.7.5 Conclusion by Reviewer Z

This option has merit, and should be considered. This option has the potential for converting depleted uranium to uranium metal in a process which is more efficient and produces less waste than the current technology.

The process is based on a modification to existing technology, and laboratory testing indicate that there is potential for full scale application.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to uranium metal would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in metal form.

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7.1.27 Evaluation of Document No. 50 (Independent Technical Reviewers' No. 28)

Respondent:

DOE Recommendation

Package 6,7,8

Conversion to Ceramic UO_2 - Existing Industrial Routes

Description of Response:

This response recommends conversion of depleted uranium hexafluoride (UF_6), utilizing the same process used for converting isotopically enriched uranium hexafluoride (UF_6), to ceramic uranium dioxide (UO_2) using either a wet or dry process, wherein the UF_6 is chemically converted to a UO_2 powder and after milling, sieving, and the addition of a lubricant, the powder is compressed under high pressure into pellets.

7.1.27.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.27.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium dioxide (UO_2) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities. The processes described in Document 28 are currently being used within private industry to produce high density and high quality ceramic uranium fuel for commercial nuclear energy plants. While there are some proprietary differences between the present processes for the production of ceramic fuel, the technical differences are not significant from the standpoint of converting large quantities of DUF_6 to UO_2 . However, even small economic and environmental differences are significant when considering the processing of the large quantity of DU.

The throughput of the several existing commercial facilities total approximately 5,000 MT of UF_6 . To process all of the DUF_6 to UO_2 would require a capacity approximately six times that of the several existing production plants.

This Document indicates that production of high density pellets of UO_2 would provide a material of lower total volume for disposal and a lower volume of DUCRETE for the same radiation shielding. Only the production processes for UO_2 are discussed in the Document, not the designation of disposal or the use of DUCRETE.

UO_2 is a relatively inert chemical form of uranium (dry brown powder or high density pellets) with low reactivity and low solubility. Long term storage or the disposal of UO_2 should be acceptable within stainless steel containers. UO_2 ceramic pellets are brittle and will fracture with a hammer blow. Thus, they are not appropriate as structural materials by themselves and subject to chipping and breakage. As a substitute for stone or sand within DUCRETE, compressive strength's would be similar, but the fracture characteristics would probable differ considerably.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The wet processes as used in the commercial industry do not attempt to recover HF, rather it is disposed of as calcium fluoride. Hydrofluoric acid is recovered from the dry process as aqueous HF. An additional step could be performed to provide anhydrous HF (AHF). Recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

The wet conversion processes result in a significant volume of calcium fluoride dissolved in water. This waste stream would need to be dewatered and the solids disposed of at a low-level radioactive waste disposal sight. The dry process recovers the HF and minimizes the need for solid waste disposal. All residues could be in the form of solid wastes that may be disposed of in conventional low-level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides

or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities.

7.1.27.1.2 Evaluation by Reviewer V

It would appear from the description that the proposed ceramic pellet form of uranium would lessen the environmental hazards associated with its handling after conversion. It seems that this conversion option will be similar to existing techniques with regard to the environmental, health and safety risks. The materials provided do not indicate any significant issues associated with current use. The final high density form will reduce the amounts of material that will have to be handled but appropriate safety measures will need to be used. Some dangerous chemicals are used in some processes, but standard industrial practices should be able to control the risks.

7.1.27.1.3 Evaluation by Reviewer X

Current installed plant capacity is sufficient for meeting domestic fuel production needs. Excess capacity apparently doesn't exist. Therefore, new plant will need to be installed. Since the applications for UO_2 using depleted uranium will not require the strict tolerances for fuel production, new dUF_6/UO_2 handling facilities can probably be installed less expensively. However, the new plant will still require licensing and permitting.

Since the technology has been in place for many years, projections of process emissions can readily be predicted. It should be expected that a new plant would incorporate equipment and processes to reduce emissions and the waste stream to lower levels than present plants.

The simpler dry conversion/treatment processes are stated to have fewer waste treatment and recycle requirements.

7.1.27.1.4 Evaluation by Reviewer Y

The Package reviews three processes to produce UO_2 from UF_6 . All three have been and are being used in accordance with extant environmental and related regulations. Without

criticality constraints for DUF₆, there are no issues other than those associated with possible handling of larger amounts of material at any time in a dedicated facility. With such upscaling, assurance must be provided that the DUF and subsequent treatments are neither intentionally or accidentally "contaminated" with enriched material. It is not clear why the AUC process is used principally in Europe while the ADU process is more "universal." The AUC process produces finer oxide powders, obviating some steps in the more expensive fabrication side; this advantage seems marginal if DUF₆ is waste or used for bulk applications. If DUF₆ is a resource for dilution of either Plutonium or enriched Uranium destined for a nuclear power or research reactor, the finer quality powder may be of interest in a system where prompt negative feedback is desired or must be assured from fuel.

7.1.27.1.5 Evaluation by Reviewer Z

This proposal, Conversion to UO₂ - Existing Industrial Routes, consists of a combination of Information Packages 6, 7, and 8. General descriptions of the existing dry and wet processes are included. All of the processes discussed are standard industry practices, and have been in commercial or government operation for many years in the United States and/or Europe. All of the environmental, safety and health issues are therefore well understood.

7.1.27.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.27.2.1 Evaluation by Reviewer U

The DUF₆ conversion to UO₂ and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

Solid process wastes are encountered. Special effort appears needed to minimize the waste volume and to recover salable products from the waste stream.

There is no current use for separated depleted UO₂. Possible use in DUCRETE in the future may be achieved. The practicality of DUCRETE is yet to be determined. Eventual

disposition of DUCRETE after the useful life of the structure constructed with DUCRETE, may entail disposition in low-level radioactive sites at a high cost.

With no practical use for the UO_2 at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process discussed will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to U_3O_8 . Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost. Another use may be to cut the cylinders in half and weld flat end caps over the open end to provide upright storage containers for U_3O_8 .

7.1.27.2.2 Evaluation by Reviewer V

The highly compact nature of the processed UO_2 powder will reduce the volume needed for disposal if the material cannot be recycled into other uses such as DUCRETE. HF by-products could be recycled into other commercial uses but otherwise would create a disposal problem. No other significant waste streams are indicated in the materials provided. The empty DUF_6 cylinders will need decontamination before recycling or disposal.

7.1.27.2.3 Evaluation by Reviewer X

The waste stream will be primarily from the dUF_6 to UO_2 conversion process. There doesn't appear to be an additional waste stream from the pelletizing process. New plants should be designed to use the latest technology for recovering the fluorides and recycling them, or preparing them for use in other industrial processes.

7.1.27.2.4 Evaluation by Reviewer Y

The generation of "comparatively large amount of gaseous and dissolved solids as wastes" would seem to preclude the AUC process for treating DUF_6 pending only UO_2 requirements that capitalize on its process advantages for specific use.

The dry process such as the IDR seems advantageous on all counts pending the ability to use only DUF₆. In most cases, this is not a limitation for a process that leads to HF recovery for commercial sale.

7.1.27.2.5 Evaluation by Reviewer Z

All of the processes discussed have well defined and understood waste streams. The reduction of the large amounts of UF₆ currently in storage will require additional facilities. If one of the existing technologies is used, the dry processes generate less waste, and would be desirable from this perspective.

7.1.27.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.27.3.1 Evaluation by Reviewer U

Since the processes described in this Document are currently in use within the U.S., the costs are reasonably well defined for both the processing plant and the operation. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a DUF₆ to UO₂ conversion facility would be typical of those for commercial UF₆ conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be low and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of UO₂ would be in the same range as the cost of storing DUF₆ over the next one to two hundred years. The weight of total UO₂ would be about twenty percent less than the DUF₆, although the volumetric space for high density pellets would be only about one third. Rectangular containers of UO₂ would pack and stack in a space more efficient than the cylindrical containers of DUF₆. However, the cost of new metal containers for the UO₂ would be a significant added cost over that of continuing to keep the UF₆ in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of UO₂, while outdoor storage of DUF₆ cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. The present worth value of retaining the DU as DUF₆, with conversion to uranium oxide one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades.

7.1.27.3.2 Evaluation by Reviewer V

No cost data is provided. It would appear that although some capacity currently exists for these conversion processes, excess capacity is very limited and new plants capable of handling 28,000 MT/yr would be needed for the entire inventory. The cost for this production capacity is probably on the same order of magnitude as other conversion options. There appears to be no assessment of the demand for ceramic UO₂ in current markets.

7.1.27.3.3 Evaluation by Reviewer X

Current pelletizing techniques are estimated to cost about \$1.00 per pound of UO₂ powder. The advantage of pelletizing is that it at least triples the density of the UO₂ fabricated in other ways. This results in a potential size advantage of the finished product, most likely to be shielding, either using UO₂ pellets or beads in a poured slurry or as an ingredient in DUCRETE.

New plant will need to be installed to handle the depleted uranium process stream separate from the enriched uranium process streams, and also to handle the increased capacity for a depleted uranium UO₂ market.

Insufficient information was provided to evaluate the cost of new plant.

7.1.27.3.4 Evaluation by Reviewer Y

Cost data are conspicuous by their absence. The Integrated Dry Route (IDR) is likely to be the least expensive process. The AUC process is likely to be the most expensive because of chemical requirements and larger process waste (not considering DUO₂ as waste).

It is reasonable to assume a cost of ~\$2/Kg to produce UO₂ powder. Cost of pelletizing (if necessary) is likely to range from \$2-5/Kg in addition to powder production, pending anticipated end use. HF sales are not likely to impact overall cost markedly.

7.1.27.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. The processes are well defined, and costs should be easily determined.

The anhydrous hydrofluoric acid recovered it has commercial value. Also, the uranium oxide is assumed to have a commercial value for use as shielding material, etc.

7.1.27.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.27.4.1 Evaluation by Reviewer U

The chemical processes are well defined since many steps of the process have been in operation in the U.S. on a relatively large scale for several decades. Technical maturity is sufficient to permit its use after the construction and operation of a pilot plant to prove out some of the details of converting aqueous HF to AHF. A relatively small amount of research and development appears needed to finalize process design.

7.1.27.4.2 Evaluation by Reviewer V

These technologies appear to be fairly mature, although some process improvements may be made.

7.1.27.4.3 Evaluation by Reviewer X

The processes described are all in common use. No new technology is involved.

New plants should be expected to use the latest waste minimization, recycling, and collection methods.

New plants built for depleted uranium applications may have simpler processes than existing plants because the specifications for depleted uranium applications will be less stringent than those for fuel pellets. However, specifications on homogeneity, voids and density will remain stringent.

Pelletizing processes can introduce additives that can provide increased stability of the pellets and final product, such as DUCRETE.

7.1.27.4.4 Evaluation by Reviewer Y

All three processes are state-of-the-art industrial practice. Product quality (DUO2 powder) may well be the arbiter of decision on process.

Without knowing end use for DUO₂, pelletizing technology may not be appropriate for less demanding uses.

7.1.27.4.5 Evaluation by Reviewer Z

The wet and dry processes discussed in this Information Package are well established commercial processes and are considered technically mature.

7.1.27.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.27.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF₆ to UO₂ pellets and AHF would be at a steady level for a couple of decades if all of the existing DUF₆ is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and only the pellet sintering step requires a high temperature. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF₆. Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.27.5.2 Evaluation by Reviewer V

The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. The siting of such a facility may face minor problems with public acceptance. Environmental risks of these processes are fairly well known. Traffic, including uranium transport, to and from the site will be examined. If the material needs to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.27.5.3 Evaluation by Reviewer X

No information was provided on staffing requirements, plant size, or possible locations. If new plants are built near current plants, they will probably receive public support for providing continued and increased employment. New plants will need to be designed with environmental considerations in mind to assure public acceptance.

7.1.27.5.4 Evaluation by Reviewer Y

Without end use definition, the processing operation plus pelletizing is likely to employ ~100-300 people. With ancillary activities, this sort of payroll is significant in a small community. Public acceptance is reasonably assured under such conditions. If the facility is dedicated to DUF_6 , some long-range planning will be necessary for when the DOE stockpile has been worked off and less process volume is anticipated.

7.1.27.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.1.27.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.27.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or

uranium oxide. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, UO_2 , is greater than the cost of converting the DUF_6 to UO_2 with associated impacts.

7.1.27.6.2 Evaluation by Reviewer V

See General Comments.

7.1.27.6.3 Evaluation by Reviewer X

None.

7.1.27.6.4 Evaluation by Reviewer Y

Without knowing the ultimate use of the DUF_6 converted material, it may be premature to pelletize the UO_2 powder. This could be stored in sizeable vessels as powder (either UO_2 or U_3O_8). Such a decision would markedly reduce near term costs, get rid of DUF_6 , and provide flexibility for future decision.

7.1.27.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to uranium oxide (UO_2). A decision to select this option should be based on the need for the uranium oxide produced. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to an oxide state, including consideration of costs of future processes which may utilize the material.

7.1.27.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.27.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to UO_2 pellets and AHF is reasonable, acceptable and the Federal regulatory requirements are understood. Most of the process steps are well defined. Operation of a pilot plant for the collection of AHF would confirm the operation and provide the final information needed to assure an effective commercial plant operation.

Since the value of the marketable AHF is less than the overall cost of recovering it from UF₆, there is a net added cost over the current storage mode cost base.

The use of UO₂ pellets as aggregate in DUCRETE is viewed as a high risk application because of the potential for area contamination, the unknown structural integrity and the challenges of eventual disposal of the structure at the end of its useful life. Consideration of such use should be limited to structures at low-level radioactive waste disposal sites or within the high level waste disposal program where the DUCRETE is disposed of as part of or within the high level waste repository.

The added cost of producing high density UO₂ pellets to achieve a lower volume for disposal does not appear to be warranted. Disposal of the more stable U₃O₈ as a compressed cake without the expense of pelletizing may be a preferred choice.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF₆ to uranium oxides. Several of the approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. Uranium oxide powder compacting appears desirable to minimize the overall volume. However, mid density flat wafers may be more economical than high density pellets. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low-level radioactive waste disposal facility should be pursued.

The organization providing Document #28 is very knowledgeable on the processing and potential uses for depleted uranium.

7.1.27.7.2 Conclusion by Reviewer V

It is difficult to assess the reasonableness of this option, because of the lack of cost and other data. The commercial nature of the processes suggests that the timing and technical maturity criteria would be met and the process is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues that are unique to this technology. In general, it would appear that the process might be reasonable depending on costs.

7.1.27.7.3 Conclusion by Reviewer X

Conversion to ceramic UO₂ provides a density advantage over U₃O₈ for use in shielding materials. This results in smaller shield thicknesses and potential handling and storage savings.

Conversion to ceramic UO_2 for permanent disposal also would result in lower total volume requirements than conversion to U_3O_8 because of the higher density. UO_2 is chemically stable, and will slowly convert to U_3O_8 if contact with air occurs.

Since current installed capacity for meeting the UO_2 pellet demand is fully utilized, new plant installation would be necessary. Any new plants should employ the latest technologies for waste capture, recycling, and minimization.

Conversion of dUF_6 to UO_2 should only be considered if applications for the product exist. Typical applications would most likely involve shielding, possibly with the production of DUCRETE.

Conversion for waste disposal should not be considered for two reasons. First, a sufficient number of applications may be developed to use the entire current inventory of dUF_6 in either metal or oxide forms. Second, disposing of UO_2 as waste would require development of a new deep burial site. The specific activity of the uranium would be too high to permit disposal in a shallow land burial site. This would result in unnecessary expense and probable difficulty with public acceptance.

Conversion of dUF_6 to UO_2 for use in DUCRETE spent fuel storage containers such as the multipurpose canisters (MPCs) would use a significant amount of inventory. If 3500 MPCs are constructed using UO_2 DUCRETE, about half the dUF_6 would be needed for this single application. Conversion rate would depend on the use rate in MPCs. New plant would need to be built to meet this use rate.

This option would meet DOE's program guidelines for the use of stored dUF_6 . MPCs using DUCRETE would be more expensive than MPCs using concrete. However, their required storage volume would be less, and their overall total weights would be less, thus lessening handling difficulties. Environmentally, this option precludes the need to develop a deep waste disposal facility by providing a use for the uranium. The need for MPCs is likely to be short term as the U.S. eventually returns to a fuel reprocessing economy similar to the rest of the world. Thus, the UO_2 utilization will occur over the next 30 years.

7.1.27.7.4 Conclusion by Reviewer Y

This is a reasonable process if the "promise" can be realized. The "promise" is not a "warmed over" expectation for mixed oxide fuel in the 1970s for either Plutonium recycle in water reactors or for the Clinch River Breeder Reactor. The promise must be restated for DUF_6 products without a clear current mission. This product would require more (~50%) space in any long-term storage facility than DU metal (oxide density ~10 gm/cc, metal density ~18 gm/cc).

7.1.27.7.5 Conclusion by Reviewer Z

This option has merit, and should be considered. This option is technically mature, and all aspects are well understood, and therefore has the potential for converting depleted

uranium to uranium oxide in quantities which will meet the objectives of the proposed program.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium, and considered in perspective with other proposed uses of the depleted uranium.

The specifications for the plant, and decision regarding the reduction to uranium oxide would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form.

7.1.28 Evaluation of Document No. 51 (Independent Technical Reviewers' No. 29)

Respondent:

Package 9

Conversion to Ceramic UO_2 - Gelation

Description of Response:

This response recommends conversion of depleted UF_6 into ceramic uranium dioxide based upon gelation methods, which is a process that uses hydrodynamics to form spheres of ammonium diuranate that are subsequently cured, dried, and sintered directly into dense uranium dioxide microspheres to be loaded into fuel rods using vibratory methods.

7.1.28.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.28.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium dioxide (UO_2) will require the design, construction, operation and eventual decommissioning of at least one new facility or several smaller duplicate facilities. The gelation process described in Document 29 has been researched for several decades and developed to a limited degree as a possible means to produce commercial nuclear fuel. The commercial industry selected the UO_2 pellets instead of microspheres as the economically preferred route to achieve high density with good repeatability. The gelation family of processes have not been developed to a level that can be considered commercially attractive for large volumes of material.

This document indicates that production of high density UO_2 microspheres through use of gelation processes should offer advantages of significant automation and high volume throughput compared to the conventional palletizing processes to provide high density UO_2 . It indicates the size of a gelation processing plant should be one fifth that of a pellet plant to provide the needed throughput to process all of the DUF_6 . Only the gelation production processes for UO_2 are discussed in the Document, not the designation of disposal or potential uses for the depleted UO_2 microspheres.

Conversion of DUF_6 to uranyl fluoride would be the same for the start of the gelation processes as performed for the pelletizing approach. The distinction is that microspheres would be produced instead of ceramic grade powder. The Document flowsheet indicates that two thirds of the fluorine would be captured as aqueous HF and one third would be captured as calcium fluoride that would be disposed of as a waste or processed further to recover the fluorine. Presumably the recovered HF could be converted to AHF and sold as a commercial chemical.

UO_2 is a relatively inert chemical form of uranium (high density microspheres from these gelation processes) with low reactivity and low solubility. Long term storage or the disposal of UO_2 should be acceptable within stainless steel containers. UO_2 microspheres are brittle and will fracture easily.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities.

7.1.28.1.2 Evaluation by Reviewer V

The characterization of gelation processes provided suggests that there may be environmental, health and safety advantages over existing mechanical processing. Gelation confines the materials more completely within the process equipment reducing potential for contact exposures or airborne exposures. The newer processes use more hazardous chemicals in processing, however, that have the potential for other kinds of risks from accidental releases, etc. These chemicals include ammonia hydroxide, oils, solvents and various "amines" (e.g. HMTA). The dense ceramic spheres that are produced would lessen the environmental hazards associated with handling after conversion. The final high density form will reduce the amounts of material but appropriate safety measures will need to be used.

It seems that this conversion option will be similar to existing techniques with regard to the overall environmental, health and safety risks from operation. Standard industrial practices should be able to control the risks from dangerous chemicals used. Similarly, the by-products of these processes such as AHF, aqueous HF and CaF_2 will need careful handling during recycling or disposal to avoid environmental contamination or exposures to the public.

7.1.28.1.3 Evaluation by Reviewer X

Current installed plant capacity for producing UO_2 pellets uses techniques other than gelation and is sufficient only for meeting domestic fuel production needs. New plants will need to be installed after development work on the process is completed. Since the applications for UO_2 using depleted uranium will not require the strict tolerances for fuel production, new dUF_6/UO_2 handling facilities can probably be installed less expensively. However, the new plant will still require licensing and permitting.

Since the technology for UO_2 production has been in place for many years, projections of process emissions can readily be predicted. A gelation plant is expected to have lower environmental, safety, and health concerns because the process is more confined than mechanical-based plants. However, the simpler dry conversion/treatment processes are stated to have fewer waste treatment and recycle requirements. It should be expected that any new plant would incorporate equipment and processes to reduce emissions and the waste stream to lower levels than present plants.

7.1.28.1.4 Evaluation by Reviewer Y

The reasons for not pursuing gel processes in general and the sol-gel process in particular related to the issue of nuclear reactor fuel material *in-situ* compaction—highly undesirable for safety reasons. A secondary reason related to lack of intimacy between the two materials (e.g., Pu and U or U235 and U238). This lack of intimacy relates to the possible Doppler reactivity sign and magnitude. The recent lack of interest in both Pu recycle and breeder development stunted further gelation development.

The decision issues noted above do not provide a basis for rejecting gelation in the DUF6 program (if continuing storage of DUF6 is ruled out).

7.1.28.1.5 Evaluation by Reviewer Z

This proposal, Conversion to Ceramic UO_2 : Gelation, was developed as Information Package 9. The sol-gel process is able to produce dense particulate having a range of small particle size which enables vibratory compaction to near maximum theoretical density. The small particle composition enables most or perhaps all of the processing to be done in closed vessels, which is favorable for containment. The dry phase processing would require process exhaust ventilation with effluent treatment. The environmental, health and safety issues associated with the gelation process should be similar to those experienced at other fuel cycle facilities, and are not expected to pose any significantly different concerns.

7.1.28.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.28.2.1 Evaluation by Reviewer U

The DUF_6 conversion to UO_2 and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

A significant volume of CaF_2 is produced as a waste stream. Considerable effort appears to be needed to minimize this waste and to convert it to a usable product.

There is no current use for separated depleted UO_2 microspheres. Possible use in DUCRETE in the future may be achieved. The practicality of DUCRETE is yet to be determined. Eventual disposition of DUCRETE after the useful life of the structure constructed with DUCRETE, may entail disposition in low-level radioactive sites at a high cost at a later date.

With no practical use for the UO_2 at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Final disposition may require deep underground

disposal. Such disposal should be less demanding than disposal of high level radioactive wastes.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process discussed will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites, at a high cost. Another use may be to cut the cylinders in half and weld flat end caps over the open end to provide upright storage containers for UO_2 microspheres produced with the gelation processes.

7.1.28.2.2 Evaluation by Reviewer V

The highly compact nature of the processed UO_2 spheres will reduce the volume needed for disposal if the material cannot be recycled into other uses such as DUCRETE. HF by-products could be recycled into other commercial uses but otherwise would create a disposal problem. No indication of the potential fate of the CaF_2 is given, however, various processing and disposal options are available. Ammonia traces from the drying process could be recycled into the process. No other significant waste streams are indicated in the materials provided. The empty DUF_6 cylinders will need decontamination before recycling or disposal. There do not appear to be any unique waste issues associated with these processes.

7.1.28.2.3 Evaluation by Reviewer X

The waste stream will be primarily from the dUF_6 to UO_2 conversion process. There doesn't appear to be an additional waste stream from the gelation process. New plants should be designed to use the latest technology for recovering the fluorides and recycling them, or preparing them for use in other industrial processes.

7.1.28.2.4 Evaluation by Reviewer Y

Waste streams should be modest and similar to those in the existing industrial processes augmented by gel formers which would tend to be organic for internal gelation. Magnitudes are difficult to estimate but likely to be manageable particularly if HF is extracted.

7.1.28.2.5 Evaluation by Reviewer Z

The waste streams for the gelation process should be similar in nature to those of other fuel cycle facilities. The gelation process should produce fewer gaseous and airborne emissions than a conventional process that produces uranium oxide powder.

7.1.28.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.28.3.1 Evaluation by Reviewer U

Since the processes described in this Document have not been developed to the point of commercial or large volume use, the costs are not well defined for either the processing plant or its operation. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a DUF_6 to UO_2 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be low and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

The cost of storage of UO_2 microspheres would be in the same range as the cost of storing DUF_6 over the next one to two hundred years. The weight of total UO_2 microspheres would be about twenty percent less than the DUF_6 , although the volumetric space would be considerably less. Rectangular containers of UO_2 would pack and stack in a space more efficient than the cylindrical containers of DUF_6 . However, the cost of new metal containers for the UO_2 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of UO_2 , while outdoor storage of DUF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. Acceptable waste form is indeterminate at this point and it is unknown whether microspheres of UO_2 would be an acceptable form. The present worth value of retaining

the DU as DUF6, with conversion to uranium oxide one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades.

7.1.28.3.2 Evaluation by Reviewer V

No cost data is provided. There are no commercial conversion processes of this type from which to draw comparable data. It is suggested from the data provided that these continuous processes will have a much larger capacity than comparable existing processes. This might suggest that the cost per unit processed will be lower, depending on the costs of all the process equipment required and the operating costs, including waste disposal. The cost for this production capacity is probably on the same order of magnitude as other conversion options. There appears to be no assessment of the demand for ceramic UO_2 in current markets.

7.1.28.3.3 Evaluation by Reviewer X

Current pelletizing techniques are estimated to cost about \$1.00 per pound of UO_2 powder. The advantage of pelletizing is that it at least triples the density of the UO_2 fabricated in other ways. This results in a potential size advantage of the finished product, most likely to be shielding, either using UO_2 pellets or beads in a poured slurry or as an ingredient in DUCRETE.

Gelation techniques have the advantage of being able to produce spheres of different sizes (in the 800-micron range). If two or three sizes of microspheres are produced, they can be loaded using vibration into containers to produce densities approaching 90% of theoretical. This would provide a denser and less expensive alternative to shield production than the use of DUCRETE.

A development program estimated to cost less than \$10 million and lasting less than five years will be necessary before a production size plant can be built.

New plant will need to be installed to handle the depleted uranium process stream separate from the enriched uranium process streams, and also to handle the increased capacity for a depleted uranium UO_2 market. Insufficient information was provided to evaluate the cost of new plant.

7.1.28.3.4 Evaluation by Reviewer Y

If the promise of this technology can be realized with R&D and requirements on the end product (e.g., gel produced UO_2) are not severe, this is very likely to be the lowest cost option to produce a product that is not DUF6 and has the character of potential use with additional work (e.g., forming, sintering) and cost at a later date.

Large sphere size is likely to be the less expensive gel option. Recognizing future requirements on the material, the fragility of the spheres may be an advantage on technology as well as cost assuming the pyrophoricity concerns are not significant.

7.1.28.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative.

The anhydrous hydrofluoric acid recovered has commercial value. Also, the uranium oxide is assumed to have a commercial value for use as shielding material.

7.1.28.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.28.4.1 Evaluation by Reviewer U

The gelation processes have not been fully developed. Considerable research and development would be required before they could be deployed on a large scale. Pilot plant and demonstration plant operation would be required for the gelation processes and for the recovery of HF as AHF. Gelation processes must be viewed as more theoretical than practical at this stage although they may at some stage become the preferred approach for large scale conversion of DUF_6 to UO_2 for eventual disposal. Additional effort appears to be needed to minimize the waste stream and to recover a useful product.

7.1.28.4.2 Evaluation by Reviewer V

These technologies appear to need some additional development before full scale plants can be built. It is estimated in the data that this could take \$10 million and up to five years in time.

7.1.28.4.3 Evaluation by Reviewer X

Conversion of UF_6 to UO_2 is a common industry practice. However, gelation methods aren't in common use and have only been tested in the laboratory. Plant designs have been developed but not built.

Process and plant development is projected to require about five years and to cost \$10 million or less.

New plants should be expected to use the latest waste minimization, recycling, and collection methods.

New plants built for depleted uranium applications may have simpler processes than existing plants because the specifications for depleted uranium applications will be less stringent than those for fuel pellets. However, specifications on homogeneity, voids and density will remain stringent.

Gelation processes are projected to provide five to ten times the throughput of a conventional pelletizing plant of equal size due to automation advantages. Applications and needs for UO_2 would determine plant size.

7.1.28.4.4 Evaluation by Reviewer Y

The technology for gel-formed UO_2 is probably in better shape than the use thereof. All past considerations focused on gel-formed UO_2 (and PuO_2) in nuclear reactor grade fuel. The potential for *in-situ* densification of vibratory compacted fuel material was not viewed with enthusiasm by nuclear power reactor designers. The potential for Doppler reactivities that could be positive in very fast transients further dampened the enthusiasm of core designers. It is these very qualities, low density, and lack of intimate contact may well provide a flexible technical option with less severe rework technology and cost at a later date.

It is very likely that a pilot scale operation can be conducted at reasonable cost and schedule.

7.1.28.4.5 Evaluation by Reviewer Z

The sol-gel process has been performed on a scale that was smaller than envisioned for depleted UF_6 . However, scale-up to the very large throughput necessary to process a large part of the depleted UF_6 inventory would have to be engineered. While the sol-gel chemical technology is more complex than most other means of converting UF_6 to UO_2 , its use has the potential of reducing the cost and time associated with conversion to UO_2 by using an alternative to the conventional pellet sintering process.

7.1.28.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.28.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to UO_2 microspheres and AHF would be at a steady level for a couple of decades if all of the existing DUF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and temperature. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.28.5.2 Evaluation by Reviewer V

The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. The amount of land required to site such a facility, including buffer zones, is not known. The siting of such a facility may face minor problems with public acceptance. Environmental risks of these processes are not well known for full scale operation, but can be extrapolated. Traffic, including uranium transport to and from the site, will be examined. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.28.5.3 Evaluation by Reviewer X

No information was provided on staffing requirements, plant size, or possible locations. If new plants are built near current plants, they will probably receive public support for providing continued and increased employment. New plants will need to be designed with environmental considerations in mind to assure public acceptance.

7.1.28.5.4 Evaluation by Reviewer Y

There are no unusual factors related to employment or regional development to other options. Local employment and development would be pronounced in a small community; most likely siting would be such.

Public acceptance would be greatest in or near communities clamoring to remove DUF₆ cylinders. Fairly low temperatures and pressures are advantageous.

7.1.28.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.1.28.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.28.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF₆ or uranium oxide. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF₆ appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, UO₂, is greater than the cost of converting the DUF₆ to UO₂ with associated impacts.

7.1.28.6.2 Evaluation by Reviewer V

See General Comments.

7.1.28.6.3 Evaluation by Reviewer X

Whether to build uranium carbide capacity depends on the cost-benefit of using carbide compounds for shielding applications relative to the same application using UO_2 . Since UO_2 microspheres or pellets will be less expensive to produce than carbide microspheres or pellets, UO_2 has a cost advantage.

UO_2 and uranium carbide microspheres can both be packed into shielding containers using vibration equipment to about 90% of theoretical density. This would be an effective way to manufacture the Multipurpose Canisters (MPCs) for long term spent fuel storage or disposal. The theoretical density of UO_2 is 10.97 gm/cc. The theoretical density of uranium carbide is 14 gm/cc. Another option is to use uranium metal which has a density of 18.68 gm/cc.

Finally, the need for MPCs is near term as the fuel storage pools at the nation's nuclear reactors become filled and the requirement to transfer spent fuel to the U.S. Government becomes more critical. Thus, this option would have to be implemented sooner than five years out.

7.1.28.6.4 Evaluation by Reviewer Y

Assuming that DUF6 should be processed into something, the gelation option may well be a choice since it is likely to be low cost (by avoiding final fabrication compaction and sintering). The gel material (brittle spheres of DUO_2) could well be the input to a product of need at a later time.

Pyrophonics of the product are unlikely but must be assured to be so.

A decision might superficially favor the ADU process. The only option that this precludes is easy DU metal fabrication.

7.1.28.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to uranium oxide (UO_2). A decision to select this option should be based on the need for the uranium oxide produced. Whether to select this option should be decided by comparison of production costs with conventional UF_6 to ADU to UO_2 pelleting processes and of the qualities of the desired product, e.g., smaller particles versus larger pellets. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to an oxide state, including consideration of costs of future processes which may utilize the material.

7.1.28.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.28.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to high density UO_2 microspheres and AHF is believed to be possible and has several attractive features. However, it is not well enough developed to be considered reasonable or practical at this time. If a need is identified for large quantities of high density UO_2 it may be desirable to pursue the development of these technologies. This effort does not appear to be supportable just to achieve lower volumes for long term storage and/or disposal. Since the value of the marketable AHF that might be recovered is less than the overall cost of recovering it from UF_6 , there is a net added cost over the current storage mode cost base.

If a decision is made to dispose of DU as an oxide, the gelation processes should be developed to determine whether it provides a lower cost way to produce the oxide. Assessment at this point suggests there are insufficient advantages to the production of high density UO_2 microspheres as compared to the more stable U_3O_8 as a compressed cake for disposal.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting DUF_6 to uranium oxides. Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. Uranium oxide compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low-level radioactive waste disposal facility should be pursued.

The organization providing Document #29 is very knowledgeable on the processing of and potential uses for depleted uranium.

7.1.28.7.2 Conclusion by Reviewer V

It is difficult to assess the reasonableness of this option because of the lack of cost and other data. The processes appear to need more time to become technically mature but eventually could meet the criteria for readiness in 10 years. The process is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues that are unique to this technology. In general, it would appear that the process might be reasonable depending on costs and progress of the development work.

7.1.28.7.3 Conclusion by Reviewer X

Conversion to ceramic UO_2 provides a density advantage over U_3O_8 for use in shielding materials. This results in smaller shield thicknesses and potential handling and storage savings.

Conversion to ceramic UO_2 for permanent disposal also would result in lower total volume requirements than conversion to U_3O_8 because of the higher density. UO_2 is chemically stable, and will slowly convert to U_3O_8 if contact with air occurs.

Since current installed capacity for meeting the UO_2 pellet demand is fully utilized, new plant installation would be necessary. Any new plants should employ the latest technologies for waste capture, recycling, and minimization.

Conversion of dUF_6 to UO_2 should only be considered if applications for the product exist. Typical applications would most likely involve shielding, possibly with the production of DUCRETE. However, the use of gelation processes will enable UO_2 microspheres to be used in shielding by loading containers with vibration techniques and avoiding the intermediate and more expensive process of making DUCRETE.

Conversion for waste disposal should not be considered for two reasons. First, a sufficient number of applications may be developed to use the entire current inventory of dUF_6 in either metal or oxide forms. Second, disposing of UO_2 as waste would require development of a new deep burial site. The specific activity of the uranium would be too high to permit disposal in a shallow land burial site. This would result in unnecessary expense and probable difficulty with public acceptance.

Conversion of dUF_6 to UO_2 for use in spent fuel storage containers such as the multipurpose canisters (MPCs) would use a significant amount of inventory. If 3500 MPCs are constructed using UO_2 microspheres, about half the dUF_6 would be needed for this single application. Conversion rate would depend on the use rate in MPCs. New plant would need to be built to meet this use rate.

This option would meet DOE's program guidelines for the use of stored dUF_6 . MPCs using UO_2 microspheres would be less expensive than MPCs using DUCRETE. Also, the required shielding thickness might be less, the required storage volume might be less, and their overall total weights might be less, thus lessening handling difficulties. Environmentally, this option precludes the need to develop a deep waste disposal facility by providing a use for the uranium.

However, if this option is embraced, it will have to be developed more quickly than the current estimates project. The need for MPCs is near term as the fuel storage pools at the nation's nuclear reactors become filled and the requirement to transfer spent fuel to the U.S. Government becomes more critical. If five years is needed to develop the process before UO_2 can be provided, many of the MPCs will have already been built and filled with fuel. Then the estimate of using UO_2 for 3500 MPCs will be too high.

The need for MPCs is likely to be short term as the U.S. eventually returns to a fuel reprocessing economy similar to the rest of the world. Thus, the UO_2 utilization will occur over the next 30 years.

7.1.28.7.4 Conclusion by Reviewer Y

The processes and manufactures defined in the package are reasonable on all counts. It would be unfortunate to implement any or all of the processes and manufacture without some definition of intent for the manufactured product. It is possible to view the process product (powder) as an intermediate objective that solves the DUF6 issue (if continuing storage is not viable) pending definition in the future. Given a choice, the IDR process seems a prudent approach that generates minimal and uncomplicated waste.

7.1.28.7.5 Conclusion by Reviewer Z

Sol-gel chemical technology is more complex than most other means of converting UF_6 to UO_2 . Its selection would need to be justified by a need for the qualities of the dense particulate UO_2 produced, by potential for automated processing, by potential fluidized flow processing, and by processing in closed vessels providing containment.

The information package did not identify a proposed use of the UO_2 particulate to enable a judgement on justification to be made. Nevertheless, this option has merit and should be considered.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium, and considered in perspective with other proposed uses of the depleted uranium.

The specifications for the plant, and decision regarding the reduction to uranium oxide would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form.

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7.1.29 Evaluation of Document No. 52 (Independent Technical Reviewers' No. 30)

Respondent:

DOE Recommendation

Package 10

Conversion to Uranium Carbide - Graphite and Gelation Approaches

Description of Response:

This response recommends conversion of uranium hexafluoride to dense uranium carbide using either a graphite or gelation process for potential use as reactor fuel for certain high temperature reactors.

7.1.29.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.29.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (DUF_6) into uranium carbide microspheres would require the design, construction, operation and eventual decommissioning of at least one new facility or several smaller duplicate facilities. The graphite and gelation processes described in Document 30 have been researched for several decades and developed to a limited degree as a possible means to produce commercial nuclear fuel for high temperature nuclear reactors. Commercial use of nuclear energy has proceeded in the U.S. with light water reactors that use uranium dioxide (UO_2) pellet fuels, not uranium carbide fuels. The high temperature gas cooled reactor proposals include the use of both UO_2 and uranium carbide microspheres as fuel particles. While still being researched and developed by the Federal Government with limited industry participation, the high temperature gas cooled reactors must be viewed as a potential long range future application. The use of DU microspheres in such reactors would only be applicable for a breeder approach of nuclear energy use. Such applicability is indeterminate at this point.

This Document indicates that production of high density uranium carbide microspheres through use of graphite or gelation processes should offer advantages of significant automation and high volume throughput compared to the conventional pelletizing processes to provide high density fuel. However, the operation to produce uranium carbide will entail more production steps than the production of similar UO_2 microspheres. Only the uranium carbide production processes are discussed in the Document, not the designation of such material as a waste form for disposal or an indication of other potential uses for the depleted uranium carbide microspheres.

Conversion of DUF_6 to uranyl fluoride would be the same for the start of the production of uranium carbide as performed for the production of UO_2 . The Document flowsheet indicates that two thirds of the fluorine would be captured as aqueous HF and one third would be captured as calcium fluoride that would be disposed of as a waste or processed further to recover the fluorine. Presumably the recovered HF could be converted to AHF and sold as a commercial chemical.

Uranium carbide must be coated to prevent the material from converting back to uranium oxide. Once coated it is a relatively inert form of uranium (high density microspheres) with low solubility. Long term storage or the disposal of DU as uranium carbide does not appear to be economical or appropriate.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the DUF_6 is now located. If only one facility is constructed at one of the three current sites, the DUF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the DUF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination and microsphere production activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities to process uranium oxides. Additional regulatory review would be required for large scale production of uranium carbide.

7.1.29.1.2 Evaluation by Reviewer V

The graphite approach seems likely to have the same kinds of effects as the existing ceramic UO_2 processes discussed in Document 28. The HF and CaF_2 could present risks of accidental exposures to these hazardous materials if not handled according to standard industry procedures. There would also be CO and CO_2 produced by the process that would need control.

The characterization of gelation processes provided in Document 29 suggests that there may be environmental, health and safety advantages over existing mechanical processing. Gelation confines the materials more completely within the process equipment reducing potential for contact exposures or airborne exposures. The newer processes use more hazardous chemicals in processing, however, that have the potential for other kinds of risks from accidental releases, etc. These chemicals include ammonia hydroxide, oils, solvents and various "amines" (e.g. HMTA). The dense carbide spheres that are produced would lessen the environmental hazards associated with handling after conversion. The final high density form will reduce the amounts of material but appropriate safety measures will need to be used.

It seems that these conversion options will be similar to existing processes described in Documents 28 and 29 with regard to the overall environmental, health and safety risks from operation. Standard industrial practices should be able to control the risks from dangerous chemicals used or produced as by-products until recycling or disposal to avoid environmental contamination or exposures to the public.

The uranium carbide product is reported to need control more for its radiological characteristics than for its chemical toxicity, having an IDLH of $30\text{mg}/\text{m}^3$ and a recommended eight-hour limit of $0.2\text{mg}/\text{m}^3$. Carbides are slightly reactive to water and moist air, however, converting slowly to UO_2 . The potential for leaching is reduced by the multiple impervious coatings that are put on the uranium carbide spheres as part of processing.

7.1.29.1.3 Evaluation by Reviewer X

Uranium carbides aren't currently produced. The processes for forming carbides use UO_2 as feedstock. Thus a uranium carbide plant would need to be built that has a front end for

converting dUF_6 to UO_2 . Current installed plant capacity for producing UO_2 pellets is sufficient only for meeting current domestic fuel production needs. New plants will need to be installed after development work on the process is completed.

Previous carbide production, in ton quantities, was for use in commercial size nuclear power reactors. Since the applications for uranium carbides using depleted uranium will not require the strict tolerances for fuel production, new dUF_6 - uranium carbide handling facilities can probably be installed less expensively. However, the new plant will still require licensing and permitting.

The technology for producing UO_2 is well known. Additional processing to produce carbides also is well known, but requires further study for determining large quantity parameters and for making the process as efficient as possible. However, projections of process emissions, environmental, health, and safety effects can readily be predicted. It should be expected that any new plant would incorporate equipment and processes to reduce emissions and the waste stream to lower levels than present plants. Chemicals involved in the processing are used in many industrial processes, are well understood, and are regulated for safe practices with existing law.

7.1.29.1.4 Evaluation by Reviewer Y

The packages are, at best, solutions seeking to solve a problem. New environmental and occupational safety precedents need negotiation in the absence of extensive recent regulatory experience.

Generally, the safety and health issues associated with carbon are tractable though sometimes difficult. Chlorinated solvents, if they must be used, pose some problems and risks.

The steps in addition to those for making DUO_2 from DUF_6 are several that have environmental, health, and safety issues. Health issues are likely to dominate with process effluents (environmental) a subsequent concern; assuming, of course, that the modest radiological concerns are tractable.

Storage and handling of Uranium Carbide will require some new though not major adaptations though small-scale experience is there.

7.1.29.1.5 Evaluation by Reviewer Z

This proposal, Conversion to Uranium Carbide, Combination Package of: Graphite approach and Gelation approach, was developed as a combination of Information Packages 10 and 11. UF_6 to UF to ADU conversion steps are also used in other conventional processes that are mature and for which there is adequate experience in controlling effluent to the environment, occupational safety, and health concerns of processing. The environmental, health and safety issues associated with either of these processes should be similar to those experienced at other fuel cycle facilities, and are not expected to pose any

significantly different concerns. The use of organic oils and solvents in the Gelation route will present a potential fire hazard which would require special measures to mitigate.

7.1.29.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.29.2.1 Evaluation by Reviewer U

The DUF_6 conversion to uranium carbide and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

There is no current use for separated depleted uranium carbide microspheres. Possible use in DUCRETE in the future may be achieved. The practicality of DUCRETE is yet to be determined. Eventual disposition of DUCRETE after the useful life of the structure constructed with DUCRETE, may entail disposition in low-level radioactive sites at a high cost at a later date.

With no practical use for uranium carbide at this time it does not appear to be appropriate to convert DUF_6 to this chemical form. Uranium oxides are more stable and the preferred form for long term storage if the DUF_6 form is determined to be unsatisfactory.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the disposition of UF_6 cylinders. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites.

7.1.29.2.2 Evaluation by Reviewer V

Uranium carbide is one of the densest forms of uranium thus reducing the volume needed for disposal if the material cannot be recycled into other uses such as shielding materials. The waste management issues for the graphite process will be similar to those for the ceramic processes in Document 28, as will the gelation process be to Document 29. HF by-products could be recycled into other commercial uses but otherwise would create a disposal problem. No indication of the potential fate of the CaF_2 is given, however, various processing and disposal options are available. Ammonia traces from the gelation drying process could be recycled into the process. No other significant waste streams are indicated in the materials provided. The empty DUF_6 cylinders will need decontamination before recycling or disposal. There do not appear to be any unique or unworkable waste issues associated with these processes.

7.1.29.2.3 Evaluation by Reviewer X

The waste stream will be primarily from the dUF_6 to UO_2 conversion process. There doesn't appear to be a significant additional waste stream from the process that converts the UO_2 to the carbide form. Use of the gelation processes is said to result in lower waste quantities than graphite-carbide processes. New plants should be designed to use the latest technology for recovering the fluorides and recycling them, or preparing them for use in other industrial processes.

7.1.29.2.4 Evaluation by Reviewer Y

No unusual waste products are anticipated, generally similar to those of both ceramic and gelation routes. Different gels may yield different wastes. It is conceivable that internal/external gelation may be optimized in a different manner for UC vs UO_2 .

7.1.29.2.5 Evaluation by Reviewer Z

The waste streams associated with these processes should be similar in nature to those of other fuel cycle facilities. The gelation process should produce fewer gaseous and airborne emissions than a conventional process that produces uranium oxide powder.

7.1.29.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.29.3.1 Evaluation by Reviewer U

Since the processes described in Document 30 have not been developed to the point of commercial or large volume use, the costs are not well defined for either the processing plant or its operation. AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a DUF_6 to uranium carbide conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be low and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. The range of acceptable waste forms is indeterminate at this point although the form of uranium carbide microspheres may not be an acceptable form.

7.1.29.3.2 Evaluation by Reviewer V

No cost data is provided. There are no commercial conversion processes doing the gelation from which to draw comparable data. No data is provided on the ceramic UO_2 processes, which are in operation at production scale. It is suggested from the data provided that continuous processes such as gelation will have a much larger capacity than comparable batch processes. This might suggest that the cost per unit processed will be lower, depending on the costs of all the process equipment required and the operating costs, including waste disposal. The cost for the production capacity for both processes is probably on the same order of magnitude as other conversion options with batch processes requiring more production lines to achieve the same output. There appears to be no assessment of the demand for uranium carbide in current markets. The only identified use is for nuclear fuel for high temperature reactors (unlikely to be a significant use for DUF_6) and for shielding materials.

7.1.29.3.3 Evaluation by Reviewer X

UO_2 pelletizing techniques are estimated to cost about \$1.00 per pound of UO_2 powder. Conversion to uranium graphite will add to this cost. No cost information was provided, however.

A development program estimated to cost \$10 to \$20 million and lasting five to ten years was stated to be needed based on analogy to programs operated in the late 1970s.

New plant will need to be installed to handle the depleted uranium process stream separate from the enriched uranium process streams, and also to handle the increased capacity for a

depleted uranium UO_2 market. Insufficient information was provided to evaluate the cost of new plant.

