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**OAK RIDGE
Y-12
PLANT**

LOCKHEED MARTIN

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**INITIAL REPORT
ON CHARACTERIZATION OF
EXCESS HIGHLY ENRICHED URANIUM**

Nuclear Materials Management and Storage

July 1996

MANAGED BY
LOCKHEED MARTIN ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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EXCESS HIGHLY ENRICHED URANIUM**

Nuclear Materials Management and Storage

July 1996

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for the
U.S. DEPARTMENT OF ENERGY
under contract No. DE-AC05-84OR21400

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
B&W	Babcock and Wilcox
C	Casting
CNWDI	Critical Nuclear Weapon Design Information
CR	Chemical Recovery
DNFSB	Defense Nuclear Facilities Safety Board
DOE	Department of Energy
DOT	Department of Transportation
EIS	Environmental Impact Statement
EM	Environmental Management
EU	enriched uranium ($> 0.711\% \text{ }^{235}\text{U}$)
FY	fiscal year
HEU	highly enriched uranium ($> 20\% \text{ }^{235}\text{U}$)
IAEA	International Atomic Energy Agency
INEL	Idaho National Engineering Laboratory
LANL	Los Alamos National Laboratory
LEU	low-enriched uranium ($> 0.711\% \text{ }^{235}\text{U}$ and $< 20\% \text{ }^{235}\text{U}$)
LLRW	low-level radioactive waste
LMES	Lockheed Martin Energy Systems, Inc.
MAA	material access area
MD	DOE Office of Fissile Materials Disposition
MSRE	Molten Salt Reactor Experiment
NDA	non-destructive analysis
NFS	Nuclear Fuel Services, Erwin, TN
NMMSS	Nuclear Materials Management and Safeguards System
ORNL	Oak Ridge National Laboratory
PCBs	polychlorinated biphenyls
PFD	process flow diagram
RINM	reactor irradiated nuclear material
SNF	spent nuclear fuel
SNM	special nuclear material
SOWA	Statement of Work Agreement
SP	special processing
SRS	Savannah River Site
USEC	United States Enrichment Corporation

CHEMICAL NOTATIONS

Al	aluminum
Al (NO ₃) ₃	aluminum nitrate
Ba (NO ₃) ₂	barium nitrate
BeO	beryllium oxide
CaF ₂	calcium fluoride
HF	hydrogen fluoride
HNO ₃	nitric acid
Mo	molybdenum
Nb	niobium
N ₂ O ₄	di nitrogen tetra oxide
NO _x	nitrogen oxides
Pb	lead
Pu	plutonium
²³⁹ Pu	plutonium isotope 239
SO ₂	sulfur dioxide
Sr(NO ₃) ₂	strontium nitrate
⁹⁹ Tc	technetium isotope 99
ThO ₂	thorium dioxide
Ti	titanium
U&F	uranium and fluorine
²³² U	uranium isotope 232
²³³ U	uranium isotope 233
²³⁴ U	uranium isotope 234
²³⁵ U	uranium isotope 235
²³⁶ U	uranium isotope 236
UF ₄	uranium tetrafluoride
UF ₆	uranium hexafluoride
UNH	uranyl nitrate hexahydrate
UO ₂	uranium dioxide
UO ₂ F ₂	uranyl fluoride
UO ₃	uranium trioxide
U ₃ O ₈	triuranium octaoxide
ZrO ₂	zirconium dioxide

UNITS OF MEASURE

kg	kilogram
kgU	kilogram of uranium
gU/g	gram uranium per gram material
MeV	million electron volts
ppm	parts per million
t	metric tons
μ g	microgram
wgt	weight

EXECUTIVE SUMMARY

The Department of Energy (DOE) Office of Fissile Materials Disposition (MD) assigned the task of preparing a report characterizing 174.4 metric tons (t) of excess highly enriched uranium (HEU) materials to the Y-12 Plant Nuclear Materials Management Organization.

Characterization of the excess materials includes identification of the excess; gathering existing data about the excess; defining the processing steps likely to be needed to prepare the material for transfer to a blending site; and, ultimately, developing a range of the preliminary cost estimates for those steps.

This initial report characterizes the excess HEU inventory by form (category and subcategory), assay (percentage of ^{235}U isotope relative to other uranium isotopes), site, presence of classified information, and potential paths forward. Characterization will focus on making commercial reactor fuel as a final disposition path. It is important to note that this initial characterization is based on assumptions for some of the materials properties which must be validated with analytical testing to reduce or eliminate the existing uncertainty in assay, isotopic content, and impurities. This characterization must be updated as those uncertainties become resolved. Also, this characterization does not involve decisions regarding whether the material will be blended for commercial use or for disposal as waste, where or when the material will be blended, or what process(es) will be utilized for blending. These issues are beyond the scope of this task.

There is some question about the breakdown of the total DOE HEU inventory as listed (Table ES-1).

Table ES-1 HEU inventories

Excess to National Security (174.4 t)	National Security (classified quantity)
Active Use	Navy Nuclear Fuel Reserve
Programmatic Reserve	Strategic Reserve
Surplus (to be dispositioned) (includes spent fuel)	Weapons Programs and Research and Development
	Mutual Defense
	Stockpile
	Active Navy Nuclear Fuel

It appears that some HEU included in the Excess to National Security list, i.e., Active Use and Programmatic Reserve, should have been included in the National Security list and vice versa. The Nuclear Materials Management and Safeguards System (NMMSS) data base is a summary-level data base and is not adequate for detailed interpretation of which materials should be included or excluded from National Security. The local site personnel and site data bases must be utilized for validation of the Excess to National Security list of materials.

The majority of the HEU which was declared Excess to National Security is located at five (DOE) sites. There are 49 percent located on the Oak Ridge Reservation, approximately

13 percent at the Idaho National Engineering Laboratory (INEL), 13 percent at the Portsmouth Gaseous Diffusion Plant, 13 percent at the Savannah River Site (SRS), and 10 percent awaiting processing by Pantex. The remaining excess HEU inventory is located at other sites (2 percent).