7.1.29.3.4 Evaluation by Reviewer Y

Certainly, the production of DUC via gelation on ADU routes will be more costly than the corresponding DUO_2 production. With the final steps of layer addition (pyrolytic, silicon carbide, pyrolytic) avoided, costs should be moderate if the material is not dedicated for nuclear reactor core or blanket use. (The layers are usually added to this material to retain fission products; U^{238} does fission in all neutron systems.)

Certainly, the cost of providing the UC can be anticipated to be on the order of \$2-5/Kg if quality and performance specifications on the product are not extreme. Sale of byproduct AHF will somewhat offset costs, but not markedly in view of start-up uncertainties.

The impact of Argon costs is unknown.

7.1.29.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the options proposed in this alternative.

The anhydrous hydrofluoric acid recovered has commercial value. Also, the uranium carbide is assumed to have a commercial value for use as shielding material, etc.

7.1.29.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.29.4.1 Evaluation by Reviewer U

The production of uranium carbide in large quantities has not been developed. Considerable research and development would be required before it could be deployed on a large scale. Pilot plant and demonstration plant operation would be required for the graphite and gelation processes and for the recovery of HF as AHF. Gelation processes must be viewed as more theoretical than practical at this stage although they may at some stage become the preferred approach for large scale conversion of DUF_6 to UO_2 for eventual disposal.

7.1.29.4.2 Evaluation by Reviewer V

These technologies appear to need a fair amount of additional development before full-scale plants can be built. Uranium carbides have been produced using the graphite process in small batches and, using the gelation process, at the bench and pilot plant scale. It is estimated in the data that this could take \$10 to \$20 million and five to ten years in time.

7.1.29.4.3 Evaluation by Reviewer X

Conversion of UF_6 to UO_2 is a common industry practice. However, Uranium carbides have been produced in ton quantities for use in demonstration-size commercial power reactors. However, a development program estimated to cost \$10 to \$20 million and lasting five to ten years was stated to be needed based on analogy to programs operated in the late 1970s.

New plants should be expected to use the latest waste minimization, recycling, and collection methods.

New plants built for depleted uranium applications may have simpler processes than previous plants because the specifications for depleted uranium applications will be less stringent than those for reactor fuel. However, specifications on homogeneity, voids and density will remain stringent.

Gelation processes are projected to provide five to ten times the throughput of a conventional pelletizing plant of equal size due to automation advantages. Applications and needs for uranium carbide would determine plant size.

7.1.29.4.4 Evaluation by Reviewer Y

The graphite approach to producing Uranium Carbide for nuclear reactor fuel elements in the USA is experience based via Ft. St. Vrain and Peach Bottom reactor fuels. There is no comparable gelation experience.

In contemplating DUF_6 to DUC conversion, the objectives are very likely to be different from those where Uranium Carbide was produced for nuclear reactor fuels.

For example, it is conceivable that the "Biso" or "Triso" coatings may not be necessary for the product contemplated in this program.

Without a defined use for the future for the DUC, it may be prudent to develop the gelation process since it will be less expensive and could leave the product in a more flexible state. The costs for development cited in the package seem reasonable as is the schedule.

7.1.29.4.5 Evaluation by Reviewer Z

A considerable amount of research and laboratory testing has been performed for various processes associated with both the Graphite approach and the Gelation approach. Some of the processes have been employed to produce sizeable quantities of uranium carbide. Additional developmental work will be required to complete the design and construction of a production scale facility to convert depleted UF_6 . There has been enough experience in sol-gel and uranium carbide production to provide reasonable assurance that it could be scaled to the larger production rate needed if depleted UF_6 were processed.

7.1.29.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.29.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF_6 to uranium carbide microspheres and AHF would be dependent upon the demand for uranium carbide. It does not appear reasonable to convert the existing DUF_6 to uranium carbide as a general approach to achieve a preferred different chemical form for DU.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low pressure and temperature. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for DUF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where DUF₆ is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.29.5.2 Evaluation by Reviewer V

The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. The amount of land required to site such a facility, including buffer zones, is not known. Siting such a facility may face minor problems with public acceptance. Environmental risks of these processes are not well known for full scale operation, but can be extrapolated. Traffic, including uranium transport to and from the site, will be examined. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.29.5.3 Evaluation by Reviewer X

No information was provided on staffing requirements, plant size, or possible locations. If new plants are built near current plants, they will probably receive public support for providing continued and increased employment. New plants will need to be designed with environmental considerations in mind to assure public acceptance.

7.1.29.5.4 Evaluation by Reviewer Y

There are no unique positive or negative features. Payrolls are large enough to be significant in a small community. Ancillary activities could enhance the impact. Public acceptance should not be serious beyond the potential difficulties of transport of DUF₆ tanks.

7.1.29.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.1.29.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.1.29.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to

store the material in a retrievable manner for a few hundred years, either as DUF_6 or uranium oxide. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of DUF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, coated uranium carbide microspheres, is greater than the cost of converting the DUF_6 to uranium carbide with associated impacts. Converting the DUF_6 to uranium carbide does not provide a desirable stable chemical form for long term storage or disposal.

7.1.29.6.2 Evaluation by Reviewer V

See General Comments.

7.1.29.6.3 Evaluation by Reviewer X

Whether to build uranium carbide capacity depends on the cost-benefit of using carbide compounds for shielding applications relative to the same application using UO_2 . Since UO_2 microspheres or pellets will be less expensive to produce than carbide microspheres or pellets, the carbides would have to offer some advantage over UO_2 .

Carbides are slightly reactive toward moist air and water and slowly convert to UO_2 over time. This may be a disadvantage over geological time.

UO_2 and uranium carbide microspheres can both be packed into shielding containers using vibration equipment to about 90% of theoretical density. This would be an effective way to manufacture the Multipurpose Canisters (MPCs) for long term spent fuel storage or disposal. The theoretical density of UO_2 is 10.97 gm/cc. The theoretical density of uranium carbide is 14 gm/cc. Another option is to use uranium metal which has a density of 18.68 gm/cc.

Finally, the need for MPCs is near term as the fuel storage pools at the nation's nuclear reactors become filled and the requirement to transfer spent fuel to the U.S. Government becomes more critical. With this option requiring five to ten years to develop before it can be implemented, the need for depleted uranium carbides may have passed by the time carbide shielding material is available.

7.1.29.6.4 Evaluation by Reviewer Y

It seems imprudent to base the DUF_6 conversion to DUC material on parameters for making the high quality specifications for nuclear reactor fuels. The final quality steps (three pyrolytic coatings) seem superfluous without specifying an application that needs

them. If DUC is the desired product, the gelation approach may be the optimum on all aspects except timing.

It is possible that DUC might be a desirable ingredient for some ducrete applications!

7.1.29.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to uranium carbide. Whether to select this option should be based on the need for the uranium carbide produced. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to an oxide state, including consideration of costs of future processes which may utilize the material. Considered alone, UC production by either the graphite or gelation process is technically sound, and scaleup to a large production rate appears feasible.

7.1.29.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.29.7.1 Conclusion by Reviewer U

This option of converting DUF_6 to high density uranium carbide microspheres and AHF is not well enough understood to be considered reasonable or practical at this time. Nor is there a defined use for uranium carbide. Conversion of DUF_6 to uranium carbide does not appear to be supportable just to achieve lower volumes for long term storage and/or disposal. Since the value of the marketable AHF that might be recovered is less than the overall cost of recovering it from UF_6 , there is a net added cost over the current storage mode cost base.

If a decision is made to dispose of DU, uranium carbide does not appear to be a desirable stable chemical form for disposal.

The organization providing Document #30 is very knowledgeable on the processing of and potential uses for depleted uranium.

7.1.29.7.2 Conclusion by Reviewer V

It is difficult to assess the reasonableness of these options because of the lack of cost data or accurate assessments of the time and steps to reach technical maturity. The processes appear to need more time to become technically mature but may be able to meet the criteria for readiness in 10 years. The process is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues that are unique to this technology. In general, it would appear that the process might be

reasonable depending on costs and progress of the development work, but should not be considered a near-term option at this time.

7.1.29.7.3 Conclusion by Reviewer X

Conversion to uranium carbide provides a density advantage over U_3O_8 for use in shielding materials. This results in smaller shield thicknesses and potential handling and storage savings.

Conversion to uranium carbide for permanent disposal also would result in lower total volume requirements than conversion to U_3O_8 because of the higher density. However, uranium carbide slowly reacts with moist air and water to form UO_2 , which is chemically more stable, and slowly converts to U_3O_8 if contact with air occurs. Since production of UO_2 will be cheaper, it is a better alternative for disposal.

Since current installed capacity for meeting the UO_2 pellet demand is fully utilized, new plant installation would be necessary. Any new plants should employ the latest technologies for waste capture, recycling, and minimization.

Conversion of dUF_6 to uranium carbides should only be considered if applications for the product exist. Typical applications would most likely involve shielding. A cost-benefit analysis should be performed to assist in selection of UO_2 or uranium carbide for shielding.

Conversion for waste disposal should not be considered for three reasons. First, a sufficient number of applications may be developed to use the entire current inventory of dUF_6 in either metal or oxide forms. Second, disposing of uranium carbide as waste would require development of a new deep burial site. The specific activity of the uranium would be too high to permit disposal in a shallow land burial site. This would result in unnecessary expense and probable difficulty with public acceptance. Finally, production of UO_2 for waste disposal would be less expensive than production of uranium carbide.

Conversion of dUF_6 to uranium carbide for use in spent fuel storage containers such as the multipurpose canisters (MPCs) would use a significant amount of inventory. If 3500 MPCs are constructed using uranium carbide microspheres, about half the dUF_6 would be needed for this single application. Conversion rate would depend on the use rate in MPCs. New plant would need to be built to meet this use rate.

This option would meet DOE's program guidelines for the use of stored dUF_6 . MPCs using uranium carbide microspheres might be less expensive than MPCs using DUCRETE, but more expensive than using UO_2 . Also, the required shielding thickness might be less, the required storage volume might be less, and their overall total weights might be less, thus lessening handling difficulties. Environmentally, this option precludes the need to develop a deep waste disposal facility by providing a use for the uranium.

The need for MPCs is near term as the fuel storage pools at the nation's nuclear reactors become filled and the need to transfer spent fuel to the U.S. Government becomes more

critical. With this option requiring five to ten years to develop before it can be implemented, the need for depleted uranium carbides may have passed by the time carbide shielding material is available.

7.1.29.7.4 Conclusion by Reviewer Y

The proposal process is reasonable on all counts except one. The necessity of developing a new technology that is likely to be more expensive than existing technology without a unique defined use is elusive.

7.1.29.7.5 Conclusion by Reviewer Z

This option has merit, and should be considered. The option has the potential of producing uranium carbide in large quantities for use as shielding and other applications. Sufficient testing has been performed to demonstrate the viability of the process.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium, and considered in perspective with other proposed uses of the depleted uranium.

The specifications for the plant, and decision regarding the reduction to uranium carbide would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in carbide form.

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7.1.30 Evaluation of Document No. 53 (Independent Technical Reviewers' No. 31)

Respondent:

DOE Recommendation

Package F1

HTGR Fuel Fabrication Using Uranium Carbide

Description of Response:

This response recommends conversion of depleted uranium hexafluoride to uranium dioxide with further conversion into uranium carbide for use as high-temperature gas-cooled reactor (HTGR) fuel.

7.1.30.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.1.30.1.1 Evaluation by Reviewer U

The high temperature gas cooled reactor (HTGR) has been under development for several decades. One demonstration plant was constructed and operated for several years, the Ft. St. Vrain plant in Colorado. While there is continuing interest in the HTGR concept, there is no apparent near term commercial interest in the construction of such energy plants. A number of fueling arrangements have been considered and research performed. One would use depleted uranium (DU). However, the quantities required for such an application are very small within the foreseeable future.

Processing of depleted uranium hexafluoride (DUF₆) into uranium carbide microspheres for the HTGR concept would require the design, construction, operation and eventual decommissioning of a new facility. The graphite and gelation processes considered for uranium carbide production have been researched for several decades and developed to a limited degree. Commercial use of nuclear energy has proceeded in the U.S. with light water reactors that use uranium dioxide (UO₂) pellet fuels, not uranium carbide fuels. The high temperature gas cooled reactor proposals include the use of both UO₂ and uranium carbide microspheres as fuel particles. While still being researched and developed by the

federal government with limited industry participation, the high temperature gas cooled reactors must be viewed as a potential long range future application.

Conversion of DUF_6 to uranyl fluoride would be the same for the start of the production of uranium carbide as performed for the production of UO_2 . The Document flowsheet indicates that two thirds of the fluorine would be captured as aqueous HF and one third would be captured as calcium fluoride that would be disposed of as a waste or processed further to recover the fluorine. Presumably the recovered HF could be converted to AHF and sold as a commercial chemical.

Uranium carbide must be coated to prevent the material from converting back to uranium oxide. Once coated it is a relatively inert form of uranium (high density microspheres) with low solubility.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Transportation of DUF_6 to a processing plant for the production of HTGR fuel would be via truck. Truck transportation is currently used for natural and low enriched UF_6 .

Site restrictions for a conversion facility are relatively few.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Use of DU in HTGR fuel would be a commercial application that would be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities to process uranium oxides. Additional regulatory review would be required for production of significant quantities of uranium carbide fuels for the HTGR.

7.1.30.1.2 Evaluation by Reviewer V

The option of using DUF_6 to produce UO_2 for fabricating LEU fuel for high temperature, gas-cooled reactors (HTGR) would raise a number of environmental, health and safety concerns. The conversion to UO_2 involves complicated industrial processes requiring hazardous materials such as ammonia and hydrogen. Large amounts of gaseous and dissolved wastes can be produced. HF can be recovered in some processes. It is likely that this conversion option will be similar to other processes with regard to the overall risks from operation. Standard industrial practices should be able to control the risks from dangerous chemicals used or produced as by-products until recycling or disposal, avoiding environmental contamination or exposures to the public.

The uranium carbide product is reported to need control more for its radiological characteristics than for its chemical toxicity, having an IDLH of $30\text{mg}/\text{m}^3$ and a recommended eight-hour limit of $0.2\text{mg}/\text{m}^3$. Carbides are slightly reactive to water and moist air, however, converting slowly to UO_2 . The potential for leaching can be reduced by coatings or incorporation into containers such as fuel assemblies.

The process of fabricating fuel for HTGR's from depleted DU would require many process steps, numerous chemicals and require the handling of radioactive materials such as 5-15% enriched UO_2 . While these processes are all regulated by the NRC which has strict operating requirements, potential risks exist and production is inherently dangerous. Chemicals associated with the process include ammonia, nitric acid, hydrogen, hydrogen fluoride, nitrogen, uranium hexafluoride, argon and hydrogen chloride. Some steps in the fabrication process will mirror commercial nuclear fuel fabrication. Worker safety would be a prime concern.

Transportation of the uranium into and out of the processing site would be carefully controlled by existing regulations, however, the potential for accidental releases will exist. Siting would be regulated by the NRC, as well as Federal, state and local requirements. Such a plant is likely to require a large site to allow appropriate buffer zones, in addition to the space required for plant operations. Significant opposition to a new nuclear fuel fabrication plant is to be expected in many locations with public concern regarding nuclear safety quite high.

7.1.30.1.3 Evaluation by Reviewer X

The necessity for an HTGR fuel fabrication plant depends on the nation's decision for the provision of additional energy sources. Unless a decision is made to go forth with additional reactors and a fuel recycling program, an HTGR carbide fuel fabrication plant won't be necessary.

Construction and operation of commercial reactors are regulated by the NRC, as are the construction and operation of a fuel fabrication plant.

Disposal of fuel from the HTGR also is regulated by the NRC. However, the HTGR fuel cycle requires recycling. Thus, the option doesn't make sense unless a decision is made to begin recycling rather than placing the spent fuel in a permanent storage facility. Recycling of fuel is commonly done in other countries. A plant was built near Barnwell, SC, but never used. If Barnwell is opened or another plant built to support the HTGR cycle, it also will be licensed to operate by the NRC.

Waste streams from the recycling will need to be evaluated. The objective of recycling is to reduce the high level radioactive waste. LLRW and non-radioactive waste streams will need to be identified.

In the fuel fabrication process, the primary waste streams will be from the production of UO_2 . The waste stream will depend on the chosen production process. These have been evaluated elsewhere.

7.1.30.1.4 Evaluation by Reviewer Y

If one has or will have many HTGR power systems, the issues of environment, safety, and health are similar to those operative during the Fort St. Vrain system and its related fabrication infrastructure. The likelihood of having enough HTGRs in the next twenty years to make a significant dent in the DUF₆ inventory is exceedingly small. If, however, one of the "off-normal" HTGR operating cycles (e.g., with DU instead of Th) is adopted, nuclear reactor operating safety characteristics would need eloquent demonstration. The likelihood of such development is exceedingly low...probably as low as converting LWRs to the Thorium cycle. However, the safety of HTGR with an "off-normal" fuel cycle is not assured *a priori*.

7.1.30.1.5 Evaluation by Reviewer Z

This proposal, HTGR Fuel Fabrication Using Uranium Carbide, was developed as Information Package F1. The environmental, health and safety issues associated with this process should be similar to those experienced at other fuel cycle facilities which fabricate and reprocess HTGR fuel elements. Due to the use of HEU in the process, and the presence of relatively high enrichments of various fissile uranium isotopes in the irradiated fuel, inadvertent criticality is a concern for both the fuel fabrication and reprocessing phases of the fuel cycle.

7.1.30.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.1.30.2.1 Evaluation by Reviewer U

The DUF₆ conversion to uranium carbide and AHF should be achievable with a closed process. That is, minimal liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low-level radioactive waste disposal facilities.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the disposition of UF_6 cylinders. Chemical cleaning of empty cylinders may be sufficient to permit them to be scraped, melted and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low-level radioactive waste sites.

7.1.30.2.2 Evaluation by Reviewer V

Production of the UO_2 for use in fuel fabrication would create a number of gaseous and solid wastes, the amount of which would vary by the process chosen. HF by-products could be recycled into other commercial uses but otherwise would create a disposal problem. The HTGR plant will also create waste streams from the fuel fabrication processes. No data on the quantities or character of the wastes has been made available to determine the magnitude of the impacts. All wastes would be tightly regulated under applicable NRC, DOE and EPA regulations. HTGR with ^{233}U recycle would use 35% less natural uranium.

7.1.30.2.3 Evaluation by Reviewer X

In the fuel fabrication process, the primary waste streams will be from the production of UO_2 . The waste stream will depend on the chosen production process. These have been evaluated elsewhere.

Spent fuel from reactor operation is currently being stored for disposal in a permanent storage facility. Retrievability of the fuel is uncertain. For an HTGR cycle to operate effectively, the spent fuel must be recycled rather than disposed of because considerable original fissionable material is left in the fuel at the end of the cycle, and additional fissionable material is produced from the fertile material. Thus, for the option to be viable, a decision in favor of recycling must be made.

7.1.30.2.4 Evaluation by Reviewer Y

Manageable waste streams are anticipated for normal or reference HTGR operation and their normal fuel cycles. The case of using DUF_6 to produce HEU (presumably by centrifuge or AVLIS) would lead to a DU product of $\sim 0.1\%$. U235 would not solve the DU inventory unless other products and uses are anticipated.

7.1.30.2.5 Evaluation by Reviewer Z

The waste streams associated with this process are well understood. The HTGR fuel cycle requires the reprocessing of the irradiated fuel assemblies in order to recover the remaining fissile material.

7.1.30.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.1.30.3.1 Evaluation by Reviewer U

Since the HTGR concept has not achieved commercial acceptance at this time, the costs are not well defined for using DU as a portion of the fuel for HTGRs.

AHF is the only salable product from the operation. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a DUF₆ to HTGR fuel facility would be typical of those for commercial UF₆ conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be low and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low-level waste disposal facilities.

7.1.30.3.2 Evaluation by Reviewer V

No data is provided showing the cost to process the UO₂ or the HTGR fuel using DU. It would appear that this option would only use 600 MT of the DU inventory over the 30 year program term. Revenues from sales of fuel fabricated under this option would be limited. Minimal value would be returned from HF product sales.

7.1.30.3.3 Evaluation by Reviewer X

Referring to Table 1, the cost in SWUs of producing fully (93%) enriched fuel from the supply of dUF₆ is seen to be nearly triple the cost of producing the fuel from natural uranium. Whether this can be economically justified is open to question and may depend on the success of new technology, such as AVLIS, that offers the potential for significantly lower cost SWUs.

7.1.30.3.4 Evaluation by Reviewer Y

The costs cited in the package can probably be almost doubled to reflect time since estimated plus enthusiasm to portray the technology in a favorable way.

The reference HTGR fuel cycle is based on an equilibrium U233-Th operation requiring HEU startup and predicated on recycle of spent fuel. All other options (e.g., LEU-Th, LEU-DU) are makeshift and will, most likely, cost more.

7.1.30.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. This option could not operate economically as a "once through" cycle, and would require reprocessing of the irradiated fuel elements in order to recover the significant amounts of fissile materials. This would require a reversal of the current federal policy against spent fuel reprocessing.

7.1.30.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.1.30.4.1 Evaluation by Reviewer U

The HTGR application has been considered for several decades without achieving commercial acceptability. The quantities of DUF_6 , that would be employed for fuel of HTGRs is believed to be very small within the next few decades and should not be considered as a reasonable means to consume large quantities of DU.

7.1.30.4.2 Evaluation by Reviewer V

These technologies for fuel fabrication are mature. Better technologies are being sought for UO_2 production. HTGR powerplants have been proposed but never built in this country. Public acceptance of the technology as mature may still be far in the future.

7.1.30.4.3 Evaluation by Reviewer X

Once the UO_2 is provided to the process, fuel fabrication is standard industrial practice. Commercial grade fuel has been produced for and operated in the Fort St. Vrain commercial HTGR in Colorado. New design is not required. However, because of the time that has elapsed since the last fuel was manufactured, new processes will probably be considered for a new plant.

7.1.30.4.4 Evaluation by Reviewer Y

HTGR fuel production schemes seem well advanced beyond the various options described for using various fuels. The HTGR promise is based on the U233-Th fuel cycle. DUF6 does not play a strong role in the reference or start-up fuel cycle. The promise of high fuel conversion (U235 $\rightarrow$ U233 with Th) is the attraction for this cycle.

The LEU system leads to some Plutonium production. It is conceivable that a LWR can operate with U233 and Th giving a conversion ratio of ~ 0.9 versus ~ 0.6 for the current cycle. Obviously, fuel recycle makes the technology whole but at the present time costs and social pressures seem major obstacles.

7.1.30.4.5 Evaluation by Reviewer Z

The HTGR is technically attractive in concept, yet only one commercial electricity-generating HTGR power plant has been operated in the United States. After a short operating life, it is being decommissioned. Experience in fabricating the HTGR fuel suggests that required modifications to it would not present a major technical problem.

Without fuel reprocessing, of which the Federal government does not approve, the advantages and technology challenges of recycling are moot issues. A fuel cycle in which spent fuel is not reprocessed could be considered. However, in a throw-away fuel cycle, thorium would be favored as the fertile fuel to extend reactor core life rather than depleted uranium.

7.1.30.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.1.30.5.1 Evaluation by Reviewer U

Employment at a facility to convert DUF₆ to HTGR fuel and AHF would be dependent upon the demand for HTGR reactors which is indeterminate at this time.

Operation of the processes to produce HTGR fuel entail relatively low pressure and temperature. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a

significant public information program is essential to present the various options in reasonable perspective for public assessment.

Performing the operation at a commercial site for the production of HTGR fuel at a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.1.30.5.2 Evaluation by Reviewer V

The construction of facilities to carry out this option would have an economic impact on the community. The amount of land required to site such a facility, including buffer zones, is not known. Siting such a facilities is likely to face significant problems with public acceptance. Traffic, including uranium transport to and from the site, will be increased. If waste materials need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.1.30.5.3 Evaluation by Reviewer X

This is the key element of this option. Public acceptance for the construction and operation of additional nuclear power plants must be apparent. More importantly, utility management must be assured by regulatory agencies that once an HTGR plant is selected, construction can proceed on a reasonable schedule, and that operation of the facility will be assured once construction is complete. Utility management and stockholders will not risk the large sums of money required to build new plants if the regulatory process, including public hearings, can delay plant startups indefinitely.

7.1.30.5.4 Evaluation by Reviewer Y

The need to recycle fuel is not likely to meet with enthusiastic public acceptance in the near future.

Obviously, a complete HTGR infrastructure would have significant local and regional impact.

7.1.30.5.5 Evaluation by Reviewer Z

Concerns about international proliferation of plutonium production and potential diversion of it into nuclear weapons has resulted in a U. S. Government policy prohibiting spent fuel reprocessing and recovery of plutonium. This federal policy would have to be reversed in order for this option to be viable.

7.1.30.6 Evaluation Factor Six - Other factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.1.30.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as DUF_6 or uranium oxide. If a decision is made to use DU as an energy resource in the future, the HTGR concept may be the chosen means to do so. However, that decision appears to be several decades away. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

7.1.30.6.2 Evaluation by Reviewer V

See General Comments.

7.1.30.6.3 Evaluation by Reviewer X**Breeder Reactor Economy and Reprocessing**

Going to a breeder reactor economy may be the ultimate choice for long-term energy self-sufficiency and protection of the environment from carbon emissions. However, this choice depends on several options not politically available at the present time.

First, it will be necessary to reprocess the fuel now being used in today's light water reactors. This choice was abandoned during the Carter administration. Though other countries are aggressively pursuing reprocessing, it is not being considered in the U.S. Instead, permanent disposal of spent fuel is being pursued.

Second, a decision will have to be made to build more nuclear power plants as our energy needs increase and as older plants, both nuclear and fossil, need to be retired.

Third, a decision to continue with development of fast-breeder reactors is necessary. Several concepts have been presented. But current research is essentially halted. The HTGR has already operated successfully and more reliable designs have been approved. The Integral Fast Reactor is another concept now being proven with the fuel cycle of EBR-2 in Idaho. If the breeder reactor concept would be aggressively and successfully pursued, additional uranium and coal would never have to be mined, and petroleum and natural gas would be available for uses for which only they are suited.

dUF₆ Consumption and Cost

Table 1 shows the feed and SWU requirements for producing 93% (fully) enriched uranium for the Highly Enriched Uranium (HEU) HTGR fuel cycle. To produce six cores/year, a plant operating with feed of 50 kg/day of fully enriched uranium would be needed. This equates to 18,250 kg/year. Using the values in Table 1 with 0.25% depleted uranium as feed and 0.1% tails, 11,300 MT of feed uranium, or 16,600 MT of dUF₆, would be required annually.

However, after removing the ²³⁵U for HTGR fuel from the dUF₆ each year, roughly the same amount of dUF₆ would be left! Thus, the supply of dUF₆ wouldn't really be consumed. Indeed, after operating for 30 years in this manner, only 600 MT would have been consumed.

Other possible cycles include several Low Enriched Uranium (LEU) combinations. For these, the total consumption of the stockpile would be between 500 and 600 MT annually.

Table 1. Enrichment Cost in Separative Work Units for Different Concentrations of Product, Feed & Tails (Source: ORO-684, Appendix 1)

		Concentration (x) in %	Concentration (x) in %	Concentration (x) in %
Concentration of Product	$x_p =$	93	93	93
Concentration of Feed	$x_f =$	0.711	0.25	0.2
Concentration of Tails	$x_t =$	0.3	0.1	0.1
Feed/Unit of Product	$F/P =$	225.54745	619.33333	929
Unit Values of Uranium at each stage	$V(x_p) =$	2.2245528	2.2245528	2.2245528
	$V(x_f) =$	4.8688834	5.9590166	6.1877557
	$V(x_t) =$	5.7713017	6.8929413	6.8929413
SWUs		199.99139	573.74228	650.44903

7.1.30.6.4 Evaluation by Reviewer Y

To "tailor" an HTGR to the destruction of DUF₆ is another way of making a Plutonium factory. There are probably easier ways to make Plutonium and easier ways to transform DUF₆ to something else.

7.1.30.6.5 Evaluation by Reviewer Z

This evaluation focuses mainly on HTGR fuel fabrication and not on the rest of the fuel cycle.

This option proposes a process for the use of depleted uranium hexafluoride in the production of fuel elements for HTGR plants. There are currently no plants in operation which utilize this fuel cycle. An advanced HTGR is being designed, but it is likely many years before the first plant is ordered, and an additional several years before the plant would go into production. However this conversion option should not be ruled out for use in the future.

The amount of depleted uranium used for this fuel cycle is not expected to make a significant contribution to the resolution of the current storage problem. An estimated 18 reactors consuming 540 to 600 tonnes dUF₆ per year would use about 0.001 of the dUF₆ inventory annually. Thus, utilization in HTGR fuel seems unlikely to consume enough dUF₆ in the near future to be a factor in disposition of dUF₆ in the same time frame.

An alternative that should be considered when deliberating use of dUF_6 in HTGR fuel should be whether to use dUF_6 or natural uranium to blend with highly enriched uranium to produce HTGR fuel.

One idea presented in the document 31 is an HEU cycle, in which HEU is blended down with depleted uranium or recycled U^{233} (from a previous HEU-Th cycle). Notably, U^{233} is a more reactive fissile material than U^{235} and would not be a candidate for blending HEU down to lower reactivity.

7.1.30.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.1.30.7.1 Conclusion by Reviewer U

This option of using DU as fuel for HTGR reactors must be viewed as a future decision that is not applicable to the consumption of significant quantities of DU anytime in the near future. This application does not fall within the guidelines of reasonableness or acceptable for the disposition of DU.

The organization providing Document #31 is very knowledgeable on the processing of and potential uses for depleted uranium.

7.1.30.7.2 Conclusion by Reviewer V

This option does not seem reasonable due to the small amount of the DU inventory it would use. This option would also require a complicated conversion process and fabrication processes that use hazardous and highly radioactive materials. For the relatively small effect on the DU disposal problem, this option requires too many resources and is likely to encounter significant public resistance.

7.1.30.7.3 Conclusion by Reviewer X

Technical questions aside, this is not a viable option unless several decisions are made to permit and encourage a closed fuel cycle with reprocessing, unlike the open fuel cycle currently practiced in the U.S.

If the necessary decisions are made, the use of dUF_6 to produce enriched uranium for the HTGR cycle will be at least about three times as expensive as the use of natural uranium UF_6 . Once the fissionable ^{235}U is extracted from the dUF_6 , essentially all the dUF_6 will be left over and available for implementation of other options.

If spent reactor fuel reprocessing is performed, HTGR construction and operation has the potential to be an effective option for electrical generation. The manufacture and use of car

bide fuels is a standard industrial practice that can occur without additional development work, although it is likely that more modern processes will be implemented to minimize the waste streams and reduce operating costs.

7.1.30.7.4 Conclusion by Reviewer Y

Most of the reasonable criteria can be met. Three are not met. There is no consistent DOE or Federal Agency Mission that is related. Most important is the inability to utilize 15% of the DUF6 inventory without making Plutonium. This must be the end product of HTGR fuel fabrication to be used in operating HTGRs. These are not likely to be operating in the USA in the timeframe of interest.

7.1.30.7.5 Conclusion by Reviewer Z

This option has little merit. Although the HTGR fuel fabrication process is technically mature, it is expected to be many years before there would be a plant in operation which would utilize the fuel produced from this proposal. Additionally, in order for the process to be economically feasible, it is expected that reprocessing of the irradiated fuel assemblies would be required.

7.2 EVALUATION OF PREVIOUSLY PROPRIETARY RECOMMENDATIONS

This section includes evaluations of responses which contained recommendations that were submitted as proprietary information. The respondents have provided either non-proprietary summaries or have released the information as non-proprietary. The Independent Technical Reviewers' evaluations have also been released as non-proprietary or have been redacted.

7.2.1 Evaluation of Document No. 6 (Independent Technical Reviewers' No. P1)

Response 6 was designated as proprietary information by the submitter, Mr. William Bear, Siemens Power Corporation. On June 7, 1995, Mr. Bear provided LLNL/SAIC a non-proprietary summary of the response submitted on December 8, 1994, and also released the following Independent Technical Reviewer evaluations as non-proprietary information.

This response recommends use of a patented dry conversion process for converting depleted UF_6 to uranium oxide (probably UO_2 , but U_3O_8 is also possible) with the concurrent production of hydrofluoric acid. The oxide may be disposed of or used in other applications and processes. The dry conversion process (UO_2) is currently operating in a Lingen, Germany, facility processing 400 tonnes/year of low-enriched uranium. A facility to handle 800 tonnes/year of uranium is being constructed in Richland, Washington.

7.2.1.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.1.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into uranium dioxide (UO_2) or triuranium octoxide (U_3O_8) and hydrofluoric acid (HF) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly several smaller duplicate facilities. The process described in Document P1 is a proprietary and patented process developed commercially by Siemens. The process is operating in a plant in Germany and a new plant designed to use the process is under construction within the U.S. Thus, it is fully developed and would

require very little additional development. Major issues of concern with the proposed process have been defined and addressed in Germany.

UO₂ and U₃O₈ are relatively inert chemical forms of uranium (dry brown or black powder or compressed cake) with low reactivity and low solubility. Long term storage of uranium oxides should be acceptable in stainless steel containers. A weather protecting building would probably be required for container storage. If at some future point, the DU is declared to be a waste, uranium oxide is likely to be the preferred chemical form for permanent disposal.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as recommended recovers the HF as aqueous HF. There is a limited market for this material in the U.S. To recover anhydrous HF (AHF), a material with greater demand, the process would need to be augmented. This change appears manageable. If the HF is converted to AHF, it could be sold and transported as a commercial chemical. However, if a lower cost operation results in trace amounts of uranium, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF₆ prior to the enrichment step.

Transportation of depleted UF₆ to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the depleted UF₆ is now located. If only one facility is constructed at one of the three current sites, the depleted UF₆ from the other sites could be transported via rail or truck to the new facility. Rail transportation of UF₆ has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF₆ is an on-going step of the nuclear fuel supply industry. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF₆ now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium oxide could be stored on the surface at the present locations of the depleted UF₆.

The conversion process is amenable to a closed liquid system with no requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or for sufficiently clean materials in sanitary land fill.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.2.1.1.2 Evaluation by Reviewer V

The option proposed is for reprocessing depleted UF_6 to produce uranium oxides (probably UO_2 , but U_3O_8 is also possible) and an aqueous HF byproduct. The uranium oxides could be used for products including shielding materials or converted into metal for other product applications. The material could also be stored or disposed of in approved low-level facilities depending on DOE program directions. Uranium oxides are a far more stable form of uranium for storage, with the chemicals largely inert and insoluble in typical ambient storage conditions. Once converted, it would pose far less risk to workers and the public than depleted UF_6 which is unstable, toxic and hazardous. The reprocessing of depleted UF_6 has environmental risks, however. The increased handling and operation of the processing facility raise issues regarding the potential for releases, spills, worker exposures and damage to the environment.

The process proposed here has extensive commercial operating experience in Germany and a 800 T/year facility is in construction in the U.S. to support LEU fuel production. The process is described as having no liquid effluent waste streams. Hydrofluoric acid is recovered and sold as a by product with a uranium content of less than .1 ppm. Emissions include offgas discharges that have HF and uranium levels well below allowed limits. The scale at which the operations would be carried out for depleted UF_6 would be much larger, however, the environmental effects are expected to be similar. Worker safety procedures have been developed, implemented and proven and accident responses planned.

The siting for this processing facility could present an issue for development. A large industrial site would be needed and would raise environmental and public health questions, depending on the location. Use of an existing site at one of the current storage facilities might minimize siting issues. The permitting for environmental, health and safety issues is not expected to present problems. With years of operating experience already available, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility.

The hydrofluoric acid byproduct is very hazardous and corrosive and has its own set of handling, storage and transportation issues that, while not unique, will require attention in operations. Depending on the processing location, the processed uranium oxides may require transportation and special storage conditions. Long term storage conditions would need to be defined, if chosen as the program direction. The availability of disposal sites might be an issue requiring further development. If the uranium oxides are densified or sintered, they will require less space. A final high density form will reduce the amounts of material that will have to be handled using appropriate safety measures.

7.2.1.1.3 Evaluation by Reviewer X

This recommendation is for use of a dry conversion process for converting dUF_6 to a uranium oxide, either UO_2 or U_3O_8 , with the concurrent production of aqueous HF. The oxide may be disposed of or used in other applications and processes. The dry conversion process currently operating in a Lingen, Germany, facility processing 400 tonnes/year of low-enriched uranium. A facility to handle 800 tonnes/year is being constructed in Richland, Washington.

The recommended process is currently operating in a prototype plant in Richland, Washington. Thus licensing and safety concerns have been addressed for a small scale plant.

A plant operating in Germany is said to have been designed to meet strict German licensing and regulatory requirements. The safety analysis was done to "ensure that operating personnel and the general public would be adequately protected in the unlikely event of postulated accidents. The facility also is being operated to maintain very low exposures to operating personnel."

A comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations.

7.2.1.1.4 Evaluation by Reviewer Y

The proposal for producing UO_2 or U_3O_8 with the dry process is probably as environmentally friendly as any proposed option. The experience of building, licensing, and operating the Lingen, Germany, facility provides a valuable base of information since the German government has been traditionally very environmentally conscious. No unusual site choices are anticipated. It is likely that a proposal could result in locations near the depleted UF_6 storage sites. The potential for a facility at Richland cannot be ruled out; this suggests some long distance transportation safety hurdles for both depleted UF_6 and product (UO_2 or U_3O_8).

7.2.1.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. William Bear proposes to process the depleted UF_6 through a patented process to convert the UF_6 to either U_3O_8 or UO_2 and to recover hydrofluoric acid.

This option would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. The currently licensed Siemens Power Corporation-Nuclear Division (SPC-ND) Richland, Washington site, which is proposed for the demonstration plant, meets current regulatory requirements. No other special siting requirements are anticipated.

7.2.1.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.1.2.1 Evaluation by Reviewer U

The depleted UF_6 conversion to uranium oxides and HF should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

There is no current use for separated depleted uranium oxides. Possible use in Ducrete in the future may be achieved. The practicality of Ducrete is yet to be determined. Eventual disposition of structures made from Ducrete may require elaborate disposal control and disposition at a prohibitively high cost. With no practical use for the uranium oxides at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Disposal of uranium oxide in a near surface or underground repository appears necessary for effective long term disposition with an indeterminate cost at this time. The task should be much easier and less contentious than the current problems associated with high level waste disposal. Final disposal should be at a dry site or one that is impervious.

Returning the U_3O_8 to the original uranium mines has been suggested. This does not appear practical since most of these mines are wet sites in sand stone rock formations that are quite pervious.

There is limited demand for aqueous HF. Thus, it would be a highly toxic material that would require strict storage or disposal as a toxic waste. However, if converted to AHF it should be marketable.

A special effort will be required for emptying, cleaning and disposing of the depleted UF_6 storage cylinders. The recommended process removes nearly all of the depleted UF_6 from the cylinders. However, a small amount will remain in the cylinder as a heel that must be removed by washing the cylinders. Conversion of material recovered this way may be achieved as a slip stream into the main process at some point or it may require a separate side stream process. Cylinder cleaning should be sufficient to allow the metal to be recycled, melted and used for other metal applications. If cleaning is insufficient to permit recycle, the cylinders may need to be disposed of at low level radioactive waste sites. Alternately, the cylinders may be modified and used as storage containers for uranium oxide.

7.2.1.2.2 Evaluation by Reviewer V

The proposed process would have limited waste streams that include hydrofluoric acid and small amounts of calcium fluoride for recycling into other industries. No other wastes are described in the response. If small amounts of other wastes that include uranium or hazardous materials are produced they would need to be handled at appropriate low level or sanitary disposal sites. The highly compact nature of the processed UO_2 powder will reduce the volume needed for disposal if the material cannot be recycled into other uses such as Ducrete. If HF by-products could not be recycled into other commercial uses, this would create a disposal problem. The empty depleted UF_6 cylinders will need decontamination before recycling or disposal.

7.2.1.2.3 Evaluation by Reviewer X

The recommended process produces a uranium oxide (UO_2 or U_3O_8), aqueous HF, and CaF_2 . U_3O_8 is recommended if the oxide is to be disposed of in an LLRW disposal site. The calcium fluoride is recycled to the steel industry. The aqueous HF would have to be distilled for use in the U.S. chemical industry.

No waste products are mentioned. It is stated that the dry conversion doesn't produce a liquid waste stream that requires treatment and disposal. HF and uranium released in the off-gas are stated to be well below applicable limits.

If the U_3O_8 must be disposed of, some location other than a low level radioactive waste (LLRW) facility will need to be found. The NRC has excluded near surface disposal as an option in NUREG-1484.

Considering the difficulty the several LLRW Compacts are having with obtaining enabling legislation in host states and siting these facilities, such an option is not likely to be available in a Compact facility. Also, dUF_6 is considered to be DOE waste under current law. It is not likely that states will allow this to become industrial waste in a transfer process to a conversion contractor. Thus, it will still need to be disposed of or stored as DOE waste.

Considering the situation in Ohio, it should be noted that the proposed Ohio facility will have both a time restriction of 20 years operation and a volume restriction of 2,250,000 cubic feet ($63,713 \text{ m}^3$), only about one-third the required volume for the current inventory of dUF_6 .

Illinois, the proposed state for the conversion plant site, has essentially restarted its LLRW siting process at Square One since it based its original process on a single volunteer site that has since been abandoned.

Several potential non-Compact sites might be available. One of these is the Envirocare of Utah, Inc., site. However, this site has a limit on contained uranium in its waste of 110,000 pCi/gm, which according to NUREG-1484 is far less than the activity in the U_3O_8 waste stream from Claiborne (I calculate this to be about 300,000 pCi/gm, but it could be higher, depending on how you treat the numbers.) The NTS in Nevada is an alternative ultimate disposal site. Its Waste Acceptance Criteria limits transuranic concentrations to less than 100,000 pCi/gm for consideration as LLRW (See EGG-MS-11297, pg. 33, with RFR #4). Thus, the U_3O_8 would need to be contained in some matrix, such as Ducrete. Also, Envirocare empties all containers. So the matrix must be stable.

7.2.1.2.4 Evaluation by Reviewer Y

This is probably a least waste option, depending on degree of product refinement (e.g., 1 w/o flouride, P. 2 of proposal $\sim 13 \text{ v/o!}$). Provision for HF sales are there if price is competitive. The calciner byproduct is the only real waste identified, maybe the CaF_2 , though potential customers are identified in the proposal. Reality here depends on quality of the product for sale. The stigma of coming from depleted UF_6 refinement may be an obstacle for both CaF_2 and HF unless very low impurities are achieved.

7.2.1.2.5 Evaluation by Reviewer Z

The process proposed in this option is not anticipated to generate waste streams which are different in characteristics than what is currently seen at operating fuel cycle facilities.

Although not specific in the proposal, it appears that this process would produce aqueous HF. It is stated that the HF produced at a similar facility in Lingen, Germany sells the hydrofluoric acid to the chemical industry. However, the market for aqueous HF in the United States is not well developed, and the hydrofluoric acid may require additional treatment to convert it to anhydrous HF (AHF) or to dispose of it as waste.

It was also stated that the Calcium fluoride compound from the off-gas scrubbing process will have a commercial value to the steel or glass industry. Experience at some of the fuel cycle facilities has shown that the uranium concentration in the calcium fluoride sludge is above the unrestricted release limits. Contamination of the off-gas sludge normally occurs during non-routine operations, such as system purging, and it is possible that the calcium fluoride would require cleanup prior to release, or be handled as a low level radioactive waste.

The proposal is to produce U_3O_8 or UO_2 which is suitable for use in commercial applications, or for disposal in either permanent or retrievable disposal areas.

7.2.1.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.1.3.1 Evaluation by Reviewer U

Since this process is currently in use in Germany, the costs are reasonably well defined for both the processing plant and the operation. Material specifications for DU oxides that will be stored or disposed of as a waste will be less rigorous than for commercial fuel and some steps of the proposed process may not be required to achieve the less rigorous specifications. A demonstration program appears appropriate to define the operational characteristics with a modified process that would produce an acceptable uranium oxide for long term storage or disposal.

Conversion of the recovered aqueous HF to anhydrous HF is the only means to achieve a salable product from the operation and a development effort would be required to define an appropriate process for converting the large quantities of aqueous HF to AHF. The market value of the recovered AHF would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

The operational and use period for the facility for the conversion of DOE material, of about two decades, may be a normal life of such chemical facilities. However, since uranium enrichment operations are continuing in the U.S., additional depleted UF_6 is being generated. Extended use of the plant may be achieved for additional conversion of this added material. After the facility has reached full economic life, it would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of uranium oxides would be in the same range as the cost of storing depleted UF_6 over the next one to two hundred years. The weight of total uranium oxide would be about twenty percent less than the depleted UF_6 , although the volumetric space would be somewhat less depending on the extent of compacting the uranium oxide powder. Rectangular containers of uranium oxide would pack and stack in a space more efficient than the cylindrical containers of depleted UF_6 . However, the cost of new metal containers for the uranium oxide would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be called for at an added cost for storing containers of uranium oxides, while outdoor storage of depleted UF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, uranium oxide would probably be the material form of choice for disposal. The present worth value of continued storage as depleted UF_6 for one hundred years and delayed conversion to uranium oxides for disposal may be considerably less than performing the conversion within the next few decades. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes. However, the cost of final disposal is indeterminate at this time.

7.2.1.3.2 Evaluation by Reviewer V

Preliminary costs provided by the respondent indicate that the costs to process depleted UF_6 to uranium oxides would be less than \$3.50/kg, or about \$1.3 billion for the entire inventory. No credit for the sales of recycled products is included in this amount. The estimate does not include the costs of transporting the material to processing or the costs of using, storing or disposing of the material after it is converted. There is no assessment of the demand for UO_2 , U metal or the products that could be fabricated from them to determine if sale of uranium oxides might offset costs. Given the advanced commercial status of this process, consideration should be given to cost-sharing or partnering with the private sector on this type of project.

7.2.1.3.3 Evaluation by Reviewer X

Siemens estimates a conversion cost of \$3.50/kgU without considering the benefit from the sale of the by-product. They state this assumes the final oxide form contains a residual fluoride level higher than that specified for nuclear fuel. This would enable the calciner to be deleted from the process stream.

As with all other proposed conversion technologies, the key element of affordability may be the identification of applications for the conversion product, whether it is U_3O_8 or uranium metal. This is the most valuable and costly product and having to dispose of it not only increases the cost of any conversion program, but also foregoes a possible cost recovery from the sale of the uranium.

7.2.1.3.4 Evaluation by Reviewer Y

Estimated conversion costs, without stated basis in proposal, of \$3.5/KgU are reasonable but probably on the low side assuming high product quality for side revenue producers. Cost proposal could become more substantive after Demonstration Program costs are identified. It is hard to extrapolate Linggen, Germany, costs to US because of exchange rate, taxes, and social costs. These all impact on extrapolation of costs. It is not clear that decommissioning costs are included in this early estimate.

7.2.1.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. Presuming fluorine or hydrofluoric acid were recovered, it would have commercial value. Also, as noted in the proposal, the production plant proposed would be larger than the existing fuel cycle plants since it would not be limited in size by the nuclear criticality issue. The larger size plant should result in some economy of scale reductions in cost.

7.2.1.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.1.4.1 Evaluation by Reviewer U

The chemical process requirements are well defined since the process has been in operation in Germany on a reasonable scale. Technical maturity is sufficient to permit its use with minimal research and development. Some effort will be required to define the acceptable purity of uranium oxide for long term storage or disposal and to refine the approach of producing anhydrous HF instead of aqueous HF.