The form of the excess HEU has been categorized with approximately 71 percent of the excess being metal, 17 percent nonoxide compounds, 5 percent oxides, 6 percent spent reactor fuel, and the other 1 percent comprising residues, liquid solutions, combustible solids, noncombustible solids, irradiated material, and miscellaneous.

Disposition options being considered for the excess HEU are shown in Figure ES-1.

- [1] USEC fuel: UF_6 - 7.5%; Metal and Oxide - 28.6%
[2] Off-spec fuel: Spent Fuel - 9.3%; Other - 23.8%
[3] Other commercial fuel: IAEA - 5.7%; Other - 22.4%

Figure ES-1 Disposition options by quantity.

In considering disposition of the excess HEU, current standards established by the American Society for Testing and Materials (ASTM) define the specifications for commercial reactor fuel. That portion of the excess HEU which appears to have the potential to meet this specification if blended appropriately is designated "fuel." Another portion of the excess HEU, which would

not likely meet current standards established by ASTM but would be suitable for commercial reactor fuel if the specifications were relaxed to accommodate a slightly higher concentration of ^{234}U and ^{236}U , is designated as "off-spec fuel." Finally, a portion of the excess HEU may not be suitable for conversion to commercial reactor fuel because of undesirable constituents or contaminants - this is considered "waste."

The DOE plans to transfer ownership of approximately 36 percent of the excess inventory to the United States Enrichment Corporation (USEC) within the next year for conversion to fuel (approximately 20 percent as UF_6 and approximately 80 percent as metal and oxides).

The data show that approximately 33 percent of the excess HEU will likely be suitable for off-spec fuel. The ultimate disposition of the material suitable for off-spec fuel will depend on the ability and willingness of nuclear fuel fabricators and nuclear utilities to use the off-spec fuel and upon Nuclear Regulatory Commission (NRC) licensing the use of the off-spec fuel. There are ongoing discussions about the possibility of blending 37 t of the 33 percent of the materials for off-spec commercial fuel. The use of this 37 t of off-spec fuel, which includes some of the spent fuel at the SRS, would increase the excess inventory that is capable of being used in reactors by 21 percent. For the remainder of the 33 percent of off-spec materials (approximately 12 percent of the excess), which also includes spent fuel, no disposition path has been established. This material may also be converted to off-spec fuel or it may be disposed of as low level waste based on further analysis.

For most batches of excess HEU, credible information on minor isotopic content of the HEU was not available, and thus their characterization is incomplete. To complete this initial characterization in lieu of such data, we have calculated a presumed isotopic content by assuming that the HEU was produced from natural uranium feed which was stripped to a reasonable ^{235}U tails assay (e.g. 0.2 percent). Using these admittedly over-simplified assumptions, the data showed an additional approximately 28 percent of the excess HEU to be candidate material for downblending to commercial fuel. This approach may be justifiable since a large portion of the inventory was produced prior to 1964 and has been associated with weapons' production which provide some confidence regarding the history of the material. For the materials associated with reactors, the assumption would be less certain and would require sampling and analysis. The remaining approximately 3 percent of the excess HEU inventory includes the ^{235}U mixed with ^{233}U , for which no disposition path has been established, and material in active use which is not available for disposition. The extent of additional sampling/analysis must be quantified, and if the requirements are extensive, the increase in disposition costs could be significant. As more data become available, the characterization data base will be updated.

As mentioned earlier in the excess versus national security discussion, there is an additional group of materials for which a decision is pending, i.e., the material required for programmatic reserve. The demand for research reactors is estimated to be a total of 18 t of HEU material over the next 20 years. If the decision is made to meet this demand using excess HEU, the commercial fuel available for sale would be decreased from approximately 28 percent to approximately 18 percent of the excess.

The characterization data base which was assembled to facilitate the characterization of the excess HEU inventory is the excess HEU inventory as of September 1994 and is the basis for the findings presented in this document.

The physical and chemical form of excess HEU dictates which processes can convert it into the chemical form acceptable for transportation and for subsequent blending operations. Process flow steps and process flow diagrams (PFDs) describing the steps required for each category are included in Appendices A and B. The PFDs will be used to estimate the costs associated with providing each material form. This initial characterization will be refined as information becomes available, and an updated version of this report will be prepared in early FY 1997.

In order to achieve the timeliness of blending down the HEU to meet the nonproliferation goals while realizing economic advantages, a one-point contact for managing the disposition of the excess HEU is desirable. This one-point contact could integrate the activities associated with the disposition of the excess HEU and provide effective strategic management of the disposition process.

Since this report is an identification and characterization of the excess HEU at "one-point-in-time," it is imperative that a configuration management system be established so that the strategy can be implemented and the results maximized. The Y-12 Plant Nuclear Materials Management Organization has presented a proposal to DOE, requesting permission to modify the project numbers to identify the excess HEU from the HEU to be held as strategic reserve. If DOE approves, and also asks other DOE sites to modify their respective project numbers, this characterization will be useful throughout the life of the MD program. This is an excellent first step in configuration management.

Another key decision which must be addressed is the availability of the excess HEU. As stated in Section 6, the availability of the material will be made on a case-by-case basis. An overall strategy/business plan should be completed in order to maximize the results of this program.

The data used in this report were September 1994 NMMSS data. As soon as DOE makes the April 1996 inventory assessment data available, the Y-12 Plant characterization data base will be adjusted with the new data. In the future, the Y-12 Plant characterization data base will be updated and maintained using data as it becomes available from DOE.

1. BACKGROUND

The end of the Cold War has terminated the nuclear weapons production and the arms race between the superpowers. As a result, significant quantities of weapons-usable fissile materials have been identified as being no longer required for national defense purposes. These excess materials could pose a danger to national and international security due to the potential for proliferation of nuclear weapons if not properly managed. To demonstrate the United States' commitment to reducing the threat of proliferation, the President announced on March 1, 1995, that more than 200 t of United States-origin fissile materials, of which approximately 174.4 t are highly enriched uranium (HEU), have been declared excess to the United States' defense stockpile.

The Department of Energy (DOE) has published an *Environmental Impact Statement (EIS)* for *Disposition of Surplus Highly Enriched Uranium* (DOE/EIS-0240) which addresses disposition of this excess HEU. In the HEU EIS, DOE proposes to eliminate the proliferation threat of excess HEU by blending it down to low-enriched uranium (LEU), which is not weapons-usable. Whenever practical, down-blended LEU will be sold as feed material for the fabrication of commercial nuclear reactor fuel to recover its commercial value. Otherwise, down-blended LEU will be disposed of as waste. In addition to the "no action" alternative (continued storage of excess HEU), the HEU EIS analyzes four alternatives that represent different ratios of blending HEU to LEU for commercial use or blending HEU to LEU for disposal as low-level radioactive waste (LLRW). The HEU EIS analyzes the blending of HEU using three different processes: uranyl nitrate hexahydrate blending, metal blending, and uranium hexafluoride blending. There are four potential blending sites: the DOE's Y-12 Plant in Oak Ridge, Tennessee; DOE's Savannah River Site (SRS) in Aiken, South Carolina; the Babcock and Wilcox (B&W) Naval Nuclear Fuels Division in Lynchburg, Virginia; and the Nuclear Fuel Services (NFS) Plant in Erwin, Tennessee. The EIS also analyzes transportation of materials.

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2. INTRODUCTION

Characterization of the 174.4 t of excess HEU is necessary before decisions related to their disposition can be made. The DOE Office of Fissile Materials Disposition assigned the task of preparing an initial characterization report for these excess HEU materials to the Y-12 Plant Nuclear Materials Management Organization. Additional materials tests may be required for some of the excess HEU before final characterization can be completed.

Characterization of the excess HEU inventory includes identification of the specific material; gathering existing data about the inventory; defining the processing steps that may be necessary to prepare the material for transfer to a blending site; and, ultimately, developing a range of the preliminary cost estimates for those processing steps.

It is important to note that this characterization is not intended to provide sufficient information to make decisions regarding whether the material will be blended for commercial use or for disposal as waste, where or when the material will be blended, or what process(es) will be utilized for blending. These decisions are the responsibility of the DOE MD Office. The findings of the materials characterization task are only one of many factors which will contribute to these decisions. The key driver in the decisions on blending is the nuclear utility customer and/or fabricator requirement, i.e., what product is desired and what product quality is required.

The information in this characterization report will support MD's decisions as follows: Once a customer is identified and the desired product characteristics and delivery dates are known, the characterization data base can be assessed to identify excess HEU materials which can be utilized. The Y-12 Plant Nuclear Materials Management characterization model will identify the processing steps required and provide a preliminary estimate of the costs associated with preparing those materials for shipping to the blending site.

It is important to document the following caveats:

1. This initial characterization report meets its objective to characterize at least 80 percent of the 174.4 t of excess HEU inventory. However, this initial characterization is based in part on assumptions which, while they are based on a reasonably good understanding of the processing history of the material, have some uncertainty and must be validated and/or refined as a specific disposition option for the material identified.
2. This report is based on data from the Nuclear Materials Management and Safeguards System (NMMSS) data base which contains both national security and excess to national security inventories. Excess uranium (to national security) is contained in the NMMSS only at a summary level. These summary-level data represent over 100,000 individual batches in site-level data bases. Due to the complexity associated with the data, a major part of this task includes more detailed analysis of the NMMSS data. This analysis is based on information gathered from the DOE (at the time this report was prepared) that allows the materials to be categorized by chemical and physical form. While the baseline used is data from NMMSS as of September 1994, as previously noted, some sites provided more recent data, and a validation or resolution between their data and the baseline data base

was necessary. The Y-12 Plant Nuclear Materials Management Office intends to update the entire data base using September 1995 data as soon as data are available. The Y-12 Plant characterization cost model will be maintained and updated as new data become available as a result of further analysis of the inventory and future disposition decisions.

3. The processing steps required to move the material from one site to another are not included in this initial report, i.e., if one site is required to send its material to another site for processing prior to shipping it to a blending facility, additional costs would be incurred. It is intended that the final report will include relocation steps.
4. Based on the uncertainties and necessary assumptions used for this report, validation of processing steps and associated costs will be required as new data become available and programmatic disposition changes occur. The data base will be updated accordingly.
5. In most cases, the information gathered to characterize the excess HEU was insufficient with respect to isotopic content. Since the ^{234}U content in down-blended products will be an important discriminator, an assumption was established which would allow a rough estimate of the amount of ^{234}U in the lots which did not have the data. The assumption is based on multicomponent cascade theory, i.e., HEU production from natural uranium feed and stripping to a reasonable tails assay in ^{235}U . Of course, HEU production operations varied over time and did not take place in simple cascades producing only HEU and operating at steady state, so the estimates provided should be recognized as approximations. More accurate isotopic data should be obtained for final decisions. It is also assumed that the sampling and assaying will take place on a case-by-case basis after a potential customer is identified even though analytical data are required before blending decisions can be made. An alternate approach would be to make a statistical sampling and analysis of lots and assign estimates to other similar lots.
6. In separating the excess HEU into groups, it was assumed that the optimum blend stock would be used to maximize the production of acceptable commercial reactor fuel.

This report discusses the characterization in two different cross-cuts:

- Excess HEU divided by site, material forms (category/subcategory), classified and unclassified, assays, and
- Excess HEU divided by potential paths forward (depending on processing requirements and known programmatic initiatives within DOE).

3. METHODOLOGY

3.1 PRELIMINARY DATA ON THE EXCESS HEU

The quantity of DOE HEU inventory excess to national security needs is shown (by location) on the U.S. map in Figure 3-1. This information was presented publicly in the February 8, 1996, DOE Press Release—DOE Facts, "DOE Declassifies Location and Forms of Weapon-Grade Plutonium and Highly Enriched Uranium Inventory Excess to National Security Needs." Also included in the February 8, 1996, release was a preliminary tabulation (as shown in Table 3-1) of the HEU excess by location and form.