7.2.1.4.2 Evaluation by Reviewer V

These technologies are in commercial operation for similar applications. Some process redesign and demonstration would be needed to convert to a different input material and to scale up by the five-fold required to process the inventory economically. The existence of a demonstration facility that is immediately available means that testing could be completed in a very short time period. Full scale commercial processes could be built in the very near future.

7.2.1.4.3 Evaluation by Reviewer X

The dry conversion process was developed in the early eighties and currently operates in a Lingen, Germany, facility processing 400 tonnes/year of low-enriched uranium. A slightly smaller prototype is operating in Richland, Washington, with a facility to handle 800 tonnes/year under construction. The uranium oxide produced is currently UO_2 , but they state other oxides could be formed. Also, the product is being made for reactor fuel, and so the specifications on fluoride content are quite strict. Siemens states that if the oxide is to be disposed of, the specification could be relaxed, and costs lowered. However, if the oxide may be used in another product, such as a metal product, then the fluorine content may need to be minimized.

The process in Germany produces aqueous HF which is not used in the U.S. That Aqueous HF is produced rather than AHF is a little surprising since the process is stated to be a dry process. Thus, distillation would be necessary prior to sale.

Siemens states that since there are no criticality concerns with handling depleted uranium, the size of the fluidized bed can readily be increased without concern for the size of the chemical reactors. About 15 reactors would be necessary to process 30,000 tons of uranium per year with recovery of about 97% of the HF for sale.

7.2.1.4.4 Evaluation by Reviewer Y

The proposal demonstration program should be the basis of refining the proposal. However, the costs for this program are conspicuous by their absence—unless they are included in the base cost. This is not likely but a basis for dialogue. It is not clear that byproduct quality in the context of impurities can be translated to the USA directly!

7.2.1.4.5 Evaluation by Reviewer Z

UF_6 conversion to a stable form such as an oxide is a mature chemical process. UF_6 Conversion to U_3O_8 , UO_3 , and UO_2 has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel.

7.2.1.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.1.5.1 Evaluation by Reviewer U

Employment at a facility to convert depleted UF_6 to uranium oxides and AHF would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure for much of the processing. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a new locality for a conversion facility for depleted UF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.2.1.5.2 Evaluation by Reviewer V

The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. Employment is not specified but labor requirements are described as "low". The siting of such a facility may face minor problems with public acceptance. Environmental risks of these processes are fairly well known. Traffic, including uranium transport, to and from the site will be examined. If the oxides need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.2.1.5.3 Evaluation by Reviewer X

Siemens states that based on their experience with their Lingen dry conversion facility, the labor requirements to operate a large dUF_6 processing facility should be relatively low. This is not further defined.

Any proposed facility would have to gain the approval of local populations.

7.2.1.5.4 Evaluation by Reviewer Y

The proposal states that "based upon the experience of our Lingen dry facility, the labor requirements...should be relatively low." It is likely that this will be a multishift operation and with ancillary quality facilities, on the order of 200-300 workers and staff are anticipated, not counting construction and decommissioning personnel. The number would be significant in communities near the depleted UF_6 storage sites or Richland, the home of Siemens Power in the USA. Public acceptance should not be a problem in these communities unless aroused by other activities.

7.2.1.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.2.1.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.2.1.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as depleted UF_6 or uranium oxide. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need

for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of depleted UF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, uranium oxide, is greater than the cost of converting the depleted UF_6 to uranium oxide in the near future, with associated impacts.

7.2.1.6.2 Evaluation by Reviewer V

See General Comments.

7.2.1.6.3 Evaluation by Reviewer X

None.

7.2.1.6.4 Evaluation by Reviewer Y

The fundamental decision to convert depleted UF_6 to UO_2 , U_3O_8 , or some other form must be made early on. If the process for making metal from UO_2 is sensible, this option may be quite attractive.

7.2.1.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.1.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.1.7.1 Conclusion by Reviewer U

This option of converting depleted UF_6 to uranium oxides using the proprietary dry process and the recovery of HF is reasonable, acceptable and the federal regulatory requirements are understood. However, to achieve a marketable form of HF it appears necessary to modify the process to provide AHF. If the depleted UF_6 is to be converted to

uranium oxide, one of the "dry" processing approaches such as the one recommended in this Document would be preferred over the more conventional "wet" processes.

Most of the process steps are well defined. Some development and demonstration appears needed to evaluate the conversion of aqueous HF to AHF prior to construction of a commercial facility. Since the value of the marketable AHF is less than the overall cost of recovering it from depleted UF_6 , there is a net added cost over the current storage mode cost base. A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting depleted UF_6 to uranium oxide. Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. Uranium oxide powder compacting appears desirable to minimize the overall volume. In all cases, the approach should be to maximize the recovery of useful and valuable by-products. Cleanup of all waste streams to minimized the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued.

Conversion of depleted UF_6 to uranium oxide for storage should be performed only if a decision is made that storage of DU as depleted UF_6 is unacceptable.

The organization submitting the recommendation in Document #P1 is well experienced and competent in the processing of uranium and UF_6 .

7.2.1.7.2 Conclusion by Reviewer V

The proposed process seems to meet all of DOE's reasonableness criteria. The commercial nature of the processes suggests that the timing and technical maturity criteria would be met and the process is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues. In general, it would appear that the process should receive further consideration.

7.2.1.7.3 Conclusion by Reviewer X

The proposed process requires scale up from a commercially operating plant size to meet DOE's goal of depleting the entire inventory of dUF_6 within 30 years. However, Siemens states there are no obstacles to such a scale up, and proposes to accomplish it with multiple reactors operating in parallel. Since the process is already proven, it should be possible, pending licensing and regulatory approvals, to begin operation within five years. With existing equipment in Richland, Washington, a demonstration program can be launched in very short order.

To eliminate the fluoride waste stream, the aqueous HF product will need to be dehydrated for use in the U.S. market.

If a commercial plant can begin production by 2000, then DOE's goal of depleting the dUF_6 inventory within 30 years can easily be met.

The waste stream is projected to consist only of UO_2 or U_3O_8 . Disposal options for the oxide haven't yet been determined.

Cost projections of \$3.50/kgU for conversion are well within the DOE guidelines. However, the ultimate solution is to find uses for the oxide so that the uranium can be sold to help defray the conversion cost, no matter what it is, and to forego any disposal cost.

The proposed process requires scale up from a commercially operating plant size to meet DOE's goal of depleting the entire inventory of dUF_6 within 30 years.

7.2.1.7.4 Conclusion by Reviewer Y

This proposal is reasonable if least volume of the converted material is not highly desirable. An easy process to produce metal backing this process up would make this process option highly desirable.

7.2.1.7.5 Conclusion by Reviewer Z

This option has a great deal of merit, and should be considered. This option has the potential for converting large amounts of depleted UF_6 to a more stable form for use in other applications, for long-term storage, or for burial. This option includes the conversion of the material to a more stable, less chemically reactive form, and suggests a final disposition for the U_3O_8 would be disposal or for beneficial use such as mixing with concrete to use as a shielding material for spent fuel or high-level waste storage casks.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to either U_3O_8 or UO_2 would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form, or that will be disposed of in burial areas.

7.2.2 Evaluation of Document No. 16 (Independent Technical Reviewers' No. P2)

Response 16 was designated as proprietary information by the submitter, Dana H. Lee, Fluor Daniel, Inc. A non-proprietary summary of the response was submitted on January 12, 1995 and on June 5, 1995, the submitter informed LLNL that the following Independent Technical Reviewer evaluations were non-proprietary.

This response provides two options for the recovery of anhydrous hydrogen fluoride (AHF) from the conversion of depleted UF_6 :

1. A two-part process for the dry conversion of depleted UF_6 to UO_2 with the dehydration of off-gases to produce AHF.
2. A two-part process for the classical conversion of depleted UF_6 to uranium metal using magnesium, with intermediate conversion to UF_4 and the resultant production of AHF recovered from MgF_2 .

7.2.2.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.2.1.1 Evaluation by Reviewer U

Options 1 & 2 - Document #P2 identifies the means of producing anhydrous HF (AHF) from aqueous HF and magnesium fluoride as well as the recovery of useful magnesium sulfate. A dry process for the production of uranium oxides is assumed and the proposed approach describes the means to recover AHF from that process. Also, the conventional AMES uranium metal production process is assumed and the proposed approach recovers AHF and magnesium sulfate from the conventional waste products of that process.

The proposed processes are applicable to the material recovery and treatment of waste and by-product streams from the conversion of depleted uranium hexafluoride (depleted UF_6) into uranium oxides and/or uranium metal. At least one large conversion plant would be required for the main processing. The additional processing steps for the recovery of useful material would supplement and complement the conventional conversion processes.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary

uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as recommended recovers anhydrous HF (AHF), a material with considerable commercial demand. If the process results in trace amounts of uranium, then it may be appropriate to allocate the HF for use in the conversion of natural uranium to UF_6 prior to the enrichment step. The recovered magnesium sulfate is a marketable product if sufficiently clean of uranium.

No additional transportation issues are encountered for the recommended processes beyond those associated with the transportation of depleted UF_6 to a new conversion facility.

Site restrictions for a conversion facility are relatively few and the additional recommended processing steps should not have an impact on siting restrictions. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

The conversion process supplemented with the recommended processing of the waste and by-product streams is amenable to a closed system with no requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or for sufficiently clean materials in sanitary land fill.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the conversion operations and the recommended supplemental waste stream processing appears to be relatively straight forward without the need for time consuming development of new regulations.

7.2.2.1.2 Evaluation by Reviewer V

Option 1 - The option proposed is for reprocessing depleted UF_6 to produce uranium oxide (UO_2) and anhydrous hydrogen fluoride (AHF). The uranium oxide could be used for products, stored or disposed of in approved low-level facilities, depending on DOE

program directions. Uranium oxides are a far more stable form of uranium for storage, with the chemicals largely inert and insoluble in typical ambient storage conditions. Once converted, it would pose far less risk to workers and the public than depleted UF_6 which is unstable, toxic and hazardous. The reprocessing of depleted UF_6 has environmental risks, however. The increased handling and operation of the processing facility raise issues regarding the potential for releases, spills, worker exposures and damage to the environment. The type of process proposed here has extensive commercial operating experience at a smaller scale. In the process, the hydrofluoric acid is recovered and dehydrated before it is sold as a by-product. The process is described as having no effluent waste streams. Emissions include offgas discharges that have HF and uranium levels well below allowed limits. The dehydration process requires the use of hazardous acids that must be carefully managed in the processes.

Siting for this processing facility could present a development concern if a large industrial site needed. Such a site would raise environmental and public health questions, depending on the location. Use of an existing site at one of the current storage facilities might minimize siting issues. With years of operating experience already available, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility and for use in permitting activities. Transportation to and from the site could have impacts, especially if accidents occur.

Disposal or storage of the uranium oxides will also create environmental concerns and siting issues. Storage of U_3O_8 would not present significant environmental, health or safety risks if designed in a manner similar to those in Europe where metal containers are housed in above-ground buildings. Accidental releases could adversely effect workers if they came in contact with the material, but its largely inert chemical form makes the hazard minimal. Releases to surrounding areas are unlikely.

Overall the environmental concerns are expected to be resolvable.

Option 2 - The option proposed is for reprocessing depleted UF_6 to produce uranium metal and anhydrous hydrogen fluoride (AHF). The process, while producing uranium metal, will have many of the same environmental issues regarding the handling of depleted UF_6 and AHF, and the operation of a large conversion facility handling hazardous and radioactive materials as discussed in Document 2-1. The major difference is the use of an improved process to convert the depleted UF_6 to metal using magnesium, where maximum recovery of the fluoride is accomplished. Only the MgF_2 conversion will constitute a new process. This latter process is typical of others in the industry, but appropriate operational procedures will be needed to assure safe operations. This process does require large quantities of sulfuric acid, but they will be handled according to industry standards. Siting and design considerations are very similar to those for the options in Document P-2-1.

The environmental, health and safety concerns regarding this option will parallel those experienced in the uranium metals industry and the nuclear fuels industry, in general. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and

toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen. Careful siting and design taking into account public concerns about these facilities will be needed. The uranium metal could be used for products, stored or disposed of in approved low-level facilities, depending on DOE program directions. The hydrofluoric acid is recovered and sold as a by-product. The process is described as having no effluent waste streams.

Siting for this processing facility could present a development concern because of the large industrial site needed. This could raise environmental and public health questions depending on the location, as discussed in Document P-1. With years of operating experience already available for the metal conversion, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility. Transportation to and from the site could have impacts, especially if accidents occur. Disposal or storage of the uranium oxides will also create environmental concerns and siting issues.

Overall the environmental concerns are expected to be resolvable.

7.2.2.1.3 Evaluation by Reviewer X

Fluor Daniel provides two processes, neither of which requires progression through laboratory-bench-pilot studies. One process produces uranium oxide and the other produces uranium metal through the intermediate step of producing UF_4 . Both processes are designed to generate no solid waste. Aqueous HF is produced in both processes, and two methods are recommended for dehydration. This review concentrates on the process to produce a uranium oxide.

Option 1- Siting and transportation are related by three concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site,
2. Transportation of the U_3O_8 to the ultimate disposal site, and
3. Transportation of the AHF product to the end user.

Even though a site is already licensed for handling some materials, license approval for handling large quantities of dUF_6 feedstock and U_3O_8 product would still be required. Thus, a comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations. The licensing process will be subject to public hearings and comment.

The above three concerns need to be evaluated from both cost and safety aspects. Since U_3O_8 is the most stable of the materials to be handled (dUF_6 , U_3O_8 , and AHF), closeness of the disposal site to the processing site should be the least concern. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to or on a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to

a non-defective cylinder prior to transport), to insert them into overpacks prior to shipping, or to transfer the dUF_6 to 2½ ton cylinders as is currently done for transportation might be required. Special measures may need to be developed for handling cylinders in overpacks.

The third concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So the first and third concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

Option 2 - Siting and transportation are related by two concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site, and
2. Transportation of the AHF product to the end user.

Even though a site is already licensed for handling some materials, license approval for handling large quantities of dUF_6 feedstock, metal product, and AHF would still be required. Thus, a comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations. The licensing process will be subject to public hearings and comment.

The above two concerns need to be evaluated from both cost and safety aspects. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to or on a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport), to insert them into overpacks prior to shipping, or to transfer the dUF_6 to 2½ ton cylinders as is currently done for transportation might be required. Special measures may need to be developed for handling cylinders in overpacks.

The second concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So both concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

7.2.2.1.4 Evaluation by Reviewer Y

Options 1 & 2 - This seemingly mature proposal will require regulatory approvals that can be obtained. The only open question pertains to whether the depleted UF_6 is or is not declared as waste! Product origins and product quality may be an issue with the sale of the commercial AHF. Definition of significant impurities (e.g., DU) may impact the viability of the commercial AHF.

7.2.2.1.5 Evaluation by Reviewer Z

Options 1 & 2 - This proposal, submitted by Mr. Dana Lee, proposes to process the depleted UF_6 to convert it to either UO_2 or uranium metal, and to recover hydrofluoric acid. These are actually two separate processes, which would be require two separate facilities or sets of equipment.

Neither process proposed by this option would present any environmental, safety or health issues which are different that those which have previously been evaluated by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated. No site location was specified.

7.2.2.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.2.2.1 Evaluation by Reviewer U

Options 1 & 2 - The depleted UF_6 conversion to uranium oxides and/or metal and AHF should be achievable with a closed process when the recommended waste stream processes are incorporated. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

7.2.2.2.2 Evaluation by Reviewer V

Option 1 - The proposed process would have limited waste streams that include hydrofluoric acid to be recycled. No other wastes are described in the response. If small amounts of other wastes that include uranium or hazardous materials are produced, they would need to be handled at appropriate low level or sanitary disposal sites. The highly compact nature of the processed UO_2 powder will reduce the volume needed for disposal if the material cannot be recycled into other uses such as Ducrete. If HF by-products could

not be recycled into other commercial uses, this would create a disposal problem. The empty depleted UF_6 cylinders will need decontamination before recycling or disposal.

Option 2 - The proposed process would have limited waste streams that include hydrofluoric acid to be recycled and magnesium sulfate for direct use or conversion to other products. No other wastes are described in the response. If small amounts of other wastes that include uranium or hazardous materials are produced, they would need to be handled at appropriate low level or sanitary disposal sites. The highly compact nature of the U metal will reduce the volume needed for disposal if the material cannot be recycled into other uses. If HF by-products could not be recycled into other commercial uses, this would create a disposal problem. The empty depleted UF_6 cylinders will need decontamination before recycling or disposal.

7.2.2.2.3 Evaluation by Reviewer X

Option 1 - The recommendation states that no solid waste will be generated in the process. The "dry conversion" process uses no liquid water, but high temperature steam instead. It is similar to the generic process described in Information Package 1 that produces uranyl fluoride (UO_2F_2) and aqueous HF. The off-gases from this process are steam, hydrogen, and the aqueous HF which is recovered through condensation and then dehydrated.

Two dehydration processes are described. One uses sulfuric acid which is recovered and recycled through the process. The other uses ethylene glycol.

Fluor Daniel has no direct experience with these processes, but simply cites the literature or parts of the industry where the processes are practiced.

If the oxide must be disposed of, some location other than a low level radioactive waste (LLRW) facility will need to be found. The NRC has excluded near surface disposal as an option in NUREG-1484.

Considering the difficulty the several LLRW Compacts are having with obtaining enabling legislation in host states and siting these facilities, such an option is not likely to be available in a Compact facility. Also, dUF_6 is considered to be DOE waste under current law. It is not likely that states will allow this to become industrial waste in a transfer process to a conversion contractor. Thus, it will still need to be disposed of or stored as DOE waste.

Considering the situation in Ohio, it should be noted that the proposed Ohio facility will have both a time restriction of 20 years operation and a volume restriction of 2,250,000 cubic feet ($63,713 \text{ m}^3$), only about one-third the required volume for the current inventory of dUF_6 .

Illinois, the proposed state for the conversion plant site, has essentially restarted its LLRW siting process at Square One since it based its original process on a single volunteer site that has since been abandoned.

Several potential non-Compact sites might be available. One of these is the Envirocare of Utah, Inc., site. However, this site has a limit on contained uranium in its waste of 110,000 pCi/gm, which according to NUREG-1484 is far less than the activity in the U_3O_8 waste stream from Claiborne (I calculate this to be about 300,000 pCi/gm, but it could be higher, depending on how you treat the numbers.). The NTS in Nevada is an alternative ultimate disposal site. Its Waste Acceptance Criteria limits transuranic concentrations to less than 100,000 pCi/gm for consideration as LLRW (See EGG-MS-11297, pg. 33, with RFR #4). Thus, the U_3O_8 would need to be contained in some matrix, such as Ducrete. Also, Envirocare empties all containers. So the matrix must be stable.

Option 2 - Fluor Daniel proposes to use an improved Ames process. dUF_4 is produced from dUF_6 in a waterless process (which they call the 6-4 process) that results in recoverable AHF. The dUF_4 is then processed with magnesium resulting in uranium metal and magnesium fluoride.

They state that magnesium fluoride has always been a contaminated waste in the past. By adding sulfuric acid and heat, they propose to produce AHF, useful magnesium sulfate, and no solid waste. They give no indication of how the contaminant will be handled.

The uranium metal will be available for sale to commercial industries or may be disposed of in a deep burial facility.

7.2.2.2.4 Evaluation by Reviewer Y

Options 1 & 2 - Clearly a low-waste process option in any of the three forms (O_2 , metal, or dual) proposed.

7.2.2.2.5 Evaluation by Reviewer Z

Options 1 & 2 - The processes as proposed in this option do not to generate any waste streams. This proposal, however, is based on the recovery of anhydrous HF (AHF) from magnesium fluoride, and also based on converting aqueous HF to anhydrous HF at a cost that makes it economically feasible. If these two factors do not prove to be feasible, then the waste streams from the process would be aqueous HF and magnesium fluoride. These wastes are similar in characteristics to those currently experienced at various fuel cycle facilities and other chemical plants in the U.S.

7.2.2.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.2.3.1 Evaluation by Reviewer U

Options 1 & 2 - Costs associated with the conversion of depleted UF_6 to oxides or metal are reasonably well defined. The added cost associated with the capture of AHF is reasonably well defined. Capture of magnesium as a sulfate has not been done on a large commercial scale, thus it is less well defined.

The market value of the recovered AHF and magnesium sulfate would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility and the supplemental facilities used to process the waste and by-product streams would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

7.2.2.3.2 Evaluation by Reviewer V

Option 1 - No cost data is provided. Sales of recycled products would produce a revenue stream. Other similar technologies have been estimated to cost \$1.2 to \$1.7 Billion to convert then entire DU inventory. These estimates do not include the costs of transporting the material to processing or the costs of using, storing or disposing of the material after it is converted. There is no assessment of the demand for UO_2 , U metal or the products that could be fabricated from them to determine if sale of uranium oxides might offset costs. Given the advanced commercial status of this process, it is suggested that this type of project be privatized.

Option 2 - No cost data is provided. Sales of recycled products would produce a revenue stream. Other similar technologies have been estimated to cost \$3.0 Billion or more to convert the entire DU inventory. These estimates do not include the costs of transporting the material to processing or the costs of using, storing or disposing of the material after it is converted. There is no assessment of the demand for U metal or the products that could be fabricated from it to determine if sale of uranium oxides might offset costs.

7.2.2.3.3 Evaluation by Reviewer X

Option 1 - No cost projections are provided. It is only stated that costs will be commensurate with commercial-scale operations. The AHF will have recoverable product value.

Option 2 - No cost projections are provided. It is only stated that costs will be commensurate with commercial-scale operations. The approximately 200,000 MT of AHF will have recoverable product value.

A demonstration cost of \$5,000,000 for the magnesium fluoride decontamination process is provided.

7.2.2.3.4 Evaluation by Reviewer Y

Options 1 & 2 - The only cost figure cited in the proposal is a demonstration cost of \$5,000,000 for the MgF to AHF process. The commercial value of \$0.50+ per pound is anticipated.

7.2.2.3.5 Evaluation by Reviewer Z

Options 1 & 2 - This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. Presuming fluorine or hydrofluoric acid were recovered, it would have commercial value. Also, as noted in the proposal, the production plant proposed would be larger than the existing fuel cycle plants since it would not be limited in size by the nuclear criticality issue. The larger size plant should result in some economy of scale reductions in cost.

If uranium metal is produced, it is assumed that it would be for a commercial application, and would therefore have a commercial value. It is also proposed that the magnesium fluoride produced from the reduction process be processed to produce AHF and magnesium sulfate, which would also have commercial value.

7.2.2.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.2.4.1 Evaluation by Reviewer U

Options 1 & 2 - The chemical process requirements for converting depleted UF₆ to uranium oxides or metal are well defined since the processes have been used for a considerable period. Maturity of the capture of AHF, while not performed within the nuclear fuel industry, is known in other industries and should be considered sufficiently mature to be dependable.

The process of recovering magnesium sulfate from magnesium fluoride is less well defined and not performed on a commercial scale. Recent development work appears to have defined a successful process for this step. Additional development and demonstration are needed to define effective operating parameters.

7.2.2.4.2 Evaluation by Reviewer V

Option 1 - These technologies are in commercial operation for similar applications. Some process redesign and demonstration would be needed to convert to a different input material and to scale up by the size required to process the inventory economically. The development needed is described as low-risk and could move forward immediately. Full scale commercial processes could be built in the very near future.

Option 2 - These technology for uranium metal production is commercial. The process recommended for recovery of AHF from magnesium fluoride would require government funding. It would still need tests at the bench scale. Some process redesign and demonstration would be needed to convert the DU metals processes to the scale required to process the DU inventory economically.

7.2.2.4.3 Evaluation by Reviewer X

Option 1 - Conversion of UF_6 to U_3O_8 using the proposed method is practiced on a commercial scale in Europe by Cogema. Fluor Daniel states it's also practiced in the U.S. on a scale of about 1,000 tons of uranium per year per facility in the production of UO_2 for reactor fuel. Since this scale is too small to work down the DOE supply in a reasonable time frame, the process would have to be scaled up by a factor of about 20. This should be possible since criticality concerns with depleted uranium and the oxide quality are not issues.

The dehydration of aqueous fluoride is said to be practiced in the petroleum industry and developed enough to require only classical process design based the required flow rates and the composition of the off-gas.

Option 2 - Conversion of dUF_6 to dUF_4 is a standard industrial practice, as is the use of magnesium to produce uranium metal and magnesium fluoride. However, the technology to convert magnesium fluoride to AHF and magnesium sulfate has never been practiced commercially.

Successful experimental results were reported by a Swiss company in 1994. The reaction requires 100+ % pure sulfuric acid. The operating temperatures are less than 750°F, low enough that commercial equipment can operate safely. Fluor Daniel proposes that a two-year demonstration project be funded for \$5,000,000 using equipment of sufficient size so that risk free scale up can be accomplished. They state that laboratory-bench-pilot studies aren't necessary because of the vast experience base with calcium fluoride which has a similar behavior to magnesium fluoride.

After the demonstration study, they propose the privatization of the rest of the program.

7.2.2.4.4 Evaluation by Reviewer Y

Options 1 & 2 - The proposal eloquently states that all facets are state-of-the-art except for the demonstration of converting MgF_2 to AHF and $MgSO_4$. The evidences for the process

experiences are cited and are credible and understood. The proposers seem to understand and have experience with the technology (or they have a very good proposal writer).

7.2.2.4.5 Evaluation by Reviewer Z

Options 1 & 2 - UF_6 conversion to a stable form such as an oxide is a mature chemical process. UF_6 Conversion to U_3O_8 , UO_3 , and UO_2 has been practiced commercially for about three decades in the fabrication of light-water-cooled nuclear power reactor fuel.

The UF_6 to uranium metal reduction process is also a mature technology. This is a two step process, which involves the reduction of UF_6 to UF_4 , and then the conversion of the UF_4 to uranium metal using the "bomb" reduction technology. This technology has been utilized for several decades to produce uranium metal.

The technology for converting aqueous HF to anhydrous HF (AHF) has not been demonstrated on a commercial scale, and therefore the economics have not been shown to make the process cost effective.

Also, the technology to convert the magnesium fluoride to AHF and magnesium sulfate has not been performed on a commercial scale. Laboratory tests have demonstrated the feasibility, but full scale testing has not been performed.

7.2.2.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.2.5.1 Evaluation by Reviewer U

Options 1 & 2 - Employment at a facility to convert depleted UF_6 to uranium oxides and/or metal and the supplemental facilities for the recovery of AHF and magnesium sulfate would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure for much of the processing. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

The additional processes steps included in this Document would probably be acceptable to the public if a depleted UF_6 conversion facility is acceptable. No additional public concerns beyond those associated with a conversion facility are expected.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.2.2.5.2 Evaluation by Reviewer V

Option 1 - The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. Employment is not specified. The siting of such a facility may face minor problems with public acceptance. Environmental risks of these processes are fairly well known. Traffic, including uranium transport, to and from the site will be examined. If the oxides need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

Option 2 - The construction of a facility to process the 28,000 tons/year required to meet the inventory reduction goal would be a major project and the economic effects would be significant locally. Employment is not specified. The siting of such a facility may face minor problems with public acceptance. Environmental risks of these processes are fairly well known. Traffic, including uranium transport, to and from the site will be examined. If the oxides need to be disposed of, LLW disposal facilities continue to be a health concern to the general public as reflected in the difficulty in siting such facilities.

7.2.2.5.3 Evaluation by Reviewer X

Option 1 - Any proposed facility would have to gain the approval of local populations.

No estimates are provided on the required work force. However, other sources estimate that a typical plant would employ about 40 management staff and 120 hourly workers. The plant would operate around the clock five days per week to meet the production requirements.

If the plant is built near an existing production facility, a trained work force should be available, although if production is not cut back at these facilities, labor rates may increase.

Reduction of the dUF_6 inventory should result in a positive public acceptance of the proposed process if the new plant is constructed near current production facilities.

Option 2 - Any proposed facility would have to gain the approval of local populations.

No estimates are provided on the required work force. However, other sources estimate that a typical plant would employ about 40 management staff and 120 hourly workers. The plant would operate around the clock five days per week to meet the production requirements.

If the plant is built near an existing production facility, a trained work force should be available, although if production is not cut back at these facilities, labor rates may increase.

Reduction of the dUF₆ inventory should result in a positive public acceptance of the proposed process if the new plant is constructed near current production facilities.

7.2.2.5.4 Evaluation by Reviewer Y

Options 1 & 2 - Depending on whether single or dual process is adopted, an employment of several hundred process workers and staff is anticipated. This does not include transportation and ultimate use (if any) of the process materials. The construction and operation of the process facilities would make a significant dent in all but sizable population centers.

The proposers' record on public acceptance is of some interest here. This reviewer is not aware of either positive or negative connotations.

7.2.2.5.5 Evaluation by Reviewer Z

Options 1 & 2 - This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.2.2.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.2.2.6.1 Evaluation by Reviewer U

Options 1 & 2 - Recovery of the maximum amount of useful products and producing the least amount of waste volume requiring disposal are important factors. The recommended processes will assist in achieving this set of factors.

7.2.2.6.2 Evaluation by Reviewer V

Option 1 - See General Comments.

Option 2 - See General Comments.

7.2.2.6.3 Evaluation by Reviewer X

Option 1 - None.

Option 2 - None.

7.2.2.6.4 Evaluation by Reviewer Y

Options 1 & 2 - Requisite quality of commercial products can exacerbate product costs beyond those cited.

7.2.2.6.5 Evaluation by Reviewer Z

Options 1 & 2 - This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.2.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.2.7.1 Conclusion by Reviewer U

Options 1 & 2 - If the depleted UF_6 is converted to oxides or metal, the use of processes to recover AHF and magnesium sulfate from the waste and by-product streams should be considered as integral and necessary process steps. However, if advanced processes are used to produce metal, such as the plasma approach, magnesium may not be part of the process. The recommended processes must be evaluated in detail with alternate waste stream recovery processes to define which ones are the more efficient and economical.

Most of the process steps are well defined. Some development and demonstration appears needed to evaluate the capture of magnesium sulfate.

The organization submitting the recommendation in Document #P2 is experienced and competent in the design and construction of chemical processing facilities.

7.2.2.7.2 Conclusion by Reviewer V

Option 1 - The proposed process seems to meet all of DOE's reasonableness criteria. The commercial nature of the processes suggests that the timing and technical maturity criteria would be met and the process is consistent with DOE program goals. There do

not appear to be any major environmental, safety, health or siting issues. In general, it would appear that the process should receive further consideration.

Option 2 - The proposed process does not meet all of DOE's reasonableness criteria. The commercial nature of the metals process meets the timing and technical maturity criteria, but the AHF recovery process needs much more work and has some degree of uncertainty. The combined costs of these technologies along with the transportation, product development and/or storage and disposal costs could make this option too costly. More development and costing is needed to consider it for the program.

7.2.2.7.3 Conclusion by Reviewer X

Option 1 - Fluor Daniel demonstrates considerable knowledge of the literature and commercial processes that convert UF_6 to oxides and aqueous HF or AHF. However, they don't describe any of their own corporate experience. Even so, the processes described utilize standard industrial methodologies and should be able to be implemented in a reasonable time frame on a scale that can convert the existing dUF_6 during a 20-year processing time. If a scaled up commercial plant can begin production by 2000, then DOE's goal of depleting the dUF_6 inventory within 30 years can easily be met.

The process uses conventional technology. It results in UO_2 or U_3O_8 and aqueous HF with no projected solid waste stream. Dehydrating the aqueous HF to produce AHF will require some research and testing, although standard processes are recommended. All chemicals are recycled, and no waste stream is projected.

Capital and operating costs were not stated. Other sources project capital costs to be less than \$300 million. An operating crew of 160 may be sufficient to staff the plant, but no operational costs are projected. Again, others have projected a conversion cost using this technology of \$3.00/kg or less. Disposal costs for deep burial (100-150m beneath the surface) would add about \$50 million to the total. These cost projections for conversion and disposal are well within the DOE guidelines.

Disposal options for the oxide haven't yet been determined. However, the ultimate solution is to find uses for the oxide so that the uranium can be sold to help defray the conversion cost, no matter what it is, and to forego any disposal cost.

This recommendation is consistent with DOE's guidelines for reasonableness.

Option 2 - Fluor Daniel demonstrates considerable knowledge of the literature and commercial processes that convert UF_6 to metal and AHF. However, they don't describe any of their own corporate experience. The proposed process for converting dUF_6 to metal is a standard industrial process. But the process for converting the magnesium fluoride to a salable commodity must be demonstrated. No mention is made of the problem of decontaminating the magnesium fluoride.

Capital and operating costs were not stated.

The ultimate solution for the metal is to develop end product uses so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

Of primary concern in the sale of the metal will be the controls necessary to assure the depleted uranium isn't randomly disposed as industrial waste when it is no longer needed. Companies currently selling uranium to private industry should be contacted to obtain information on licensing practices. It would seem that selling metal for large scale applications would provide for easier license maintenance than small scale applications. For instance, large quantities of uranium used for counterweights would be easier to track than small quantities used for wheel balancing.

Construction of a commercial scale plant should be feasible pending the success of the demonstration study and success in obtaining regulatory and community approvals. However, it isn't clear that Fluor Daniel is as familiar with the processes as are other companies.

7.2.2.7.4 Conclusion by Reviewer Y

Options 1 & 2 - This process proposal is reasonable on all grounds except two:

1. Costs are not cited except "no government funding required," and
2. Disposition of material following process is not proposed.

Clarification of 1) above can be ascertained by further dialogue or formal bid process.

Clarification of 2) is outside the process scope which is ultimately defined elsewhere (DOE) and could well be a separate proposal (e.g., a strategic depleted Uranium reserve).

7.2.2.7.5 Conclusion by Reviewer Z

Options 1 & 2 - This option has merit, and should be considered. This option has the potential for converting large amounts of depleted UF_6 to UO_2 or uranium metal for use in other applications, for long-term storage, or for burial. The primary conversion steps are based on proven technology. The untested processes relate to the processing of the waste streams to produce commercially valuable products. If these processes do not prove to be cost effective, the waste streams which are produced are similar to those which are currently found in the nuclear fuel cycle industry.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to either UO_2 or uranium metal would also be dependent upon the designated use for the product. The production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide or metal form, or that will be disposed of in burial areas.

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7.2.3 Evaluation of Document No. 24 (Independent Technical Reviewers' No. P4)

Response 24 was designated as proprietary information by the submitter, Dennis J. Lehan, Nuclear Materials, Inc. (NMI). On June 5, 1995, Mr. Lehan informed Lawrence Livermore National Laboratory that the response (excluding the unsolicited proposal, which remains proprietary) and the following Independent Technical Reviewer evaluations are released as non-proprietary.

This response recommends three options for long-term management of depleted UF₆.

1. Utilize the UF₆ in metal or oxide forms in a variety of product applications.
2. Convert the UF₆ to metal using the Ames process and develop a leaching process to first decontaminate the MgF₂ and then use it with H₂SO₄ as feedstock to produce AHF.
3. Develop a new process for High Temperature Continuous Reduction (HTCR) of the UF₄ to produce uranium metal.

7.2.3.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.3.1.1 Evaluation by Reviewer U

Option 1 - A list of sixteen potential uses for depleted uranium (DU) was provided in Document #P4. An estimated amount of DU that might be used in each application was provided without backup basis for the use or the amount. Further, the Document stated that "These uses could be expanded through the development of lower cost metal." The primary Document recommendations were on means to reduce the cost of producing uranium metal and the evaluation of those recommendations are provided under Documents P4b and P4c. This evaluation covers the five largest potential uses.

The large volume potential uses were listed as; 1- HLW Cask, 2- Tails Stripping in AVLIS, 3- Tails Stripping in Centrifuge, 4- Breeder Blanket, and 5- Concrete Aggregate, each with a maximum potential use of greater than 100,000 metric tons (MT). Uses one and two would require the DU to be converted to uranium metal. Uses four and five would require the DU to be converted to an oxide, while use three would employ the depleted uranium hexafluoride (depleted UF₆) directly without the need to convert it to

another form. Although not indicated in the Document, the initial volumes that may be used would probably be relatively low and considerably less than the estimated maximum provided in the Document #P4. Thus, the production of the uranium oxide and uranium metal could be provided within current existing facilities or with some expansion of existing facilities. If the applications proved to be advantageous and large volumes of material called for, at least one new large conversion facility would be required.

The use of DU as radiation shielding material in high level waste shipping casks should permit a smaller size for the cask and possibly a larger weight of spent fuel in each shipment. This application is being evaluated by the Radioactive Waste Management Section within DOE and a determination will be made on the basis of economics as well as applicability. Other materials, such as lead, may provide a more economical overall cask design.

Using DU as feed stock for additional uranium enrichment with the AVLIS process appears possible, but may not be practical within a time frame of several decades. The AVLIS process has been under development for approximately thirty years without achieving necessary results to permit the process to be deployed commercially. The only new uranium enrichment plant that has been proposed in the U.S. during the past fifteen years, employs the developed centrifuge process. While the AVLIS process may turn out to be a dependable low cost means for enriching uranium, a significant pilot plant operation would be required to prove out the technology on a commercial scale. Relatively large quantities of good grade uranium ore have been defined in Canada and Australia that can be developed to provide low cost natural uranium feedstock for uranium enrichment, equivalent to projected needs for many decades. Stripping ^{235}U from the DU would be higher in cost than from natural uranium. To deploy this use, two new facilities would be required; 1- conversion of depleted UF_6 to metal and 2- a very large AVLIS enrichment plant.

Using depleted UF_6 as feed stock for additional uranium enrichment with the centrifuge process appears possible, but may not be practical within a time frame of several decades. A new centrifuge plant has been planned for the U.S. and is yet to be built. The capacity of the planned plant would not be sufficient to process large quantities of DU. Stripping ^{235}U from the DU would be higher in cost than from natural uranium. To deploy the centrifuge process for further stripping of the depleted UF_6 it would require the design construction and operation of a new large centrifuge plant.

The use of DU in Breeder Blankets should permit the recovery of substantial quantities of energy from the DU. However, the breeder reactor program is not progressing very rapidly and it will be many decades before a determination is made to deploy breeder reactors.

The specific application of the use of DU as aggregate in concrete would provide a smaller volume structure for radiation shielding. The uranium oxide, either as a sand and/or pellets would be used as the aggregate within the concrete mix. Eventual disposition of the DU containing concrete, after the useful life of the shielding material, would require approved disposal criteria for uranium containing material. It is unknown whether

approval for disposal in low-level radioactive facilities would be permitted by regulation or state permitting. However, if used in the high level waste program and disposed of as a component of the high level waste repository, or as a structure for containment of low level radioactive waste at low level waste disposal sites, the use of DU as aggregate may be an appropriate means of achieving disposal of a significant quantity of the DU. However, it does not appear to be a reasonable application on a general basis as a substitute for stone aggregate for radiation shielding concrete.

Overall Federal regulation for safety could be under the existing DOE regulations for the conversion of depleted UF_6 to oxides or to metal when it is performed at DOE facilities. Otherwise, regulation would be under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). Basic regulations have been in place for several decades and several licenses granted by the NRC for the production of uranium metal. However, regulations for the operation of an AVLIS facility would need to be developed. No basic regulations are in place for commercial use of depleted uranium as aggregate in concrete and a lengthy process may be encountered to establish such regulations.

Option 2 - Document #P4 identifies a need for the demonstration of reclamation of magnesium fluoride (MgF_2), that results from the production of uranium metal, to reduce low level radioactive waste disposal costs and provide a recycle stream for the material. The MgF_2 slag by-product volume of the magnesiothermic reduction process used to convert UF_4 to metal is large and it contains a relatively high amount of uranium, in the range of one to seven percent. This renders the MgF_2 unusable for other applications and it must be disposed of at considerable expense in a low level radioactive waste burial site.

Grinding, multistage leaching, precipitation of UF_4 , recovery of anhydrous HF (AHF) and recovery of magnesium are briefly described in Document #P4. Pilot demonstration of the proposed steps would be necessary to assure that satisfactory and usable products are recovered from the slag. This set of processes would be applicable to the conventional Ames process for the production of uranium metal as well the other continuous reduction processes.

Processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into uranium metal and the recovery of AHF and magnesium will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities at several sites as a supplement to the conversion facility for the production of uranium metal.

The supplemental processes described in Document P4 are uniquely addressed to minimize waste volume and recover recyclable materials from the waste streams of conventional processing. The process to recover AHF is reasonable well defined. Recovery of magnesium would require development efforts to define the appropriate parameters for successful recovery. The magnesium would be recycled back as feedstock for the production of uranium metal.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as recommended recovers anhydrous HF, a material with considerable commercial demand. If the process results in trace amounts of uranium, then it may be appropriate to allocate the HF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Processing of the magnesium fluoride slag waste stream generated during the production of uranium metal would not entail additional transportation beyond that required for the conversion facility. It would reduce the volume of waste needing disposal by a considerable amount.

Site restrictions for a conversion facility are relatively few and the added processes for the waste stream would not create additional site requirements. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

The conversion process is amenable to a closed liquid system with no requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or for sufficiently clean materials in sanitary land fill.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed processing of the slag appears to be relatively straight forward without the need for time consuming development of new regulations.

Option 3 - Document #P4 identifies a unique process to produce uranium metal--high temperature continuous reduction. Early development work directed to produce an iron-uranium alloy as feedstock for the AVLIS process has defined an approach of continuous metal production from uranium tetrafluoride (UF_4) with magnesium and a

diluent molten salt. Details of the process are not provided. However, the basic concept has been demonstrated at a temperature that provides the iron-uranium alloy. A higher temperature operation would be required to produce a pure uranium metal. If the depleted uranium (DU) is designated to be a waste material for disposal, and uranium metal an acceptable waste form, the production of a uranium-iron alloy at the lower temperature may be appropriate for waste disposal. A pilot plant and demonstration plant operation would be required to determine the practicality and economics of a continuous metal reduction process. The first step of converting depleted uranium hexafluoride (depleted UF_6) to UF_4 would be the same for the continuous process as for the conventional Ames batch process. Cleaning of slag and recovery of usable products would entail the same technology for both approaches.

Processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into uranium metal and the recovery of AHF and magnesium will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities at several sites.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as recommended recovers anhydrous HF (AHF), a material with considerable commercial demand. If the process results in trace amounts of uranium, then it may be appropriate to allocate the HF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Transportation of depleted UF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the depleted UF_6 is now located. If only one facility is constructed at one of the three current sites, the depleted UF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of UF_6 has occurred between the three uranium enrichment sites for decades and truck transport of natural and low enriched UF_6 is an on-going step of the nuclear fuel supply industry. A site independent and away from the existing storage sites could be used with either rail or truck transport from the three storage sites.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

The conversion process is amenable to a closed liquid system with no requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or for sufficiently clean materials in sanitary land fill.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.2.3.1.2 Evaluation by Reviewer V

Options 1, 2 & 3 - This option proposes the use of depleted uranium, primarily in the form of uranium metal, in dense material products and for shielding materials in uses such as the MPC which DOE is developing. This would require the production and use of uranium metal on a much wider scale than it is currently used. The conversion of depleted UF_6 to uranium metal has the same environmental issues as discussed in Document 5 regarding the handling of depleted UF_6 and HF, hazardous and radioactive materials. The environmental, health and safety concerns regarding this option will parallel those experienced in the uranium metals industry in general. Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations, but will need to be made explicit in the environmental permitting and reviews for the specific plant design chosen.

This recommendation addresses the residual magnesium fluoride sludge that is produced. Conventional Ames processes leave significant quantities of magnesium sludge which must be treated as a low-level waste. In the improved process suggested here, multi-stage leaching is performed using HCl and HNO_3 to remove uranium to the point where the sludge can be handled in a sanitary landfill. Uranium is removed from the leach liquor by precipitation with HF and recycled into DU metal production. These processes require hazardous chemicals that must be handled according to industry standards. After processing the sludge can be disposed of in an environmentally responsible way that does not require treating it as a low level waste. Workers safety concerns are minimal in product fabrication, however, there is the potential for exposure to radiological and hazardous material risks. Properly controlled operations should keep these at acceptable levels for health maintenance.

Careful siting and design taking into account public concerns about metal conversion facilities will be needed. The permitting for environmental, health and safety issues is not

expected to present problems, but again should be carefully thought through and checked in the material licensing process. Transportation of depleted UF_6 , uranium metals and uranium metal products will need to be conducted under applicable safety requirements.

The overall risks from conversion and metals fabrication are expected to be minimal if carried out in plants licensed for this type of activity that follow required safeguards. After the end products are retired from their applications, careful disposal will be required.

This response also mentions the development of a high temperature continuous reduction process for DU metal production. The details of the process and its characteristics at commercial scale are not identified. The environmental, health and safety implications will need further definition.

7.2.3.1.3 Evaluation by Reviewer X

NMI is the owner of Carolina Metals, Inc., in Barnwell, SC, a UF_6 to metal conversion facility. They currently use the Ames process with contaminated MgF_2 slag as a waste product. They propose to develop a leaching process to first decontaminate the MgF_2 and then use it with H_2SO_4 as feedstock to produce AHF. A second conversion process also is proposed. This High Temperature Continuous Reduction (HTCR) process also results in contaminated MgF_2 slag as a waste product. Thus the process discussed in this review applies to both the venerable Ames process and the new HTCR process.

Options 1 & 2 - Siting and transportation are related by two concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site, and
2. Transportation of the AHF product to the end user.

Even though a site is already licensed for handling some materials, license approval for handling large quantities of dUF_6 feedstock, metal product, and AHF would still be required. Thus, a comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations. The licensing process will be subject to public hearings and comment.

The above two concerns need to be evaluated from both cost and safety aspects. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to or on a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport), to insert them into overpacks prior to shipping, or to transfer the dUF_6 to 2½ ton cylinders as is currently done for transportation might be required. Special measures may need to be developed for handling cylinders in overpacks.

The second concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So both concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

The current NMI site is near the Barnwell LLRW disposal facility and far from the GDPs where the dUF_6 is stored. However, NMI has been transporting dUF_6 from the GDPs to their site apparently without incident.

Options 1 & 3 - Siting and transportation are related by two concerns:

1. Transportation of feedstock, namely dUF_6 cylinders to the processing site, and
2. Transportation of the AHF product to the end user.

Even though a site is already licensed for handling some materials, license approval for handling large quantities of dUF_6 feedstock, metal product, and AHF would still be required. Thus, a comparable or much larger facility would need to meet U.S. environmental, nuclear, and occupational regulations. The licensing process will be subject to public hearings and comment.

The above two concerns need to be evaluated from both cost and safety aspects. Damage to dUF_6 cylinders during transport to the processing site may be a concern. Locating the conversion site close to or on a current storage site would alleviate this concern. Also, not transporting currently defective cylinders (thus requiring DOE to transfer the dUF_6 to a non-defective cylinder prior to transport), to insert them into overpacks prior to shipping, or to transfer the dUF_6 to 2½ ton cylinders as is currently done for transportation might be required. Special measures may need to be developed for handling cylinders in overpacks.

The second concern is for the proximity of an AHF user. AHF can be recycled into the enrichment process. So both concerns can be satisfied by locating the site near current storage sites if the enrichment facilities are to stay in operation.

Other siting issues related to geological, groundwater, flood plain, local population concerns, and availability of a trained work force must also be considered.

The current NMI site is near the Barnwell LLRW disposal facility and far from the GDPs where the dUF_6 is stored. However, NMI has been transporting dUF_6 from the GDPs to their site apparently without incident.

7.2.3.1.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - This demonstration program could facilitate environmental concerns regarding the major waste product from the conversion of depleted UF_6 to DU metal. The MgF_2 slag will contain several weight percent depleted Uranium. The proposal is to develop a process that will facilitate disposal and use of MgF_2 along with the development of a continuous versus a batch process for producing DU metal. The proposal is to use five (5) DOE supplied depleted UF_6 cylinders. This reviewer surmises that the Barnwell facility will be used for the MgF_2 purification and processing work (months 1-12) and the

Y-12 facility will be used for the demonstration of continuous processing (months 6-18). No unusual environmental problems and issues are likely to arise. Transport safety of the five depleted UF₆ tanks will have to be dealt with as will worker safety in the presence of depleted UF₆ and the various demonstration flows.

7.2.3.1.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - This proposal, submitted by Mr. Dennis Lehan, proposes to process the depleted UF₆ to convert it to uranium metal.

The process proposed by this option would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies. The first phase of the process, as proposed is a 12 month research and development program to address the MgF₂ waste stream generated by the present uranium metal production process. If this phase of the project is successful, and presuming that the fluorine is recovered from the process, there would be no hazardous waste streams from the process, and the radioactive waste generated would be minimal.

Any facility handling and processing UF₆ will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF₆ from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated. The DOE site near Barnwell, South Carolina should meet all of the siting requirements.

7.2.3.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.3.2.1 Evaluation by Reviewer U

Option 1 - Waste streams would entail those associated with a conversion plant for the production of uranium oxides and metal from depleted UF₆. In addition, eventual disposal of concrete with DU aggregate after the structure has completed its useful life presents a new disposal challenge.

Disposal of DU after being stripped of ²³⁵U by either the AVLIS or centrifuge processes would entail the same disposal issues as imposed for disposal of DU without stripping. The difference in the total amount of material would be very small.

Option 2 - The depleted UF_6 conversion to uranium metal with the recovery of AHF and magnesium should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

Secondary processing of the MgF_2 slag to recover the entrained uranium, AHF and Mg would reduce the amount of waste from the metal production step by a significant amount. The generation of contaminated waste that would need to go to a low level radioactive waste burial facility would be relatively small.

Option 3 - The depleted UF_6 conversion to uranium metal with the high temperature continuous reduction process and the recovery of AHF and magnesium should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

Secondary processing of the MgF_2 slag to recover the entrained uranium, AHF and Mg would reduce the amount of waste from the metal production step that would require disposal by a significant amount. The generation of contaminated waste that would need to go to a low level radioactive waste burial facility would be relatively small.

7.2.3.2.2 Evaluation by Reviewer V

Options 1, 2 & 3 - As discussed above the major waste stream of concern is the magnesium sludge from metal production. If it is a low-level waste, disposal capacity will need to be located for it. If the proposed process is successful, it promises to reduce the volume of waste that would require this special handling. The HF produced in the conversion process is likely to be recycled into industrial uses. depleted UF_6 will be recycled into metals production. The fabrication process would produce small amounts of slag and lubricants that also would need to be disposed of in a low-level waste facility or sanitary landfill depending on the radioactivity levels of the material. The wastes streams from the proposed high temperature continuous reduction DU metal process are not identified.

7.2.3.2.3 Evaluation by Reviewer X

Options 1 & 2 - NMI proposes to use an improved Ames process. dUF_4 is produced from dUF_6 in a waterless process that results in recoverable AHF. The dUF_4 is then processed with magnesium resulting in uranium metal and magnesium fluoride.

Magnesium fluoride is currently disposed of from their process as LLRW. By adding sulfuric acid and heat, they propose to produce AHF and magnesium sulfate that could be recycled in the process, disposed of as industrial waste, or further processed to recover the

Mg. The disposition of the MgSO_4 will be determined during their proposed bench, pilot, and plant scale program.

NMI reports that recent bench scale testing has shown that it is possible to reduce the uranium content of the slag to less than 200 ppm, which would exempt it from being classified as LLRW.

The uranium metal will be available for sale to commercial industries or may be disposed of in a deep burial facility.

Options 1 & 3 - Bench scale tests of the CMR process have resulted in MgF_2 slag having lower levels of contamination than the Ames process. If the contamination levels are low enough (less than 100 to 200 ppm), the slag can be dealt with as non-radioactive material, thus saving the cost of LLRW disposal. Other materials would be recycled into the process.

The current bench tests have been done at temperatures that result in the uranium being contaminated or mixed with iron. This product is the appropriate feedstock for the AVLIS process. To produce uranium for the commercial marketplace, the iron would have to be removed. This has the potential for an additional waste stream, or the process could be refined to operate at a higher temperature that would result in higher purity uranium.

Magnesium fluoride is currently disposed of from NMI's Ames process as LLRW. By using the CMR process, producing a less contaminated magnesium fluoride, this waste stream could be reduced or eliminated. Even if the magnesium fluoride is too contaminated for non-LLRW disposal, less leaching would be necessary to decontaminate it. NMI proposes to add sulfuric acid and heat to produce AHF and magnesium sulfate that could be recycled in the process, disposed of as industrial waste, or further processed to recover the Mg. The disposition of the MgSO_4 will be determined during their proposed bench, pilot, and plant scale program.

NMI reports that recent bench scale testing has shown that it is possible to reduce the uranium content of the slag to less than 200 ppm, which would exempt it from being classified as LLRW.

The uranium metal will be available for sale to commercial industries or may be disposed of in a deep burial facility.

7.2.3.2.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - The proposal is a very likely reduction in waste from a "to be " mature process. In particular, LLRW wastes are likely to be minimized.

7.2.3.2.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - As noted above, the first phase of this option is to address the contaminated MgF_2 waste stream generated by the uranium metal production process.

This is the most significant waste stream for this process, and if the R&D program is successful, it will significantly reduce the waste from this process.

The remaining waste stream is the fluoride recovered from the reduction process, as well as fluorine recovered from the MgF_2 slag. This waste stream will also be addressed during the R&D program.

7.2.3.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.3.3.1 Evaluation by Reviewer U

Option 1 - Conversion of depleted UF_6 to oxides and metal are reasonably well defined. It is doubtful that the value of the DU in any of the five large uses indicated, except stripping by centrifuge, will be equivalent to the cost of converting the material to the form needed for the application. However, the conversion cost may be required at some time in the future for eventual disposal of DU. Using uranium oxide as aggregate in concrete would then entail only the added cost of processes to provide the proper aggregate sizes and the production of the concrete structures. Special controls would be required to contain the aggregate during the construction of concrete structures. Conventional aggregate materials are low cost sand and gravel with limited need for environmental containment control. Substituting uranium oxides for the conventional low cost aggregates will result in much higher cost. Thus, the only advantage of using DU as concrete aggregate is where applications that require shielding also are space limited.

Relatively low cost estimates for uranium enrichment have been made by the research organization developing the AVLIS process. However, the overall cost of obtaining enriched uranium from DU through the use of AVLIS is indeterminate at this time and is anticipated to be at a higher cost than using natural uranium as feedstock.

Option 2 - Costs associated with the conversion of depleted UF_6 to metal are reasonably well defined. The added cost associated with the secondary processing of the MgF_2 slag is unknown. The recovered AHF and Mg value may be less than the cost of recovery, but the reduction in radioactive waste volume and associated disposal costs should offset a portion of the cost of recovery.

The market value of the recovered AHF and magnesium would be only a fraction of the overall cost of building facilities for the conversion and performing the operations to produce uranium metal and perform the slag cleaning operations.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

Option 3 - Costs associated with the conversion of depleted UF_6 to metal with continuous reduction are not well defined at this point. Document #P4 indicates that a cost reduction of 75 percent over the conventional Ames process without slag cleaning should be achievable. The added cost associated with the secondary processing of the MgF_2 slag is unknown. The recovered AHF and Mg value may be less than the cost of recovery, but the reduction in radioactive waste volume and associated disposal costs should offset a portion of the cost.

The market value of the recovered AHF and magnesium would be only a fraction of the overall cost of building facilities for the conversion and performing the operations to produce uranium metal and perform the slag cleaning operations.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

7.2.3.3.2 Evaluation by Reviewer V

Options 1, 2 & 3 - A general estimate of the cost to produce and cast uranium metal is about \$10-11/kg. This response suggests that disposal costs for the magnesium sludge alone are \$2.40/kg and that overall process costs could be reduced by 50% with their improvements. No information has been presented regarding the cost of products made from the DU metals. The disposal costs for the retired end products are not known, but could effect overall cost. In the response, it is suggested that metal processing costs could be reduced by 75% using the proposed high temperature continuous production process, if the concept proves successful. Much better information needs to be developed on the size of the potential markets and the potential revenues that could be generated from sales of the end products in order to justify major efforts at metal conversion.

7.2.3.3.3 Evaluation by Reviewer X

Options 1 & 2 - Costs for conversion are not provided directly. However, perhaps they can be derived.

NMI states the current cost of disposing of the MgF_2 is "\$1.09/lbU [\$2.40/kgU], which represents a significant cost of producing depleted uranium derby metal." By decontaminating the slag, they can avoid LLRW burial costs. Thus, the cost of decontamination can be offset partially by avoidance of these charges. Of course, they would also realize a sale value in the AHF produced. This is about \$0.50/lb. You get 0.50 kg of AHF for every kg of uranium in the dUF_6 . So the AHF is worth about \$0.55/kgU of feed.

NMI goes on to say they will reduce the conversion cost from the venerable Ames process by 50% using their proposed low risk modified Ames process. Adding the cost avoidance and the sale value of the AHF, and assuming this to represent the total savings, the eventual conversion cost will be about \$3.00/kgU. This is probably low because there also is a cost for decontamination of the slag, and high because of the possible sale value of residual Mg and H_2SO_4 . So, perhaps \$3.00 is close. Others have predicted about \$3.50. At either cost, the total would be less than \$1.5 billion.

This leaves some 361,000 MT of depleted uranium to either dispose of or sell. If a market can be developed, the whole process could turn profitable at as low as \$5.00/kgU. For this market, NMI provides a lengthy list of potential uses that would deplete the entire inventory of metal more than once. The goal of their proposal is "to drastically reduce the costs of the metal product which will dramatically increase the uses of depleted uranium."

Options 1 & 3 - Costs for conversion are not provided directly. However, perhaps they can be derived.

NMI states the current cost of disposing of the MgF_2 is "\$1.09/lbU [\$2.40/kgU], which represents a significant cost of producing depleted uranium derby metal." By decontaminating the slag, they can avoid LLRW burial costs. Thus, the cost of decontamination can be offset partially by avoidance of these charges. Of course, they would also realize a sale value in the AHF produced. This is about \$0.50/lb. You get 0.50 kg of AHF for every kg of uranium in the dUF_6 . So the AHF is worth about \$0.55/kgU of feed.

NMI goes on to say that by using CMR they will reduce the conversion cost from the venerable Ames process by 75%. Adding the cost avoidance and the sale value of the AHF, and assuming this to represent the total savings, the eventual conversion cost will be about \$1.50/kgU. This is probably low because there also is a cost for decontamination of the slag, and high because of the possible sale value of residual Mg and H_2SO_4 . So, perhaps \$1.50 is close. Others have predicted about \$3.50. At either cost, the total would be less than \$1.5 billion, and possibly less than \$800,000.

This leaves some 361,000 MT of depleted uranium to either dispose of or sell. If a market can be developed, the whole process could turn profitable at as low as \$3.00/kgU. For this market, NMI provides a lengthy list of potential uses that would deplete the entire inventory of metal more than once. The goal of their proposal is "to drastically reduce the costs of the metal product which will dramatically increase the uses of depleted uranium."

To develop these two technologies, NMI is proposing an 18-month R&D program estimated to cost \$2 million. They would subcontract to the Martin-Marrietta Y-12 plant for validation of the processes and cost models, and to develop a specification for depleted uranium for use in commercial applications. They state that in addition to the technology benefits, at the end of the R&D program, they will be in a position to quote a fixed price to convert the dUF_6 to metal, including the private financing of capital upgrades to their current facility in Barnwell, SC.

7.2.3.3.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - The cost of all or part of the proposal for Research and Demonstration is cited ~\$2M. This is probably on the low side even if there are no capital cost writeoffs for the existing facilities at Y-12. If the proposal were to cost ~\$10M and only part of the objectives are met, the R&D cost seems acceptable.

The prospect of obtaining 50% cost reduction by modifying the Ames process for MgF_2 cycle and 75% by adopting a continuous versus batch reduction make this investment in R&D very prudent.

The possibility that "NMI will be in a position to provide the DOE with a low cost fixed price to convert their UF_6 to metal" is a very strong statement in the absence of the demonstrations proposed, but probably reflects confidence in success.

7.2.3.3.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. Presuming fluorine or hydrofluoric acid were recovered, it would have commercial value. Also, as noted in the proposal, the second phase of the R&D effort is to develop the High Temperature Continuous Reduction process. If successful, this process should result in a substantial reduction in the production costs for this process.

If uranium metal is produced, it is assumed that it would be for a commercial application, and would therefore have a commercial value. It is also proposed that the magnesium fluoride produced from the reduction process be processed to produce AHF and magnesium sulfate, which would also have commercial value.

7.2.3.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.3.4.1 Evaluation by Reviewer U

Option 1 - Uranium metal production and the processing of metal into large components for shielding is reasonably well developed and should be considered as a dependable technology.

Construction of concrete structures using conventional aggregate materials is fully mature. Substitution of uranium oxides as the aggregate would require the development of techniques to achieve the appropriate aggregate sizes, distribution within the matrix, consistent uniformity, defining structure strength and establishing controls during construction to assure containment of the uranium oxides. Concrete construction is a rough and tumble type of activity that does not entail the need for highly skilled personnel. Using uranium oxide aggregates where substantial controls would be required would entail a culture change of significant magnitude in the construction of such concrete structures. This significant change in how the materials must be controlled and structures constructed will be difficult to achieve.

The centrifuge process for uranium enrichment has been fully developed in Europe and a small plant proposed within the U.S. While considerable development has been completed for the AVLIS uranium enrichment process, practicality is yet to be determined. Obtaining enriched uranium from DU by either the centrifuge or the AVLIS processes should be considered as a long term possibility, not a near term use.

Option 2 - The chemical process requirements for converting depleted UF_6 to uranium metal are well defined since the processes have been used for a considerable period. Recovery of usable products from the MgF_2 slag appears reasonable and should be able to achieve satisfactory results after a limited amount of development and demonstration work.

Option 3 - The chemical process requirements for converting depleted UF_6 to UF_4 are well defined since the process has been used for a considerable period. Research, development and demonstration of the continuous reduction process would be required to determine the effectiveness and economics of the process. Recovery of usable products from the MgF_2 slag appears reasonable and should be able to achieve satisfactory results after a limited amount of development and demonstration work.

7.2.3.4.2 Evaluation by Reviewer V

Options 1, 2 & 3 - The conversion process for uranium metal is commercial. The proposed improvements to the Ames process will require less than six months to test and be ready for commercial application. The proposed High Temperature Continuous Production Process is still in development and could take an additional year for testing. This would be a higher risk endeavor and is expected to cost \$2 million in Federal funding. Fabrication of many of the products listed is not expected to present significant hurdles. The MPC application of DU metals is still under development.

7.2.3.4.3 Evaluation by Reviewer X

Options 1 & 2 - Conversion of dUF_6 to dUF_4 is a standard industrial practice, as is the use of magnesium to produce uranium metal and magnesium fluoride. NMI states that the processing will take place using standard operating procedures currently in place.

The proposed R&D effort relates to the minimization of the waste streams normally generated in the processing of dUF_6 . The technology to convert magnesium fluoride to AHF and magnesium sulfate has never been practiced commercially.

NMI describes a (proprietary) method for acid leaching the uranium from the slag, producing UF_4 that can be recycled in the process, and MgF_2 that can be feedstock for producing AHF.

They are proposing an 18-month bench, pilot, and plant scale program to optimize the process parameters in leaching and HF production along with the HTRC process.

The current plant would probably have to be enlarged to handle DOE's long term goal for timeliness.

Options 1 & 3 - Conversion of dUF_6 to dUF_4 is a standard industrial practice, as is the use of magnesium to produce uranium metal and magnesium fluoride. Conversion to dUF_4 is the first step in the CMR process. NMI states that this part of the process will take place using standard operating procedures currently in place.

The proposed R&D effort relates to increasing the throughput of dUF_6 and minimization of the waste streams normally generated in the processing of dUF_6 . The CMR process has only been bench tested. The technology to convert magnesium fluoride to AHF and magnesium sulfate has never been practiced commercially.

NMI describes a (proprietary) method for acid leaching the uranium from the slag, producing UF_4 that can be recycled in the process, and MgF_2 that can be feedstock for producing AHF.

They are proposing a 12-month bench, pilot, and plant scale program to optimize the process parameters in leaching and AHF production, and a 12-month program to investigate the CMR process in a half-scale reactor at temperatures that would produce

pure uranium. Since the two efforts would overlap, the total program will last for 18 months.

The current plant would probably have to be enlarged to handle DOE's long term goal for timeliness.

7.2.3.4.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - The two processes to be demonstrated are understood but have not been tested on large scale. The R&D proposed for the Mg clean-up and the continuous production process seems prudent before great investments are planned. The probability of success seems very high for achieving part of the objectives and seems reasonably high for achieving all of the objectives. The proposal includes attention to Uranium clean-up of commercial products to facilitate market entry. This proposal is one of the very few that takes this question seriously; this may impact on achieving the objectives of product quality at low cost.

7.2.3.4.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - The UF_6 to uranium metal reduction process is a mature technology. The process proposed in this response proposes a two phase R&D process which will address the MgF_2 slag waste from the process, and will also develop the High Temperature Continuous Reduction process. These technologies are still in the laboratory test phase, and have not been proven on a commercial scale.

7.2.3.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.3.5.1 Evaluation by Reviewer U

Option 1 - Employment at a facility to convert depleted UF_6 to uranium oxides or uranium metal for most of the applications listed would be exposed to considerable up and down employment cycles that would be dependent upon demand for the service or changing customer desires. The use of DU metal in HLW casks would be required over many decades and should be fairly uniform and consistent for a couple of decades.

Construction of concrete structures with DU aggregate would likely be performed at the site where the shielding structures are needed. This would result in employment cycles that depend on the need for such structures at each site.

Stripping of fissionable uranium isotopes from the DU by either the AVLIS or centrifuge processes would be a long term project of facility operation of several decades.

Performing uranium processing operations at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such operations would be helpful for encouraging related locality development.

General public acquiescence should be achievable, although concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any nuclear material processing activity, a significant public information program is essential to describe operations and the reasons for performing the tasks.

Option 2 - Employment at a facility to convert depleted UF_6 to uranium metal and the processing of the by-product slag would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure for much of the processing. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment. A major hurdle to overcome is the history of the Fernald uranium metal production plant. Considerable uranium contamination was experienced with this plant, operated for the Federal Government for several decades. Much better material control technology would be employed at a new plant. However, the extensive challenges at Fernald establish a difficult threshold to overcome.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

Option 3 - Employment at a facility to convert depleted UF_6 to uranium metal and the processing of the by-product slag would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

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In today's social environment, it may not be possible to achieve an open approval from a new locality for a conversion facility for depleted UF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.2.3.5.2 Evaluation by Reviewer V

Options 1, 2 & 3 - A conversion plant could constitute a significant industrial construction and operation project with direct and indirect impacts, if a large volume of metal is required for this application. If existing plants are used, impacts would be insignificant. The metal fabrication would have fewer impacts. There may be some traffic generated by operations at the various facilities but the effects will be site-specific. The conversion facility may arouse public scrutiny, but is likely to be accepted.

7.2.3.5.3 Evaluation by Reviewer X

Options 1 & 2 - NMI estimates that a long term program will create over 100 jobs in the Barnwell, South Carolina, facility, and additional at other customer processing sites, such as at the Martin-Marietta Y-12 facility.

Construction of a larger plant would have to obtain regulatory and community approvals.

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Construction of a larger plant would have to obtain regulatory and community approvals.

7.2.3.5.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - This proposed R&D program should not have a problem with public acceptance. Clear delineation that it could lead to a very low waste option should make this desirable in the context of public acceptance. Employment or regional development would be significant (~200 people for processing) if R&D proves successful. Both areas mentioned as R&D centers would be candidates if process is implemented.

7.2.3.5.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.2.3.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.2.3.6.1 Evaluation by Reviewer U

Option 1 - The depleted uranium does contain potentially recoverable energy values that could be captured with the deployment of breeder reactors. While the economic value of the energy resources is insufficient to recover the values in the near term, economic recovery may be achieved at some future date—possibly one hundred years or more hence. Thus, an important factor may an assessment of potential energy values recoverable through isotope separation or as fertile material in future energy programs.

Option 2 - If a large quantity of the depleted UF_6 is converted to metal, the reduction in the volume of waste that would require disposal would be substantial with the development of slag processing and material recycle.

Option 3 - If large quantities of depleted UF₆ are to be converted to uranium metal, the continuous reduction concept along with recovery of fluorine and magnesium from the by-product stream would reduce the amount of waste requiring disposal by a substantial amount.

7.2.3.6.2 Evaluation by Reviewer V

See General Comments.

7.2.3.6.3 Evaluation by Reviewer X

Options 1 & 2 - If the decontamination process is successful, it will also reduce the inventory of LLRW going to the Barnwell LLRW disposal facility. This has nationwide implications.

The Barnwell LLRW disposal facility was the last disposal facility open to the nation's LLRW generators. It closed to non-Southeast Compact members permanently in June 1994. In late April 1995, the Governor of South Carolina suggested the facility reopen for compacts making progress toward establishing their own facilities. (His rationale is that the per cubic foot surcharge would provide significant funds for the State's schools.) This would be a temporary measure until the new sites could open.

Only the Ward Valley site in California is closer than ten years from opening, and it's currently being held up in court, the U.S. Department of Interior, and Congress. Thus, a successful significant reduction in the wastes going to Barnwell from within the Southeast Compact could help solve the LLRW problem for the rest of the country.

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7.2.3.6.4 Evaluation by Reviewer Y

Options 1, 2 & 3 - "Marriage" of the proposed R&D program to the AVLIS R&D effort may be prudent for future implementations with some cost recovery.

Dealing with contamination of product from Y-12 is an unknown to this reviewer but would have to be dealt with for open market products. Minimizing Uranium content in commercial AHF to erase origin may add additional process costs.

7.2.3.6.5 Evaluation by Reviewer Z

Options 1, 2 & 3 - This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.3.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.3.7.1 Conclusion by Reviewer U

Option 1 - Stripping of uranium isotopes using either the AVLIS or centrifuge processes should be viewed as a long term potential and not considered as a reasonable application within the next few decades. If performed, it would reduce the volume of existing DU by only one to three percent.

Using the DU in breeder reactor blankets may be appropriate at some distant time in the future. It should not be considered as a reasonable use within the next few decades.

Using DU aggregate in concrete structures may be appropriate for structures within both low level radioactive waste disposal sites and the high level waste repository. Such applications do not appear to be reasonable for general radiation shielding applications where the material will require removal and eventual disposition at the end of its useful life.

Option 2 - If the depleted UF_6 is converted to metal using a magnesium reduction step, the development of processes to capture AHF and magnesium from the slag should be included in the process steps. A comparative assessment of the alternate approaches for slag cleaning and material recovery would be required to determine the more successful and economical approach to use on a production basis. However, if advanced processes are used to produce metal, such as the plasma approach, magnesium may not be part of the process.

Most of the process steps are well defined. Some development and demonstration appears needed to evaluate the recovery of useful products from the slag.

The organization submitting the recommendation in Document #P4b is experienced and competent in the conversion of UF_6 to uranium metal.

Option 3 - This option of converting depleted UF_6 to uranium metal using the high temperature continuous reduction process should be developed as an alternate to the Ames batch process if a demand for large quantities of uranium metal is forthcoming. If the DU is declared to be a waste, it appears more economical to convert the depleted UF_6 to uranium oxide for disposal instead of to the metal form. Also, the oxide form may be more economical and preferable to the metal form for long term storage. If the depleted UF_6 is converted to metal using a magnesium reduction step, the development of processes to capture AHF and magnesium from the slag should be included in the process steps. However, if advanced processes are used to produce metal, such as the plasma approach, magnesium may not be part of the process.

The organization submitting the recommendation in Document #P4c is experienced and competent in the conversion of UF_6 to uranium metal.

7.2.3.7.2 Conclusion by Reviewer V

Options 1, 2 & 3 - Based on DOE criteria, the use of an improved process to produce uranium metal at a lower cost for a variety of product applications would appear to be reasonable. The volumes of metal required could be large enough to be significant. In parallel with technology development, market analysis should be completed to justify any commercial scale production of DU metal. Cost is the key area of concern, particularly the life cycle cost.

7.2.3.7.3 Conclusion by Reviewer X

Options 1 & 2 - NMI has considerable experience with the commercial processes that convert UF_6 to metal and AHF. The proposed process for converting dUF_6 to metal is a standard industrial process. But the process for decontaminating the magnesium fluoride and producing salable AHF must be demonstrated.

Capital and operating costs were not stated, but a stated goal of the proposal is to reduce the cost of producing depleted uranium metal to make it more attractive for use in other applications, a log list of which is provided. Even without sale of the depleted uranium, the total cost for conversion should be less than \$1.5 billion, well within DOE's definition of reasonable.

The ultimate solution for the metal is to develop the listed uses so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

Elimination of the contaminated slag waste stream from their current process would free up space in the Barnwell, SC, LLRW disposal facility. This might enable the facility to receive wastes from other LLRW Compacts throughout the U.S. This facility closed to all non-Southeast Compact states in June 1994. However, the Governor of South Carolina has

proposed the facility reopen to some compacts on a temporary basis. This would have a significant impact on the country's LLRW problem.

Capacity of the current plant is said to be able to handle short-term DOE needs. NMI states that if required by demand, they would internally finance expansion. This should be feasible pending the success of the bench and pilot studies, and success in obtaining regulatory and community approvals.

Options 1 & 3 - NMI has considerable experience with the commercial processes that convert UF_6 to metal and AHF. The proposed process for converting dUF_6 to dUF_4 is a standard industrial process. But the CMR process for separating the uranium and fluoride and producing metal has only been bench tested, and the process for decontaminating the magnesium fluoride and producing salable AHF must still be demonstrated.

Capital and operating costs were not stated, but a stated goal of the proposal is to reduce the cost of producing depleted uranium metal to make it more attractive for use in other applications, a long list of which is provided. Even without sale of the depleted uranium, the total cost for conversion should be less than \$1.0 billion, well within DOE's definition of reasonable.

The ultimate solution for the metal is to develop the listed uses so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

Of primary concern in the sale of the metal will be the controls necessary to assure the depleted uranium isn't randomly disposed as industrial waste when it is no longer needed. Companies currently selling uranium to private industry should be contacted to obtain information on licensing practices. It would seem that selling metal for large scale applications would provide for easier license maintenance than small scale applications. For instance, large quantities of uranium used for counterweights would be easier to track than small quantities used for wheel balancing.

Elimination of the contaminated slag waste stream from their current process would free up space in the Barnwell, SC, LLRW disposal facility. This might enable the facility to receive wastes from other LLRW Compacts throughout the U.S. This facility closed to all non-Southeast Compact states in June 1994. However, the Governor of South Carolina has proposed the facility reopen to some compacts on a temporary basis. This would have a significant impact on the country's LLRW problem.

Capacity of the current plant is said to be able to handle short-term DOE needs. NMI states that if required by demand, they would internally finance expansion. This should be feasible pending the success of the bench and pilot studies, and success in obtaining regulatory and community approvals.

7.2.3.7.4 Conclusion by Reviewer Y

Options 1, 2 & 3 - The proposed R&D program could lead to a very reasonable technology for implementation. The proposal *per se* is simply a mechanism that could provide assurance that the goals would be reached. Potential for contamination by Y-12 as well as related quality activities are only briefly cited for commercial non-source materials.

7.2.3.7.5 Conclusion by Reviewer Z

Options 1, 2 & 3 - This option has merit, and should be considered. This option has the potential for converting large amounts of depleted UF_6 uranium metal for use in other applications. The proposal is for a research and development program to improve a current technology. The untested processes relate to the processing of the waste streams to produce commercially valuable products and to improve the efficiency of the reduction process by developing a continuous feed process. If these processes are developed successfully, there would be substantial improvements in the areas of economics and waste management.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to either UO_2 or uranium metal would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in metal form.

7.2.4 Evaluation of Document No. 29 (Independent Technical Reviewers' No. P5)

Response 29 was designated as proprietary information by the submitter, Harry A. Nesteruk, M4 Environmental Management. On June 5, 1995, Mr. Nesteruk provided LLNL a non-proprietary version of the original response. On June 9, 1995, he released the following assessments as non-proprietary information, identifying reservations about certain comments by the evaluators.

In this response, M4 recommends applying their patented Catalytic Extraction Process (CEP) to convert UF_6 to either uranium oxide or uranium metal. The company proposes to utilize an existing DOE facility, or else to construct a new 45,000 square-foot facility. The company further proposes to fund the research, development, demonstration, and construction, and decommissioning in order to minimize the cost to DOE.

7.2.4.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.4.1.1 Evaluation by Reviewer U

Document #P5 recommends a unique, patented, Catalytic Extraction Process (CEP) concept for the conversion of depleted uranium hexafluoride (depleted UF_6) into either oxides or uranium metal. Anticipated environmental and economic advantages are discussed in the Document along with the basic elements of the unique molten metal bath process.

Processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into uranium oxides or metal with this unique CEP approach will require the design, construction, operation and eventual decommissioning of at least one new facility of a type and size unmatched in industry to date. The process described in Document #P5 is unusual and not related to more conventional nuclear material processing technologies that have been in operation for several decades in the U.S. The unique nature of the proposed process, supposedly will provide uranium oxides or metal and anhydrous hydrofluoric acid (AHF) as directly recovered items from a single step molten metal processing operation. If doable, it may be an attractive means to convert depleted UF_6 into an oxide or metal form for disposal or potential other uses. The resulting uranium oxides and/or metal would contain impurities of the molten metal bath which should not be objectionable if the

material is to be disposed of as a waste. However, secondary purification steps would probably be required if pure uranium oxides or metal are required for subsequent useful products.

Many operational issues of the process are undefined and would require substantial research and development efforts to achieve the anticipated results. Since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers AHF, a material with considerable demand in the U.S. Pilot plant demonstration of the unique components would be required. The recovered AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step. Another by-product of the process is synthesis gas (CO and H_2), which could be recovered and used for the contained energy values.

Transportation of depleted UF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the depleted UF_6 is now located. If only one facility is constructed at one of the three current sites, the depleted UF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades, and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites

The conversion process is indicated as amenable to a closed system with no liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill. Gas effluent streams would be completely filtered, removing entrained material and HF removed to provide an essentially clean gas effluent.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the uranium oxides or metal could be stored on the surface at the present locations of the depleted UF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with pyrometallurgy technology, chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC).

A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities to produce uranium oxides and metal. However, extensive regulatory evaluation and possibly new regulations should be anticipated for this unique process.

7.2.4.1.2 Evaluation by Reviewer V

The option proposed is for reprocessing depleted UF_6 to produce uranium oxides (probably UO_2 , but U_3O_8 is also possible) and an anhydrous HF byproduct. The uranium oxides could be used for products including shielding materials. The material could also be stored or disposed of in approved low-level facilities depending on DOE program directions. Uranium oxides are a far more stable form of uranium for storage, with the chemicals largely inert and insoluble in typical ambient storage conditions. Once converted, they would pose far less risk to workers and the public than depleted UF_6 , which is unstable, toxic and hazardous. The reprocessing of depleted UF_6 has environmental risks, however. The increased handling and operation of the processing facility raise issues regarding the potential for releases, spills, worker exposures and damage to the environment.

The process proposed here uses a molten metallic catalyst to react depleted UF_6 with other coreactants to produce uranium oxides (or metals if the process is designed for this) and AHF. The components of the process and the chemistry of this DU application are well known. Similar processes are now being operated at the commercial scale to handle mixed hazardous wastes. The process is described as totally contained, single-staged and requiring no handling of intermediate products. It is said to have no significant emissions or liquid effluents. The central processing unit and the systems handling the oxide products would be double contained with independent ventilation and air filtration systems. The AHF would be collected and sold as a by product, as would synthesis gas from the process. The process can also be used to dispose of contaminated waste water from other operations and contaminated nickel and iron scrap metal. Worker safety procedures have been developed, implemented and proven.

The siting for this processing facility could present an issue for development. A large industrial site would be needed and would raise environmental and public health questions, depending on the location. Use of an existing site at one of the current storage facilities might minimize siting issues. The permitting for environmental, health and safety issues is not expected to present problems. With years of related operating experience already available, the routine emissions from these facilities should be well known and could provide a good base of data to evaluate the potential impacts for a new facility.

The AHF byproduct is very hazardous and corrosive and has its own set of handling, storage and transportation issues that, while not unique, will require attention in operations. Depending on the processing location, the processed uranium oxides may require transportation and special storage conditions. Long term storage conditions would

need to be defined if chosen as the program direction. The availability of disposal sites might be an issue requiring further development. If the uranium oxides are densified or sintered, they will require less space.

7.2.4.1.3 Evaluation by Reviewer X

M4 is proposing to apply their patented Catalytic Extraction Process (CEP) to dUF_6 conversion to either uranium oxide or metal. They propose to construct a new 45,000 square-foot facility on current DOE land or to use an existing DOE facility. Three-shift operation would employ about 100 people. M4 states they will totally fund research, development, demonstration, and construction, and they can have an operating facility by the end of 1995. They state the CEP has limited environmental effect and will prove to cost significantly less than any other alternative.

M4 proposes to place a CEP facility at or in an existing DOE facility. This would have the advantage of not forcing transportation of dUF_6 cylinders further than is current practice for GDP operations. It also would provide for an essentially permitted site.

7.2.4.1.4 Evaluation by Reviewer Y

It is likely that the favored operating temperature of the CEP will limit site choice somewhat. Similarly, high temperature operations will provide need for demonstrating that operations can be safely conducted under upsets to or accidents with the process system. Seismic and tornado (with airborne missiles) safety would be candidate conditions as well as those leading to overpressures at high temperatures.

7.2.4.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. Harry Nesteruk, proposes a single process to process the depleted UF_6 to convert it to either uranium oxides or uranium metal, and to recover anhydrous hydrofluoric acid. The processes for converting UF_6 to uranium oxides are presented, and it is described that the final uranium compound can be varied based on changes to the operating parameters. The process could produce UO_2 for shielding applications, or U_3O_8 for long term storage or disposal. The process for direct production of uranium metal is not described in the submittal.

The process proposed by this option would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies. The process offers some advantages in that it can utilize radioactive contaminated waste water from other processes as a feed material for this process. The process also utilizes a molten metal catalyst of either iron, nickel, or copper, and can use contaminated metal, such as from the empty cylinders, as the catalyst feed.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated. It is proposed that a review be

conducted of existing sites in order to determine whether one is suitable for this plant. If not, a new site would be selected for the facility.

7.2.4.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.4.2.1 Evaluation by Reviewer U

The depleted UF_6 conversion to uranium oxides and/or metal and AHF using the CEP approach should be achievable with a closed process. That is, essentially no liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

There are a few speculative potential uses for the recovered uranium oxides and/or metal. However, defining uses is not a part of the recommendation of Document #P5.

With very limited potential use for depleted uranium oxides or metal at this time, they must either be stored or disposed of as a waste. Uranium oxides may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Since uranium metal oxidizes quite rapidly, storage and/or disposal would require that it be enclosed in a sealed metal container.

There is reasonable demand for AHF in the U.S., several times that of the recovered AHF. Availability of AHF from this source would impact the AHF market and current suppliers.

The recommended process may provide a means of decontaminating and recovery of the metal of the depleted UF_6 cylinders. As indicated in the Document, the cylinders could be processed through the molten metal bath to remove traces of uranium. Presumably, this would require cutting the cylinders into pieces to permit feeding into the molten metal bath. Alternately, chemical cleaned of empty cylinders may be sufficient to permit them to be scraped, melting and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, the CEP process should be evaluated as one means to achieve a recyclable metal.

7.2.4.2.2 Evaluation by Reviewer V

The proposed process would have limited waste streams, primarily AHF and synthesis gas. No other wastes are described in the response. If small amounts of other wastes that include uranium or hazardous materials are produced they would need to be handled at appropriate low level or sanitary disposal sites. The UO_2 powder produced could be further compacted to reduce the volume needed for disposal, if the material cannot be recycled into other uses such as Ducrete. If HF by-products could not be recycled into other commercial uses, this would create a disposal problem. The empty depleted UF_6 cylinders will need decontamination before recycling or disposal. The process may be able to feed these metals into the molten metal catalyst. As described above, the process can recycle waste water and other metals from totally unrelated processes, thus serving as a waste processing facility.

7.2.4.2.3 Evaluation by Reviewer X

M4 states that the CEP is essentially ventless and produces no liquid wastes. Gaseous wastes are CO and H_2 , both of which can be captured for recycle or use in other processes. Excess water dissociates at the high temperatures of the process, and therefore doesn't end up with the HF, which will thus be anhydrous. Thus, no secondary waste stream is produced to convert aqueous HF to AHF.

The output of the CEP is UO_2 , U_3O_8 , or uranium metal, depending on the system thermodynamics. These would be available for storage, reuse, or disposal. The process can be adjusted to produce a slag with various ceramic properties for direct use in products such as shielding, ballast, or refractory materials.

7.2.4.2.4 Evaluation by Reviewer Y

This looks like a minimum or least waste proposal. In addition, the process can utilize waste water from other industrial operations. There are a number of process parameters that can be adjusted to vary the waste magnitude and composition. While oxide production is treated in detail, the potential for metal production (whose possible uses are cited) is not detailed; therefore, comparative waste estimates for this add-on must be guessed at. Presumably, this is a conversion from oxide (UO_2 or U_3O_8) to the metal with pure or impure Mg molecules.

7.2.4.2.5 Evaluation by Reviewer Z

The processes as proposed in this option do not to generate any waste streams. This proposed facility would recover anhydrous HF (AHF) from the process to be used or sold. The uranium product from the facility can be varied for various applications, for either commercial use or for long term storage or permanent disposal. If the facility functioned as proposed, very little radioactive or hazardous waste would be generated.

7.2.4.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.4.3.1 Evaluation by Reviewer U

Since this CEP process is in early stages of development and use, cost estimates at this stage are speculative at best. However, if the concept is able to achieve commercial practicability, it should be economically attractive compared to other concepts for the conversion of depleted UF_6 to uranium oxides and/or metal for disposal as an impure material. Added processing steps and associated costs are anticipated to provide a pure uranium product subsequent to this proposed processing.

AHF and the synthesis gas by-product are potentially salable products from the operation. The market value of these materials would be only a fraction of the overall cost of building facilities for the conversion and performing the operations.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility using the CEP process are unknown. However, they should be similar to those required for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of retaining the DU as depleted UF_6 , with conversion to U_3O_8 one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades.

7.2.4.3.2 Evaluation by Reviewer V

Preliminary costs estimates are not available, but the respondent suggests that they will be competitive with alternative processes. The respondent is currently investing in the process testing equipment and development costs. If a processing contract is awarded, the government would not be required to fund any capital costs or decommissioning costs. Revenues would be generated by the sale of AHF and synthesis gas, as well as processing fees from waste water and metal disposal. The costs of transporting the material to processing, and the costs of using, storing or disposing of the material after it is

converted, would be additional. There is no assessment of the demand for UO_2 , U metal or the products that could be fabricated from them to determine if sale of uranium oxides might offset costs.

7.2.4.3.3 Evaluation by Reviewer X

M4 states the CEP will be significantly less expensive than other conversion processes. However, they give no other cost estimate information. So cost cannot be evaluated at this time.

7.2.4.3.4 Evaluation by Reviewer Y

The only estimate on cost in the proposal suggests that "this application will be very cost competitive with other alternatives." This is a reasonable expectation since the "alternatives" have not been well priced for range of processes and products that can be obtained with the process. The material and lifetime of the CPU Reactor could significantly impact on costs. On the plus side, this proposal will have minimal capital cost requirements relative to a number of alternatives, particularly if existing DOE facilities can be converted for these applications. Product quality requirements will impact process costs in non-trivial ways. It is likely that product costs will not exceed the current natural Uranium ore costs which are expected to rise as fossil fuels become less available and fossil fuel environmental costs rise (e.g., CO_2 and other emission taxes and control technology).

7.2.4.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. Presuming fluorine or hydrofluoric acid were recovered, it would have commercial value. Also, the uranium products would have commercial value. Cost credit could also be achieved by the use of contaminated water and contaminated metal as feed stock for the processes.

7.2.4.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.4.4.1 Evaluation by Reviewer U

The recommended CEP process is in early stages of being used for cleanup of hazardous materials. A small research facility is being built to attempt to apply the technology to radioactive material. Results of this research effort will provide indications on whether the process has applicability to such materials. There are a significant number of unknowns related to application of the CEP process for the conversion of depleted UF_6 to uranium oxides and/or metal. The process must be considered immature at this stage and there is considerable doubt of whether it will be applicable for depleted UF_6 conversion.

While the Document stated that the CEP process has its roots in the steel industry, it does not indicate how it is used in any application within that industry. The initial facility for use of the process for hazardous materials, Fall River Research & Development Facility was built in 1992 and experience from that facility is only peripherally helpful in determining if the process is applicable to the conversion of depleted UF_6 .

A indication of the limited knowledge for depleted UF_6 processing with the CEP approach is provided in the process description of the recommendation—calling for a gas compressor to boost the depleted UF_6 feed to 150 psig. Even at relatively modest pressures, the depleted UF_6 will be a liquid. The means of feeding depleted UF_6 to the molten metal bath will require extensive research and development.

7.2.4.4.2 Evaluation by Reviewer V

Commercial scale CEP systems are in use with other input materials. Process verification using depleted uranium, chemical kinetics, process optimization and refractory studies and testing need to be completed. It is estimated that this information will be available in 18 months and that commercial development could begin immediately thereafter. The existence of a demonstration facility that is immediately available will facilitate the effort.

7.2.4.4.3 Evaluation by Reviewer X

M4 states that CEP has its roots in the steel industry and that all aspects of the process are mature. However, they currently have no experience with the process for use with radioactive materials, let alone with dUF_6 . They are currently installing a CEP system at an Oak Ridge Hot Lab to study the processing of radioactive material.

The CEP operates at a significantly higher temperature than other proposed processes, and there is no significant process information or industrial experience involving the conversion of dUF_6 at these higher temperatures. While individual parts of the process have been demonstrated, the integrated process has not. Technical uncertainties include the chemical kinetics of the uranium reactions in the molten metal medium, and the selection of a durable refractory. A design uncertainty is the ceramic phase removal system.

A Radioactive Process Unit (RPU) is currently being installed with DOE funding at Oak Ridge. This system will be operational within four to six months, and process verification

will be complete within the next six months. However, this system must be redesigned for handling dUF_6 .

Approximately two years will be required to obtain sufficient dUF_6 conversion data and large-scale CEP experience to allow design of a production-scale CEP for bulk conversion of dUF_6 .

7.2.4.4.4 Evaluation by Reviewer Y

If technical details were consistent with technical maturity, this proposal could be a "winner." The proposal is quite realistic about outstanding issues except one. Nothing is said about the makeup of the CPU Reactor (container and liner, if any). This could impact economics (lifetime) and product impurities.

The oxide and AHF production processes defined are based largely on steel industry experiences. The ability to obviate liquid wastes is very attractive. Similarly, the location of the CEP would facilitate the use of copious quantities of waste water from other processes.

While similar processes with other materials are state-of-the-art, this process with Uranium is virtually untested at large scales.

The Quantum-CEP facility (RPU) at Oak Ridge could be an early demonstration for this proposal. However, it is likely that two years may not be enough time to define the details of a full size CEP system. It is likely that considerable parameter variation will have to be studied to optimize the CEP for low impurity products.

7.2.4.4.5 Evaluation by Reviewer Z

The individual steps of the process for conversion of UF_6 to uranium oxides have been demonstrated at various industrial or laboratory facilities. Some have been in commercial application for several years. The chemical process for direct conversion to uranium metal is not well described in the proposal. The integrated process has not been demonstrated, and will require a minimum of 18 to 24 months of laboratory and bench testing before a commercial scale facility can be designed. Additional time would be required for construction and testing.

7.2.4.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.4.5.1 Evaluation by Reviewer U

Employment at a facility that uses the CEP process to convert depleted UF_6 to uranium oxides and/or metal would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails unique molten metal baths that operate at a high temperature. However, the quantities of radioactive material and HF involved in process inventory are relatively small and the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for depleted UF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. If the unique CEP process proves to be successful for the conversion of depleted UF_6 , it may provide the basis for a major new industry of safely processing and disposing of hazardous materials. Such an operation may be helpful for encouraging related locality development of different application for the CEP process.

7.2.4.5.2 Evaluation by Reviewer V

The construction of a commercial scale facility to meet the inventory reduction goal, would be a major project and the economic effects would be significant locally. Construction labor will be determined by whether an existing facility can be used. If a new facility is built, the temporary effect on labor could be significant. Permanent employment is expected to be about 100. The respondent claims great latitude in potential

sites due to the limited environmental effect of the plant and the active public outreach approach taken to siting and gaining community acceptance. Traffic, including uranium transport to and from the site, could have an impact and should be examined. If the oxides need to be disposed of, LLW disposal facilities will be needed. As they continue to be a health concern to the general public, there will be difficulty in siting such facilities.

7.2.4.5.3 Evaluation by Reviewer X

M4 states that a plant operating with three-shifts would employ about 100 people. If the plant were built on a current GDP site, it would provide continuing employment for an experienced staff currently being reduced in size.

Also, if the plant were built on a current GDP site, it should receive positive public acceptance since it is reported to have no hazardous emissions and since it will help to eliminate the dUF_6 inventory.

Local and regional development would be minimal since the plant presumably would employ a work force already at the site which otherwise might be unemployed.

7.2.4.5.4 Evaluation by Reviewer Y

The process could be developed to have favorable public impact. It is "different" and has no water effluent. The high-pressure/high-temperature operations may lead to problems but may be favorably impacted by related large-scale experiences.

It is a process that will generate about the same or slightly lower number of jobs as competing processes (~200+ employees). If accomplished at a government reservation using existing ancillary facilities (e.g., power), construction economies might be realized.

7.2.4.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics. The proposal emphasized the importance of public acceptance as one aspect of the facility.

7.2.4.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.2.4.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as depleted UF_6 or U_3O_8 . At some future point, probably within two hundred years, a national decision

may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of depleted UF_6 appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U_3O_8 , is greater than the cost of converting the depleted UF_6 to U_3O_8 with associated impacts.

7.2.4.6.2 Evaluation by Reviewer V

See General Comments.

7.2.4.6.3 Evaluation by Reviewer X

None.

7.2.4.6.4 Evaluation by Reviewer Y

It is refreshing to see a new approach that has promise as well as unresolved questions. The ability to vary process parameters may be the key to providing high quality commercial products. In addition, the ability to ultimately retrieve DU with low impurity content (particularly Flouride) will simplify future uses.