Figure 3-1 DOE HEU excess inventories, as announced by Secretary H. O'Leary, February 1996.

**Table 3-1 Location and forms of HEU excess to national security needs
(data in metric tons)**

Location	Metal	Oxides	Unirradiated fuel	Irradiated fuel	Other forms	Total
Oak Ridge Y-12 Plant, K-25 Site, ORNL	63.1	2.7	10.6	0.6	7.9	84.9
Idaho National Engineering Lab. Site	1.6	1.7	2.8	16.6	0.6	23.4
Portsmouth Gaseous Diffusion Plant	-	7.3	-	-	15.2	22.5
Savannah River Site**						22.0
Pantex Plus Planned Dismantlements	16.7	-	-	-	-	16.7
Rocky Flats Site	1.9	<0.1	0.6	-	0.4	2.8
Hanford Site	<0.1	0.1	0.1	0.3	0.1	0.6
Los Alamos National Laboratory	<0.1	0.3	0.1	<0.1	0.1	0.5
Brookhaven National Laboratory*	-	-	-	0.2	<0.1	0.3
Sandia National Laboratories	<0.1	0.1	<0.1	0.1	<0.1	0.2
Other Sites	<0.1	0.2	0.2	<0.1	<0.1	0.5
TOTAL						174.4

Note: Totals may not add up due to rounding.

*Not a Weapons Program Facility.

**Form of material is classified.

The excess HEU inventory was identified, and the data base shows 174,436 kgU of material. Based on this preliminary data, the task was defined to characterize the excess HEU.

3.2 DESCRIPTION OF THE CHARACTERIZATION TASK (INCLUDING MILESTONES)

This task was divided into specific milestones as follows:

1. Develop a methodology (including input and output data sheets) for characterization of excess HEU inventory. [Completed 2/29/96]
2. Prepare preliminary material process flow diagrams for excess material. [Completed 2/29/96] Complete the material process flow diagrams for other forms (by site) of excess material (irradiated, unirradiated, and other chemical forms). [To be completed 9/30/96]
3. Develop criteria for use by other DOE sites in evaluation of the excess HEU stored at their respective sites. [Completed 3/22/96]
4. Complete initial characterization (to cover 80 to 90 percent of excess HEU inventory). [Completed 6/30/96] Complete characterization of excess HEU. [To be completed 9/30/96]

Once the excess HEU was identified by site, it was divided by form, including category (i.e., compound) and subcategory (i.e., U_3O_8). For each specific form of material, information was gathered, i.e., quantity of uranium (by isotopic content, major chemical constituents, and

gross weight by category or subcategory of excess HEU); and "existing" representative analytical data (including isotopic analysis by physical form and subcategory of excess HEU).

After the categories and subcategories were established, processing steps potentially required to prepare the material for blending to LEU were defined. For each processing step required to prepare material for blending to LEU, a cost was estimated. And, lastly, the schedule for disposition was suggested, i.e., when could the excess materials be ready for blending to LEU.

To manage this information efficiently, a processing cost model for the excess HEU was tied into the Y-12 Plant Nuclear Materials Management inventory data base. This cost model sorts the materials into manageable groups and calculates the costs of preparing the excess HEU for transfer to a blending site.

3.3 ASSUMPTIONS

In order to ensure a consistent approach for each DOE site's excess HEU and to utilize existing DOE program initiatives and plans, reasonable assumptions were made regarding material forms, process flow diagrams, and potential paths forward.

3.3.1 Material Forms

For the purposes of this initial characterization, material forms have been divided into categories and subcategories. There are six major categories, comprised of 34 subcategories, plus miscellaneous (for materials which did not clearly fall into a specific category).

In this initial characterization report, the excess HEU which is contained in transuranics or ^{233}U , i.e., spent fuel, will be segregated from the other material forms, and details of the processing steps and associated costs will not be included. The definition of *spent fuel* is "fuel which is currently in a reactor or has been removed from a reactor and has not been reprocessed."

3.3.2 Process Flow Diagrams (PFDs)

The process flow diagram assumptions include:

- Excess HEU in the form of unclassified metal will be delivered as is to the blender. The decision on whether recasting will be required for classified metal shapes (to remove Critical Nuclear Weapon Design Information [CNWDI] before delivery to the blender) has not been determined. If CNWDI can be delivered, then classified metal will be shipped to the blenders. (PFDs were also prepared, including the steps required, for converting metal to U_3O_8 .)
- Materials other than metal will be converted to U_3O_8 before shipping to a blender.
- The excess HEU material forms will be divided into categories/subcategories which share a common process flow.
- Process flow diagrams will be developed for each of the categories/subcategories.
- Estimated costs will be included for each step in the process from the time the excess HEU arrives on the dock until it is returned to the dock for shipping off site. Any costs incurred

prior to receipt on dock or after it is returned to the dock are not included. For example, if material is sent from one site to another for processing or storage, and if that site is not the blending site, there will be additional costs associated with moving the material to the blending facility.

- For excess metal extracted from weapons, the pedigreed analysis of the material will be used, and no analytical sampling or purification will be included in the estimated costs of processing. (It is assumed that additional sampling [for isotopic/chemical analysis] and purification will take place on a case-by-case basis after the potential customer is identified.)
- Clean UO_2 or UO_3 will be converted to U_3O_8 without going through purification.
- The costs for blending and the costs of blend stock will not be included in the processing estimate. The customer's desired product, delivery-date requirements, and discount factors must be understood before the costs and sales price can be estimated. (It is assumed that the customer will select the blending facility, and the blending costs will be borne by the customer; and the customer will specify product specs which dictate the required blend stock, and thus, the costs associated with the blend stock will be borne by the customer.)
- If additional processing (dismantlement, demilitarization, purification, or conversion) is required to prepare the material for blending, it may be necessary to ship the material to an appropriate processing site (assuming the material meets the processing site's acceptance criteria).
- If material does not require additional processing and is ready for blending in its existing state, it will be shipped directly to the blending facility of the customer's choice. (The EIS lists four potential blending facilities—B&W, NFS, SRS, and the Y-12 Plant.)
- Processing waste streams (generated during processing) will not be analyzed, and cost estimates are not included for processing waste.
- Information will be gathered during this task so it can be utilized in the "Blending Models for Decisions on Commercial Use and Waste Disposal."