How Flouride contaminated oxide behaves in glass logs for permanent disposal options is a question that must be considered!

7.2.4.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.4.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.4.7.1 Conclusion by Reviewer U

This option of using the CEP process for the conversion of depleted UF_6 to uranium oxides and/or metal is viewed as speculative at best. Many elements of the process have not been demonstrated, developed or implemented for processing radioactive material. Considerable research and development would be required to determine if the process will work and to define the appropriate parameters for a successful application. The process is viewed as a paper concept that might work, but will entail considerable time and research to verify its applicability and associated economics. It can not be viewed as reasonable or acceptable at this stage.

Conversion of depleted UF_6 to uranium oxides and/or metal should be pursued at this time only if a determination is made that continued storage of DU as depleted UF_6 is unacceptable. The cost of conversion is greater than the value of recovered products. Since there are no apparent economical uses for large quantities of DU in any form and there is the potential of needing the DU as an energy resource at some point in the distant future, it should be stored for at least one hundred years or until a decision is made that it will not be used as an energy resource. Storage should be achieved in the most economical material form, which may be depleted UF_6 .

The organization submitting the recommendation in Document #P5 is attempting to exploit the unique CEP process wherever possible. While it may turn out to be applicable to the conversion of depleted UF_6 , there is not enough knowledge or understanding at this point to make a reasonable judgment in that regard. The organization does not have experience or practical understanding of processing of uranium, UF_6 and AHF.

7.2.4.7.2 Conclusion by Reviewer V

The proposed process seems to meet all of DOE's reasonableness criteria. The commercial nature of the processes suggests that the timing and technical maturity criteria would be met and the process is consistent with DOE program goals. There do not appear to be any major environmental, safety, health or siting issues. The potential for private funding of construction is a cost advantage. In general, it would appear that the process should receive further consideration.

7.2.4.7.3 Conclusion by Reviewer X

The CEP integrates several proven industrial processes into a system that requires verification of its feasibility for use converting dUF_6 to either oxide or metal form. It operates at significantly higher temperatures than other proposed processes. This will make refractory selection more difficult and may increase maintenance requirements.

Approximately nine months are projected for process verification, optimization, and calculation of scale up and cost factors. An additional two years is projected for gaining sufficient experience with the process to allow detailed design of a production scale facility. If construction takes one year, a plant would be in operation in about four years.

To meet DOE's program goal of converting the entire current dUF₆ inventory, the production scale plant would need to convert about 21,000 MT/year. This is a reasonable amount relative to other processes. To minimize dUF₆ transportation, it would be prudent to build similar plants at each GDP site or at least at the sites that are expected to remain in operation.

M4 states that the cost of this conversion method will be significantly less than the cost of other conversion technologies. However, no cost data was provided. Indeed, they state that cost estimates will not be available until the end of the bench-scale testing nine months after start of a new program.

The CEP is projected to produce no additional waste streams. The only products will be a uranium oxide, metal, or some specified combination, and AHF.

The ultimate solution is for the conversion process to be to the metal form and to develop uses so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

If the CEP can be developed for cost-effective production-scale implementation, the process will meet DOE's goals for conversion and be consistent with the Department mission.

7.2.4.7.4 Conclusion by Reviewer Y

The process as proposed is "reasonable" on all counts without requiring specification of end products and end uses at this time. There is some risk in this process pending viable demonstration of details at large scale. That requirement may lengthen development time somewhat relative to more established processes.

It is possible that some melt refining experience with the IFR could bring some valuable insights to the proposal.

7.2.4.7.5 Conclusion by Reviewer Z

This option has merit, and should be considered. This option has the potential for converting large amounts of depleted UF₆ to uranium oxides or uranium metal for use in other applications, for long-term storage, or for burial. The primary conversion steps are based on proven technology or established chemical processes.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to either UO₂ or uranium metal would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide or metal form, or that will be disposed of in burial areas.

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7.2.5 Evaluation of Document No. 30 (Independent Technical Reviewers' No. P6)

Response 30 was designated as proprietary information by the submitter, Dr. John D. Hewes, Allied Signal, Inc. On June 1, 1995, the submitter provided LLNL/SAIC redacted copies of the original response and the Independent Technical Reviewer evaluations and provided corrections to previously submitted cost data. On June 6, 1995, Dr. Hughes provided revised copies of the redacted Independent Technical Reviewer evaluations. The non-proprietary version of the evaluations follows. The phrase *** Information removed which was designated proprietary by respondent to RFR *** has been inserted for material which was marked out of the evaluations. The full text may be found in the proprietary addendum to the *Technology Assessment Report*.

This response recommends the conversion of depleted UF_6 to U_3O_8 for disposal or reuse with the concurrent production of commercially valuable hydrofluorocarbons (HFCs) and anhydrous hydrogen fluoride (AHF). The conversion process is an Allied Signal invention that is currently in the research phase of development.

7.2.5.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.5.1.1 Evaluation by Reviewer U

Processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into marketable fluorine products and triuranium octoxide (U_3O_8) will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly several smaller duplicate facilities. The process described in Document #P6 appears to be a reasonable expansion of technology that has been in operation for several decades in the U.S. Several of the basic processes have been developed and used in conjunction with the conversion of natural uranium to uranium hexafluoride (UF_6) and the conversion of UF_6 to uranium dioxide (UO_2) at commercial nuclear fuel production plants. The unique component of the process as proposed relates to the direct recovery of commercially valuable hydrofluorocarbon (HFC) and anhydrous hydrofluoric acid (AHF) as an integral step of the process.

U_3O_8 is a relatively inert chemical form of uranium (dry black powder or compressed cake) with low reactivity and low solubility. Long term storage and/or eventual disposal of

U_3O_8 should be acceptable within stainless steel containers. A weather protection building would probably be required for storage of the containers of uranium oxide.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

The process as proposed recovers both HFC and AHF, materials with considerable demand in the U.S. *** Information removed which was designated proprietary by respondent to RFR *** The recovered HFC and AHF could be sold and transported as a commercial chemical. However, if a lower cost operation is possible that leaves trace amounts of uranium in the AHF, then it may be appropriate to allocate the AHF for use in the conversion of natural uranium to UF_6 prior to the enrichment step.

Transportation of depleted UF_6 to a new processing plant would be an on-site task, assuming new facilities are located on the sites where the depleted UF_6 is now located. If only one facility is constructed at one of the three current sites, the depleted UF_6 from the other sites could be transported via rail or truck to the new facility. Rail transportation of uranium hexafluoride (UF_6) has occurred between the three uranium enrichment sites for decades, and truck transportation is currently used for natural and low enriched UF_6 . A site independent and away from the existing storage sites could be used with rail or truck transport from the three storage sites

The conversion process is amenable to a closed system with minimal liquid steps and does not require dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or, for sufficiently clean materials, in sanitary land fill.

Site restrictions for a conversion facility are relatively few. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs. Also, the U_3O_8 could be stored on the surface at the present locations of the depleted UF_6 .

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would

probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the proposed conversion operations appears to be relatively straight forward without the need for time consuming development of new regulations.

7.2.5.1.2 Evaluation by Reviewer V

This recommendation suggests the processing depleted UF_6 to produce hydrofluorocarbon (HFC) and anhydrous hydrogen fluoride (AHF) for sale to commercial chemical markets, and U_3O_8 for storage or disposal. The current storage of depleted UF_6 without processing has some potential for environmental risks. When exposed to ambient air it can react to moisture producing HF acid and UO_2F_2 , both hazardous. The uranium is a toxic heavy metal that is quite hazardous. However, the reprocessing of depleted UF_6 also has environmental risks. The increased handling and operation of the processing facility raises issues regarding the potential for releases, spills, worker exposures and damage to the environment. Toxicity and hazardous qualities of the materials will require careful operation. The AHF, being hazardous and corrosive, will have its own set of handling, storage and transportation issues that again should not present unique or new technical issues. HFC's will require special handling, however, because they do not deplete the ozone layer, they will be environmentally attractive substitutes for CFC's.

The process being proposed in this recommendation is new, however, it is based on known chemical processes. The process would react depleted UF_6 with *** Information removed which was designated proprietary by respondent to RFR *** feedstocks to produce fluorochemicals and *** Information removed which was designated proprietary by respondent to RFR ***, which would then be reacted with *** Information removed which was designated proprietary by respondent to RFR *** to produce AHF and uranium oxides, probably U_3O_8 . *** Information removed which was designated proprietary by respondent to RFR *** Until that time it will be difficult to assess the specific environmental, health and safety implications of this recommendation. The respondent has indicated that the processes will minimize the production of any mixed wastes due to the high disposal costs of these materials. As with most technologies for converting depleted UF_6 , this process will have risks associated with its complex processes and hazardous materials that will need careful management. The permitting for environmental, health and safety issues is not expected to present problems, but again should be carefully thought through and checked in the licensing process. Siting a large industrial facility with hazardous materials should be carefully planned to protect environment, health and safety in the surrounding community. *** Information removed which was designated proprietary by respondent to RFR ***

The processed U_3O_8 will require transportation and storage or disposal in quantities that are much larger than previously encountered. This will create risks for accidental releases of the material, however, they are less likely to present a large hazard due to the stability of this chemical form. Disposal would not present a problem technically, however, the availability of sites might be an issue requiring further development or design to make sites more acceptable in new locations. If the option proposed by the NRC for deep mine disposal is adopted, special precautions to protect groundwater will be needed. Storage of

U_3O_8 would not present significant environmental, health or safety risks with careful design. Accidental releases could adversely effect workers if they came in contact with the material, but its largely inert chemical form makes the hazard minimal. Releases to surrounding areas are unlikely.

7.2.5.1.3 Evaluation by Reviewer X

This recommendation is for the conversion of dUF_6 to U_3O_8 with the concurrent production of not only AHF but also more valuable HFCs. The U_3O_8 may be disposed of or used in other applications and processes. The conversion process is an ASI invention currently under development.

From Allied Signal, Inc. (ASI), this is a recommendation competing with another recommendation from both GA and ASI. *** Information removed which was designated proprietary by respondent to RFR *** The licensing process will be subject to public hearings and comment.

ASI has an established experience record for handling all the chemicals involved. They also have an in-house training program for their employees that extends to their external customers for fluoride products. The Metropolis Works has produced natural UF_6 for about 30 years.

The transportation of the dUF_6 , uranium oxides, HFCs, and AHF are stated to not present new problems based on ASI's long experience.

7.2.5.1.4 Evaluation by Reviewer Y

There are no major issues here for the *** Information removed which was designated proprietary by respondent to RFR *** phase proposed. The process chemistry phase will provide early indication of environmental issues associated with both SNM and fluorine compounds. Transportation of materials and existing containers will pose a public-at-large issue for depleted UF_6 and the emerging products.

It is interesting that the hydrofluorocarbons that emerge from this proposal are needed to solve another environmental problem (e.g., refrigerants). Quality of fluorine compounds must be high enough so that fluorine source (depleted UF_6) cannot be identified. *** Information removed which was designated proprietary by respondent to RFR *** that is being sought will be beneficial to all questions related to safety, health, and environment.

7.2.5.1.5 Evaluation by Reviewer Z

This proposal, submitted by Dr. John Hewes proposes to process the depleted UF_6 through a patented process to convert the UF_6 to uranium oxide and to fully recover the fluorine as hydrofluorocarbons (HFC) and anhydrous hydrofluoric acid (AHF). No specific use for the uranium oxides was proposed, other than possible commercial uses or disposal.

The most obvious environmental issue presented by this option is the possibility for the production of mixed oxide wastes. All other environmental, safety or health issues presented by this option are similar to those which have previously been evaluated and are addressed by current technologies.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. Allied Signal proposes that the site selected would be one which currently handles or has previously handled uranium hexafluoride and associated chemicals, *** Information removed which was designated proprietary by respondent to RFR ***. The use of various organic compounds and the generation of both RCRA and mixed wastes may effect the siting and license/permit requirements for the facility.

7.2.5.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.5.2.1 Evaluation by Reviewer U

The depleted UF_6 conversion to U_3O_8 , HFC and AHF should be achievable with a closed process. That is, no liquid effluents and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the uranium or the solids may be disposed of in low level radioactive waste disposal facilities.

There is no current use for separated depleted U_3O_8 . Possible use in Ducrete in the future may be achieved. The practicality of Ducrete is yet to be determined. Eventual disposition of Ducrete after the useful life of the structure constructed with Ducrete, may entail disposition in low level radioactive sites at a high cost.

With no practical use for the U_3O_8 at this time, it must either be stored or disposed of as a waste. It may be stored in metal containers for a considerable period until a use is defined or a decision is made for final disposal. Final disposition may require deep underground disposal. Such disposal should be less demanding than disposal of high level radioactive wastes.

There is reasonable demand for both HFC and AHF in the U.S., several times that of the recoverable material. Availability of AHF from this source would impact the AHF market and current suppliers.

Not included in the proposal is any discussion on the removal of UF_6 heels from cylinders, cleaning of the cylinders or their eventual disposition. The main process discussed will remove nearly all of the UF_6 from the cylinders. However, there will be a small amount of UF_6 that must be removed by washing the inside of the cylinders. The UF_6 recovered this way will require a small side stream operation for conversion to U_3O_8 . Chemical cleaned of empty cylinders may be sufficient to permit them to be scraped, melting and recycled for other uses of the metal. If cleaning is insufficient to permit recycle, it may be necessary to dispose of the cylinders at low level radioactive waste sites, at a high cost. Another use may be to cut the cylinders in half and weld flat end caps over the open end to provide upright storage containers for U_3O_8 .

7.2.5.2.2 Evaluation by Reviewer V

This option recycles HFC's and AHF back into commercial uses. The process will minimize effluents, emissions and waste production. Careful review of the process should be made when the final flow diagram is available to assure that no waste discharges are involved. The U_3O_8 waste stream may be stored or need disposal at a low level waste site using shallow burial. However, the NRC has recommended deep geologic disposal because of the waste volume involved, so the disposal of this material must be carefully considered. Additional uses for this material could be sought. It may be possible to use it in Ducrete or other products. Empty depleted UF_6 cylinders will need to be recycled or disposed of in an acceptable manner. U_3O_8 storage is not expected to generate any additional wastes except those associated with construction of the containers and buildings used to store it.

7.2.5.2.3 Evaluation by Reviewer X

It's not clear from the recommendation whether mixed wastes will be produced since a complete materials balance is not available "due to the proprietary nature of the process." However, it is stated that mixed wastes will not be tolerated, and that the question is being addressed in the engineering/research program. It also is stated that HFCs and AHF will be produced with no detectable uranium, and that uranium oxides will be produced with organic and inorganic fluoride contaminants with levels at or below permitted levels. However, this is a major question that must be resolved since it will be difficult and costly to dispose of any mixed wastes.

One objective of the recommended process is to produce no wastes other than U_3O_8 which can be disposed of or stored for reuse. The disposition of U_3O_8 isn't addressed further by the recommendation.

ASI emphasizes that a ready market exists for both the HFCs and AHF produced in its process. Not mentioned is that ASI has a ready facility for recycling the anhydrous HF in its UF_6 production process. No estimates are given as to how the chemicals would impact

the market. However, since the total U.S. market for AHF currently exceeds 200,000 tons, added AHF from a plant that would convert dUF_6 to U_3O_8 shouldn't have a major market impact (Total available AHF in the dUF_6 stores is about 210,000 tons.). The HFC market is currently growing as they are being used to replace ozone-depleting chemicals such as CFCs which are currently banned.

If the U_3O_8 must be disposed of, some location other than a low level radioactive waste (LLRW) facility will need to be found. The NRC has excluded near surface disposal as an option in NUREG-1484.

Considering the difficulty the several LLRW Compacts are having with obtaining enabling legislation in host states and siting these facilities, such an option is not likely to be available in a Compact facility. Also, dUF_6 is considered to be DOE waste under current law. It is not likely that states will allow this to become industrial waste in a transfer process to a conversion contractor. Thus, it will still need to be disposed of or stored as DOE waste.

Considering the situation in Ohio, it should be noted that the proposed Ohio facility will have both a time restriction of 20 years operation and a volume restriction of 2,250,000 cubic feet ($63,713 \text{ m}^3$), only about one-third the required volume for the current inventory of dUF_6 .

*** Information removed which was designated proprietary by respondent to RFR ***

Several potential non-Compact sites might be available. One of these is the Envirocare of Utah, Inc., site. However, this site has a limit on contained uranium in its waste of 110,000 pCi/gm, which according to NUREG-1484 is far less than the activity in the U_3O_8 waste stream from Claiborne (I calculate this to be about 300,000 pCi/gm, but it could be higher, depending on how you treat the numbers.). The NTS in Nevada is an alternative ultimate disposal site. Its Waste Acceptance Criteria limits transuranic concentrations to less than 100,000 pCi/gm for consideration as LLRW (See EGG-MS-11297, pg. 33, with RFR #4). Thus, the U_3O_8 would need to be contained in some matrix, such as Ducrete. Also, Envirocare empties all containers. So the matrix must be stable.

7.2.5.2.4 Evaluation by Reviewer Y

The proposal is not specific on details of waste produced. The "proprietary nature of the process" is cited as the reason for no proposed material balance; this seems like a weak crutch since provisions for waste must be made *** Information removed which was designated proprietary by respondent to RFR *** If mixed waste is to be minimized, the metallic option might be interesting. If the hydro-flouro-carbons are considered "waste," this is a very positive proposal for utilizing recycled waste. Waste to erase origin from commercial products has neither been estimated nor does not mean a matter for concern.

7.2.5.2.5 Evaluation by Reviewer Z

The process proposed in this option will produce radioactive waste in forms and quantities similar to other fuel cycle facilities. It also has the potential for producing mixed wastes. This could present a problem due to the current lack of regulations governing mixed wastes, and due to the lack of approved treatment or disposal facilities. Resolution of the mixed waste issue will require regulatory changes by both the Nuclear Regulatory Commission and the Environmental Protection Agency.

The proposal is to produce uranium oxides which are suitable for use in commercial applications, or for disposal. If applications for the uranium oxides are not designated prior to conversion, then the product will have to be stored or disposed of in an approved location. An approved permanent or retrievable disposal area has not been identified.

7.2.5.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.5.3.1 Evaluation by Reviewer U

Since many elements of this process are currently in use within the U.S., the costs are reasonably well defined for both the processing plant and the operation. HFC and AHF are the only salable products from the operation. *** Information removed which was designated proprietary by respondent to RFR ***

Since uranium enrichment activities are continuing in the U.S., there is a continuing buildup in the quantity of depleted UF₆. Thus, after the DOE material has been converted, the facility may be used for conversion of depleted UF₆ generated by others. The operational period for the facility, a few decades, is a normal life of such chemical facilities. After use, the facility would be torn down with all contamination removed from the site. The site could be returned to uncontrolled use.

Decontamination and decommissioning costs for a depleted UF₆ conversion facility would be typical of those for commercial UF₆ conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

The cost of storage of U_3O_8 would be in the same range as the cost of storing depleted UF_6 over the next one to two hundred years. The weight of total U_3O_8 would be about twenty percent less than the depleted UF_6 , although the volumetric space would be somewhat less dependent upon the amount of compacting performed on the material. Rectangular containers of U_3O_8 would pack and stack in a space more efficient than the cylindrical containers of depleted UF_6 . However, the cost of new metal containers for the U_3O_8 would be a significant added cost over that of continuing to keep the UF_6 in the present containers, replacing only those that need to be replaced for integrity reasons. Also, a building would probably be added at additional cost for storing containers of U_3O_8 , while outdoor storage of depleted UF_6 cylinders appears to be adequate.

If a decision is made at a future date to dispose of the material in a geologic disposal facility, U_3O_8 would probably be the material form of choice for disposal. The present worth value of retaining the DU as depleted UF_6 , with conversion to U_3O_8 one hundred years hence for disposal, may be considerably less than performing the conversion within the next few decades.

7.2.5.3.2 Evaluation by Reviewer V

The preliminary costs identified by the respondent for this option are as follows:

19*****	*****	in operating and capital costs
19*****	*****	in operating costs for a pilot scale demo plant plus unknown capital costs
20*****		Unknown costs for construction of manufacturing plant
2016	*****	million for decommissioning.

*** Information removed which was designated proprietary by respondent to RFR ***

No average processing costs per kgU are suggested. For the commercial plant, careful examination of costs should be made. The respondent reports significant markets for the fluorine products produced. They expect revenues from HFC's and AHF to significantly offset the cost of manufacturing. This option should be examined for potential cost sharing opportunities.

Disposal of U_3O_8 in shallow burial sites could cost from \$170 million to \$658 million according to current estimates. These costs may rise as requirements change. The additional costs for deep storage are unknown and could vary significantly depending on the specific site. If safe cavities can be found, the cost of disposal might be reduced as special packaging and handling becomes less critical. However, construction and/or monitoring costs could be quite high. Transport costs to disposal sites would probably not be excessive but could increase the cost incrementally depending on the location.

7.2.5.3.3 Evaluation by Reviewer X

*** Information removed which was designated proprietary by respondent to RFR ***

As with all other proposed conversion technologies, the key element of affordability may be the identification of applications for the conversion product, whether it is U_3O_8 or uranium metal. This is the most valuable and costly product and having to dispose of it increases the cost of any conversion program.

7.2.5.3.4 Evaluation by Reviewer Y

Early *** Information removed which was designated proprietary by respondent to RFR *** costs are estimated and cited. Operating costs (as opposed to capital costs) seem reasonable but low for the first three phases (through 1998). D&D costs cited may be high if the contractor is dealing with a facility dedicated to depleted UF_6 . *** Information removed which was designated proprietary by respondent to RFR ***

The stated "cost of manufacturing should be offset significantly by sales of fluorine products generated from the depleted UF_6 tails." Whether the stated "return" of fluorine products *** Information removed which was designated proprietary by respondent to RFR *** range is or is not "significant" becomes of interest only relative to the cost of the process and what return, if any, there is for the DU "product." The latter is going to be governed by the cost of the equivalent natural Uranium product on the market. The perception, real or imagined, of fluorine impurities on the DU product will have really significant impact on "return" in the open market!

7.2.5.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. Presuming the fluorine is recovered as either hydrofluorocarbons or hydrofluoric acid, it would have commercial value which would help to offset the cost of the conversion process. If a commercial use for the uranium were identified, it would also help to offset the conversion costs, as well as reduce the disposal cost.

7.2.5.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.5.4.1 Evaluation by Reviewer U

Most of the chemical process requirements are reasonably well defined since many steps of the process have been in operation in the U.S. on a relatively large scale for several decades. Additional development and demonstration would be required for direct recovery of clean HFC and AHF. **** Information removed which was designated proprietary by respondent to RFR **** relatively small amount of research and development appears needed to finalize process design.

7.2.5.4.2 Evaluation by Reviewer V

**** Information removed which was designated proprietary by respondent to RFR **** While the system is expected to be commercially viable, the specific processes are not yet identified leaving some uncertainty. Some uncertainty must be attributed to the commercial scale operation and its costs. Some uncertainty regarding storage or disposal techniques still exists.

7.2.5.4.3 Evaluation by Reviewer X

The proposed technology is **** Information removed which was designated proprietary by respondent to RFR **** ASI states they have demonstrated **** Information removed which was designated proprietary by respondent to RFR **** They have applied for a patent on the process.

**** Information removed which was designated proprietary by respondent to RFR **** The production plant is projected to be sized to handle both the dUF₆ current inventory and the annual addition to this inventory from operation of the USEC GDPs.

**** Information removed which was designated proprietary by respondent to RFR ****

ASI projects that standard manufacturing equipment will be used for the process.

7.2.5.4.4 Evaluation by Reviewer Y

The proposal is specific on requirements to develop the state-of-the-art by going through stages of research, process chemistry, pilot scale demo, and ultimately to a manufacturing plant. The proposed schedule minimizes technical risk by making the phases essentially sequential.

The proposal is mature in that it does not assume success. The provision for Go/No Go decision points is evidence for the mature approach. The proposal clearly recognizes need for "materials of construction resistant to corrosives..." The recognition that **** Information removed which was designated proprietary by respondent to RFR **** substantially decrease capital costs" is a major facet of early technical investigation.

The intent to focus on U_3O_8 with no consideration of other forms (e.g., UO_2 or metal) does limit options. However, the potential for producing both AHF and HFC has impacts far beyond the revenue from sale.

Impurities (e.g., DU) in commercial products may exacerbate marketing of the fluorine compounds unless investments in quality are made early on.

7.2.5.4.5 Evaluation by Reviewer Z

*** Information removed which was designated proprietary by respondent to RFR ***

One of the primary goals of the R&D effort will be to minimize the capital-intensive process conditions *** Information removed which was designated proprietary by respondent to RFR *** The success of this R&D effort will also have an effect on the overall cost of the project, both for capital investment and operating costs.

7.2.5.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.5.5.1 Evaluation by Reviewer U

Employment at a facility to convert depleted UF_6 to U_3O_8 and recover HFC and AHF would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating period of the plant.

Operation of the process entails relatively low temperature and low pressure. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

General public acceptance should be achievable, although serious concerns undoubtedly will be raised about the processing of any nuclear material. Since it is doubtful that concurrence is obtainable from all interested parties for any option that is selected, a significant public information program is essential to present the various options in reasonable perspective for public assessment.

In today's social environment, it may not be possible to achieve an open approval from a locality for a conversion facility for depleted UF_6 . Perception may be that the benefits do not outweigh the risks, even as small as they are. Efforts to achieve acceptance from any locality may require an approach that seeks acquiescence rather than open approval. The subtle difference is very important. A community advisory committee may be appropriate to assist in the achievement of acquiescence.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.2.5.5.2 Evaluation by Reviewer V

A commercial scale plant seems likely to have positive economic benefits for the local economy around the site. Economic impacts from construction of a production facility could ultimately be two to three times the amount of the capital costs. During operation, the creation of a number of highly skilled jobs would have a positive effect on disposable income in the immediate area and would create secondary service jobs. Ongoing purchases of materials and services for operation would also improve the local economy. Construction of storage or disposal facilities could also have positive economic impacts, but the impact of their operation would be minimal.

Siting could be a significant public acceptance issue. Even in locations where processing, storage or disposal facilities are already in operation, growing concerns about the project specific and cumulative effects of such facilities could prolong or endanger the permitting process. The NRC permitting process as well as state and local reviews that would be necessary for this option must be seen as potential barriers to implementation. If a new low-level disposal facility were required, additional siting time and effort would be required. Where possible, existing sites should be used to minimize the costs required to permit, including Federally-owned sites.

Transportation risks might also be a significant factor inducing public concern. If depleted UF_6 is to be transported in large quantities for the first time, and the HFC's, AHF and U_3O_8 are then trans-shipped to other locations, the number of vehicle trips and potential for accidents will be increased. Questions are already being raised about radioactive shipments in certain areas and at certain times because of high traffic volumes. Within the immediate vicinity of the processing activities, the communities may have serious concerns regarding transportation safety and impacts on roads.

The land use implications for this option could be significant. The processing facility would be a large industrial site. Even if it is located on an existing site, the increased intensity of use could present problems. Similarly, the cumulative effect of the additional land required for disposal somewhere in the country must be evaluated in light of other demands for disposal capacity.

7.2.5.5.3 Evaluation by Reviewer X

*** Information removed which was designated proprietary by respondent to RFR ***

7.2.5.5.4 Evaluation by Reviewer Y

The ultimate plant payroll (~200-400) in 1998 ff will have significant impact on a moderate sized community. The extent toward use of plant production payroll toward Plant D&D will be a management challenge to minimize costs.

Public acceptance is not likely to be a major problem except for the potential transport of aging cylinders containing depleted UF₆.

The nature of the dry process should facilitate public acceptance.

*** Information removed which was designated proprietary by respondent to RFR ***

7.2.5.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.2.5.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.2.5.6.1 Evaluation by Reviewer U

Since there is a large potential energy content and a possible need for depleted uranium (DU) at some future point as an energy resource, a prudent decision at this time may be to store the material in a retrievable manner for a few hundred years, either as depleted UF₆ or U₃O₈. At some future point, probably within two hundred years, a national decision may be forthcoming that availability of other energy resources preclude the need for ever using DU as an energy source. Then would be the proper time to decide on the means, containment and final chemical form for material disposal.

A prominent factor for all options is whether there is a need to replace the current approach of storage any time in the near term. Safe storage of depleted UF₆ appears to be achievable for some extended period with the current approach. An assessment needs to be performed of whether the benefits of storage in a more stable chemical form, U₃O₈, is greater than the cost of converting the depleted UF₆ to U₃O₈ with associated impacts.

7.2.5.6.2 Evaluation by Reviewer V

See General Comments.

7.2.5.6.3 Evaluation by Reviewer X

None.

7.2.5.6.4 Evaluation by Reviewer Y

Of the many alternatives posed by the proposal, the alternative for the DU product is conspicuous by its absence. This contractor, if favored by an R&D contract, should be encouraged to pursue energy requirements to make various alternative products (e.g., UO_2 , DU metal) and how to retrieve such products from DU_3O_8 . Thus, it is possible that these variations along with process **** Information removed which was designated proprietary by respondent to RFR **** could be overall optimized.

7.2.5.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.5.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.5.7.1 Conclusion by Reviewer U

This option of converting depleted UF_6 to U_3O_8 , HFC and AHF is reasonable, acceptable and the federal regulatory requirements are understood. Most of the process steps are well defined. Operation of a pilot plant would confirm the operation and provide the final information needed to assure an effective commercial plant operation. **** Information removed which was designated proprietary by respondent to RFR ****

This recommendation should be considered one of the best options for management of DU if a determination is made that UF_6 is not an acceptable storage form.

A detailed cost and safety evaluation is needed to compare the several somewhat different approaches of converting depleted UF_6 to U_3O_8 . Several approaches appear to be acceptable. However, small differences in cost will amount to a significant total cost difference for the large quantity to be processed. An evaluation of the acceptable product specification for long term storage or disposal may reveal that a less pure product is acceptable that may be achieved at a lower cost through small modifications of the recommended processes. U_3O_8 powder compacting appears desirable to minimize the

overall volume. Cleanup of all waste streams to minimize the volume of waste that must be disposed of in a low level radioactive waste disposal facility should be pursued and the approach should attempt to maximize the recovery of useful and valuable by-products.

The organization submitting the recommendations in Document #P6 is well experienced and competent in the processing of uranium, UF_6 , HFC and AHF.

7.2.5.7.2 Conclusion by Reviewer V

This option promises to be reasonable with regard to DOE guidelines. The costs are the major area of uncertainty. As the process specifics are determined, the costs and environmental concerns can be further examined. The technology would be operational to meet processing deadlines for inventory disposal, if projected development schedules are met. An important concern is the cost of storing or disposing of the U_3O_8 after processing. This could increase overall program costs but provide significant environmental and economic benefits in the long run over continued depleted UF_6 storage.

7.2.5.7.3 Conclusion by Reviewer X

*** Information removed which was designated proprietary by respondent to RFR ***
However, it has the added benefit of producing an additional byproduct (HFCs) that may enable greater cost recovery.

If a commercial plant can begin production by 2000, then DOE's goal of depleting the dUF_6 inventory within 30 years can easily be met. ASI even proposes to size a plant capable of handling the continuing additions to the dUF_6 inventory from current GDP operations.

The waste stream is projected to consist only of U_3O_8 . Disposal options for the U_3O_8 haven't yet been determined.

Cost projections weren't complete, and so no evaluation can be made. However, the ultimate solution is to find uses for the U_3O_8 so that the uranium can be sold to help defray the conversion cost, no matter what it is, and to forego any disposal cost.

7.2.5.7.4 Conclusion by Reviewer Y

The proposal is "reasonable" on all counts. The proposal features a sequence of events for making decisions to optimize process decisions. The proposal is commendable for attempting the dry process and producing the environmentally acceptable HFCs. The proposal might be more reasonable if the depleted UF_6 or rather the U_3O_8 were considered a resource rather than as a waste.

7.2.5.7.5 Conclusion by Reviewer Z

This option has some merit, and should be considered. This option has the potential for converting large amounts of depleted UF_6 to a more stable form for use in other

applications, for long-term storage, or for burial. This option includes the conversion of the material to a more stable, less chemically reactive form, and provides for the complete recovery of the fluorine as either hydrofluorocarbons or anhydrous hydrofluoric acid. No specific use of the uranium product is proposed other than that it is suitable for disposal in the form U_3O_8 , or that it might be used for other commercial purposes.

*** Information removed which was designated proprietary by respondent to RFR ***

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the form of the oxide produced would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in oxide form, or that will be disposed of in burial areas.

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7.2.6 Evaluation of Document No. 41 (Independent Technical Reviewers' No. P8)

Response 41 was designated as proprietary information by the submitter, Stephen M. Schutt, Advanced Recovery Systems, Inc. (ARS). On May 30, 1995, Mr. Schutt informed LLNL that the original response dated January 12, 1995 and the following assessments were released as non-proprietary information.

This response recommends utilizing two potential technologies to decontaminate the MgF_2 low level radioactive waste (LLRW) resulting from the conversion of depleted UF_6 to uranium metal. The first, a patented hydrometallurgical process (DeCaf[™]), has been bench proven and is moving to the pilot plant testing stage. The second, a thermal recovery process (TherMag[™]), is under development.

7.2.6.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.6.1.1 Evaluation by Reviewer U

Document #P8 identifies the means of processing fluorine containing wastes having a uranium content to recover both uranium and magnesium metal values and useful fluoride salts. The primary proprietary process was developed by this organization to recover low enriched uranium and fluorides from the waste stream encountered in the production of commercial nuclear fuel. The primary waste stream from these fuel fabrication operations is a uranium contaminated calcium fluoride liquid stream. Advanced Recovery Systems has developed and put into operation a system to convert the fluoride waste into non-hazardous, non-radioactive residues and a high value salt used in aluminum smelting. The process appears to be applicable to the processing and cleaning up the waste streams of depleted uranium (DU) if the depleted uranium hexafluoride (depleted UF_6) is converted to uranium oxides using the conventional wet process and may be applicable to the processing of magnesium fluoride (MgF_2) slag by-product from the Ames process for the production of uranium metal. A second recovery process is under development that may be more economical for the processing of MgF_2 slag produced during conventional uranium metal production.

The processing steps described in this Document apply to the waste streams and slag generated during the production of uranium oxides or metal to recover recyclable

materials. The secondary recovery processes proposed are unique. The processes recommended recovers fluorine as fluoride salts as differentiated from other processes that recover the fluorine as hydrofluoric acid, aqueous or anhydrous. This Document does not identify uses for the recovered uranium, nor does it identify the primary processing steps for depleted UF_6 . The recommended processes would require additional recovery facilities supplemental to conventional processing of large quantities of depleted uranium hexafluoride (depleted UF_6) into uranium oxides and/or uranium metal. Such activities will require the design, construction, operation and eventual decommissioning of at least one new facility or possibly smaller duplicate facilities at several sites.

Operational issues include well understood controls for handling nuclear material and since the material is depleted uranium, there is no concern related to criticality. The primary uranium health concern is the heavy metal toxicity potential. Unique handling techniques are required for HF, which as a very active acid will burn skin and lung tissues. However, the potential health concerns are well known and when properly handled, effectively controlled.

Since the processes recommended in this Document would be added to larger conversion facilities for the production of uranium oxides and/or metal, there would be no additional transportation required beyond that associated with the conversion facility.

Site restrictions for a conversion facility are relatively few and the addition of the facilities to process the waste streams does not add further restrictions. However, it appears most reasonable to locate such a facility on or near one of the sites where the depleted UF_6 now resides or at a location when uranium is being or has been processed. A current storage site location would minimize transportation costs.

The processing of the waste streams is amenable to a closed liquid system with no requirement for dispose of liquid effluents. All residues could be in the form of solid wastes that may be disposed of in conventional sanitary landfill or low level radioactive waste disposal facilities.

Workers trained or experienced in the handling and processing of UF_6 at the enrichment facilities, familiar with chemical processing of uranium and dealing with highly toxic chemicals, such as HF, are appropriate for the recommended operation.

Overall Federal regulation for safety of system design and operation for the defluorination activity could be either under the existing DOE regulations or under 10 CFR Part 40, "Domestic Licensing of Source Material," of the Nuclear Regulatory Commission (NRC). A DOE processing facility located on a DOE site, such as the present storage sites, and operated by a contractor to DOE would generally be regulated by DOE. However, if the facility is owned and operated by a contractor as a service function for the DOE, it would probably be regulated by the NRC. Basic regulations have been in place for several decades and several licenses granted by the NRC for operating facilities. Adaptation of these existing regulations for the conversion operations and the recovery of useful materials from the waste streams appears to be relatively straight forward without the need for time consuming development of new regulations.

7.2.6.1.2 Evaluation by Reviewer V

This recommendation addresses two proposed technologies for treating the magnesium fluoride sludge generated by processes currently used to produce DU metal, particularly the Ames process. The first technology is a modification of a process in commercial use which involves hydrometallurgical treatment to produce fluoride and magnesium salts for chemical markets. The second uses a thermal recovery process to extract HF products and magnesium salts of commercial value. Because the processes are still in early development it is difficult to characterize the environmental issues. The technologies are described by the respondent as "standard nuclear chemical processing operations that are well known and have been previously assessed on a risk/cost basis." As the processes reach final design, more complete environmental, health and safety analyses would be possible. The operation of these technologies will generate certain potential risks and require standard industry safety practices. These technologies are not expected to present unusual siting problems. The input is a low-level waste and the outputs include hazardous chemicals. The risks and safety protection measures involved will need to be explained to the host community.

The environmental, health and safety concerns regarding this option will include those associated with DU metal production which is the necessary precursor to MgF_2 sludge production (see Document 5). Increased production of uranium metal will require the handling, transportation, conversion and ultimate disposal or use of materials with significant radiological and toxicological risks. Careful siting and design taking into account public concerns about these facilities will be needed.

7.2.6.1.3 Evaluation by Reviewer X

Advanced Recovery Systems, Inc. (ARS) presents two potential technologies to decontaminate the MgF_2 low-level radioactive waste resulting from the conversion of dUF_6 to uranium metal. Both have the potential of recovering the uranium and producing magnesium and fluoride chemicals for industrial use. ARS has patented a hydrometallurgical process (DeCaf™) and is developing a thermal recovery process (TherMag™). DeCaf™ has been bench proven and is moving to the pilot plant testing stage. Both are currently being tested on MgF_2 matrices generated from the manufacture of depleted uranium metal. ARS is a subsidiary of NFS Technologies, Inc., a part of Nuclear Fuel Services, Inc., the sole manufacturer of fuel for the U.S. Navy nuclear fleet.

The recommended technologies are stated to be based on standard nuclear chemical processing operations.

ARS has experience within the Nuclear Fuel Services organization handling uranium, HF, and other related hazardous chemicals. This includes the receipt of and maintenance of permits for the handling of these materials. Any new plant would require a review of these permits, or possibly the issuance of new or revised licenses and permits.

7.2.6.1.4 Evaluation by Reviewer Y

"Waste minimization, resource recovery and recycle are the cornerstones of ARS' business." If the proposal can "deliver," the processes described are powerful in the context of environmental friendliness and waste minimization (below). The processes are designed to facilitate product purity when the conversion of depleted UF_6 to DU metal for recycle or storage is the desired option.

The process proposed is an extrapolation on an operating process to minimize Uranium content thus reducing activity of the waste or, more likely, utilizing the activity free CaF_2 in other process industry. The extrapolation is not assured but has reasonable prospects, if not for the Low Temperature Process, the proposed high temperature process should provide more favorable results with MgF_2 . Chemical safety may be the major issue if high temperature operation is the preferred mode in a location where "external events" must be considered.

7.2.6.1.5 Evaluation by Reviewer Z

This proposal, submitted by Mr. Stephen Schutt, proposes to process the depleted UF_6 to convert it to uranium metal. This would be done by using current reduction technology, and the resulting MgF_2 would be processed by one of two proposed processes to remove the contamination and recover the magnesium and fluoride salts for industrial use.

The process proposed by this option would not present any environmental, safety or health issues which are different than those which have previously been evaluated by current technologies.

The first process proposed would convert fluoride wastes into non-hazardous, non-radioactive residues, extract contained uranium for recycle or disposal as a volume-reduced material, recover metal values for recycle, and recover fluoride as a high value salt used in aluminum smelting.

The second option proposed utilizes a process in which the uranium-contaminated magnesium fluoride is pretreated thermally to quantitatively recover fluoride values. Subsequent processing of the pretreated matrix is achieved by a hydrometallurgical process for uranium and magnesium recovery.

Either of these processes, if proven effective would significantly reduce the amount of waste material to be disposed of, and thereby reduce the environmental impact of the process. No new waste streams are identified.

Any facility handling and processing UF_6 will need a large enough site, sufficient controls, and site emergency plan to protect members of the public in the event of spillage of UF_6 from its storage vessels or process systems, and any subsequent atmospheric dispersion. No other special siting requirements are anticipated. No specific site was identified.

7.2.6.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.6.2.1 Evaluation by Reviewer U

The depleted UF_6 conversion to uranium oxides and/or metal and the use of the proposed processes for cleaning the waste streams should be achievable with a closed process. That is, liquid effluent streams would be minimal and gaseous streams fully scrubbed to eliminate discharge of contaminated or noxious components. Solids collected from processing may contain traces of uranium. Special purification steps could be performed to remove the contamination or the solids may be disposed of in low level radioactive waste disposal facilities.

7.2.6.2.2 Evaluation by Reviewer V

The hydrometallurgic process, called DeCaF, would generate about 26,000 MT of uranium concentrate and undissolved residues over the project life that would need disposal in a low level waste facility. There would be a ten fold reduction in the volume of materials needing LLW handling as a result of the processing. About 150,000 MT of fluoride salts and 270,000 MT of magnesium salts would be generated for sale in chemical markets. The thermal process, called TherMag, is expected to generate less than 8,000 MT of low level wastes requiring disposal over the project life. That process would produce an estimated 120,000 MT of HF products and 380,000 MT of magnesium salts for resale. When final process configurations are complete, waste streams could be reviewed in more detail, however, no other significant streams are anticipated. Other wastes would include the empty and decontaminated cylinders from the depleted UF_6 , which would be recycled or disposed. Although the volumes generated are relatively small, identification of a LLW facility and acceptance of the residues must be planned.

7.2.6.2.3 Evaluation by Reviewer X

The objective of the proposed processes is to reduce or eliminate the LLRW waste stream. Tested in the laboratory, the DeCaF[™] process reduces the original MgF_2 quantity by at least 90% and recovers >99.5% of the uranium. Further testing is planned to improve on these numbers.

ARS has been decontaminating 1.5 tons of CaF_2 per day in a "trouble-free" facility using the DeCaf™ process since 1991. Waste fluoride sediments contained a residue of <9 pCi/gm uranium activity, enabling them to be released to a non-radioactive landfill.

Laboratory scoping tests of the TherMag™ process succeeded in recovering 99% of the fluoride values. A hydrometallurgical process recovers the uranium and magnesium.

Current waste projections for the two processes are found in the following table. These values assume the feedstock will be the total MgF_2 slag from a dUF_6 to metal conversion process, an amount totaling 200,000 MT with 2 wt% contained uranium.

Waste Product	Process	
	DeCaf™	TherMag™
Uranium Concentrate (MT)	6,000	6,000
Undissolved Residue (MT)	20,000	$<2,000$

No mention was made of the possibility of converting the uranium concentrate to useful metal to further reduce the waste stream. The economics of recovering this small amount of residual waste might be prohibitive, but should be evaluated during the development phase.

7.2.6.2.4 Evaluation by Reviewer Y

The recovery and recycle of reagent chemicals is a strong plus for minimizing waste. The denaturing of Uranium activity from the fluorides should provide a product for broad commercial usage. Even if that goal is not realized, the waste requirements for disposal would not have the SNM specifics.

Unfortunately, the proposal does not speak to the contamination of bulk Uranium metal. If the Uranium metal is to be used in specific application, Fluoride contamination might be limiting, thus the potential for considerable waste emerges. Pyrometallurgical processes could refine the metal, albeit at some cost.

7.2.6.2.5 Evaluation by Reviewer Z

As noted above, this option is to address the contaminated MgF_2 waste stream generated by the uranium metal production process. This is the most significant waste stream for this process, and if the R&D program for either or both of the options identified is successful, it will significantly reduce the waste from this process.

For the 560,000 metric tons of depleted uranium hexafluoride presently in storage, it is expected that 200,000 tons of MgF_2 slag would be produced if all of the material were reduced to uranium metal. The first option proposed would reduce the waste volume to approximately 26,000 metric tons, with 150,000 metric tons of fluoride salt product and

270,000 metric tons of magnesium salt product available as saleable products. The second proposed option would reduce the waste from 200,000 metric tons of contaminated MgF_2 slag to 8,000 metric tons of waste and 500,000 tons of saleable products.

7.2.6.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.6.3.1 Evaluation by Reviewer U

Costs associated with the conversion of depleted UF_6 to oxides or metal are reasonably well defined. The added cost associated with the processing of the waste stream and slag is not well defined.

The market value of the recovered fluorine and magnesium salts would be less than the overall cost of building facilities for the conversion and performing the recovery operations.

Decontamination and decommissioning costs for a depleted UF_6 conversion facility and the associated facilities for processing of waste streams would be typical of those for commercial UF_6 conversion plants and low enriched uranium fabrication plants. The level of radioactivity would be small and much of the facility could be decontaminated with mechanical and chemical cleaning. Clean up residues and some processing equipment may require disposal in controlled low level waste disposal facilities.

7.2.6.3.2 Evaluation by Reviewer V

The respondent has identified the following costs (millions):

	<u>Option 1</u>	<u>Option 2</u>
Res. & Dev't	\$1.5-2.0	\$1.5-2.0
Capital/Construct.	15-20	15-20
Operations-20 yrs	100	150
Revenues-Products	\$135-185	\$203-265

Based on the information provided, it would appear that the sludge processing might be done at little or no cost to the government. The cost of waste residue disposal will have to

be included in any final cost estimates. The overall economics of both options seem favorable.

The cost to convert depleted UF₆ to metal has been estimated at between \$10 and \$11 per kg. Information must be collected on the total cost to DOE of this alternative before any serious evaluation can be made. Current market production of DU metal seems to be 7,000 tons per year. Conversion of even a part of the inventory at the assumed 20,000 tons per year scale presented, would more than double the supply to a market where prices are very sensitive to demand. It is not clear that markets exist for this material. A better analysis of potential users needs to be made. Another cost item of concern for DU metal remains the cost of disposal. Even with reduced quantities, the cost of packaging, transport and disposal can be significant.

7.2.6.3.3 Evaluation by Reviewer X

Development and demonstration costs are estimated at \$1.5 to \$2.0 million. Plant construction costs could be about \$20 million, not including decommissioning costs.

Based on ARS's projections for operating costs and value of the fluoride salt, AHF, and magnesium salt product, potential profits of \$34 to \$62 million are possible.

Not included in these projections is the cost avoidance factor of not having to dispose of the feedstock as low-level radioactive waste.

ARS states all their cost estimates have a potential uncertainty of $\pm 50\%$.