3.3.3 Material Divided by Potential Paths Forward

Materials are divided into potential paths forward depending on processing requirements and known programmatic initiatives within DOE. The paths forward were selected to assist MD in its understanding of the characteristics of the material which can be dispositioned and are discussed in Section 5.1.5.

4. DESCRIPTION OF THE DATA

4.1 LIST OF MATERIAL CATEGORIES AND SUBCATEGORIES

The data base shows approximately 85 t (or 49 percent) of the 174.4 t of excess HEU are located on the Oak Ridge Reservation. The excess HEU located at the Y-12 Plant is made up of six major categories and 34 subcategories. The majority of the remaining 51 percent is located at the INEL, Portsmouth Gaseous Diffusion Plant, the SRS, and Pantex. In addition to the six major categories mentioned above, the excess HEU inventory separately identified two subcategories (oxides and UF_6), and also includes spent fuel, irradiated material, and miscellaneous. The major categories and subcategories list is shown in Table 4-1.

Table 4-1 List of material categories and subcategories

Categories	Subcategories
Metal	<ol style="list-style-type: none">1. Subassemblies and/or Units2. Discrete Parts3. Broken Metal and Pieces4. Right Solid Cylinders and/or Logs5. Alloyed:<ul style="list-style-type: none">• Aluminum• Molybdenum• Niobium• Titanium• Zirconium• Other6. Clad (Unirradiated):<ul style="list-style-type: none">• Aluminum• Cadmium• Stainless Steel• Zirconium• Other
Compounds	<ol style="list-style-type: none">1. Oxides (Relatively Pure)2. Oxides (Impure)3. Oxides containing ZrO_2, ThO_2, BeO, and etc.4. Fluorides (UO_2F_2, UF_4, and miscellaneous)5. Nitrates6. Halides other than Fluorides7. Carbides
Residues	<ol style="list-style-type: none">1. Dry Leachable Ash2. Wet Slurries3. Reduction Residues (CaF_2, Slag)4. Discard Solids
Solutions	<ol style="list-style-type: none">1. Uranyl Nitrate (Pure)2. Uranyl Nitrate (Impure)3. Laboratory Solutions

Table 4-1 List of material categories and subcategories

Categories	Subcategories
Solutions (continued)	<ol style="list-style-type: none"> 4. Oil/Organics 5. Chloride 6. Sulfate 7. Phosphate 8. General Salvage <ul style="list-style-type: none"> • Mop Water • Impure Dilute Solutions • Acid Wash Solutions from Noncombustibles 9. Basic (Caustic Pickling)
Combustibles	<ol style="list-style-type: none"> 1. Miscellaneous Forms <ul style="list-style-type: none"> • Paper • Rags and Gloves • Chemical Wipes • Mop Heads • Other Combustible Scrap 2. Bag Filters and Other Combustible Filters 3. Carbon/Graphite Scrap (from Casting Operation) 4. Embedded EU in Plastic
Noncombustibles	<ol style="list-style-type: none"> 1. Filters <ul style="list-style-type: none"> • Metallic, Ceramic, or Other Noncombustible Filters 2. Metal Scrap <ul style="list-style-type: none"> • Piping, Hardware, Tools, and etc. 3. Glass 4. Plastics <ul style="list-style-type: none"> • Teflon, Tygon Tubing
Miscellaneous	<ol style="list-style-type: none"> 1. Multicategory

The amount of material by category, including the additional breakdown, is graphically illustrated in Figure 4-1.

Figure 4-1 Material by category.

4.2 CHARACTERIZATION PARAMETERS

The characterization data base includes parameters from NMMSS as well as parameters developed specifically for this task. Table 4-2 shows the parameters and their respective definitions. Currently approximately 80 percent of the parameter fields are populated. The remaining 20 percent will require sampling and analysis and are dependent on programmatic decisions and funding.

The characterization model can sort by any one of these parameters.

Table 4-2 Parameters used in characterization

Parameters	Definition
I.D.	References line to original spreadsheet/Headquarters
RIS	Reporting Identification Symbol (NMMSS ID)
Project	Identification by which material is programmatically controlled/managed
Title	Description of project numbers
COEI	Composition of Ending Inventory (NMMSS Material Forms)
ANSI	American National Standards Institute (scrap detailed)
MTC	Material Type Code (% ²³⁵ U range)
Assay %	% ²³⁵ U content
Element kgU	kg of uranium
Isotope	kg of ²³⁵ U
DOE Compos	Headquarters (NMMSS) roll-up of material form
Model Categ (new)	Local level material form (major)
Subcateg (new)	Local level material form (further broken down)
Info.	Detailed information about material
Class	Determination of material to a weapons classification configuration
ACT	Determination of material with a programmatic requirement or currently being used
DIS	Potential disposition path
Major Contaminant	Further detail of some materials such as alloy metals
²³² U, ²³³ U, ²³⁴ U, ²³⁶ U, ²³⁸ U%	Levels of
Th Pu ^{239/241}	Levels of
Irradiated (spent fuel)	Spent nuclear material from reactors (not processed)
Site	Complex identified from RIS

4.3 VERSATILITY OF THE CHARACTERIZATION MODEL

The Y-12 Plant nuclear materials data base was modified to include the characterization parameters. These parameters allow the data to be sorted and evaluated. The modification to the data base also includes processing steps and associated costs coupled to the data; for a given material with specific parameters, the processing steps can be identified, and the costs can be estimated for preparing that material for shipping and subsequent blending to LEU.

As additional information is made available, it will be added to the data base.

5. RESULTS OF FINDINGS

(Depending on Processing Requirements and Known Programmatic Initiatives Within DOE)

5.1 SUMMARY OF THE DATA

The excess HEU inventory was identified and the data base shows 174.4 kgU of material.

5.1.1 Quantities (kgU) of Excess HEU by Site

The data show that 49 percent of the excess HEU is located on the Oak Ridge Reservation; 13 percent at the INEL; 13 percent at the Savannah River Site; 13 percent at the Portsmouth Gaseous Diffusion Plant; 10 percent awaiting processing by Pantex, and the remaining 2 percent located at 15 other sites.

5.1.2 Quantities by Category and Subcategory

According to the data base, approximately 71 percent of the material is metal; 17 percent is compounds; 5 percent is oxides; and 6 percent is spent fuel. The remaining 1 percent is comprised of combustibles, irradiated material, noncombustibles, residues, solutions, and miscellaneous.

5.1.3 Quantities by Classified and Unclassified

Approximately 70 percent of the excess HEU is unclassified. While the quantity of excess HEU containing CNWDI is known (approximately 30 percent of the excess HEU), the need for removal of the CNWDI before shipping to a blending site is not known.

5.1.4 Quantities by Assay

The data base includes a ^{235}U assay range for the excess HEU. The summary is shown in Table 5-1-4.

Table 5-1-4 Assay range

Assay Range	> or = 20 < 35	> or = 35 < 45	> or = 45 < 80	> or = 80 < 92	> or = 92 < 94	> or = 94
kgU	9.21%	26.35%	39.88%	5.58%	14.68%	4.30%

5.1.5 Quantities by Potential Paths Forward

From the analysis of the excess HEU, it was determined that the HEU could be divided by potential paths forward depending on processing requirements and known programmatic initiatives within DOE. Disposition paths have been established for some of the materials, and this report assumes that MD will be able to utilize the established paths. Table 5-1-5 depicts the excess HEU by potential paths forward.

Table 5-1-5 Excess HEU by potential paths forward

Group	Amount (t) ^[2]	Location (site)	Percent of 174.4 t
HEU mixed with ²³³ U	1.1	Oak Ridge	<1.0
Potential commercial fuel identified for transfer/sale to USEC		Oak Ridge, Portsmouth, Other	
– UF ₆	13.0		7.5
– metal and oxide	50.0		28.6
Other sources of potential commercial fuel ^[1]		Oak Ridge, INEL, Portsmouth, Pantex, Rocky Flats, Hanford, LANL, Sandia, Other	
– IAEA	10.0		5.7
– Other inventories of potential commercial fuel	39.4		22.4
Off-spec potential commercial fuel		Oak Ridge, INEL, Portsmouth, SRS, Rocky Flats, Hanford, LANL, Sandia	
– Spent fuel	16.3		9.3
– Other off-spec potential commercial fuel	41.5		23.8
In programmatic use		Oak Ridge, INEL, SRS, Hanford, LANL, Brookhaven, Sandia, Other	
– Active use	3.4		2.0

[1] If the decision is made to reserve 18 t of the excess HEU materials for programmatic reserve requirements, the 49.4 t for other commercial fuel will be decreased to 31.4 t.

[2] Totals do not add up due to rounding.

Figure 5-1-5 graphically illustrates the amount of excess HEU by potential paths forward.

[1] If the 18 t of Programmatic Reserve comes from the Other Commercial Fuel, then the Other Commercial Fuel decreases to 31.4 t.

Figure 5-1-5 Material by potential paths forward.

The following sections offer a discussion of the excess HEU by potential paths forward.

5.1.5.1 Highly Enriched Uranium Mixed With ^{233}U

In relation to conventional HEU (enriched in ^{235}U), there are relatively small quantities of ^{233}U in the DOE excess inventory (approximately 1.1 t). Figures 5-1-5-1.1 and 5-1-5-1.2 illustrate the HEU mixed with ^{233}U by location and by category, respectively.

The Oak Ridge National Laboratory is currently designated as the ^{233}U National Repository for DOE Defense Programs. Some of this ^{233}U material is mixed with ^{235}U which is not chemically separable. All ^{233}U inventories contain ^{232}U as a contaminant in trace amounts. About two-thirds of the ^{233}U contains less than 10 ppm ^{232}U , about 10 percent contains 10 to 50 ppm ^{232}U , and 23 percent contains more than 50 ppm ^{232}U .

ORNL
100%

Figure 5-1-5-1.1 Location of uranium-233.

Metal
3%

Oxide
97%

Figure 5-1-5-1.2 Uranium-233 by category.

Uranium-233 requires glovebox-type confinement for processing because of the high-alpha activity of ^{233}U , ^{232}U , and daughters. Also a ^{232}U daughter thallium-208 emits a high-energy (2.6-MeV) gamma requiring heavy shielding. Because of these constraints and possible NRC compliance requirements, the ^{233}U is less attractive as a blend stock for commercial reactor fuel.

Chemical separation of the ^{232}U contaminant from HEU is not possible. However, an intermediate daughter product of ^{232}U (thorium-228) could be chemically removed, reducing the alpha and gamma radiation significantly for a period of weeks before the ^{232}U rebuilds.

Uranium-233 may have a demand as a source for its daughter product thorium-229 which is the radioisotope used in preparing alpha emitting radiopharmaceuticals such as Bismuth-213.

Because of the unique characteristics of ^{233}U , a Trade Study¹ has been proposed to the Nuclear Materials Stabilization Task Group (DOE-EM66) within the framework of the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 94-1.

5.1.5.2 Potential Commercial Fuel Identified for Transfer/Sale to USEC

Approximately 13 t of UF_6 and 50 t of metal and oxide have been identified for transfer/sale to the USEC.

5.1.5.2.1 Uranium Hexafluoride (UF_6) (13 Metric Tons)

A disposition path has been established for approximately 13 t of high quality uranium hexafluoride (UF_6). This material was transferred to USEC under the terms of a Determination Order upon the creation of USEC as a government corporation. The transfer was a means of reimbursing USEC for performing certain tasks which were the responsibility of DOE under the terms of the Energy Policy Act of 1992 and subsequent, negotiated agreements. This material is being blended at a low rate into LEU in the top stages of the LEU cascade at the Portsmouth Gaseous Diffusion Plant; the HEU stream mixes with the circulating UF_6 flow inside the process equipment.