7.2.6.3.4 Evaluation by Reviewer Y

The costs for producing Uranium-free Fluoride is likely to be on the same order of magnitude as producing products (e.g., DU metal, MgF₂). Thus, the anticipate revenues would be very close to covering salt and HF production costs. With a 50% uncertainty on production costs at this time, it is likely that revenues will not cover costs unless there is a DU metal revenue stream; this is unlikely in the commercial arena for the next few years. However, the US government may consider it prudent to "purchase" DU metal for a strategic Uranium reserve. Perhaps the work of Ludtka to develop a "new process to form uranium metals more simply and inexpensively with less waste..." could facilitate the overall economics of pure products.

Quality costs! How much this quality cost is very hard to define from the proposal.

7.2.6.3.5 Evaluation by Reviewer Z

This reviewer has no numeric data on costs of building, maintaining, or operating facilities to execute the option proposed in this alternative. The reduction in the amount of waste which requires disposal and the recovery of large amounts of saleable product would provide significant cost savings.

If uranium metal is produced, it is assumed that it would be for a commercial application, and would therefore have a commercial value.

7.2.6.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.6.4.1 Evaluation by Reviewer U

The chemical process requirements for converting depleted UF_6 to uranium oxides or metal are well defined since the processes have been used for a considerable period.

Maturity of the secondary processes proposed in this Document for the capture of fluorine and magnesium salts are less well defined. The basic chemistry has been demonstrated and the operation of pilot and demonstration facilities should define the operating parameters with a high probability of success.

7.2.6.4.2 Evaluation by Reviewer V

Research, development and demonstration of both technologies is expected to require 5 years. Scoping test have been completed on the DeCaF process, but further testing "to improve dissolution of feedstock, identify all unit operations necessary for a pilot study, refine ROM operating and capital costs and recover magnesium as a usable salt" is needed. The TherMag process is still in initial laboratory investigations. Scale-up bench tests in 1995 will look at improved reactor design and full flowsheet testing. Both processes are described as technically feasible. The respondent is looking for \$1.5-2.0 million in funding to complete development. It is expected to be an additional 5 years before engineering, construction and initial operations can be completed.

7.2.6.4.3 Evaluation by Reviewer X

ARS has been decontaminating 1.5 tons of CaF_2 per day in a "trouble-free" facility using the DeCaF™ process since 1991. Waste fluoride sediments contained a residue of <9 pCi/gm uranium activity, enabling them to be released to a non-radioactive landfill.

Scoping tests in the laboratory using the DeCaF™ process reduced the original MgF_2 quantity by at least 90% and recovered $>99.5\%$ of the uranium. Further testing is planned to improve on these numbers. The theoretical maximum volume reduction is 50:1.

Thermag™ provides a higher efficiency for the recovery of the uranium, fluoride, and magnesium values. Further scale up bench tests are planned for 1995.

Thus, both processes are still at the bench test level, although DeCaF™ is used at the tons/day level to successfully decontaminate CaF_2 . To process 200,000 MT of MgF_2 over a ten year period, this plant would have to be increased in size about 22 times, assuming three-shift 200 days/year operation.

Further research, development, and demonstration are projected to require about five years. Engineering and construction will enable a new plant to be operational with the next five years.

7.2.6.4.4 Evaluation by Reviewer Y

The proposal states that "Both 'breakthrough' recovery technologies described herein have shown promising results at the bench..." In addition, the DeCaF™ has been operating at 1.5 tons per day plant since 1991 without trouble. Evidence for reducing cost liabilities for decontaminated wastes have been realized (without any indication of cost magnitudes (or percentages)).

How well Mg chemistry can be extrapolated or inferred from Ca chemistry is an open question. The promissory bench results are encouraging. The promise of the TherMag™ process is technically reasonable (even if costs are not).

No mention is made, nor is it part of the proposal, of DU metal quality (e.g., fluorine impurities). This quality may be limiting for DU metal for any use in nuclear reactor systems. The corrosive nature of such impurities may well be go-no-go situations. On the other hand, the pyrometallurgical or similar process may obviate this concern by focusing mainly on effluent control. This quality process control is not standard industrial practice and will require versatile pilot scale development.

7.2.6.4.5 Evaluation by Reviewer Z

The UF_6 to uranium metal reduction process is a mature technology. The process proposed in this response proposes a R&D process which will address the MgF_2 slag waste from the process. The two technologies which are to be tested are still in the laboratory test phase, and have not been proven on a commercial scale.

7.2.6.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.6.5.1 Evaluation by Reviewer U

Employment at a facility to convert depleted UF_6 to uranium oxides and/or metal, including waste stream processing as proposed in this Document would be at a steady level for a couple of decades if all of the existing depleted UF_6 is converted. The large backlog of material to be converted eliminates the up and down processing rates customarily experienced at chemical facilities where operation is dependent upon demand for the service or changing customer desires.

There would be a temporary increase in skilled construction employment over two to five years for construction of the facility. However, operation and maintenance employment should essentially be constant for the operating life of the plant.

Operation of the process entails relatively low temperature and low pressure for much of the processing. Thus, the potential of releasing large quantities of hazardous material or encountering a significant accident that would impact the public are relatively small.

The concern on general public acceptance will relate to the conversion facility. The addition of the processing steps to recover materials from the waste streams should be a welcomed item for the operation.

Performing the operation at one or all three of the existing sites where depleted UF_6 is stored or a location where uranium is presently being processed, should be viewed as a reasonable extension of current activities. This should not change the character of the locality or adversely impact alternate development in the region. There is little expectation that such an operation would be helpful for encouraging related locality development.

7.2.6.5.2 Evaluation by Reviewer V

The construction and operation of the facilities described are not expected to have a major economic impact. The construction would occur over 1-2 years and the operating staff is estimated at 4-8 operators. This would not result in significant impacts on the surrounding community or region.

Construction of a facility capable of producing 20,000 tons of uranium metal annually would constitute an major industrial construction project. This would significantly impact communities in which it might be located. It is estimated that operations could require on the order of 300 permanent employees. In a small community this would stimulate significant economic growth, two to three times the size of the direct impact.

The siting and permitting of the MgF_2 treatment facility should not present any insurmountable hurdles in most communities. There is likely to be close scrutiny of the public health risks and environmental effects. Traffic to and from the site could be significant with hazardous chemical shipments creating public concern in areas of traffic congestion. Eventual public acceptance would be expected.

7.2.6.5.3 Evaluation by Reviewer X

ARS estimates that a production operating 200 days/year on three shifts would require four to six operators. If this is per shift, then a maximum staff size of about 40 would result.

No suggestions are provided for potential locations. However, it's reasonable to locate the plant adjacent to a dUF₆ to uranium metal conversion plant. Thus, the plant would have a minor effect on local employment. During construction, more workers would be expected to be required. If the plant is on or near a GDP site, operations could provide continued employment for released GDP employees.

Since the purpose of the plant is to decontaminate slag from dUF₆ conversion, it is likely to receive public acceptance.

ARS also states that site selection might be limited by effluent criteria.

7.2.6.5.4 Evaluation by Reviewer Y

While total employment for these quality production processes will be quite low, local development will benefit from activities before and after the proposed process.

Public acceptance should be high for anyone concerned with minimizing waste and the character thereof. Public acceptance could be jeopardized if local subsidies are encouraged to locate the facility.

7.2.6.5.5 Evaluation by Reviewer Z

This reviewer has no specific information related to the impacts of the implementation of the proposed option on socioeconomics.

7.2.6.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.
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7.2.6.6.1 Evaluation by Reviewer U

Recovery of the maximum amount of useful products and producing the least amount of waste volume requiring disposal are important factors. The recommended processes will assist in achieving this set of factors.

7.2.6.6.2 Evaluation by Reviewer V

See General Comments.

7.2.6.6.3 Evaluation by Reviewer X

None.

7.2.6.6.4 Evaluation by Reviewer Y

This process proposal cannot be evaluated without some intent(s) for other facets of the problem. This is necessary to establish realistic overall revenue, and process and disposal costs. In that context, this proposal seems like a vital ingredient to 1) provide a product purity (Uranium-free) that is amenable to normal commercial processes involving fluorine. The market forces will determine product economics. It is less than clear that either a capital or operating subsidy will not be required. The best that can be hoped for, but probably not realized, is that the quality process will roughly equal the fluorine product revenue.

7.2.6.6.5 Evaluation by Reviewer Z

This option proposes a process for the conversion of depleted UF_6 to a more stable, less reactive form. A decision to select this option should include consideration of the intense amount of energy and resources already invested to purify the uranium and convert it into uranium hexafluoride. All potential future uses for the depleted uranium should be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

7.2.6.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.6.7.1 Conclusion by Reviewer U

If the depleted UF_6 is converted to oxides or metal, the use of processes to recover fluorine and magnesium salts from the waste and by-product streams should be included in the process steps. However, if advanced processes are used to produce metal, such as the plasma approach, magnesium may not be part of the process. The recommended processes must be evaluated in detail with alternate recovery processes to define which ones are the more efficient and economical.

Most of the process steps are well defined. Some development and demonstration appears needed to evaluate the capture of fluorine and magnesium salts on a large scale.

The organization submitting the recommendation in Document #P8 is experienced and competent in the development of chemical processes and the design and operation of facilities for processing radioactive materials.

7.2.6.7.2 Conclusion by Reviewer V

It appears that this option would fit within the reasonableness criteria established by DOE. The uncertainty about the technical maturity and the time to implement are areas of concern. Cost may also become a concern depending on the process development results and the success in recycling most of the products at attractive prices. This option must be considered in the context of the viability of DU metal conversion options. As with other technologies, opportunities for public/private ventures should be examined.

7.2.6.7.3 Conclusion by Reviewer X

The two technologies proposed by ARS are in the bench testing phase. The DeCaf™ technology has been used successfully for four years to decontaminate CaF_2 . Further testing, scaling, and plant engineering and construction is projected to require another ten years. Thus, a plant sized to accept 20,000 MT of MgF_2 slag per year would reduce the entire slag inventory from dUF_6 conversion to metal within DOE's stated 30-year guideline.

Both technologies are projected to reduce the amount of material having to go to an LLRW site from about 200,000 MT to 6,000 MT, with 20,000 MT or less of material to go to a hazardous material disposal site. This would have a significant positive impact on licensed LLRW disposal facilities and a positive cost avoidance effect.

The cost of further testing to refine the processes and construct an operating plant would be about \$22 million. Projections of operating costs and the value of recovered material available for resale result in a potential profit of over \$34 million during the life of the plant.

A full scale plant would require an operating crew of fewer than 40 workers. Thus, it could employ current GDP personnel likely to be laid off, but otherwise would have minimal impact on the local economies.

The recommendation assumes that the entire dUF_6 inventory would be converted to metal. It projects a uranium concentrate as a waste product. However, further processing might enable this residue to also be converted to metal, although the small amount might not be economical.

Once converted to metal, uses will need to be developed so the uranium can be sold to defray or completely pay for the conversion cost, even with a profit, and to forego any disposal cost.

7.2.6.7.4 Conclusion by Reviewer Y

Assuming the bench scale and pilot plant performances are realized as expected, this technology is "reasonable" on all counts except one...cost! The costs estimated in the proposal are but part of incurred total costs including those of transport, conversion of depleted UF_6 to metal, and production of quality commercial products with markedly

reduced wastes. If there is subsidy for a national strategic depleted Uranium preserve, with or without an intermediary AVLIS process, then the quality processes proposed can make a lot of long-term sense. Quality costs!

7.2.6.7.5 Conclusion by Reviewer Z

This option has merit, and should be considered. The processes to be tested relate to the processing of the waste streams to produce commercially valuable products. If these processes are developed successfully, there would be substantial improvements in the area of waste management.

Selection of this option should be dependent upon the decision that is made for final disposition of the depleted uranium. The specifications for the plant, and decision regarding the reduction to either UO_2 or uranium metal would also be dependent upon the designated use for the product. Sizing of the production facility should be sized to process the amount of depleted uranium which will be used for other applications in metal form.

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7.2.7 Evaluation of Document No. 47 (Also Identified As No. P9)

Response 47 was designated as proprietary information by the submitter, Steven M. Baker, EG&G Environmental, Inc. On June 1, 1995, Mr. Baker informed LLNL that only the thermodynamic analysis in the memo attached to their submittal is proprietary and that the following evaluation is non-proprietary. Due to time constraints, the response was reviewed internally.

This response recommends reacting UF_6 gas with alumina (Al_2O_3) or aluminum metal to produce aluminum trifluoride (AlF_3) and a combination of uranium compounds (UO_3 , UO_2 or uranium metal). Aluminum trifluoride is a primary material used by the aluminum industry in electric cells (or "pots") that reduce alumina to aluminum metal.

7.2.7.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.7.1.1 Evaluation by Reviewer

The thrust of this brief proposal is to convert uranium hexafluoride to a more stable, non-fluoride form and simultaneously incorporate the fluorine into the aluminum trifluoride (AlF_3) form for direct use in the manufacture of aluminum metal. The proposed conversion process is stated to be completely closed with no discharges. However, the gravimetric separation step is not described to assess the associated ES&H impacts, and in addition, it is not clear that a closed system is practical for all conversion options. This concept avoids the handling and transport of anhydrous HF and on the surface minimizes environmental (e.g., emissions) and worker safety issues.

7.2.7.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.7.2.1 Evaluation by Reviewer

From an overall system standpoint, the concept minimizes wastes. The fluorine content of the hexafluoride is recycled into a useful chemical form for the aluminum metal manufacturing industry. The implicit assumption is that the uranium contamination level of the AlF_3 is sufficiently low for unrestricted use. The proposal does not, however, address this issue.

7.2.7.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.7.3.1 Evaluation by Reviewer

No cost estimates (including RD&D) were given for the concept, and there is inadequate technical data to make meaningful facility cost estimates. However, one would anticipate that such a facility would utilize conventional unit operations and industrial equipment. Cost avoidance of the handling/storage/transport of anhydrous HF would be significant. Since the conventional route to AlF_3 involves the hydrofluorination of aluminum oxide, one might expect a specific byproduct credit comparable or greater than the value of HF.

7.2.7.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.7.4.1 Evaluation by Reviewer

The proposal is highly conceptual: It is supported by simple, but not complete thermodynamic calculations that do not rule out significant quantities of other possible and undesirable reaction products. Bench scale feasibility has not been established, and no kinetics data appear to be available. A viable process will require an AlF_3 byproduct with very low (but undefined) uranium contamination levels. It is unclear that simple separation approaches will enable a very "clean" byproduct. The potential requirements for complex separations or added decontamination steps can significantly reduce or eliminate the ES&H and waste management features of this concept as well as adversely impacting the overall costs. The probability of success (i.e., achieving the stated goals) is judged to be no greater than 50%.

7.2.7.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.7.5.1 Evaluation by Reviewer

Public acceptance of the proposed concept would be positive with respect to the avoidance of the storage and transport of HF. Although there would be enhanced regional employment, this is not considered to be a major factor.

7.2.7.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.2.7.6.1 Evaluation by Reviewer

It is questionable if the construction of a pilot facility is the next step, as implied in the proposal. Additional (and substantial) analyses are first required. If warranted, the feasibility analyses would be followed by off-line bench scale experiments to obtain critical design data.

7.2.7.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.7.7.1 Conclusion by Reviewer

The concept is innovative and offers desirable features. The concept is at a very early stage of analysis, and has significant technical risks. Further analyses and extensive R&D are required to evaluate the technical feasibility and overall practicality of the concept.

7.2.8 Evaluation of Document No. 48 (Also Identified As No. P10)

Response 48 was designated as proprietary information by the submitter, Charles Chisholm, PDI. On June 2, 1995, Susan Noble provided LLNL a non-proprietary summary of the response submitted on March 10, 1995. On June 15, 1995, the following evaluation was released as non-proprietary information. Due to time constraints, the response which was dated June 2, 1995, was reviewed internally because it was submitted after January 31, 1995. The response was not forwarded to the Independent Technical Reviewers.

This response proposes that a mined geologic formation be considered for the long term management of the depleted uranium hexafluoride or products of processing the depleted UF_6 . The use of an existing underground mine as a full scale model to study issues involved in the long term management of depleted uranium hexafluoride was also offered. The existing mined cavity is stated to be stable, dry, and large, and currently used for seismic monitoring purposes. The response indicates that the underground mine has a long history of site information including geologic mapping, geochemical mapping, electromagnetic aerial surveys, ecosystem studies, hydrologic studies, and environmental studies.

7.2.8.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

7.2.8.1.1 Evaluation by Reviewer

Specific ES&H information is not provided in the response. The mined cavity is already in existence and the stated stability and size indicate little or no additional excavation would be required to use the existing facility as a model. The mine is also inspected on a routine basis, and no water intrusion or subsidence has been detected. No mention is made of any mine reclamation or restoration activities, and no environmentally sensitive issues (e.g., endangered species) are identified. These points imply a compatibility with the regulations for past utilization of the mine. The response does not mention any requirements, licenses, or permits for testing or actual use of the mine; however, the site appears to be suitable for the proposed use. While a detailed performance assessment would have to be conducted, the mine in the response would appear to meet the requirements for mine disposal of depleted uranium as outlined by the Nuclear Regulatory Commission in

the Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center and is therefore a good candidate for a model to study these issues.

7.2.8.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

7.2.8.2.1 Evaluation by Reviewer

Specific waste management information is not provided in the response. The response indicates the mine is in existence and consists of numerous large tunnels and caverns. Thus, little or no additional waste would be anticipated from any excavation activities involved in preparing the mine for use as a model.

7.2.8.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

7.2.8.3.1 Evaluation by Reviewer

No cost information is provided in the response. The use of the proposed, existing mine to study the long term management of depleted uranium hexafluoride would avoid significant site characterization and excavation expenses associated with the development of a new mine facility as a model thus implying a certain cost effectiveness.

7.2.8.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

7.2.8.4.1 Evaluation by Reviewer

No specific information is provided in the response. Since the excavated mine, operational, and characterization-related information exist, the facility could be considered technically mature as a model for studying the issues involved in the long term management of depleted uranium hexafluoride. However, while the response represents a strong candidate for use as an analytical and/or experimental model, no actual mine storage or disposal facility for radioactive materials or wastes has been licensed in the United States.

7.2.8.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

7.2.8.5.1 Evaluation by Reviewer

Limited socioeconomic information is provided in the response. The response indicates a very low population density around the mine site. It does not provide any information on local conditions, current employment levels at the site, historical employment levels during full mining operations, or projected employment levels for modeling operations. Conceptually, use of the facility as a model would be expected to have modest but positive economic and employment effects. The proposed use would be consistent with the over one-hundred year operational history of the mine and the mining district in which it is located.

7.2.8.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

7.2.8.6.1 Evaluation by Reviewer

Although not clearly stated, the response implies a large facility with considerable characterization information and documentation.

7.2.8.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

7.2.8.7.1 Conclusion by Reviewer

The summary information presented in the response indicates an excellent candidate facility is available for use as a model to facilitate the long term management of depleted uranium hexafluoride. The concept of using a mined geologic formation for the long term management of the depleted uranium is reasonable.

7.3 Other Evaluations

This section includes evaluations of seven responses containing recommendations that were not reviewed by the Independent Technical Reviewers, including late responses. The Independent Technical Reviewers were convened at an orientation meeting on January 31, 1995, and only recommendations submitted after that date were not forwarded due to schedule constraints. These late responses were evaluated internally by LLNL/SAIC staff using the same evaluation factors.

7.3.1 Evaluation of Document No. 17

Document No. 17 is from the Portsmouth/Piketon Residents for Environmental Safety & Security (P.R.E.S.S.). The response recommends that DOE modify and improve storage facilities and procedures and criticizes the current conditions and late change in the semi-annual meeting agenda to include the depleted UF₆ program. The response also asks that if armament is going to be manufactured, then waste generation should be mitigated and health risks assessed. It also raises questions about the viability of using depleted UF₆ as canister liners for radioactive waste disposal due to concern about toxicity of decaying uranium.

7.3.1.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

The environmental, safety, and health issues associated with storing depleted UF₆ in its present chemical form and current storage locations are well known and effectively controlled. Depleted UF₆ presents more of a chemical hazard than a radiological hazard. When exposed to air, it reacts with the moisture present to form UO₂F₂ and HF. Hydrogen fluoride is a corrosive and irritating acid vapor that can cause skin and lung damage. The fluorides and uranium can have toxic effects if ingested.

Improvements to current storage facilities and procedures would mitigate the existing environmental, safety, and health issues. Although the respondent does not specify the changes in storage conditions and procedures, improvements might include changes to facilitate inspection, a more frequent and rigorous inspection system, cylinder refurbishment or replacement, and placing the cylinders inside a building.

7.3.1.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

The waste streams associated with storage improvements are minimal. Minor amounts of low level waste would be generated from disposal of substandard or empty cylinders and the depleted UF₆ rinsed from the inside of emptied cylinders as well as other normal maintenance activities. Sanitary waste streams would also be minimal. It is noted that the respondent asks the agency to take responsibility for its waste generation.

7.3.1.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

Although specific recommendations for improvement to the existing DOE facilities are not given, the costs would, nonetheless, be expected to be higher than continuing the current storage practices and planned upgrades to cylinder yards. Current costs have been estimated in the range of \$83-\$129 million for 375,000 MTU (less than the current inventory) through the year 2020. The costs for storing the cylinders in newly constructed buildings have been estimated to be approximately \$360 million plus an additional \$129 million for inspection and maintenance through the year 2020. This is considerably less than expected cost for conversion and disposal options, however.

7.3.1.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

The storage of depleted UF₆ has been accomplished for several decades and improvements to the existing storage facility (such as replacing the cylinders and placing them on concrete pads and/or in covered storage buildings) would pose no new technological challenges.

7.3.1.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

Major improvements to the existing storage facilities or operations would provide additional capital and operating funds to the community during the construction period. Routine operations and maintenance after the construction period should be viewed as an extension of current activities with little or no impact on employment or regional development. There appears to be a negative public perception of risk, and improvements to current storage may result in increased public acceptance. Providing the public with additional information on the risks and operating history would seem warranted to address this perception.

7.3.1.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

By leaving the material in its present chemical form, maximum flexibility for future uses is preserved.

7.3.1.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

Although this recommendation lacks specificity, suggestions to improve the existing storage facility are reasonable. Leaving the depleted UF₆ in its current form provides maximum flexibility for future uses. The total cost of \$489 million for improvements and monitoring through the year 2020 is approximately an order of magnitude less than the costs for conversion and disposal options. A cost/benefit analysis should be conducted to determine if the projected risk reduction is justified by the expense. Additional information on the risks and operating history should be made available to the public.

7.3.2 Evaluation of Document No. 38

This response is from the State of Tennessee Department of Environment and Conservation, DOE Oversight Division. Although this letter responds to the request for comments on the Advance Notice of Intent rather than the Request for Recommendations and will be considered in the preparation of the Environmental Impact Statement (EIS), a recommendation to gradually convert the depleted UF_6 to an oxide over a 15 to 20 year period in order to mitigate short-term costs is made. The respondent suggests that the deteriorating cylinders be converted first thereby allowing the use of smaller refurbishment facilities and fewer cylinder storage pads.

7.3.2.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

The response does not identify a specific oxide or conversion process. Design, construction, operation, and eventual decommissioning of one large or several smaller conversion facilities would be required to complete conversion of 560,000 MT of depleted UF_6 in 15-20 years. There are several established processes for converting to either UO_2 or U_3O_8 which could be used. These were evaluated in the Independent Technical Reviewers assessments (e.g., Document Nos. 6, 9, 10, 16, 30, 35, etc.). Operational issues and controls for handling nuclear material of this type are well understood.

Nuclear criticality is not an issue for depleted uranium. The chemical toxicity of the uranium as a heavy metal and the corrosive hydrofluoric acid which is formed when UF_6 is exposed to air are the principal environmental, safety, and health issues associated with the existing chemical form. Oxide forms offer increased chemical stability. Uranium octaoxide, for example, is non-reactive under normal conditions and has a very low solubility in water. It is the preferred form for long-term storage in other countries and at new uranium enrichment facilities being proposed in the U.S.

Converting the material in the deteriorating cylinders first is consistent with an approach to decrease the potential for accidents. Locating the conversion facilities on existing sites would minimize risks from transporting the depleted UF_6 . Rail transportation of enriched UF_6 has occurred safely for decades, however, and this is not expected to be a significant issue.

7.3.2.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

Based on information related to existing conversion processes, conversion to an oxide could be expected to generate minimal liquid effluents and scrubbed gas streams. Most processes would yield an anhydrous hydrogen fluoride byproduct, which could be sold in the U.S. market or neutralized with slaked lime and disposed of as calcium fluoride, a non-radioactive waste (provided uranium contamination was controlled to an acceptable level).

7.3.2.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

Conversion costs have been estimated up to \$3 billion for converting depleted UF_6 to U_3O_8 . The potential sale of AHF would slightly offset costs.

7.3.2.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

There are several mature processes for conversion to oxide.

7.3.2.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

There would be a temporary increase in employment during plant construction. Gradual conversion of the depleted UF_6 would provide for continued employment of skilled nuclear workers. Public perception may be negative regarding the risks of plant operation.

7.3.2.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

A dense oxide such as UO_2 would occupy a considerably smaller volume than the depleted UF_6 . Conversion to oxide would limit future uses as compared to the current form.

7.3.2.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

The recommendation to spread the oxide conversion costs out over a 15 to 20 year period is reasonable. Oxide forms offer increased chemical stability and can occupy smaller volumes than the depleted UF_6 . It would seem appropriate to identify a final disposition which requires the oxide form before committing to the conversion expense and limiting future uses.

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7.3.3 Evaluation of Document No. 39

Document No. 39 is from Ms. Sue Whyne, a citizen near the Paducah Gaseous Diffusion Plant expressing concern that radioactive materials be stored in a seismically safe manner. The response recommends relocation and compensation of residents who have already been affected, and also recommends that onsite, aboveground concrete storage be "earthquake-proof" and high enough to be monitored for leaks. This response is similar to Document Nos. 26 and 33. The Independent Technical Reviewers' evaluations of these documents provide additional information.

7.3.3.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

The environmental, safety, and health issues associated with storing depleted UF_6 in its present chemical form and current storage locations are well known and effectively controlled. Depleted UF_6 presents more of a chemical hazard than a radiological hazard. When exposed to air, it reacts with the moisture present to form UO_2F_2 and HF . Hydrogen fluoride is a corrosive and irritating acid vapor that can cause skin and lung damage. The fluorides and uranium can have toxic effects if ingested.

Improvements to current storage facilities and procedures would mitigate the existing environmental, safety, and health issues. The response suggests above ground storage should be concrete, earthquake proof, and high enough to be monitored for surface leaks and radioactive releases. Placing the depleted UF_6 in concrete structures would provide a second level of containment which would increase the level of environmental protection. Seismic analyses to identify potential impacts from earthquakes should be used in the design of concrete structures. The large mass of material and the low center of gravity indicate considerable force would be required to move the containers from their current positions. Monitoring for leaks and releases would be an integral part of any storage program, including the current program.

7.3.3.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

The waste streams associated with providing earthquake-proof concrete structures are minimal. Minor amounts of low-level waste would be generated from disposal of substandard or empty cylinders and the depleted UF₆ rinsed from the inside of emptied cylinders as well as other normal maintenance activities. Sanitary waste streams would also be minimal, and could include replaced wooden saddles.

7.3.3.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

It is unlikely that "earthquake-proof" structures can be provided at reasonable cost, but a higher level of seismic integrity could be achieved. Building above ground earthquake-resistant structures and conducting seismic analyses would be significantly more expensive than continuing to store the material in the current configuration.

7.3.3.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

The storage of depleted UF₆ has been accomplished for several decades and seismic improvements would pose no new technological challenges.

7.3.3.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

Major improvements to the existing storage facilities or operations would provide additional capital and operating funds to the community during the construction period. Routine operations and maintenance after the construction period should be viewed as an extension of current activities with little or no impact on employment or regional development.

7.3.3.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

By leaving the material in its present chemical form, maximum flexibility for future uses is available.

7.3.3.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

The depleted UF₆ has been stored safely for several decades. Monitoring for leaks and releases would be an integral part of any storage program, including the current storage scenario. Suggestions to improve the existing storage facility are reasonable, although having "earthquake-proof" structures does not appear to be warranted. A cost/benefit analysis should be conducted to determine if the projected risk reduction is justified by the expense. Leaving the depleted UF₆ in its current form provides maximum flexibility for future uses.

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7.3.4 Evaluation of Document No. 47 [P9 (Proprietary Notebook)]

Document No. 47 was designated as proprietary information by the submitter, Steve Baker, EG&G Environmental. This response was sent on March 8, 1995. The review was released by the respondent as non-proprietary information and may be found in Section 7.2.7.

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7.3.5 Evaluation of Document No. 54 [P11 (Proprietary Notebook)]

Document No. 54 was designated as proprietary information by the submitter, Yoshihiko Sugano, Mitsubishi Materials Corporation. This response was dated April 24, 1995. The review may be found in the proprietary addendum to the *Technology Assessment Report*.

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7.3.6 Evaluation of Document No. 55

Document No. 55 was from GenCorp Aerojet Ordnance Tennessee (AOT)/Babcock and Wilcox (B&W) and was dated February 15, 1995. This document provides complementary information to their original response (Document No. 15), which was forwarded to the Independent Technical Reviewers. This response proposes the conversion of depleted UF_6 to metal using the following batch metallothemic process: (1) hydrogen reduction of the hexafluoride to the tetrafluoride, and (2) batch metallothemic reduction of the tetrafluoride to the metal using magnesium.

7.3.6.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

This is an existing industrial process, and as stated: "Existing emissions for the proposed process meet all regulatory agency rules and regulations, and no new emissions are contemplated." Emission and related data were not provided.

7.3.6.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

The proposal recognizes the need to decontaminate the byproduct slag material (MgF_2). The decontamination technology with waste minimization objectives has been developed and demonstrated. Effluent and flowsheet data were not provided. Identified recycle opportunities (or cost avoidance) include anhydrous HF produced from the conversion of UF_6 , and decontaminated MgF_2 (e.g., use as fluxing agent or construction filler material). No estimates, however, were given for the MgF_2 market sizes.

The implicit assumption is that the decontaminated MgF_2 can be disposed in a sanitary landfill. Although this is the case today, it is unclear whether routine exemptions will be the case in the future, especially for the sustained production of much larger annual volumes of byproduct. Based on current or projected low-level waste disposal costs, this could substantially impact the metal cost.

7.3.6.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

Although stated to have been generated, no cost (or price) data were provided for either the current capacity or an expanded production capacity.

7.3.6.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

The technologies for the conversion processes are standard industrial technologies.

7.3.6.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

Public acceptance for an enhanced mission seems reasonable based on current community acceptance and the proposed ES&H improvements. Based on the proposal data, employment levels (skilled and semi-skilled personnel) could increase by as much as 130 people (over 2 sites), assuming conversion of the entire stockpile to metal over 20 years. No data was provided on the non-skilled labor force.

7.3.6.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

The AOT/B&W team's opinion is that depleted uranium metal is preferable to U_3O_8 for long-term storage or disposal from a "chemical/physical state." The primary argument is that the density of the metal is higher and therefore the storage or disposal volumes would be lower. This is a valid argument (particularly for disposal), but one needs to also consider (tradeoff) the comparative economics of conversion to the metal and the octaoxide. Existing documentation indicates a substantially higher cost for conversion to the metal than the oxide. There is also a counter-argument that the metal is pyrophoric and, therefore, is not a preferred long-term storage form.

7.3.6.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

The proposed technology for conversion to metal is a standard industrial technology, and the indicated improvements provide important environment, safety and health, and waste management benefits. The viability for expanded missions (e.g., disposal, storage, Atomic Vapor Laser Isotope Separation Process reenrichment) depends on the direct conversion cost and the assumption that the decontaminated byproducts can be disposed as a non-low-level waste or utilized for cost avoidance.

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7.3.7 Evaluation of Document No. 57

Document No. 57, dated April 17, 1995, is from Los Alamos National Laboratory (LANL) and is an explanation of their current project with Nuclear Fuel Services Inc., on conversion of depleted UF₆. The objective of the project is recovery of depleted uranium in a stable oxide form from depleted UF₄ and recovery of the fluoride as hydrogen fluoride and/or a variety of fluorocarbons. The response proposes the direct use of uranium hexafluoride as the fluorinating agent in the manufacturing of fluorocarbons, which would subsequently be used for chlorofluorocarbons replacement and polymer manufacturing. The uranium hexafluoride would be converted to the tetrafluoride, and the tetrafluoride would either be converted to uranium oxide by pyrohydrolysis with steam or be stored.

7.3.7.1 Evaluation Factor One - Environmental, Safety and Health

Consider the following issues of concern to workers, the public, and the environment:

- *issues that may arise as the result of operations, transportation, handling, storage and disposal, including effluents and emissions.*
- *issues that may restrict site choices when constructing or operating a facility that employs this technology or application.*
- *design configurations, specifications, or operational requirements that pose problems of nuclear, chemical, or other safety issues involving workers or the public.*

Specific environmental, safety, and health information is not provided in the response. However, the response suggests that the processes are an evolutionary modification of existing processes for which acceptable environment, safety, and health approaches have been developed.

7.3.7.2 Evaluation Factor Two - Waste Management

While this factor might well be included in the Environmental, Safety and Health Factor, its potential significance deserves special attention.

- *Radiological, nonradiological, hazardous, toxic, mixed or solid waste streams and waste volumes, or residual material that may pose problems of storage, transportation, treatment, or disposal.*
- *Potential for waste minimization in use or manufacture.*
- *Potential for recycling.*

Specific waste management information is not provided in the response. The use of uranium hexafluoride as a fluorinating agent would raise concerns about the possible volumetric contamination of the fluorocarbon and polymer products, which could result in

increased waste generation as compared to other processes. This would have to be experimentally demonstrated. Also, storage of uranium tetrafluoride would have to be investigated further; such storage has been dismissed by regulatory agencies in the recent past.

7.3.7.3 Evaluation Factor Three - Costs

Consider costs which are associated with the development or use of a technology or the use of product, or which could preclude consideration of a recommendation.

- *Capital costs, both initial (including R&D) and continuing.*
- *Annual operating and maintenance costs.*
- *Decontamination and decommissioning costs.*
- *Value of any product or facility salvage.*
- *Cost avoidance through sale of any byproducts.*

Specific cost information is not provided in the response. Costs for using the hexafluoride as the fluorinating agent would be higher as compared to the use of non-radioactive fluorinating compounds. Relative life cycle costs and trends cannot be ascertained from the response.

7.3.7.4 Evaluation Factor Four - Technical Maturity

For technologies or uses that have no prior history, estimate the time-to-availability. Consider the probability of success. Which of the following developmental stages describes the technology:

- *Design - conceptual or detailed.*
- *Bench or small scale.*
- *Developed but untested on a large scale.*
- *Tested or used on a large scale, but not standard industrial practice.*
- *Standard industrial practice.*

The response includes an outline of a technology development program that would require at least 3 years and \$3 million dollars, and would culminate with a demonstration of the process using around 100 kg of uranium hexafluoride. Development time and costs beyond this are unknown. No proof of principle results are stated. Unspecified, alternate methods for the conversion of the tetrafluoride to the oxide would also be evaluated in the test program.

7.3.7.5 Evaluation Factor Five - Socioeconomics

Consider the effects of the application of a product or the use of a management technology on the following:

- *Employment.*
- *Public acceptance.*
- *Local or regional development.*

Specific socioeconomic information is not provided in the response. The response notes that the fluorocarbons would have a greater value than anhydrous hydrogen fluoride, although this would be reduced somewhat by the quantity produced and additional processing and handling requirements to avoid uranium contamination of the products. Construction and operation of a plant using this process would be expected to have a modest, positive influence upon the local community and its economy.

7.3.7.6 Evaluation Factor Six - Other Factors

Add any other information believed to be pertinent to the feasibility of the submission.

None.

7.3.7.7 Conclusions

Based on the evaluation above and the guidelines for establishing reasonability provided in the Independent Technical Review Manual, provide a determination as to whether or not this option is reasonable and a brief justification of this conclusion.

A determination of reasonability could not be made using the existing criteria since the response lacks specificity in many areas. As presented, it would appear that any potential advantages would be offset by potential contamination of the products with uranium.

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8 SUMMARY AND CONCLUSIONS PRESENTED BY LAWRENCE LIVERMORE NATIONAL LABORATORY and SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

8.1 Feasibility Analysis

This section provides a brief summary of the Independent Technical Reviewers' evaluations of each response, focusing on the conclusions presented by each reviewer on reasonability. In addition, this section offers some general observations made by the reviewers in their evaluations of the responses. No conclusions should be drawn by the reader on the basis of which observations from Section 7 were carried forward to the Section 8 summary and which were not. Instead, the reader should refer to the full, verbatim evaluations in Section 7. The feasibility analysis presented in this section is a summary of the Independent Technical Reviewers' assessments, as interpreted by LLNL and SAIC.

Several responses contained multiple recommendations, and some reviewers evaluated each recommendation separately. As often as possible, the feasibility analysis is shown for each separate recommendation.

After Section 8.1 was completed, it was forwarded to the Independent Technical Reviewers for review. The purpose of this review was to ensure that the summaries accurately capture the essence of each Reviewer's evaluations and that important information was not omitted or misstated. Comments were received and modifications were made to the summaries on the basis of the input.

In addition to providing specific comments on Section 8.1, some of the Independent Technical Reviewers forwarded general observations on the consolidated assessments. These observations follow.

General Observations by Independent Technical Reviewer U

- Every recommendation received in response to the Federal Register RFR would result in additional expenditures by the Federal Government. The value of recovered products in all cases was less than the cost of conversion and recovery. One exception may be the use of depleted uranium as shielding material in the high-level radioactive waste disposal program—although the useful quantity for such applications would be a small portion of the quantity of depleted uranium.
- To prevent the expenditure of funds inappropriately, it appears premature to convert the depleted UF_6 to any other chemical or physical form until a basic issue is defined—should the depleted uranium be retained for possible future useful applications or should a decision be made to proceed with permanent disposal.
- An approach of declaring the depleted uranium to be a waste material for permanent disposal entails many unknowns such as when a decision should be made that useful applications are not expected to be identified, whether shallow land burial would be

acceptable for the large quantity or whether deep geologic disposal is required, what form and density of material is required for acceptable disposal (oxides and/or metal), the extent of federal disposal regulations, the mechanism for disposal site selection and the extent of involvement of designated disposal site localities in the process for assured safety of disposal.

- Many of the responses to the Federal Register RFR entail processes for the conversion of the depleted UF_6 to oxides or metal as a means of achieving a safer and more stable material form for storage or disposal without identifying an economic use for the depleted uranium. New, large capacity production processing facilities, with high capital cost and challenging siting considerations, would be required for the conversion of large quantities of depleted UF_6 . The summary touches on this item very briefly under one or two of the recommendations.
- If the depleted UF_6 is converted to oxides or metal, a major task of cleaning and disposing of a large number of storage cylinders will be involved. Is it practical to recover the metal for uncontrolled other uses or will it be necessary to dispose of these cylinders as a waste stream requiring controlled waste disposal?

General Observations by Independent Technical Reviewer V

- These observations are included in Section 7.1.

General Observations by Independent Technical Reviewer X

- Reviewer X provided no general observations.

General Observations by Independent Technical Reviewer Y

- The energy balances are generally conspicuous by their absences. These could have profound impacts on future costs.
- The quality requirements for products (e.g., AHF, HFC, depleted uranium metal, depleted UO_2) are both understated or conspicuous by their absence. (How many ppm of depleted uranium are acceptable in a depleted UO_2 , depleted uranium metal or depleted uranium carbide product that ends up in a hostile or consumer environment?) These costs could well exceed returns for commercial sales of AHF.
- The impact of already contaminated facilities on commercial product or technical usage qualities is conspicuous by its absence.

General Observations by Independent Technical Reviewer Z

- While many of the alternatives may be feasible or reasonable, what seems lacking in the overall document are recognitions that resources have been expended to raise the uranium to its state of purity and chemical potential; that continued storage in present form and locations is feasible; and that a technical or safety need should be a requisite

demonstration to justify the expense of an alternative to existing management of the UF₆, especially one which would diminish its potential as a resource.

8.1.1 Feasibility Analysis of Document No. 1 (Independent Technical Reviewers' No. 1) from Mr. A. N. Tschaeche**8.1.1.1 Description of Document No. 1**

Document No. 1 recommends that the depleted UF_6 remain in its current form, at its present location, and that it be used to make blanket material for breeder reactors for generating electricity and plutonium for use in electric generating nuclear power plants. The responder states that maintaining this material in its current form will allow future generation of plutonium for use in electric generating nuclear power plants.

8.1.1.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 1

The Independent Technical Reviewers all agreed that continued storage of depleted UF_6 at present locations is feasible. DOE is able to monitor and maintain depleted UF_6 for a long-term period, however, improvements in current storage practices are advisable. Storage can be implemented immediately and would handle all existing inventory. The depleted UF_6 would then be a resource available for future use. The cost of this option is relatively low.

The Independent Technical Reviewers agreed that there is a known potential energy resource value associated with depleted UF_6 , but that breeder reactors requiring blanket material are not likely to be developed in the United States by the year 2020. However, in the more distant future, the depleted uranium may become an economical and valuable energy resource. It is suggested that the material be used in other applications to justify long-term storage of the total inventory. One of the Independent Technical Reviewers concluded that even if 100 breeders were built, less than 1% of the current inventory of depleted UF_6 would be used.

8.1.2 Feasibility Analysis of Document No. 2 (Independent Technical Reviewers' No. 2) from Mr. Mark Strauch**8.1.2.1 Description of Document No. 2**

Document No. 2 contains four recommendations for the disposition of the depleted uranium. These include: (Option 2-1) retention of enough depleted uranium as UF_6 to blend down the highly enriched uranium from retired nuclear weapons to an enrichment level sufficient for use in nuclear reactors; (Option 2-2) retention of enough depleted uranium as UF_6 to blend down the highly enriched uranium from the former Soviet Union and its satellite states' retired nuclear weapons and stockpiles; (Option 2-3) use of depleted uranium in the design of a Multi-Purpose Canister (MPC) for storage and disposition of spent nuclear fuel and other high-level waste; and (Option 2-4) reduction of UF_6 to a metal state for safer long-term storage and management.

8.1.2.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 2

Options 2-1 and 2-2: The Independent Technical Reviewers concluded that using depleted UF_6 to blend highly enriched uranium from retired U.S. and former Soviet Union nuclear weapons and stockpiles was feasible. Issues raised by the Independent Technical Reviewers are whether the material will be released by the governments, the actual volume reduction of depleted UF_6 (estimated to be approximately 2 percent of the total existing volume), the cost of using depleted UF_6 in the blending process as compared to using natural uranium, and the continued storage of depleted UF_6 .

Option 2-3: The Independent Technical Reviewers concluded that conversion of depleted UF_6 into metal for the purpose of constructing MPCs is a feasible option. The concerns raised by the Independent Technical Reviewers are whether there will be a market for these or other shielding purposes, the cost of the conversion, and the volume of depleted UF_6 that would be converted into metal. It was noted that the quantity of depleted UF_6 that might be used for this application (20,000 to 40,000 metric tons) is less than half the amount considered feasible (84,000 metric tons) under the guidelines presented to the Independent Technical Reviewers.

Option 2-4: Four of the Independent Technical Reviewers concluded that conversion of depleted UF_6 into a metal state for long-term storage was feasible. They cautioned that this should not be done unless uses for the metal are identified, environmental affects of conversion are controlled, the current storage practice was found to be unacceptable and uranium metal is determined to be better and more economical than uranium oxide for long-term storage.

One Independent Technical Reviewer found Option 2-4 not feasible because of the pyrophoric and oxidation properties of metallic uranium.

8.1.3 Feasibility Analysis of Recommendation in Document No. 3 (Independent Technical Reviewers' No. 21) from Mr. Peter Lenny

This document corresponds to Document No. 35 (see Section 8.1.35).

8.1.4 Feasibility Analysis of Recommendation in Document No. 4 (Independent Technical Reviewers' No. 3) from Davis Transport**8.1.4.1 Description of Document No. 4**

Document No. 4 offers two categories of recommendations: reduction to oxide and reduction to metal. These recommendations are: (Option 4-1) use the oxide reduction program offered by Allied/GA or a variation of the oxide reduction program to include running the anhydrous hydrogen fluoride waste stream back through Allied's UF_6 plant, sending resultant waste solids to the Nevada Test Site (NTS) for disposition; (Option 4-2) use the CMI at Barnwell, South Carolina, to reduce a portion of the stockpile to metal for storage.

8.1.4.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 4

Option 4-1: The majority of the Independent Technical Reviewers concluded that the option of converting depleted UF_6 to triuranium octaoxide (U_3O_8) and anhydrous hydrogen fluoride is a feasible option. Concerns were raised by the Independent Technical Reviewers as to the need to convert if the current practices are acceptable; however, it was also recognized that U_3O_8 is a more stable chemical form for storage or disposal. In addition, cost studies would need to be performed to compare the net value of converting to anhydrous hydrogen fluoride with the current cost associated with storage. One Independent Technical Reviewer did not believe the response proposed any specific options regarding the use or disposition of the depleted UF_6 and did not conduct a detailed evaluation.

Option 4-2: Four Independent Technical Reviewers concluded that conversion of depleted UF_6 to a metal for storage and disposal was a feasible option; however, further study was required concerning the cost of storing and disposing of the metal as compared to existing storage practices, or the cost of storing and disposing of the material in the form of uranium oxide. Additionally, one Independent Technical Reviewer expressed concern regarding the overall environmental, health and safety risks of the multiphase conversion and disposal process.

One Independent Technical Reviewer did not believe the response proposed any specific options regarding the use or disposition of the depleted UF_6 and did not conduct a detailed evaluation.

8.1.5 Feasibility Analysis of Document No. 5 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory**8.1.5.1 Description of Document No. 5**

Document No. 5 consists of three recommendations on use and one technological recommendation for disposal of the depleted uranium stockpile. The recommendations on use include: (Option 5-1) use of UF_6 to produce DUCRETE, which can be used instead of conventional concrete as the shielding material in the fabrication of storage containers for use with spent nuclear fuel; (Option 5-2) conversion of depleted uranium into metal for use in energy storage flywheels; and (Option 5-3) conversion of depleted uranium to a metal using an Idaho National Engineering Laboratory (INEL) plasma process, and using the metal as feedstock for the Atomic Vapor Laser Isotope Separation (AVLIS) enrichment process. A DUCRETE storage container is also stated as suitable for spent fuel shielding at the monitored retrievable storage (MRS) site or for lag storage at the repository prior to emplacement. Option 5-4 is a technological recommendation that proposes use of a conversion process developed at INEL in support of DUCRETE efforts, wherein the conversion process of UF_6 to triuranium octaoxide (U_3O_8) would produce a high-density stabilized uranium oxide rock for direct disposal at sites without requiring further stabilization.

8.1.5.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 5

Option 5-1: The Independent Technical Reviewers all agree that the use of depleted UF_6 to produce DUCRETE as a shielding material in spent nuclear fuel containers is a feasible option. The benefits cited include better shielding with less weight and volume than equivalent concrete containers, resulting in handling, transportation, and disposal advantages. Concerns were raised about the life cycle cost of this option and about the ultimate disposal of the DUCRETE if the containers are not placed in a repository. In this case, disposal of the DUCRETE at the end of its useful life would have to be accomplished at a low-level radioactive waste disposal facility. While it seemed feasible to use DUCRETE in spent nuclear fuel storage containers going into the high-level waste repository, utility site storage containers, multi-purpose transport and storage containers, and shielding structures made from DUCRETE show less promise.