5.1.5.2.2 Metal and Oxide (50 Metric Tons)

A disposition path has also been established for 50 t of HEU under the terms of the USEC Privatization Act of 1996. Figures 5-1-5-2-2.1 and 5-1-5-2-2.2 show the potential commercial fuel identified for USEC by location and by category, respectively.

¹ Tasking Statement for Trade Study on Stabilization and Interim Management of ^{233}U

Figure 5-1-5-2-2.1 Potential commercial fuel identified for USEC (50 t) by location.

Figure 5-1-5-2-2.2 Potential commercial fuel identified for USEC (50 t) by category.

According to the Privatization Act of 1996, Section 3112 of the Act, Uranium Transfers and Sales, states:

(c) Transfers to the Corporation:

- (1) The Secretary shall transfer to the Corporation without charge up to 50 metric tons of enriched uranium and up to 7,000 metric tons of natural uranium from the Department of Energy's stockpile, subject to the restrictions in subsection (c) (2).
- (2) The Corporation shall not deliver for commercial end use in the United States—
 - (A) any of the uranium transferred under this subsection before January 1, 1998;
 - (B) more than 10 percent of the uranium (by uranium hexafluoride equivalent content) transferred under this subsection or more than 4,000,000 pounds, whichever is less, in any calendar year after 1997; or
 - (C) more than 800,000 separative work units (SWU) contained in low enriched uranium transferred under this subsection in any calendar year.

In anticipation of the Act being passed in 1995 the following schedule (Table 5-1-5-2-2) was tentatively established for transfer of the material from DOE to the private enrichment corporation.

Table 5-1-5-2-2 Availability schedule for transfer of HEU to USEC

Fiscal year	Completion date of transfer	Quantity (in metric tons)
1996	By September 30, 1996	2
1997	By September 30, 1997	5
1998	By September 30, 1998	10
1999	By September 30, 1999	11
2000	By September 30, 2000	11
2001	By September 30, 2001	11

It is now anticipated that USEC will not be privatized until the end of calendar year 1996. Therefore, a new schedule will have to be negotiated with the new enrichment entity. In an earlier version of the draft memorandum of agreement for the transfer of the 50 t of HEU, it was also stated that USEC would be responsible for the blending of the HEU to LEU, including the selection of the entity to perform the blending. The draft agreement also stated that the 50 t of HEU identified for transfer to USEC would be material which DOE believes can be blended to commercial specification reactor fuel.

5.1.5.3 Other Sources of Potential Commercial Fuel

Using the assumptions discussed earlier in this report, there is an additional 49.4 t of excess HEU which can be blended to power reactor fuel grade LEU (meeting the existing American Society for Testing and Materials [ASTM] specifications). Figures 5-1-5-3.1 and 5-1-5-3.2 illustrate the potential commercial fuel by location and category, respectively.

Figure 5-1-5-3.1 Location of other sources of potential commercial fuel.

Figure 5-1-5-3.2 Other sources of potential commercial fuel by category.

The ASTM Specification C996-90 governs UF₆ enriched to less than 5 percent ²³⁵U. The specification states the following limits (Table 5-1-5-3.1) on the presence of uranium minor isotopes in the LEU to be used as fuel:

Table 5-1-5-3.1 Uranium minor isotopes limits for LEU

Uranium isotope	Enriched from commercial natural UF ₆	Enriched from reprocessed UF ₆
²³² U	0.002 µg/g ²³⁵ U	0.050 µg/gU
²³⁴ U	10,000 µg/g ²³⁵ U	2,000 µg/gU
²³⁶ U	5,000 µg/g ²³⁵ U	Subject to buyer-seller agreement

HEU can be blended down using a variety of alternative blend stocks, including natural uranium, tails from past enrichment operations, and slightly enriched uranium made from either natural uranium or partially depleted feed stocks. These potential blend stocks differ in uranium minor isotope abundancies. The choice of blend stock will depend primarily on which blend stock yields a product meeting the ASTM limits given above. This choice will also depend on blend stock costs and overall blending costs. Blending with tails or other depleted uranium results in the smallest amount of blended product per kilogram of HEU blended at a specified assay; however, the selection of depleted uranium is limited because it is difficult to meet spec when blending with tails. Its use, however, leads to the lowest cost, blended product if it meets specifications. Natural uranium is readily available; and compared with blending with tails, its use results in more blended product per kilogram of HEU with only a modest increase in product cost. Use of enriched blend stocks leads to the most blended product per kilogram of HEU; it also leads to the highest blended-product cost due to the need to purchase SWUs to make the enriched blend stock. Its use as blend stock will be required with some HEU materials in order to meet LEU product specification.

Assuming commercial natural uranium is used as the blend stock, reactor-grade LEU containing 5 wgt % ²³⁵U (meeting the above uranium minor isotopes limits) can be made from HEU in which no uranium minor isotope exceeds the levels shown in Table 5-1-5-3.2:

Table 5-1-5-3.2 Limits for minor isotopes (in weight percent)

²³⁵ U Content of HEU (weight percent)	²³² U Presence	²³⁴ U Presence	²³⁶ U Presence
90	0.19 x 10 ⁻⁶	0.93	0.48
60	0.13 x 10 ⁻⁶	0.62	0.32
30	0.62 x 10 ⁻⁷	0.31	0.16

Of the 49.4 t of HEU which meet the criteria stated in Table 5-1-5-3.1, 10 t are under IAEA inspection. The United States and the IAEA have been working on approaches that might allow the agency to monitor those materials as they are processed from weapons-related facilities into forms usable for nondefense purposes. Suitability of any lot of HEU for blending to reactor fuel will be determined by the uranium isotope criteria in Table 5-1-5-3.2 which was derived from Table 5-1-5-3.1.

5.1.5.4 Off-Spec Potential Commercial Fuel

As stated in Section 5.1.5.3, ASTM Specification C996-90 governs the amount of impurities (or minor isotopes) allowed in uranium hexafluoride (under 5 percent ^{235}U) intended for use in producing commercial reactor fuel.