The environmental safety and health effects of the conversion process from depleted UF_6 to oxide was thought to be the most significant concern for this option, for example, dust creation and dispersal during DUCRETE manufacture would have to be contained. Conversion processing and DUCRETE manufacture will require the handling, transportation, and ultimate disposal or use of materials with significant radiological and toxicological risk. Properly controlled operations should keep these at acceptable levels. Some provision for venting gases likely to be formed in the DUCRETE from the uranium decay and radiolysis would have to be addressed. It was noted that no basic regulations are in place for commercial use of uranium as an aggregate in concrete and a lengthy process may be encountered to establish such regulations.

Option 5-2: The majority of the Independent Technical Reviewers concluded that the use of depleted uranium in energy storage flywheels is feasible; however, the amount of depleted UF_6 used for this option was noted to be small. The environmental, health, and safety concerns regarding this option will parallel those experienced in the uranium metals industry in general. Increased production of uranium metal will require the handling, transportation, conversion, and ultimate disposal or use of materials with significant radiological and toxicological risks. The conversion of this metal to final products and their use also presents the potential for additional risks. These risks are well known and characterized from previous operations. Worker safety concerns would be the most significant environmental issue for flywheel fabrication. There is the potential risk of exposure to radiological and hazardous material during the fabrication process; however, properly controlled operations should keep these at acceptable levels for health maintenance. Ultimate disposal of the metal, life cycle cost, and the potential market are important issues to be considered if this option is adopted. Perceived safety aspects associated with the use of uranium in vehicles are also difficult hurdles to overcome.

Option 5-3: The majority of the Independent Technical Reviewers agreed that the application proposed by INEL to convert depleted UF_6 to metal using the plasma process and subsequently using the metal as feedstock for the AVLIS enrichment process was feasible to pursue; however, the process is not technically mature to predict when it will be available for commercial deployment. Production of uranium metal would have greater

environmental, health, and safety risks than processes currently in use. An attractive feature of this conversion option is that it may not produce a waste stream since the process only produces uranium metal and anhydrous hydrogen fluoride for sale as a product. It was noted that using the depleted uranium as feedstock for AVLIS enrichment may be appropriate within a one - two hundred year time span when low cost uranium ore resources are no longer available. Such use does not appear appropriate in the next few decades.

Option 5-4: The Independent Technical Reviewers agree that the conversion of depleted UF_6 to uranium oxides, which would then be stabilized into a "rock" that can be accepted at disposal sites, is a feasible option to consider. However, the costs would need to be carefully reviewed. The increased production of uranium oxides will require the handling, transportation, conversion, and ultimate disposal or use of these materials, which also has radiological and toxicological risks. Uranium oxides, however, are the most chemically stable forms in which to handle depleted uranium. A key concern will be defining and locating an acceptable disposal site. There is uncertainty whether the "rock" could be disposed in a low-level waste site or would require a deep geologic disposal site depending upon the classification of the waste form activity. One Independent Technical Reviewer noted that because the bulk density of the U_3O_8 would be increased in order to reduce disposal volume, the specific activity of the material would increase thereby precluding near surface burial and requiring deep geologic disposal technologies to be considered.

8.1.6 Feasibility Analysis of Recommendation in Document No. 6 (Independent Technical Reviewers' No. P1) from Siemens Power Corporation**8.1.6.1 Description of Document No. 6**

This response recommends use of a patented dry conversion process for converting depleted UF_6 to produce uranium oxide (probably UO_2 , but U_3O_8 is also possible) with the concurrent production of hydrofluoric acid.

8.1.6.2 Summary of the Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 6

The Independent Technical Reviewers all agree that conversion to oxide using this dry process is a reasonable option. Some process redesign and demonstration were thought to be needed to scale up the existing design and augment it to recover anhydrous hydrogen fluoride (AHF). Several Independent Technical Reviewers noted that there is a limited market for hydrofluoric acid in the United States and that the process would probably need to be modified to recover AHF or dispose of the hydrofluoric acid as waste. The primary environmental, safety, and health issues identified were the heavy metal toxicity of the uranium and the hazardous and corrosive nature of HF, which has the potential to burn skin and lung tissue. The potential health concerns were said to be well understood and effectively controllable. This conversion process was cited as being amenable to a closed liquid system producing no liquid effluents, fully scrubbed gaseous streams, and small amounts of calcium fluoride (CaF_2) which may be recyclable to other industries (e.g., steel and glass). The stigma of coming from a depleted UF_6 refinement was mentioned as a possible obstacle for marketing both the CaF_2 and HF by-products unless very low impurities are achieved.

Although the processing of depleted UF_6 to produce an oxide has environmental risks, it was noted that the resultant oxide would pose less risk than the depleted UF_6 . A cost/benefit assessment was recommended to determine whether the benefits of storage in the oxide form were greater than the cost of converting the depleted UF_6 to the oxide with associated impacts. It was stated that selection of this option should be dependent upon the decision that is made for the final disposition of depleted uranium.

8.1.7 Feasibility Analysis of Recommendation in Document No. 7 (Independent Technical Reviewers' No. P5) from M4 Environmental Management, Inc.

This document corresponds to Document No. 29 (Independent Technical Reviewers' No. P5) which is a proprietary response. The review of Document No. 29 is included in the separate proprietary addendum to this *Technology Assessment Report*.

8.1.8 Feasibility of Document No. 8 (Independent Technical Reviewers' No. 24) from Mr. Dennis Wright**8.1.8.1 Description of Document No. 8**

Document No. 8 recommends using a titan missile or a space shuttle to send the depleted UF_6 to the sun, and to refrain from generating more pollution from depleted UF_6 on the earth.

8.1.8.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 8

The Independent Technical Reviewers all agreed that using a titan missile or a space shuttle to send the depleted UF_6 to the sun and to refrain from generating more pollution from depleted UF_6 on the earth is not a feasible option.

This recommendation presents significant environmental, safety, and health concerns. Several points raised in regard to sending the material to the sun included the number of rocket launchings that would be necessary for such a large quantity of material, and the amount of pollution generated from rocket fuel exhaust. It was noted that both uranium and fluorine are materials that are plentiful on earth, and removal of the depleted UF_6 would not significantly change the overall amount of either element within the environment. There is the potential for accidents upon launching those rockets, as well as the risk of the material never reaching the sun and the depleted UF_6 being released into the atmosphere. This recommendation probably would get public acceptance initially because it would be a stimulant to the aerospace industry and it would generate economic activity. However, preparation of the material for loading, processing, and packaging would both generate waste and expose workers to safety risks. While this recommendation is technically feasible using existing technology, it would be accomplished at a potentially high cost and be unacceptable to the public because of the environmental, safety, and health risks involved.

8.1.9 Feasibility Analysis of Recommendation Contained in Document No. 9 (Independent Technical Reviewers' No. 5) from General Atomic and Allied Signal, Inc.

8.1.9.1 Description of Document No. 9

Document No. 9 recommends use of a conversion process patented by General Atomic, wherein the conversion of depleted UF_6 to triuranium octaoxide (U_3O_8) will produce anhydrous hydrogen fluoride, a commercially valuable product.

8.1.9.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendation Contained in Document No. 9

The Independent Technical Reviewers all agree that processing depleted UF_6 into triuranium octaoxide (U_3O_8) and the recovery of anhydrous hydrogen fluoride is a feasible option. The Independent Technical Reviewers raised issues concerning the proposed burial of U_3O_8 as a low-level waste since the Nuclear Regulatory Commission (NRC) has suggested that this may not be acceptable, the potential uses of U_3O_8 , and the potential cost of storing and disposing U_3O_8 . The Independent Technical Reviewers agree that there is a market for anhydrous hydrogen fluoride. Some of the Independent Technical Reviewers cautioned that further cost and energy studies should be done to confirm the need to convert the depleted UF_6 into any other form such as U_3O_8 .

8.1.10 Feasibility Analysis of Recommendation Contained in Document No. 10 (Independent Technical Reviewers' No. 6) from COGEMA, Inc.

8.1.10.1 Description of Document No. 10

Document No. 10 recommends construction and operation of a conversion facility for the long-term storage in the form of triuranium octaoxide (U_3O_8), and the recycling of hydrofluoric acid into United States commercial markets.

8.1.10.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendation Contained in Document No. 10

The majority of the Independent Technical Reviewers concluded that processing depleted UF_6 into triuranium octaoxide (U_3O_8) and hydrofluoric acid is a feasible option. The Independent Technical Reviewers raised issues concerning the proposed burial of U_3O_8 as a low-level waste, the U.S. market for hydrofluoric acid, potential uses for U_3O_8 , the volume of depleted UF_6 from existing inventories consumed by this process, and the cost of conversion as compared to current storage practices. While a principal advantage of this process is that no hazardous waste is produced, one Independent Technical Reviewer expressed concerns about the cost of retrieving the depleted uranium from U_3O_8 for future energy production needs, stating that it is highly preferable to convert the depleted UF_6 to UO_2 for long-term storage.

8.1.11 Feasibility of Document No. 11 (Independent Technical Reviewers' No. 7) from Mr. A. N. Tschaeché

8.1.11.1 Description of Document No. 11

Document No. 11 recommends the use of depleted UF_6 in breeder reactors to generate electricity, and suggests no further action at this time (i.e., continued use of current storage and management practices). The respondent made reference to a previous submittal identified here as Document No. 1.

8.1.11.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 11

This response is essentially the same as Document No. 1, also submitted by Mr. Tschaeché. Please refer to the feasibility summary provided in Section 8.1.1.2.

8.1.12 Feasibility Analysis of Recommendation Contained in Document No. 12 (Independent Technical Reviewers No. 8) from Manufacturing Sciences Corporation

8.1.12.1 Description of Document No. 12

Document No. 12 recommends direct reduction of UF_6 to metal, by-passing the uranium tetrafluoride (UF_4) stage, by using a technique that involves reduction by hydrogen in a high-temperature plasma. Metal from this process can be used as radiation shielding for a universal containment system for spent nuclear fuel.

8.1.12.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendation Contained in Document No. 12

The majority of Independent Technical Reviewers concluded that the direct conversion from depleted UF_6 to metal using a plasma is a feasible option only to the extent that further research has merit; however, there is no assurance at this stage of development that the process will work and be available for large-scale operations. The process has the potential for increased environmental, health, and safety impacts, but lower production cost and the elimination of slag waste are potentially attractive. The Independent Technical Reviewers raised issues concerning the demand for uranium metal and the uncertainty of the process availability due to its early stage of development.

8.1.13 Feasibility Analysis of Document No. 13 (Independent Technical Reviewers' No. 9) from Mr. Patrick F. Brown**8.1.13.1 Description of Document No. 13**

Document No. 13 provides DOE three principal recommendations for the disposition of the depleted uranium stockpiles and related materials. These recommendations include: (Option 13-1) conversion of depleted UF_6 to fluorine compounds; (Option 13-2) storage of the oxide in steel boxes made from the depleted UF_6 cylinders; (Option 13-3) recovery of ^{235}U for value as separative work units and or ^{238}U for use in breeder reactors.

8.1.13.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 13

The Independent Technical Reviewers concluded that there were feasible aspects contained in Document No. 13, but as a whole, the approach might not be feasible at this time. The processes need a great deal of further development and costs of the multiple stage processes have not been assessed. Several reviewers thought the potential benefits of siting facilities in, for example, the western desert, would be more than offset by the transportation and handling requirements, costs, and potential accidents. The feasibility of the three principal recommendations included in Document No. 13 is summarized below.

Option 13-1 (Conversion of UF_6 to fluorine compounds and uranyl nitrate): The Independent Technical Reviewers determined this recommendation to be feasible after additional research and development. Environmental, safety, and health requirements would be similar to existing plants and processes, although adequate training would be necessary. The reviewers thought costs would be greater than indicated in the document.

Option 13-2 (Storage of the oxide in steel boxes made from the depleted UF_6 cylinders): The Independent Technical Reviewers generally agreed that conversion to the oxide and subsequent storage is a feasible approach. The reviewers also felt that recycling the cylinders as steel storage boxes is beneficial and should be considered along with other cylinder disposition options.

Option 13-3 (Recovery of ^{235}U for value as separative work units, and ^{238}U for use in breeder reactors): The Independent Technical Reviewers concluded that the emulsion enrichment process was interesting, but without any additional information, felt its costs and implementation were understated. Several reviewers noted that enrichment for ^{235}U use would only consume a small percentage of the current depleted uranium inventory, about 20 tonnes. Two reviewers also thought breeder reactors might make sense in the long-term, but implementation could be decades or even a century away. Therefore, while possible and practical, this recommendation does not appear feasible for large-scale disposition of depleted uranium in the near future.

In comparing the enrichment cost in separative work units for different concentrations of product, feed, and tails, an Independent Technical Reviewer concluded that the excessive

cost of extracting additional ^{235}U from depleted UF_6 relative to natural uranium could not be justified unless natural uranium became extremely rare.

8.1.14 Feasibility Analysis of Document No. 14 (Independent Technical Reviewers' No. 10) from the American Nuclear Society**8.1.14.1 Description of Document No. 14**

Document No. 14 recommends that management of the depleted uranium continue in the present mode of storage. The respondent states that depleted UF_6 could be used as blanket material for breeder reactor production of electricity at some future date.

8.1.14.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 14

The Independent Technical Reviewers generally agreed that continued storage of depleted UF_6 is feasible. Such storage has been accomplished for several decades, and it appears to be feasible to monitor and maintain safe storage of depleted UF_6 for a long-term period; however, improved cylinder maintenance is needed for safety and environmental protection. While the use of depleted uranium as blanket material in breeder reactors is assessed to be feasible, the Independent Technical Reviewers pointed out that the likely development of breeder reactors in the United States would occur well beyond the year 2020. Therefore, it is stated that other applications for the material should be found. There is a need for risk analysis to identify the risks to workers and the general public, to determine whether to build confinement facilities, when and at what rate to replace specific cylinders, and to consider other factors important to long-term storage.

8.1.15 Feasibility Analysis of Recommendation in Document No. 15 (Independent Technical Reviewers' No. P7) from A.B. Machine Company, Ltd.

This document corresponds to Document No. 36 which was designated as proprietary. The review of Document No. 36 is included in the separate proprietary addendum to the *Technology Assessment Report*.

8.1.16 Feasibility Analysis of Recommendation in Document No. 16 (Independent Technical Reviewers' No. P2) from Fluor Daniel, Inc.**8.1.16.1 Description of Document No. 16**

Document No. 16 recommends two options for the recovery of anhydrous hydrogen fluoride (AHF) from the conversion of depleted UF_6 :

1. A two-part process for the dry conversion of depleted UF_6 to UO_2 with the dehydration of off-gases to produce AHF.
2. A two-part process for the classical conversion of depleted UF_6 to uranium metal using magnesium, with the intermediate conversion to UF_4 and the resultant production of AHF recovered from magnesium fluoride (MgF_2).

8.1.16.2 Summary of the Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 16

The Independent Technical Reviewers generally agree that the recovery of anhydrous hydrogen fluoride (AHF) from the dry conversion of depleted UF_6 to UO_2 and the classical conversion of depleted UF_6 to uranium metal are reasonable. It was stated that selection of this option should be dependent upon the decision that is made for the final disposition of depleted uranium. Except for the step in the metal conversion process to capture the magnesium sulfate and AHF from MgF_2 , the processes proposed were noted to have extensive commercial operating experience at a smaller scale. One Independent Technical Reviewer stated that since this AHF recovery process needs more work and has some degree of uncertainty associated with it, it does not meet all the criteria for reasonableness. Another Independent Technical Reviewer noted that the recommendations appeared reasonable on all grounds except that costs were not cited other than to say "no government funding required" and no disposition of the material following the processes was proposed.

Considerable commercial demand for AHF and the marketability of recovered magnesium sulfate were identified as benefits. Although the processing of depleted UF_6 to produce an oxide has environmental risks, it was noted that the resultant oxide would pose less risk than the depleted UF_6 for long-term storage. The primary environmental, safety, and health issues identified were the heavy metal toxicity of the uranium and the hazardous and corrosive nature of the AHF which has the potential to burn skin and lung tissue. The potential health concerns were said to be well understood and effectively controllable. This conversion process was cited as being amenable to a closed liquid system producing no liquid effluents, emissions with AHF and uranium levels well below allowable limits, and solid wastes that may be disposed of in conventional low level radioactive waste disposal facilities or sanitary landfills. It appeared most reasonable to several Independent Technical Reviewers to locate a conversion facility on or near one of the current depleted UF_6 storage sites and thus minimize transportation risks.

8.1.17 Feasibility of Document No. 17 (Independent Technical Reviewers' No. n/a) from Portsmouth/Piketon Residents for Environmental Safety and Security (P.R.E.S.S)**8.1.17.1 Description of Document No. 17**

Document No. 17 is from the Portsmouth/Piketon Residents for Environmental Safety & Security and was dated December 12, 1994. The response recommends that DOE modify and improve storage facilities and procedures as the preferred alternative, and criticizes the current conditions and late change in the semiannual meeting agenda to include the depleted UF₆ program. The response also offers that if armament is going to be manufactured, then waste generation should be mitigated and health risks assessed. It also raises questions about the viability of using depleted UF₆ as canister liners for radioactive waste disposal due to concern about toxicity of decaying uranium.

8.1.17.2 Summary of Reviewer's Conclusions on Feasibility of Recommendations Contained in Document No. 17

This recommendation was reviewed by LLNL/SAIC staff using the same evaluation factors as were used by the Independent Technical Reviewers.

The internal review concluded that even though this recommendation lacks specificity, suggestions to improve the present depleted UF₆ storage facilities at the Portsmouth Gaseous Diffusion Plant would be feasible since it would pose no new technological challenges, it would initially provide additional capital and operating funds to the community, and because the cost for improvements and monitoring through the year 2020 would be approximately an order of magnitude less than the cost for a conversion and disposal program. It was noted that leaving depleted UF₆ in its current form provides maximum flexibility for future uses. The comment that DOE should refrain from considering uses for depleted UF₆ is not applicable at this time since DOE is seeking all reasonable options for long-term management.

8.1.18 Feasibility of Document No. 18 (Independent Technical Reviewers' No. 11) from the Ohio Valley Regional Development Commission**8.1.18.1 Description of Document No. 18**

Document No. 18 consists of three recommendations. Two of the recommendations on recycling include: (Option 18-1) refeeding the stored depleted uranium cylinders back into the gaseous diffusion plant cascades; or (Option 18-2) using the AVLIS process, which may decrease the amount of ^{235}U remaining in the depleted UF_6 . The third recommendation (Option 18-3) relates to stabilization of local employment; that is, to limit construction of any new manufacturing process designed to convert or use the depleted UF_6 to the affected plant site to stabilize regional employment.

8.1.18.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 18

Option 18-1 (using depleted uranium as feedstock in gaseous diffusion): This option was considered infeasible by three Independent Technical Reviewers, and one indicated it would be cost effective only if the cost for enrichment alone is less than the cost of the entire front end of the fuel cycle plus enrichment using natural uranium. It was noted that this recommendation would use only about 900 MTU metal as ^{235}U , and therefore would not significantly deplete the current inventory of depleted UF_6 .

Option 18-2 (using depleted uranium as feedstock with AVLIS): One Independent Technical Reviewer indicated using AVLIS may be appropriate within a longer time period, but it cannot be viewed as a near-term practical activity. Two Independent Technical Reviewers indicated the use of AVLIS may be cost effective and feasible, while one Independent Technical Reviewer indicated the viability of the AVLIS would depend on the cost of producing metal from conversion of depleted UF_6 and the cost of producing metal from natural uranium together with the cost of using enriched uranium from conversion of the depleted UF_6 rather than using natural uranium metal feedstock.

One Independent Technical Reviewer indicated that the use of the gaseous diffusion plant process is unlikely at this time due to high energy costs relative to the improved gas centrifuge process currently in the permitting process with the NRC. Suggestions offered by the Independent Technical Reviewers varied based on the amount and types of waste generated with either the gaseous diffusion plant process or the AVLIS.

The one Independent Technical Reviewer who specifically addressed Option 18-3 (limiting future construction of facilities for the conversion or use of depleted UF_6 to the affected plant sites) considered this a reasonable recommendation.

8.1.19 Feasibility of Document No. 19 (Independent Technical Reviewers' No. 12) from the U.S. Department of Energy**8.1.19.1 Description of Document No. 19**

Document No. 19 recommends the use of depleted uranium metal in support of both the Multi-Purpose Canister (MPC) subsystem and the General Atomics truck cask subsystem. The respondent states that for the MPC subsystem, the depleted uranium metal can be used as the gamma shielding material for the lid or shield plug in the fabrication of a standardized sealable metal canister that is capable of holding multiple spent fuel assemblies and in the fabrication of two transportation casks into which the canister will be placed. For the truck cask subsystem design, the responder states that the depleted uranium metal can also be used as shielding material for the cask.

8.1.19.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 19

The majority of Independent Technical Reviewers agree that the use of depleted uranium metal in support of both the MPC subsystem and the General Atomics truck cask subsystem is feasible. Although, the proposed recommendation does not meet the Assessment of Reasonableness criteria for Programmatic Impact for using at least 15 percent of the inventory it was estimated to use about 12% and be a worthwhile use of depleted uranium. The technology is developed to a point where it could provide quality production of uranium metal components in the near term with existing technology and with modification of existing facilities. A major issue of concern is better definition of cost. The conversion of depleted UF_6 to metal can be accomplished within existing facilities or reasonable expansion of these facilities. There do not appear to be major environmental, health and safety, or siting concerns in regard to this recommendation. Potential health concerns are well known, and when properly handled, they are effectively controlled. Only a minor amount of waste will be generated, and it will be disposed of along with high-level wastes or spent fuel contained within the MPC. It is unlikely this recommendation will have any significant economic impact.

8.1.20 Feasibility Analysis of Recommendation in Document No. 20 (Independent Technical Reviewers' No. P3) from Mr. Tom Roberts

This document was designated proprietary and is included in the separate proprietary addendum to the *Technology Assessment Report*.

8.1.21 Feasibility Analysis of Recommendation in Document No. 21 (Independent Technical Reviewers' No. n/a) from the U.S. Department of Energy

This document was a summary of ongoing activities within the DOE, and therefore not separately reviewed.

8.1.22 Feasibility Analysis of Recommendation Contained in Document No. 22 (Independent Technical Reviewers' No. 13) from Mr. Charles Schmidt**8.1.22.1 Description of Document No. 22**

Document 22 recommends conversion of the depleted UF_6 to uranium trioxide (UO_3), which the responder states is stable and non-corrosive, using a process where water is reacted with the UF_6 to produce uranyl fluoride (UO_2F_2) and hydrogen fluoride, and the resultant UO_2F_2 is mixed with lime (CaO) to produce the UO_3 . According to the responder, this second process step will also produce calcium fluoride (CaF_2).

8.1.22.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of the Recommendation Contained in Document No. 22

Four Independent Technical Reviewers concluded that the process of converting depleted UF_6 to UO_3 is feasible to pursue as a research and development effort. However, one reviewer did point out that UO_3 decomposes to U_3O_8 when heated, and that, if conversion to an oxide form is selected, U_3O_8 would be a better oxide choice. The major concerns raised by the Independent Technical Reviewers were that there was not a sufficient market in the United States for hydrofluoric acid, the potential disposal issues related to fluorine as calcium fluoride (CaF_2) and the need for further research and development.

One Independent Technical Reviewer concluded that the recommendation, as proposed, was not feasible because there is insufficient information presented.

8.1.23 Feasibility of Document No. 23 (Independent Technical Reviewers' No. 14) from the Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards**8.1.23.1 Description of Document No. 23**

Document No. 23 recommends a long-term management option of converting the depleted UF_6 to triuranium octaoxide (U_3O_8) and placement of the material in a mined cavity, possibly an exhausted uranium mine.

8.1.23.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 23

The Independent Technical Reviewers concluded that a long-term management option of converting the depleted UF_6 to triuranium octaoxide (U_3O_8) is a feasible option. The U_3O_8 is chemically and physically more stable than UF_6 , is less toxic than depleted UF_6 , and retains the material in a form that would permit potential future use as an energy resource. Environmental, safety, or health concerns are well known, and when properly handled, are effectively controlled.

Two of the five Independent Technical Reviewers stated that placement of the depleted UF_6 in a mined cavity, possibly an exhausted uranium mine, was not feasible in the near term and was not likely to occur due to the uncertainty of receiving regulatory approval. More importantly, they stated that it was not reasonable to classify the UF_6 as waste. Of the remaining three Independent Technical Reviewers, one cited the placement of U_3O_8 in a mined cavity as reasonable with the major uncertainty being identification of a suitable site, its certification and licensure for disposal, and the cost of preparing the mine. The fourth Independent Technical Reviewer suggested that long-term retrievable storage methods for depleted uranium should be evaluated relative to the costs and risks involved. The fifth reviewer stated that the option has a great deal of merit, but said that only a limited quantity of the material can be buried in the current near-surface disposal areas at substantial costs. Burial in deep structures will require additional time and expense for full development. Deep storage or disposal is costly compared to surface facilities at the current storage sites.

8.1.24 Feasibility Analysis of Recommendation in Document No. 24 (Independent Technical Reviewers' No. P4) from Nuclear Metals, Inc.**8.1.24.1 Description of Document No. 24**

This response recommends three options for long-term management of depleted UF₆:

1. Utilize the UF₆ in metal or oxide form in a variety of product applications.
2. Convert the UF₆ to metal using the Ames process and develop a leaching process to first decontaminate the magnesium fluoride (MgF₂) and then use it with sulfuric acid (H₂SO₄) as feedstock to produce AHF.
3. Develop a new process for high temperature continuous reduction (HTCR) of the UF₆ to produce uranium metal.

Option 1 - The Independent Technical Reviewers generally agreed that the recommendation to utilize uranium in metal or oxide form in a variety of product applications is reasonable (four of the Independent Technical Reviewers did not focus their review on these recommended uses, but on the conversion process options). Use of uranium metal in shielding and use of uranium oxide in concrete aggregate (DUCRETE) were considered reasonable for certain applications. One of the Independent Technical Reviewers indicated that use of uranium as feed material for Atomic Vapor Laser Isotope Separation or gas centrifuge enrichment operations or in breeder reactor blankets should not be considered reasonable applications within the next few decades.

Options 2 & 3 - The Independent Technical Reviewers generally agreed that the proposal to convert the UF₆ to metal using the Ames process and develop a leaching process to first decontaminate the MgF₂ and then use it with H₂SO₄ as feed material to produce AHF is a reasonable option. Elimination or minimization of the contaminated MgF₂ slag waste stream was cited as a benefit, but is predicated on demonstrating the effectiveness of the leaching process. Although the cost of conversion by the Ames method is well established, additional costs associated with the decontamination step were not known. It was noted that transportation costs would be minimized if the conversion facility were located at a storage site.

The Independent Technical Reviewers also generally agreed that development of the HTCR process to produce high purity uranium metal is a reasonable option. The potential benefits of fewer waste management concerns and substantially lower processing costs led the reviewers to conclude that this recommendation merits consideration as a feasible option. One of the noted advantages of this process is that conversion to metal would occur in a closed system with no liquid waste streams requiring disposal. However, the reviewers stated that the HTCR conversion process has only been bench tested and is, therefore, speculative. The reviewers indicated that selection of either of these conversion processes as options would be dependent upon development of a future demand for large quantities of uranium metal. Another expressed concern had to do with the need for controls to ensure proper safety and disposal actions if the metal is sold to private industry.

8.1.24.2 Summary of the Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 24

Option 1 - The Independent Technical Reviewers generally agreed that the recommendation to utilize uranium in metal or oxide form in a variety of product applications is reasonable (four of the Independent Technical Reviewers did not focus their review on these recommended uses, but on the conversion process options). Use of uranium metal in shielding and use of uranium oxide in concrete aggregate (DUCRETE) were considered reasonable for certain applications. One of the Independent Technical Reviewers indicated that use of uranium as feed material for Atomic Vapor Isotope Separation or gas centrifuge enrichment operations or in breeder reactor blankets should not be considered reasonable applications within the next few decades.

Options 2 & 3 - The Independent Technical Reviewers generally agreed that the proposal to convert the UF_6 to metal using the Ames process and develop a leaching process to first decontaminate the MgF_2 and then use it with H_2SO_4 as feed material to produce AHF is a reasonable option. Elimination or minimization of the contaminated MgF_2 slag waste stream was cited as a benefit, but is predicated on demonstrating the effectiveness of the leaching process. Although the cost of conversion by the Ames method is well established, additional costs associated with the decontamination step were not known. It was noted that transportation costs would be minimized if the conversion facility were located at a storage site.

The Independent Technical Reviewers also generally agreed that development of the HPCR process to produce high purity uranium metal is a reasonable option. The potential benefits of fewer waste management concerns and substantially lower processing costs led the reviewers to conclude that this recommendation merits consideration as a feasible option. One of the noted advantages of this process is that conversion to metal would occur in a closed system with no liquid waste streams requiring disposal. However, the reviewers stated that the HPCR conversion process has only been bench tested and is, therefore, speculative at the current time. The reviewers indicated that selection of either of these conversion processes as options would be dependent upon development of a future demand for large quantities of uranium metal.

8.1.25 Feasibility of Document No. 25 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet**8.1.25.1 Description of Document No. 25**

Document No. 25 recommends reducing the depleted UF_6 to depleted uranium tetrafluoride (UF_4) and then to metal for further processing into products and/or for long-term storage or disposal.

The following is a list of existing or potential products and markets: armor and anti-armor munitions, bomb door reinforcements, shape charge devices and drill collars for the petroleum industry, storage or shipping devices for radioactive/hazardous waste, and Navy ballast and kinetic energy storage devices.

The responder also states that uranium metal is currently used as starting material for the AVLIS process, and when the metal is vaporized in the process, uranium enriched in ^{235}U is separated and solidified as depleted uranium alloy. It is stated that the tails can be reduced to metal, prepared as starting material for the AVLIS process, and used to produce an enriched product at a lower cost for enrichment than the current gaseous diffusion process.

8.1.25.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 25

All five of the Independent Technical Reviewers concluded that it is feasible to convert the depleted UF_6 to metal form for further processing, storage, or disposal. However, it is specifically stated that conversion to metal should be done only when a useful metal product has been determined. Several specific uses are cited that are determined to be generally feasible (e.g., armor and anti-armor munitions, bomb door reinforcements, shape charge devices and drill collars for the petroleum industry, storage or shipping devices for radioactive/hazardous waste, and Navy ballast and kinetic energy storage devices). There appears to be reservation in the use of kinetic energy storage technology. While the high density of uranium metal provides attractive attributes, composite material containment of the uranium and potential perceived safety aspects with the use of uranium in vehicles are difficult hurdles to overcome. Each application would have to be evaluated on its own merit, with consideration given to the changes in regulations, control of licensed material, and ultimate disposal of the product after its useful life.

Another part of the response included reduction of depleted UF_6 to metal prepared as starting material for the AVLIS process. This conversion and use with the AVLIS process seems reasonable. However, the time span for such activities could be as long as 100 to 200 years to use the depleted uranium as feed-stock. This use does not appear appropriate within the next several decades.

8.1.26 Feasibility Analysis of Document No. 26 (Independent Technical Reviewers' No. 16) from the Coalition for Health Concern**8.1.26.1 Description of Document No. 26**

Document No. 26 recommends on-site aboveground storage of the radioactive wastes located at the Paducah Gaseous Diffusion Plant in earthquake-proof concrete structures to allow for monitoring of surface leaks and radiation releases. The respondent further recommends that residents living near the site be relocated and compensated for damages done to their property by DOE.

8.1.26.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 26

The continued storage of depleted UF_6 is considered feasible by the Independent Technical Reviewers. However, one reviewer stated that aboveground earthquake-proof concrete structures for long-term storage do not appear to be warranted; another stated that seismic protection monies could be more effectively applied to other civilian population services and facilities; and a third stated that permanent above-ground seismically qualified structures would not solve the current long-term storage issue (e.g., requirement for perpetual controls). Another reviewer recommended the performance of risk analysis to inform the public and to serve as a basis for decisions on such issues as whether to build confinement facilities and which type of seismic protection would be appropriate. It is further stated that it does not appear appropriate to define the depleted UF_6 as a waste at this time.

DOE decisions regarding the relocation of citizens living near its sites and compensation for property damage are site-specific risk issues relating to existing site conditions, which in general, are beyond the scope of this study. Siting a storage site at a location like the Paducah Gaseous Diffusion Plant poses risks that are considered to be effectively mitigated by existing confinement techniques.

8.1.27 Feasibility of Document No. 27 (Independent Technical Reviewers' No. 17) from Kansas State University**8.1.27.1 Description of Document No. 27**

Document No. 27 recommends converting ^{238}U to ^{239}Pu for use as reactor fuel to produce electricity. Since this is described as a long-term prospect, it is recommended that the depleted UF_6 be converted to a more stable chemical form, such as an oxide, and stored for future use as an energy source.

8.1.27.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 27

The majority of the Independent Technical Reviewers agreed that conversion of depleted UF_6 to a chemical form that is relatively more stable (such as an oxide) and storing it for the energy value is feasible. One of the Independent Technical Reviewers stated that while conversion and storage of depleted UF_6 strictly for future use in reactors may not be a feasible option for consideration at this time, the material would be preserved as a resource for years to come. A major drawback cited was that the material would not be used to produce useful products within 30 years. It was noted that preserving it as a resource for future uses that may have higher value has merit and that the proposal states the benefits inherent in the depleted UF_6 .

8.1.28 Feasibility Analysis of Recommendation in Document No. 28 (Independent Technical Reviewers' No. n/a) from Ms. Mildred Serra

This document contained no recommendations for technologies or uses. See Section 6.2.6.5.

8.1.29 Feasibility Analysis of Recommendation in Document No. 29 (Independent Technical Reviewers' No. P5) from M4 Environmental Management, Inc.**8.1.29.1 Description of Document No. 29**

In this response, M4 recommends applying their patented Catalytic Extraction Process (CEP) to the conversion of UF_6 to either uranium oxide or metal. The company proposes to utilize an existing DOE facility, or else to construct a new 45,000-square-foot facility. The company further proposes to fund the research, development, demonstration, construction, and decommissioning in order to minimize the cost to DOE.

8.1.29.2 Summary of the Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 29

Three of the Independent Technical Reviewers agreed that the recommendation to apply the Catalytic Extraction Process (CEP) to convert UF_6 to either uranium oxide or metal is a reasonable option. The effort required to demonstrate the applicability of this process led one of the reviewers to conclude that this recommendation should not be considered as a reasonable option at this time. The reviewer supported this conclusion by noting that many of the operational details of the process are undefined, and process costs would increase substantially if secondary purification steps would be required to achieve the requisite metal or oxide purities. Another Independent Technical Reviewer said that the process would meet DOE's goals for conversion and be consistent with the Department's mission if it can be developed for cost-effective production-scale implementation. The Independent Technical Reviewers noted that the proposed process has been demonstrated only for certain hazardous materials, and application of the process to conversion of depleted uranium hexafluoride is somewhat problematic.

A principle benefit cited for this process is the ability to convert UF_6 in a closed process without generating any liquid or gaseous contaminated waste streams. The reviewers were unable to provide quantitative cost estimates due to the state of technical maturity of this process, but they generally assumed that the facility would have lower capital and operating costs than those of other UF_6 conversion alternatives. It was suggested that two years of development would be required before this process would be ready for full-scale design and additional time would be required for construction and testing. The reviewers also agreed that use of a DOE facility to construct the CEP converter was beneficial.

8.1.30 Feasibility Analysis of Recommendation in Document No. 30 (Independent Technical Reviewers' No. P6) from Allied Signal, Inc.**8.1.30.1 Description of Document No. 30**

This response recommends the conversion of depleted UF_6 to U_3O_8 for disposal or reuse, with the concurrent production of commercially valuable hydrofluorocarbons (HFCs) and anhydrous hydrogen fluoride (AHF). The conversion process is an Allied Signal invention that is currently in the research phase of development.

8.1.30.2 Summary of the Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 30

The majority of the Independent Technical Reviewers concluded that the conversion of depleted UF_6 to U_3O_8 for disposal or reuse with the concurrent production of commercially valuable hydrofluorocarbons (HFCs) and anhydrous hydrogen fluoride (AHF) is a reasonable option. It was noted that the HFCs which would be produced are needed to solve another environmental problem (i.e., refrigerants) and that there is reasonable demand for both HFC and AHF in the U.S. Reservations expressed related to cost and technical maturity. The chemical process requirements were said to be reasonably well defined because many steps of the process have been in operation in the U.S. on a large scale for decades; however, additional development and demonstration would be required for direct recovery of clean HFC and AHF. It was recommended that all potential future uses for the depleted uranium be considered prior to reducing the uranium to a less reactive state, including consideration of costs of future processes which may utilize the material.

The Independent Technical Reviewers noted that the disposition of U_3O_8 was not addressed, but that it must either be stored or disposed of as a waste. The cost of new metal containers (and probably a building) for storing the U_3O_8 would be significantly more than continuing to keep the depleted UF_6 in the present containers. It was stated that conversion to U_3O_8 , HFC, and AHF should be achievable with a closed process.

8.1.31 Feasibility of Document No. 31 (Independent Technical Reviewers' No. 18) from the Department of the Army, Life Cycle Readiness Division

8.1.31.1 Description of Document No. 31

Document No. 31 recommends using the depleted uranium stockpile in the production of drill collars, well penetrators, and well shape charge perforators for use in the U. S. oil well drilling industry.

8.1.31.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 31

The Independent Technical Reviewers generally agreed that use of depleted uranium metal for drill collars, well penetrators, and shape charge perforators is feasible. The recommendation does not identify a method for converting the depleted UF_6 . The Independent Technical Reviewers noted that economic assessments by potential users will determine the viability of these options. Development of the options will also depend on environmental restraints imposed by civilian uses, since the proposed application has the potential to contaminate the environment with uranium metal lost through abrasion or chemical explosion. Potential liability issues will need to be addressed by the government and private users of the applications.

One Independent Technical Reviewer considered the applications unlikely to meet the 15 percent consumption guideline provided by LLNL and therefore not feasible. This Independent Technical Reviewer agreed that in combination with other uses, the applications identified in this recommendation would be beneficial.

8.1.32 Feasibility of Document No. 32 (Independent Technical Reviewers' No. 19) from Ms. Velma Shearer**8.1.32.1 Description of Document No. 32**

Document No. 32 recommends against the no action alternative of maintaining current storage and management practices based on health and safety concerns and against the use as shielding for other nuclear materials or in the production of armaments. The responder does recommend conversion of the depleted uranium at plants built at Portsmouth, Ohio, or Paducah, Kentucky, to an unspecified solution that would produce fluorides, which could be sold for other industrial uses, or to metal to be mixed with concrete slurry or sand and returned for deposit in abandoned uranium mines.

8.1.32.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of the Recommendation Contained in Document No. 32

Three of the five Independent Technical Reviewers evaluated as not feasible the siting of unspecified conversion plants at both the Paducah and Portsmouth Gaseous Diffusion Plants, which would produce fluorides for sale or produce uranium metal that could be mixed with concrete slurry or sand and be returned for deposit in abandoned uranium mines. The likely waste form, if depleted UF_6 is declared to be a waste, is stated to be a uranium oxide, not metal. Converting depleted UF_6 to an oxide for disposal appears to be a better approach than converting depleted uranium to metal as the first step. Disposal in abandoned uranium mines, which generally contain high water content permeable soils, does not appear to be appropriate. Disposal in mines requires further development. A major uncertainty exists in the identification of a suitable site, its certification and licensing for this use, and the cost of preparing it. It appears that conversion of the depleted UF_6 to triuranium (U_3O_8) or uranium dioxide (UO_2) would be a less expensive and more compatible alternative for the recommended disposal method. Furthermore, one of the reviewers stated that the totality of declaring depleted UF_6 as waste with only fluorine commercial sales would be an unfortunate legacy for future generations that could ultimately result in a "uranium rush" in about 150 years. If the burial option is selected, the chemical form should be an oxide rather than a metal. Due to the low specific activity of uranium (both natural and depleted), it is not necessary to dilute it to natural background levels prior to deposition in underground locations.

8.1.33 Feasibility of Document No. 33 (Independent Technical Reviewers' No. 20) from Lamb Wheel Alignment

8.1.33.1 Description of Document No. 33

Document No. 33 recommends that the depleted uranium located at the Paducah Gaseous Diffusion Plant be maintained at that site in aboveground, earthquake-proof, non-corrosive concrete storage structures that are off the ground so that monitoring for surface leaks and radiation release can be performed. The responder also recommends that DOE stabilize and clean the affected site area and adjacent lands to the extent required by law and offer relocation or compensation to landowners for damages to their land and homes.

8.1.33.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 33

Four of the five Independent Technical Reviewers agreed that the response to continue storage at the present locations is feasible. The Independent Technical Reviewers consider technologies to be available that protect against earthquakes, avoid corrosion damage, and provide monitoring for surface leaks and radiation releases. Decisions on site-specific cleanup, relocation of affected citizens, and compensation of affected citizens are site-specific issues relating to existing conditions, which in general, are beyond the scope of this study.

8.1.34 Feasibility Analysis of Recommendation in Document No. 34 (Independent Technical Reviewers' No. n/a) from Serpent Mound/Ohio Brush Creek Alliance

This document contained no recommendation for technologies or uses. See Section 6.2.6.6.

8.1.35 Feasibility of Document No. 35 (Independent Technical Reviewers' No. 21) from Cameco Corporation**8.1.35.1 Description of Document No. 35**

Document No. 35 recommends use of a defluorination process to recover anhydrous hydrogen fluoride and depleted uranium oxide, preferably depleted triuranium octaoxide (U_3O_8) in powder form, for storage or use in the production of various products. The respondent states that U_3O_8 could be used in the fabrication of shielding components, production of high-density concrete products, or be conditioned with or without additives for disposal in either an underground facility or an engineered surface disposal of shallow depth. Another future use recommended by the respondent is the conversion of the depleted UF_6 to uranium metal, along with recovery of anhydrous hydrogen fluoride and other useful by-products, for use as feed material for the AVLIS process or as high density material for shielding (e.g., spent fuel casks and high-level nuclear waste disposal facilities). The respondent recommends three defluorination process options for conversion of the depleted UF_6 : (Option 35-1) use of a multistate pyrohydrolysis process with steam and hydrogen or ammonia to produce triuranium octaoxide (U_3O_8) and uranium dioxide (UO_2); (Option 35-2) use of respondent's process that uses H_2SO_4 to convert UF_6 into a uranyl sulfate complex which is subsequently subjected to a thermal decomposition process producing U_3O_8 and an off-gas; and (Option 35-3) use of a uranium metal/magnesium sulfate process to recover uranium metal, with further conversion of the resulting magnesium fluoride to anhydrous hydrogen fluoride and crystallized magnesium sulfate.

8.1.35.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 35

Option 35-1 (Conversion of depleted UF_6 to U_3O_8 or UO_2 using multi-stage pyrolysis with steam and hydrogen or ammonia): The Independent Technical Reviewers concluded that this is a feasible option. Concerns raised about this option are the uncertainty currently associated with disposing of conditioned U_3O_8 after defluorination, and the potential cost associated with the process, including storage costs for depleted uranium over the period. This process has the potential of producing no liquid waste, and other material will be recycled.

Option 35-2 (Conversion of depleted UF_6 to U_3O_8 using aqueous sulfuric acid (H_2SO_4)): The Independent Technical Reviewers concluded that this is a feasible option. The main concern raised about this option is its technical maturity (i.e., process for which a patent is pending).

Option 35-3 (Conversion of depleted UF_6 to metal using a uranium metal/magnesium sulfate process): The Independent Technical Reviewers concluded that this was a feasible option, but all agree that prior to implementing this option, it should be clear that a market exists for the metal, and DOE must carefully consider whether the current storage practice is unacceptable. Some concerns regarding commercial readiness of the conversion technology were voiced along with ones for siting conversion and disposal facilities.

8.1.36 Feasibility Analysis of Recommendation in Document No. 36 (Independent Technical Reviewers' No. P7) from A.B. Machine, Ltd.

This document was designated proprietary and is included in the separate proprietary addendum to the *Technology Assessment Report*.

8.1.37 Feasibility of Document No. 37 (Independent Technical Reviewers' No. 22) from the Oak Ridge National Laboratory**8.1.37.1 Description of Document No. 37**

Document No. 37 recommends that depleted UF_6 be converted into small borosilicate glass beads for use as a backfill material inside repository waste packages containing light water reactor (LWR) spent nuclear fuel (SNF).

8.1.37.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 37

In general, the Independent Technical Reviewers concluded that this option was not feasible or that it was difficult to determine if the option had merit due to a lack of critical information and cost data. Two Independent Technical Reviewers indicated this option holds merit or was feasible to pursue. Several reviewers mentioned that substantial research and development would be required to implement the option. One reviewer indicated that depleted uranium disposal should involve development of beneficial, commercial uses of the material, and that the material should not be used as backfill in disposal efforts. Quantities of waste streams produced by conversion to glass beads are largely unknown. In the area of technical maturity, several reviewers stated that the technology exists to convert to glass beads, but more extensive research needs to be completed to determine if this is a viable option.

8.1.38 Feasibility of Document No. 38 (Independent Technical Reviewers No. n/a) from the State of Tennessee**8.1.38.1 Description of Document No. 38**

Document No. 38 responds to the request for comments on the Advance Notice of Intent rather than to the Request for Recommendations. A recommendation is included to gradually convert the depleted UF₆ to an oxide over a 15 to 20 year period.

Document No. 38 requests the following items be included in the EIS for disposition of depleted UF₆: incorporate and evaluate information in unpublished document entitled, "Project Management Plan for the UF₆ Cylinders Project for the Oak Ridge K-25 Facilities"; construction of new cylinder storage pads; costs for each alternative; conversion of UF₆ to an oxide for long-term storage and construction of a cylinder refurbishment facility; gradual conversion of UF₆ to an oxide over a 15- to 20-year time frame; and production and treatment of all waste byproducts resulting from any action or inaction.

8.1.38.2 Summary of Reviewer's Conclusions on the Feasibility of Recommendations Contained in Document No. 38

The option to gradually convert depleted UF₆ to an oxide over a 15 to 20 year period is considered feasible. The response does not identify a specific oxide or conversion process; however, there are several established processes which have been evaluated by the Independent Technical Reviewers (e.g., Document Nos. 6, 9, 10, 16, 30, 35). It was noted that oxide forms offer increased chemical stability and that it would seem appropriate to identify a final disposition which requires the oxide form before committing to the conversion expense and limiting future uses.

8.1.39 Feasibility of Document No. 39 (Independent Technical Reviewers' No. n/a) from Ms. Sue Whayne

8.1.39.1 Description of Document No. 39

Document No. 39 is from a private citizen residing near the Paducah Gaseous Diffusion Plant, and is dated January 9, 1995. The response expresses concern that radioactive materials be stored in a seismically safe manner, and who wants relocation and compensation of residents who have already been affected.

The response recommends that onsite, aboveground concrete storage be "earthquake proof" and the cylinders be stacked high enough off the ground to be monitored for leaks.

8.1.39.2 Summary of Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 39

The response recommends that on-site, above-ground concrete storage be earthquake-proof and high enough off the ground to be monitored for surface leaks and radioactive releases. Several other responses, including Document Nos. 26 and 33, were similar to this response and were reviewed by the Independent Technical Reviewers. The reader is directed to the Feasibility Analysis for these responses (see Sections 8.1.26 and 8.1.33). The conclusion of this review is that the provision of above-ground, earthquake-proof concrete pads does not appear to be warranted at this time; however, other improvements to current storage methods may be reasonable.

8.1.40 Feasibility of Document No. 40 (Independent Technical Reviewers' No. 25) from Purdue University**8.1.40.1 Description of Document No. 40**

Document No. 40 recommends that the ^{238}U in the depleted uranium be maintained so that it is available for potential use in the production of plutonium fuel in breeder reactors.

8.1.40.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 40

Two Independent Technical Reviewers agreed that the uranium in depleted UF_6 is feasible as a resource for future use in producing plutonium fuels in breeder reactors. One reviewer indicated there is some merit to depleted UF_6 as a potential fuel source in breeder reactors. One Independent Technical Reviewer, using the evaluation criteria said that use in breeder reactors did not appear viable. One reviewer suggested conversion of depleted UF_6 to oxide, which preserves a future option to use the material in a breeder program. This conversion would allow the material to be stored in a more stable form. Benefits of using the material in a breeder reactor include the ability to store depleted UF_6 until a time when breeder reactors become economically feasible. However, it is estimated that only a small percent (about 15 percent) of the current inventory would be consumed. Estimates of depleted UF_6 consumption for breeder reactors depend on projections for the growth of usage of this technology. The environmental, safety and health factors for commercial operation of breeder reactors are somewhat well known from European experience. The use of ^{238}U in the breeder will require revisiting safety and environmental uses versus the alternatives.

8.1.41 Feasibility Analysis of Recommendation in Document No. 41 (Independent Technical Reviewers' No. P8) from Advanced Recovery Systems**8.1.41.1 Description of Document No. 41**

This response recommends utilizing two potential technologies to decontaminate the MgF_2 low level radioactive waste (LLRW) resulting from the conversion of depleted UF_6 to uranium metal. The first, a patented hydrometallurgical process (DeCaF[™]), has been bench proven and is moving to the pilot plant testing stage. The second, a thermal recovery process (TherMag[™]), is under development.

8.1.41.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 41.

The majority of the Independent Technical Reviewers concluded that the two potential technologies to decontaminate the MgF_2 LLRW resulting from the conversion of depleted UF_6 to uranium metal were reasonable. One Independent Technical Reviewer noted that magnesium would not be used if an advanced process such as plasma were employed to produce metal. Uncertainties about technical maturity and cost were identified as concerns. The cost for producing uranium-free fluoride was estimated to be on the same order of magnitude as producing depleted uranium metal and MgF_2 . Although most of the process steps are well defined, some development and demonstration was thought to be necessary to evaluate the capture of fluorine and magnesium salts on a large scale.

The Independent Technical Reviewers stated that both technologies are projected to considerably reduce the amount of material having to go to an LLRW or a hazardous material disposal site. One reviewer suggested this would have a positive impact on licensed LLRW disposal facilities. The Independent Technical Reviewers concluded that performing the proposed operation at one or all three of the existing sites where depleted UF_6 is currently stored should be viewed as a reasonable extension of current activities, whereas construction of a new facility would be a major undertaking that would require greater levels of public acceptance and approval.

8.1.42 Feasibility Analysis of Recommendation in Document No. 42 (Independent Technical Reviewers' No. 23) from R&R International, Inc.**8.1.42.1 Description of Document No. 42**

Document No. 42 recommends creation of a Kentucky Wastes and Energy Interim Storage and Transportation Facility (KY WEST) to centralize the depleted uranium stockpile for interim storage. This would involve construction of waste staging and shipping areas at each of the three current storage sites, and an upgrade of the respondent's interim storage and transfer facility for use as the interim centralized repository in order to meet near-term storage needs and to prepare for final disposition of this material. The respondent states that development of this concept can be done in five phases, with private funding for phase I, Government funding for phase II, which involves the detailed planning, and possible funding by DOE and/or private sector firms for phases III through V (construction, operations, shipment).

8.1.42.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 42

Three of the five Independent Technical Reviewers concluded that it does not appear to be warranted to relocate depleted UF_6 cylinders to a private storage site. One reviewer stated that such a site would simply receive depleted UF_6 cylinders and prepare them either for long-term storage or transfer to a processor, and presuppose establishment of a depleted $\text{UF}_6/\text{U}_3\text{O}_8$ conversion plant nearby. The reviewers stated that the costs would be higher than current DOE on-site storage, and that no additional value, beyond a tank handling capability, would be gained. The Independent Technical Reviewers generally agreed that this option would require transportation of cylinders from all three sites which would increase risks of public exposure without any foreseeable permanent use or permanent disposal alternative being identified.

8.1.43 Feasibility Analysis of Recommendation in Document No. 43 (Independent Technical Reviewers' No. n/a) from Fluor Daniel

This document was a non-proprietary summary submitted for Document No. 16 which was designated proprietary and is included in the separate proprietary addendum to the *Technology Assessment Report*.

8.1.44 Feasibility Analysis of Recommendation in Document No. 44 (Independent Technical Reviewers' No. n/a) from Mr. William Tewes

This document contained no recommendations for technologies or uses. See Section 6.2.6.8

8.1.45 Feasibility of Document No. 45 (Independent Technical Reviewers' No. 26) from St. Helen's Trading, Ltd.

8.1.45.1 Description of Document No. 45

Document No. 45 states the responder may be interested in the depleted uranium stockpile if it can be converted into a solid form in order to recycle Naturally Occurring Radiation Material (NORM) into shielding bricks to serve as a bulk shielding medium for contaminated facilities at Chernobyl.

8.1.45.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 45

The majority of the Independent Technical Reviewers agreed that this option is feasible, i.e., conversion of the depleted UF_6 to a solid form to recycle NORM into shielding bricks to serve as bulk shielding medium in the former Soviet Union. However, one reviewer stated that the use of depleted UF_6 for shielding at the Chernobyl reactor appears inappropriate and unreasonable, given that it would add more radioactive material to Chernobyl and would not help to achieve a resolution for this major environmental problem. There is an excess of depleted uranium within the former Soviet Union countries that could be considered and used for such application. Another reviewer amplified that the political implications of this option need careful consideration. Other questions raised had to do with who would bear the costs and whether the Ukrainian agencies would assure safe handling controls.

8.1.46 Feasibility Analysis of Recommendation in Document No. 46 (Not assigned to the Independent Technical Reviewers' No. n/a) from Nuclear Fuels Services, Inc.

This document was a statement of capabilities and therefore was not reviewed. See Section 6.2.6.9.

8.1.47 Feasibility Analysis of Recommendation in Document No. 47 (Independent Technical Reviewers' No. n/a) from EG&G Environmental, Inc.**8.1.47.1 Description of Document No. 47**

This response recommends a use for the fluorine in the UF_6 conversion process by reacting the UF_6 gas with alumina (Al_2O_3) or aluminum metal. The process would produce aluminum trifluoride (AlF_3), a primary material used by the aluminum industry in electric cells (or "pots") that reduce alumina to aluminum metal.

8.1.47.2 Summary of the Reviewer's Conclusions on the Feasibility of Recommendations Contained in Document No. 47

The reviewer determined that reacting the uranium hexafluoride gas with alumina or aluminum to produce aluminum trifluoride is a reasonable option for further study, although the innovative and potentially beneficial aspects are somewhat tempered by the lack of technical maturity and availability of cost data. The cited benefits of this process include elimination of the magnesium or calcium fluoride waste streams associated with current anhydrous hydrogen fluoride (HF) conversion methods, the utilization of fluoride as a marketable by-product (aluminum trifluoride) in the aluminum industry, and cost avoidance of the handling/storage/transport of anhydrous HF. The reviewer found the assumption that uranium contamination levels of the AlF_3 would be sufficiently low for unrestricted use of the product was not supported with sufficient details to describe how a single conversion step would achieve this result.

8.1.48 Feasibility Analysis of Recommendation in Document No. 48 (Independent Technical Reviewers' No. n/a) from PDI**8.1.48.1 Description of Document No. 48**

This response proposes that a mined geologic formation be considered for the long term management of the depleted uranium or products resulting from the processing of the depleted uranium. The use of an existing underground mine as a full scale model to study issues involved in the long-term management of depleted uranium hexafluoride was also offered. The existing mined cavity is stated to be stable, dry, and large, and currently used for seismic monitoring purposes. The response indicates that there is a large amount of site information for the underground mine, including geologic mapping, geochemical mapping, electromagnetic aerial surveys, ecosystem studies, hydrologic studies and environmental studies.

8.1.48.2 Summary of the Reviewer's Conclusions on the Feasibility of Recommendations Contained in Document No. 48

The reviewer determined that the concept of using a mined geologic formation for the long term management of the depleted uranium is reasonable. It was noted that the summary information presented in the response indicates that an excellent candidate facility is available for use as a model to facilitate the long-term management of depleted uranium hexafluoride. Although specific environmental, safety, and health information is not provided in the response, the general characteristics and lack of water intrusion or subsidence suggested to the reviewer that this site would be suitable as a model for studying underground disposal. However, the reviewer noted that a mine storage or disposal facility for radioactive materials has yet to be licensed in the United States. The use of the proposed, existing mine to study the long-term management of depleted uranium hexafluoride was said to imply a certain cost effectiveness.

8.1.49 Feasibility of Document No. 49 (Independent Technical Reviewers' No. 27) from the U.S. Department of Energy**8.1.49.1 Description of Document No. 49**

Document No. 49 (an option under consideration by DOE) recommends replacing the batch reduction process with a continuous metallothermic reduction process to reduce depleted UF_6 first to uranium tetrafluoride, then reduce the uranium tetrafluoride to uranium metal to provide a uranium/iron metal alloy for the Uranium-AVLIS process.

8.1.49.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 49

The Independent Technical Reviewers generally agreed that the continuous metallothermic reduction technology was feasible, although additional development work would be required. All of the reviewers, however, raised questions about the purity of the by-products (anhydrous hydrogen fluoride and magnesium fluoride), the residual uranium levels in these materials, market effects, and the potential unknowns of high temperature operations with uranium (including potential emissions). One reviewer noted that the prospects for using this technology are good, even with uncertainty on product, use, and quality. The other four reviewers, however, were more negative and thought that this technology should be pursued only if the decision on the end use of the depleted uranium requires the metal and the noted questions were addressed. One reviewer even noted that, given all of the uncertainties, the technology does not seem reasonable for this program at this time. Regarding the use of the depleted uranium as feedstock for the uranium-AVLIS process, one reviewer remarked that this may be appropriate within 100-200 years, when the available low cost natural uranium ore resources are depleted, but does not appear appropriate within the next few decades.

8.1.50 Feasibility of Document No. 50 (Independent Technical Reviewers' No. 28) from the U.S. Department of Energy**8.1.50.1 Description of Document No. 50**

Document No. 50 recommends conversion of depleted UF_6 using the same process used for converting isotopically enriched UF_6 to ceramic uranium dioxide, using either a wet or dry process. The depleted UF_6 is chemically converted to the uranium dioxide powder, and after milling, sieving, and the addition of a lubricant, the powder is compressed under high pressure into pellets.

8.1.50.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 50

The Independent Technical Reviewers generally agreed that the conversion processes found in the recommendation were feasible. In general, the Independent Technical Reviewers had favorable comments on the conversion of depleted UF_6 to ceramic uranium dioxide. The reviewers thought these technologies were satisfactorily established but would require some extrapolation to the quantities required for the depleted uranium inventory and new plant installation would be necessary. The reviewers appeared to be undecided as to which of the three processes might offer the most advantages; two thought the integrated dry route (IDR) process provided the best combination, another thought the quality of ammonium uranyl carbonate-derived (AUC) powders would be advantageous, while another thought the ultimate application would determine which conversion process would be most advantageous. Two reviewers expressed concerns about the potential use of uranium dioxide pellets, and postulated that other geometrical forms might be more suitable. The reviewers thought the conversion of the UF_6 to the ceramic dioxide would depend upon the costs and ultimate use of the material. Two reviewers felt the conversion to the ceramic was not warranted for disposal because a deep disposal site would require development, and significant shielding applications may exist.

8.1.51 Feasibility of Document No. 51 (Independent Technical Reviewers' No. 29) from the U.S. Department of Energy**8.1.51.1 Description of Document No. 51**

Document No. 51 recommends conversion of depleted UF_6 into ceramic uranium dioxide based upon gelation methods, which is a process that uses hydrodynamics to form spheres of ammonium diuranate. These spheres are subsequently cured, dried, and sintered directly into dense uranium dioxide microspheres to be loaded into fuel rods using vibratory methods.

8.1.51.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 51

Two Independent Technical Reviewers indicated the conversion of depleted UF_6 using gelation conversion methods appears feasible or has merit. One Independent Technical Reviewer indicated the conversion to uranium dioxide should only be considered if applications for the product exist. One reviewer said it was difficult to assess this option due to the lack of cost and other data. One reviewer indicated the option has several attractive features, but is not well enough developed to be considered reasonable at this time. Several concerns were raised about the applications or need for the end product resulting from conversion to ceramic uranium dioxide. In addition, several Independent Technical Reviewers indicated this conversion would require the construction of a new plant or several smaller facilities. At least three reviewers indicated there may be several environmental, health, and safety advantages to this option when compared with existing mechanical processes.

8.1.52 Feasibility of Document No. 52 (Independent Technical Reviewers' No. 30) from the U.S. Department of Energy**8.1.52.1 Description of Document No. 52**

Document No. 52 recommends conversion of UF_6 to dense uranium carbide using either a graphite or gelation process for potential use as a reactor fuel for certain high temperature reactors.

8.1.52.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 52

Two of the five Independent Technical Reviewers indicated the conversion of depleted UF_6 to uranium carbide may be feasible or contain merit. One of these reviewers, however, qualified the statement by highlighting the necessity for developing a new technology that is most likely more expensive than existing technology without a defined end use of the product. One reviewer indicated that conversion should only be considered if applications for the product exist. This same reviewer indicated that conversion to uranium carbide provides a density advantage over U_3O_8 and would result in a lower total volume of material for shielding applications. Two reviewers stated the conversion to uranium carbide microspheres and anhydrous hydrogen fluoride is not understood well enough to be considered feasible and that it is impossible to determine the merits of this process without cost data. Three reviewers indicated that a new plant or processing facility would have to be built to apply the new technology.

8.1.53 Feasibility of Document No. 53 (Independent Technical Reviewers' No. 31) from the U.S. Department of Energy

8.1.53.1 Description of Document No. 53

Document No. 53 recommends conversion of depleted uranium hexafluoride to uranium dioxide, with further conversion into uranium carbide for use as high-temperature gas-cooled reactor (HTGR) fuel.

8.1.53.2 Summary of Independent Technical Reviewers' Conclusions on the Feasibility of Recommendations Contained in Document No. 53

The Independent Technical Reviewers concluded that the high-temperature gas-cooled reactor fuel did not constitute a feasible option for depleted uranium disposition at this time. The Independent Technical Reviewers noted that the high-temperature gas-cooled reactors have been considered for several decades without achieving commercial acceptability. Fuel fabrication requirements were mature technologies, although some technology development would be required (particularly for depleted uranium use) and the market potential is extremely limited for the foreseeable future. All five reviewers thought high-temperature gas-cooled reactor fuel consumption of depleted uranium would be too small and limited and have little or no impact upon the overall depleted uranium inventory.

8.1.54 Feasibility Analysis of Recommendation in Document No. 54 (Independent Technical Reviewers' No. P11) from Mitsubishi Materials Corporation

This document was designated proprietary and is included in the separate proprietary addendum to the *Technology Assessment Report*.

8.1.55 Feasibility of Document No. 55 (Independent Technical Reviewers' No. n/a) from Gencorp Aerojet**8.1.55.1 Description of Document No. 55**

Document No. 55 was complementary information to the original response (Independent Technical Reviewers' No. 15), which was forwarded to the Independent Technical Reviewers. This response recommends the conversion of depleted UF_6 to the tetrafluoride and batch metallothermic reduction of the tetrafluoride to the metal using magnesium.

8.1.55.2 Summary of Reviewer's Conclusions on the Feasibility of Recommendations Contained in Document No. 55

The internal review stated that this recommendation to convert depleted UF_6 to the tetrafluoride and batch metallothermic reduction of the tetrafluoride to the metal using magnesium is feasible. The proposed technology for conversion to metal is an existing industrial process, and the indicated improvements provide important environmental, safety and health, and waste management benefits. The viability for expanded missions depends on the direct conversion cost and the assumption that the decontaminated by-product can be disposed as a non-low-level waste or used for cost avoidance.

8.1.56 Feasibility Analysis of Recommendation in Document No. 56 (Independent Technical Reviewers' No. n/a) from Scientific Ecology Group, Inc.

This document was a notification of intent to submit an unsolicited proposal and was therefore not reviewed. See Section 6.2.6.10.

8.1.57 Feasibility of Document No. 57 (Independent Technical Reviewers' No. n/a) from Los Alamos National Laboratory

8.1.57.1 Description of Document No. 57

Document No. 57 recommends use of depleted UF_6 as a fluorinating agent to produce fluorocarbons rather than production of anhydrous hydrogen fluoride (HF). The respondent proposes management of depleted UF_6 to allow maximum flexibility for future uranium processing (e.g., conversion to uranium tetrafluoride (UF_4) for further conversion to uranium metal, uranium dioxide (UO_2), uranium trioxide (UO_3), or triuranium octaoxide U_3O_8).

8.1.57.2 Summary of Reviewer's Conclusions on the Feasibility of Recommendations Contained in Document No. 57

Inadequate information was provided in order to make a determination of feasibility at the present time. However, the option warrants further investigation before dismissal, since flexibility for future uranium processing is advisable.

8.2 Summary

This section summarizes the results of the feasibility analysis which is based on the Independent Technical Reviewers' and LLNL/SAIC's evaluations. Table 8.1 identifies each response by its assigned Document Number, the Independent Technical Reviewers' Number (if any), and the Respondent, and shows whether the analysis resulted in a conclusion that the recommendation be considered feasible or not feasible.

**Table 8.1 Depleted Uranium Hexafluoride Management Program
Responses to Request for Recommendations (59 FR 56324)**

Summary of Feasibility

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
1	1	Mr. A.N. Tschaeché 1693 Claremont Lane Idaho Falls, Idaho 83404 phone number not provided	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
2	2	Mr. Mark Strauch 48 Glacier Place Livermore, California 94550 phone number not provided	2-1 • 2-2 • 2-3 • 2-4 •	
3	n/a	Mr. Peter Lenny Cameco 2121 - 11th Street West Saskatoon, Saskatchewan Canada S7M 1J3 306/956-6200	See Document No. 35	
4	3	Mr. Bert Jody, Jr. President Davis Transport Box 1139 1345 S. 4th Street Paducah, Kentucky 42002-1139 502/444-7224	4-1 • 4-2 •	
5	4	Mr. William Quapp Idaho National Engineering Laboratory P.O. Box 1625 Idaho Falls, Idaho 83415 phone number not provided	5-1 • 5-2 • 5-3 • 5-4 •	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
6	P1	Mr. William Bear Siemens Power Corporation 155 108th Avenue NE P.O. Box 90777 Bellevue, Washington 98009-0777 206/453-4300	•	
7	n/a	Mr. Harry A. Nesteruk M4 Environmental Management, Inc. 151 Lafayette Drive Suite 210 Corporate Center Oak Ridge, Tennessee 37830 615/220-4164	See Document No. 29	
8	24	Mr. Dennis Wright phone number not provided		•
9	5	Mr. Frank Warner General Atomics 3550 General Atomics Court San Diego, California 92121-1194 619/455-3973 Mr. Sanford Rock Allied Signal, Inc. P.O. Box 8005 Morristown, New Jersey 07962-8005 201/455-3893	•	
10	6	Mr. Frank A. Shallo COGEMA, Inc. 7401 Wisconsin Avenue Bethesda, Maryland 20814-3416 301/986-8585	•	
11	7	Mr. A.N. Tschaeche 1693 Claremont Lane Idaho Falls, Idaho 83404 phone number not provided	See Document No. 1	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
12	8	Mr. Dennis R. Floyd Manufacturing Sciences Corporation 3265 Fenton Street Denver, Colorado 80212 303/237-8576	• with qualifier – further development on plasma technology required	
13	9	Mr. Patrick F. Brown 113 Columbia Drive Oak Ridge, Tennessee 37830 615/483-1774	13-1 • 13-2 • 13-3 • (with qualifier – implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
14	10	Mr. Alan Waltar American Nuclear Society 555 North Kensington Avenue La Grange Park, Illinois 60525 708/352-6611	•	
15	n/a	Mr. Steven Pattinson A.B. Machine Company, Ltd. 140 Milner Avenue Unit #2 Scarborough, Ontario Canada M1S 3R3 416/293-0977	See Document No. 36	
16	P2	Dana Lee Fluor Daniel, Inc. 3333 Michelson Drive Irvine, California 92730 714/975-2000	•	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
17	n/a	Ms. Vina Colley c/o Portsmouth/Piketon Residents for Environmental Safety and Security 3706 McDermott Pond Creek McDermott, Ohio 45652-4688 phone number not provided	•	
18	11	Mr. Steven T. Carter Ohio Valley Regional Development Commission 740 Second Street Room 102 Portsmouth, Ohio 45662-4088 614/354-7795	18-2 • (no consensus – concerns about time and cost of implementing AVLIS	18-1 •
19	12	Mr. Jeffrey R. Williams Engineering Division Department of Energy Washington, D.C. 202/586-9620	• (with qualifier – may not use 15 % of inventory)	
20	P3	Mr. Tom Roberts Rental Enterprise P.O. Box 7069 Paducah, Kentucky 42002-7069 502/442-4397	Proprietary	
21	n/a	Mr. Carl Cooley Department of Energy Office of Demonstration, Testing and Evaluation Germantown, Maryland 301/903-7276	Contained no recommendations (see Section 6.2.6.4)	
22	13	Mr. Charles R. Schmitt 110 Adelphi Road Oak Ridge, Tennessee 37830 615/483-6922	• (with qualifier – conversion to UO ₃ is possible to pursue as R&D)	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
23	14	Mr. Robert Bernero, Director Office of Nuclear Material Safety and Safeguards United States Nuclear Regulatory Commission Washington, D.C. 20555-0001 301/415-7298 (POC, Michael Weber)	•	
24	P4	Mr. Dennis Lehan Manager, Specialty Products Nuclear Metals, Inc. 2229 Main Street Concord, Massachusetts 01742 508/369-5410	24-1 • 24-2/3 •	
25	15	Mr. Charles Montford GenCorp Aerojet P.O. Box 399 Jonesborough, Tennessee 37659 (submittal by Aerojet Ordnance Tennessee (AOT) and Babcock & Wilcox (B&W)) 615/753-1200	•	
26	16	Corrine Whitehead Coalition for Health Concern Route 9, Box 25 Benton, Kentucky 42025 502/527-1217	• (with qualifier that earthquake proof storage is not warranted)	
27	17	Mr. N. Dean Eckhoff Kansas State University 137 Ward Hall Manhattan, Kansas 66506-2503 913/532-5624	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
28	n/a	Ms. Mildred Serra 2110 West Adair Drive Apartment 7 Knoxville, Tennessee 37918 phone number not provided	Contained no recommendations (see Section 6.2.6.5)	
29	P5	Mr. Harry A. Nesteruk M4 Environmental L.P. 151 Lafayette Drive Suite 210 Corporate Center Oak Ridge, Tennessee 37830 615/220-4163	•	
30	P6	Dr. John D. Hewes Allied Signal, Inc. Research and Technology P.O. Box 1021 Morristown, New Jersey 07962-1021 201/455-3591	•	
31	18	Mr. Thomas McWilliams Chief, Life Cycle Readiness Division Department of the Army U.S. Army Production Base Modernization Activity Picatinny Arsenal, New Jersey 07801-5000 201/724-3049 (POC, George O'Brien)	•	
32	19	Dr. Velma Shearer 124 Chestnut Street, #210 Englewood, Ohio 45322 phone number not provided		•
33	20	Mr. Ronald Lamb Lamb Wheel Alignment 10990 Ogden Landing Road Kevil, Kentucky 42053 502/462-3495	• (with qualifier that earthquake proof storage is not warranted)	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
34	n/a	Ms. Diana Salisbury Serpent Mound/Ohio Brush Creek Alliance 7019 Ashridge Arnheim Road Sardinia, Ohio 45171 513/446-2763	Contained no recommendations (see Section 6.2.6.6)	
35	21	Mr. Peter L. Lenny Director, Marketing International Cameco Corporation 2121 - 11th Street West Saskatoon, Saskatchewan Canada S7M 1J3 306/956-6287	35-1 • 35-2 • 35-3 •	
36	P7	Mr. Stephen Pattinson Export Sales Manager A.B. Machine Company Ltd. 140 Milner Avenue, Unit #2 Scarborough, Ontario Canada M1S 3R3 416/293-0977	Proprietary	
37	22	Dr. Charles Forsberg Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, Tennessee 37831 615/574-6783		•
38	n/a	Mr. Earl Leming Director State of Tennessee Department of Environment and Conservation 761 Emory Valley Road Oak Ridge, Tennessee 37830-7072 phone number not provided	•	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
39	n/a	Ms. Sue Whayne Route One Clinton, Kentucky 42031 phone number not provided	• (with qualifier that earthquake proof storage is not warranted)	
40	25	Mr. Victor Ransom Purdue University 1290 Nuclear Engineering Building West Lafayette, Indiana 47907-1290 phone number not provided	• (with qualifier -- implementation of breeder reactors is tentative and, if employed, likely to occur beyond 2020)	
41	P8	Mr. Stephen Schutt Executive Vice President Advanced Recovery Systems 1219 Banner Hill Road Erwin, Tennessee 37650 615/743-6186	•	
42	23	Mr. Jerry Hutchison Operational Quality R&R International, Inc. 1234 S. Cleve.-Mass. Road P.O. Box 4383 Akron, Ohio 44321 216/665-3773		•
43	n/a	Dana Lee Fluor Daniel 3333 Michelson Drive Irvine, California 92730 714/975-2000	See Document No. 16	
44	n/a	Mr. William Tewes 304 E. Forest Road Oak Ridge, Tennessee 37830 615/482-2728	Contains no recommendations (see Section 6.2.6.8)	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
45	26	Mr. Peter MacDowell St. Helen's Trading, Ltd. P.O. Box 911 Azusa, California 91702-0911 818/969-0911	•	
46	n/a	Mr. Archer Haskins Nuclear Fuels Services, Inc. 5096 Boonsboro Road Lynchburg, Virginia 24503 804/384-0113	Contains no recommendations (see Section 6.2.6.9)	
47 (P9)	n/a	Mr. Steven Baker EG&G Environmental, Inc. 2128 Hudson Avenue Richland, Washington 99352	•	
48 (P10)	n/a	Mr. Charles Chisholm PDI P.O. Box 9927 Reno, Nevada 89507 702/342-0200	•	
49	27	Package 5 Continuous Metallurgical Reduction to Uranium Metal	• (with qualifier — additional work required on metallurgical reduction technology)	
50	28	Package 6, 7, 8 Conversion to Ceramic UO ₂ Existing Industrial Routes	•	
51	29	Package 9 Conversion to Ceramic UO ₂ Gelation	• (warrants further development)	
52	30	Package 10 Conversion to Uranium Carbide - Graphite and Gelation Approaches	•	

Document Number	Independent Technical Reviewer Number	Respondent	Feasible	Not Feasible
53	31	Package F1 HTGR Fuel Fabrication Using Uranium Carbide		•
54	P11	Mr. Yoshihiko Sugano Mitsubishi Materials Corporation Energy and Ecosystem Business Division 1-3-25 Koishikawa, Bunkyo-ku, Tokyo 112, Japan	Proprietary	
55	n/a	Mr. Charles Montford GenCorp Aerojet P.O. Box 399 Jonesborough, Tennessee 37659 615/753-1200	•	
56	n/a	Mr. William H. Carder Scientific Ecology Group, Inc. P.O. Box 2530 1560 Bear Creek Road Oak Ridge, Tennessee 37831-2530 615/376-8032	Notification of Intent to Submit An Unsolicited Proposal (see Section 6.2.6.10)	
57	n/a	Mr. Mike H. West Mr. John FitzPatrick Los Alamos National Laboratory CST-7, G739 Los Alamos, New Mexico 87545 505/665-1761	• (with qualifier -- more information is needed)	

8.3 Grouping of Responses into the Recommended Technologies for Consideration

This section identifies and groups the technology and application recommendations submitted in response to the Request for Recommendations that could facilitate the long-term management of depleted UF₆. It also includes other options previously identified by DOE and its contractors. This collective set of options comprise the building blocks for the depleted UF₆ disposition strategies. Options have been included because they have been determined to be technically feasible by the Technology Assessment process.

As shown in Table 8.2, there are four categories of options into which the recommendations can generally be placed: conversion, storage, recycle/reuse, and disposal. Section 8.3.1 describes the conversion options. Conversion encompasses chemical processes for converting UF₆ into other forms, primarily either an oxide or a metal. Conversion of the depleted UF₆ to another form such as oxide or metal is needed to implement most of the alternatives. Section 8.3.2 describes the suboptions for storage. Section 8.3.3 summarizes the options for recycle/reuse, where the steps to the end product are principally physical or manufacturing in nature. Section 8.3.4 briefly describes the options for disposal. The non-proprietary responses to the Request for Recommendations are listed in the sections describing each of the options. Proprietary information is not included here, nor is reference made to the respondents providing such information. Proprietary responses and their evaluations are being published in a separate proprietary addendum to the *Technology Assessment Report*. Responses listed more than once contain more than one recommended technology or use.

TABLE 8.2

**Depleted Uranium Hexafluoride Management Program
Technology Assessment Report - Option Categories**

OPTION CATEGORY		RECOMMENDATION (Per Document No.)
B.1 CONVERSION	a. $\text{UF}_6 \rightarrow \text{oxide}$	
	1. U_3O_8	4-1, 9, 10, 13-1, 23, 30, 35-1, 35-2, 38-2
	2. UO_2	27, 35-1, 50, 51, 57
	3. UO_3	22
	b. $\text{UF}_6 \rightarrow \text{U}_{\text{metal}}$	2-4, 4-2, 5-3, 12, 16-2, 24-2, 24-3, 25-1, 29, 35-3, 41, 49, 55-1
	c. $\text{UF}_6 \rightarrow \text{UC}, \text{UC}_2$	52
B.2 STORAGE	a. UF_6 storage	14, 17, 26, 33, 38, 39
	b. Oxide	13-2, 25-3, 27, 55-3
	c. Metal	25-3, 55-3
B.3 RECYCLE/ REUSE	a. Dense Material Applications	5-2, 25-2, 31, 55-2
	b. Re-enrichment (AVLIS, Centrifuge, Re-feed/Blending)	2-1, 2-2, 5-3, 13-3, 18-2, 25-2, 55-2
	c. Shielding	2-3, 5-1, 19, 45
	d. Advance fuel cycle (LWR, MOX, FBR, IFR, PU DISP.)	1, 11, 13-3, 14-2, 27, 40,
B.4 DISPOSAL	a. Oxide	5-4, 23, 25-3, 55-3
	b. Metal	8, 25-3, 32-2, 55-3

8.3.1 Conversion Technology Options

Respondents to the Request for Recommendations recommended conversion of the depleted UF_6 to the oxide forms, triuranium octaoxide (U_3O_8), uranium dioxide (UO_2), and uranium trioxide (UO_3) and also to uranium metal and uranium carbide (UC , UC_2). Process options for conversion of UF_6 to these forms are grouped below.

8.3.1.1 UF_6 to oxide

8.3.1.1.1 U_3O_8

The following responses to the Request for Recommendations contained recommendations for conversion of UF_6 to U_3O_8 .

- Document No. 4-1 (Independent Technical Reviewers' No. 3) from Davis Transport
- Document No. 9 (Independent Technical Reviewers' No. 5) from Allied Signal, Inc. and General Atomics
- Document No. 10 (Independent Technical Reviewers' No. 6) from COGEMA, Inc.
- Document No. 13-1 (Independent Technical Reviewers' No. 9) from Mr. Patrick F. Brown
- Document No. 23 (Independent Technical Reviewers' No. 14) from the Office of Nuclear Material Safety and Safeguards U.S. States Nuclear Regulatory Commission
- Document No. 30 (Independent Technical Reviewers' No. P6) from Allied Signal, Inc.
- Document No. 35-1 and 35-2 (Independent Technical Reviewers' No. 21) from Cameco Corporation
- Document No. 38-2 (Independent Technical Reviewers' No. n/a) from the State of Tennessee Department of Environment and Conservation

The conversion of the fluoride to the octaoxide is commonly referred to as defluorination. The by-product of the defluorination process is either hydrofluoric acid or anhydrous hydrogen fluoride (AHF), depending on the process used.

Several of the respondents made specific recommendations regarding the defluorination processes to be used, while others made a general recommendation for conversion to U_3O_8 . The specific recommendations include a process for defluorination with hydrofluoric acid by-product (Document No. 10), a process for defluorination with anhydrous hydrogen fluoride by-product (Document No. 9), and a process for defluorination with anhydrous hydrogen fluoride by-product and the concurrent production of hydrofluorocarbons (Document No. 30).

Document No. 35-1 recommends a significantly different chemistry than other processes. The UF_6 is reacted with sulfuric acid rather than steam to produce anhydrous hydrogen fluoride and an insoluble uranyl sulfate complex. After drying, the sulfate complex is thermally decomposed to U_3O_8 and an off-gas of sulfur trioxide (SO_3) and oxygen.

8.3.1.1.2 UO_2

The following responses to the Request for Recommendations contained options for conversion of UF_6 to UO_2 .

- Document No. 6 (Independent Technical Reviewers' No. P1) from Siemens Power Corporation
- Document No. 16 (Independent Technical Reviewers' No. P2) from Fluor Daniel, Inc.
- Document No. 27 (Independent Technical Reviewers' No. 17) from Kansas State University
- Document No. 35-1 (Independent Technical Reviewers' No. 21) from Cameco Corporation
- Document No. 47 (Independent Technical Reviewers' No. P9) from EG&G Environmental, Inc.
- Document No. 50 (Independent Technical Reviewers' No. 28) from the U.S. Department of Energy
- Document No. 51 (Independent Technical Reviewers' No. 29) from the U.S. Department of Energy.
- Document No. 57 (Independent Technical Reviewers' No. n/a) from Los Alamos National Laboratory

The conversion of UF_6 to ceramic UO_2 is industrially practiced in the fuel fabrication industry, either by a "wet" or "dry" process. Document Nos. 6 and No. 16 contain recommendations for dry conversion processes. Document No. 27 contains a general recommendation for conversion of UF_6 to UO_2 without identifying a particular process. Document No. 35-1 is a variation of the defluorination with hydrofluoric acid by-product process discussed in section 8.3.1.1.1 wherein UO_2 rather than U_3O_8 is produced. The conventional wet processes for conversion of UF_6 to UO_2 were recommended in Document No. 50. These processes are known as the ammonium diuranate process and the ammonium uranyl carbonate process. All of these processes involve manufacturing a step where the oxide powder is pressed or sintered into pellets. The gelation process recommended in Document No. 51 enables the elimination of the pressing step and allows for higher throughput equipment for the sintering step. Document No. 47 recommends a process for producing aluminum trifluoride and a combination of uranium by-products

(UO_3 , UO_2 , and uranium metal). Document No. 57 is a recommendation to convert the depleted UF_6 to UF_4 which would either be converted to oxide by pyrohydrolysis with steam or stored. The depleted UF_6 would be used as the fluorinating agent in the manufacture of fluorocarbons.

8.3.1.1.3 UO_3

One response to the Request for Recommendations contained an option for conversion of UF_6 to UO_3 . This response was submitted from Mr. Charles Schmitt (Document No. 22 [Independent Technical Reviewers' No. 13]). The technology recommended involved the reaction of UF_6 with water to form uranyl fluoride and HF then precipitating the UO_3 with lime (CaO).

8.3.1.2 UF_6 to U_{metal}

The following responses to the Request for Recommendations contained recommendations for conversion of UF_6 to U_{metal} :

- Document No. 2-4 (Independent Technical Reviewers' No. 2) from Mr. Mark Strauch
- Document No. 4-2 (Independent Technical Reviewers' No. 3) from Davis Transport
- Document No. 5-3 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory
- Document No. 12 (Independent Technical Reviewers' No. 8) from Manufacturing Sciences Corporation
- Document No. 16-2 (Independent Technical Reviewers' No. P2) from Fluor Daniel, Inc.
- Document No. 24-2 and 24-3 (Independent Technical Reviewers' No. P4) from Nuclear Metals, Inc.
- Document No. 25-1 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 29 (Independent Technical Reviewers' No. P5) from M4 Environmental Management, Inc.
- Document No. 35-3 (Independent Technical Reviewers' No. 21) from Cameco Corporation
- Document No. 41 (Independent Technical Reviewers' No. P8) from Advanced Recovery Systems
- Document No. 49 (Independent Technical Reviewers' No. 27) from the U.S. Department of Energy
- Document No. 55-1 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet.

The standard industrial process for producing depleted uranium metal has been the batch metallothermic reduction of uranium tetrafluoride with magnesium (Mg) metal (Ames process). This process generates a magnesium fluoride (MgF_2) by-product slag which is contaminated with uranium in various forms. There are a variety of options to decontaminate the slag, including options which also recover the fluorine value for recycle. "Improved Ames Process" refers to the treatment of the by-product slag to remove the uranium contaminant. Document Nos. 25-1 and 55-1 recommended the conversion of UF_6 to U_{metal} using a batch process with decontamination of the slag.

Document Nos. 16-2, No. 24-2, and No. 35-3 included recommendations for conversion of UF_6 to U_{metal} using a batch metallothermic process with slag decontamination and recovery of anhydrous hydrogen fluoride.

A continuous metallothermic reduction process is another option that offers higher throughput than the currently practiced batch process (Ames) and a MgF_2 by-product with a lower level of uranium contamination. The Continuous Metallothermic Reduction process for the magnesium reduction of UF_4 in a molten salt medium is discussed in Document Nos. 24-3 and No. 49.

High temperature plasma dissociation of UF_6 gas is an advanced concept for the direct reduction of UF_6 to uranium metal as recommended in Document Nos. 5-3 and 12. In the presence of a hydrogen quench, the end-products are uranium metal and anhydrous hydrogen fluoride.

Document Nos. 2-4 and 4-2 contain general recommendations for conversion of UF_6 to metal without identifying a particular process. Document No. 29 recommends a catalytic extraction process for the conversion to metal. Document No. 41 recommends two potential technologies to decontaminate the MgF_2 resulting from conversion to metal.

8.3.1.3 UF_6 to UC or UC_2

One response to the Request for Recommendations contained a recommendation for conversion of UF_6 to UC or UC_2 . This recommendation was submitted by DOE (Document No. 52 [Independent Technical Reviewers' No. 30]). The recommendation included two routes for carbide conversion: (1) the graphite route for the reduction of uranium dioxide with carbon and (2) gelation routes.

8.3.2 Storage

Storage options are defined by the type of storage facilities and the chemical form of uranium stored. The generic types of storage facilities are: (1) outside yards, (2) buildings, and (3) vaults. The uranium forms are: (1) UF_6 , (2) U_3O_8 , (3) UO_2 (ceramic), and (4) U_{metal} .

8.3.2.1 UF_6

The following Request for Recommendations/Advance Notice of Intent responses contained recommendations for storage of UF_6 :

- Document No. 14 (Independent Technical Reviewers' No. 10) from the American Nuclear Society
- Document No. 17 (Independent Technical Reviewers' No. n/a) from Portsmouth/Piketon Residents for Environmental Safety and Security (P.R.E.S.S.)
- Document No. 26 (Independent Technical Reviewers' No. 16) from Coalition for Health Concern

- Document No. 33 (Independent Technical Reviewers' No. 20) from Lamb Wheel Alignment
- Document No. 38 (Independent Technical Reviewers' No. n/a) from the State of Tennessee Department of Environment and Conservation
- Document No. 39 (Independent Technical Reviewers' No. n/a) from Ms. Sue Whayne

8.3.2.2 Oxide

Storage as the oxides U_3O_8 or UO_2 was recommended in the following responses to the Request for Recommendations.

- Document No. 13-2 (Independent Technical Reviewers' No. 9) from Mr. Patrick F. Brown
- Document No. 25-3 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 27 (Independent Technical Reviewers' No. 17) from Kansas State University
- Document No. 55-3 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet

8.3.2.3 Metal

The following Request for Recommendations/Advance Notice of Intent responses contained recommendations for storage of metal.

- Document No. 25-3 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 55-3 (Independent Technical Reviewers' No. n/a) also from GenCorp Aerojet

8.3.3 Recycle/Reuse

This section contains a summary of the principal use or application options that have been recommended. Conversion of the depleted UF_6 to another form such as oxide or metal is needed to implement most of these options. The application categories are shown below.

- Dense Material Applications: metal and oxide (8.3.3.1)
- Re-enrichment: UF_6 and metal (enrichment feedstocks) (8.3.3.2)
- Radiation Shielding: metal and oxide (8.3.3.3)

- Advanced Reactor Fuel Cycles: metal and oxide (8.3.3.4)

The following Request for Recommendation/Advance Notice of Intent response contained a broad range of recommendations for uses.

- Document No. 24-1 (Independent Technical Reviewers' No. P4) from Nuclear Metals, Inc.

8.3.3.1 Dense Material Applications (DMA)

The following responses to the Request for Recommendations contained options for recycle/reuse of UF_6 in dense material applications.

- Document No. 5-2 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory
- Document No. 25-2 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 31 (Independent Technical Reviewers' No. 18) from the U.S. Department of the Army
- Document No. 55-2 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet

This category includes the use of depleted uranium metal for armor piercing munitions (penetrators), vehicle armor, and industrial uses such as counterweights and ballasts. The use of depleted uranium metal for energy storage flywheels, drill collars for the petroleum industry and other industrial/military applications is also included in this category. Dense material applications where the uranium provides enhanced radiation attenuation are discussed under Radiation Shielding in this section (8.3.3.3).

8.3.3.2 Re-enrichment (Atomic Vapor Laser Isotope Separation, Centrifuge, Re-feed-blending)

The following responses to the Request for Recommendations contained recommendations for recycle/reuse of UF_6 in re-enrichment applications.

- Document No. 2-1 and 2-2 (Independent Technical Reviewers' No. 2) from Mr. Mark Strauch
- Document No. 5-3 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory
- Document No. 13-3 (Independent Technical Reviewers' No. 9) from Mr. Patrick F. Brown

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- Document No. 18-2 (Independent Technical Reviewers' No. 11) from the Ohio Valley Regional Development Commission
 - Document No. 25-2 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
 - Document No. 55-2 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet

The isotopic dilution of surplus weapons usable highly enriched uranium (>20% U-235) using depleted uranium (U-238) to produce low-enriched uranium (3-5% U-235) for fuel in conventional light water reactors was recommended in Document Nos. 2-1 and 2-2. Re-enrichment using Atomic Vapor Laser Isotope Separation was recommended in Document Nos. 5-3, 18-2, 25-2 and 55-2. Isotope separation was recommended in Document No. 13-3.

8.3.3.3 Shielding

The following responses to the Request for Recommendations contained recommendations for recycle/reuse of UF₆ as shielding.

- Document No. 2-3 (Independent Technical Reviewers' No. 2) from Mr. Mark Strauch
- Document No. 5-1 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory
- Document No. 19 (Independent Technical Reviewers' No. 12) from the U.S. Department of Energy
- Document No. 45 (Independent Technical Reviewers' No. 26) from St. Helen's Trading, Ltd.

The two basic shielding sub-options recommended in the above responses are uranium metal and a uranium oxide containing concrete (DUCRETE). These sub-options are further discussed below. A variation on this use was recommended in Document No. 45 which advocated recycling naturally occurring radioactive material into shielding bricks for use at contaminated facilities in Chernobyl.

Depleted Uranium Metal Shielding

Uranium metal provides an effective gamma shield, and there are a variety of recommendations based on this characteristic. DOE has announced its intent to prepare an Environmental Impact Statement for the Fabrication and Deployment of a Multi-Purpose Canister system for the management of Civilian Spent Nuclear Fuel (59 FR 53442). Depleted uranium is being considered as a shielding material for the multi-purpose canister shield plug and the transportation cask body and in various preliminary designs for the alternatives. Document Nos. 2-3 and 19 commented or provided information on this option.

DUCRETE Shielding

Another recommended option involves converting the UF_6 into oxides and using it as a component in a concrete spent nuclear fuel storage container. Normal concrete contains sand, aggregate (gravel), and cement. DUCRETE is a higher density, modified concrete where either or both the sand and aggregate components have been replaced with a uranium oxide(s). Document No. 5-1 commented or provided information on this option.

8.3.3.4 Advanced Fuel Reactor Fuel Cycle (Mixed Oxide Fuel, Fast Breeder Reactor, IFR, Plutonium Disposition)

The following responses to the Request for Recommendations contained recommendations for recycle/reuse of UF_6 in reactor fuel applications.

- Document Nos. 1 and 11 (Independent Technical Reviewers' No. 1) from Mr. A.N. Tschaeche
- Document No. 13-3 (Independent Technical Reviewers' No. 9) from Mr. Patrick Brown
- Document No. 14-2 (Independent Technical Reviewers' No. 10) from the American Nuclear Society
- Document No. 27 (Independent Technical Reviewers' No. 17) from Kansas State University
- Document No. 40 (Independent Technical Reviewers' No. 25) from Purdue University

Most of the respondents listed above recommended continuing to store the depleted UF_6 for eventual use in breeder reactors (blanket material).

8.3.4 Disposal

Disposal options are defined by the uranium chemical form, the wasteform, and the characteristics of the disposal site. The principal uranium chemical forms recommended for disposal are oxides (U_3O_8 , and UO_2) and metal. The material can be containerized, encapsulated, vitrified or possibly disposed as a bulk material. The following response to the Request for Recommendations proposed a mined geologic formation be considered for the long-term management of depleted uranium and offered the use of an existing underground mine as a full scale model.

- Document No. 48 (Proprietary Document No. P10) from PDI

8.3.4.1 Oxide

The following responses to the Request for Recommendations contained recommendations for disposal as an oxide.

- Document No. 5-4 (Independent Technical Reviewers' No. 4) from Idaho National Engineering Laboratory
- Document No. 23 (Independent Technical Reviewers' No. 14) from U.S. Nuclear Regulatory Commission
- Document No. 25-3 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 55-3 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet

U₃O₈ is a very inert chemical form of uranium and is insoluble in water. UO₂ is also insoluble, but will slowly convert to U₃O₈ in air at ambient temperature. If sintered, however, UO₂ can be stabilized with a density substantially greater than bulk or compacted oxides. Conversion to a dense stabilized oxide and disposal was recommended (Document No. 5-4), as was conversion to U₃O₈ for disposition (Document Nos. 25-3 and 55-3) by placement in a mined cavity (Document No. 23).

8.3.4.2 Metal

The following responses to the Request for Recommendations contained recommendations for disposal as a metal. Uranium metal (the most dense form of uranium) would require the least disposal volume but is more reactive than the oxide.

- Document No. 25-3 (Independent Technical Reviewers' No. 15) from GenCorp Aerojet
- Document No. 55-3 (Independent Technical Reviewers' No. n/a) from GenCorp Aerojet