In past practices, the definition of "off-spec material" has included a slight difference in ^{234}U and a significant difference in ^{236}U , i.e., low enriched uranium resulting from the blending down of U.S. weapons-grade HEU may contain on the order of 11,000 $\mu\text{g } ^{234}\text{U}/\text{g } ^{235}\text{U}$ and a much higher-than-specification concentration of ^{236}U (on the order of 10,000 $\mu\text{g } ^{236}\text{U}/\text{g } ^{235}\text{U}$). Higher ^{236}U concentration would require specific analysis for ^{232}U and ^{99}Tc , which are significant radiation contributors associated with reprocessed uranium. The acceptable limits of ASTM Specification C996-90 including the limits for "off-spec" material are summarized in Table 5-1-5-4.

Table 5-1-5-4 Acceptable limits for off-spec fuel

Uranium isotope	Enriched from commercial natural UF_6	Enriched from reprocessed UF_6
^{232}U	0.002 $\mu\text{g}/\text{g } ^{235}\text{U}$	0.050 $\mu\text{g}/\text{gU}$
^{234}U	10,000 $\mu\text{g}/\text{g } ^{235}\text{U}$ [1]	2,000 $\mu\text{g}/\text{gU}$
^{236}U	5,000 $\mu\text{g}/\text{g } ^{235}\text{U}$ [2]	Subject to buyer-seller agreement

[1] Limit of 11,000 $\mu\text{g}/\text{g } ^{235}\text{U}$ subject to buyer-seller agreement.

[2] Limit of 10,000 $\mu\text{g}/\text{g } ^{235}\text{U}$ subject to buyer-seller agreement.

Approximately 57.8 t of HEU material which cannot reasonably be blended to meet the ASTM Specification C996-90, but which could be considered to be a candidate material for blending to off-spec commercial reactor fuel, have been identified. Figures 5-1-5-4.1 and 5-1-5-4.2 illustrate the off-spec potential commercial fuel by location and category, respectively. Of this material, 16.3 t are spent fuel (which is discussed separately in Section 5.1.5.4.1). Also, of the 57.8 t of HEU, approximately 37 t are being considered for blending at the SRS.

Figure 5-1-5-4.1 Location of off-spec potential commercial fuel.

Figure 5-1-5-4.2 Off-spec potential commercial fuel by category.

5.1.5.4.1 Spent Fuel

For this report, the definition of *spent fuel* is "fuel which is currently in a reactor or has been removed from a reactor and has not been reprocessed." Reprocessing will be required before the excess HEU can be used as off-spec fuel. The 16.3 t of spent fuel are located in the INEL, SRS, and the Los Alamos National Laboratory (LANL). Figures 5-1-5-4-1.1 and 5-1-5-4-1.2 illustrate the spent fuel by location and category respectively.

The establishment of a disposition path for DOE's spent nuclear fuel has been an ongoing task for several years. One option currently being discussed is to blend some of the spent fuel into "off-spec" commercial fuel at the SRS (this is a part of the 37 t mentioned previously). However, no decision has been announced. A high-level characterization of the spent fuel was completed during a comprehensive baseline assessment of the condition of spent fuel stored at DOE facilities in late 1993 and early 1994.

The spent fuel was used to fuel research reactors, production reactors, and commercial reactors. The types of fuel element cladding include: zircaloy, aluminum, stainless steel, and graphite/carbon. According to the Spent Nuclear Fuel Working Group Report, many DOE spent fuel storage facilities contain some spent fuel that is uncharacterized.² Irradiated fuel rods manufactured from a wide variety of materials (e.g., metal alloys, carbides, oxides) were cut up and examined in hot cells and then stored in sealed cans. Fuel rods damaged in a reactor or during subsequent storage also have been canned and stored in both wet and dry storage facilities. Some irradiated nuclear material has been stored dry, inside casks or other shielded containers, and some have been buried. Most of these containers have not been opened in many years to analyze the condition of the material. Some fuels (both canned and uncanned) stand in pools and are also not characterized to the degree necessary to determine future handling and disposition. Encapsulated reactor irradiated nuclear material (RINM) is difficult to inspect. Lastly, sludge in the bottom of some DOE wet storage facilities contains irradiated nuclear material of unknown concentrations and composition.

An EIS addressing the complex wide storage of all RINM has been completed, and it evaluates various alternative plans for safely storing RINM until the year 2035.

5.1.5.5 In Programmatic Use

Excess highly enriched uranium for which there is a programmatic need, now and in the future, may be reserved. The HEU required for programmatic use will fill two needs: fuel in research reactors and fuel for programmatic reserve.

² Spent Nuclear Fuel Working Group Report

Figure 5-1-5-4-1.1 Location of spent fuel.

Figure 5-1-5-4-1.2 Spent fuel by category.

5.1.5.5.1 Programmatic Reserve

The DOE supports the domestic and foreign (Belgium, Canada, Denmark, France, Germany, Japan, Netherlands, and the United Kingdom) research reactor fuel requirements. Based on the letters entitled "FY 1996 Nuclear Materials Allotments for Y-12 (U)"³ and "Establishment of new project numbers,"⁴ the requirements for 20 years for these research reactors is 18 t (13 t at 37.5 percent ²³⁵U plus 5 t at 93 percent ²³⁵U) and are to be held in reserve. These reactors support the following programs: Basic Research Sciences; Facilities, Fuel Cycle, and Test Program; University and Science Education Program; Environmental Management; Facility Transition and Technical Support; and Actinide Recycle.

Because of the specific requirements, an analysis of several options should be evaluated:

- Option 1. The DOE could move additional material from National Security to excess.
- Option 2. The 10 t under IAEA inspection could be held in reserve and blended as required. However, doing so could compromise processing facilities, (e.g., the Y-12 Plant, B&W, NFS) because IAEA would gain access to their respective operations. Utilizing the IAEA tracked material could also be a tremendous inconvenience for the research reactors utilizing this fuel for the next 20 years.
- Option 3. Material that is 37.5 percent ²³⁵U could be blended down to meet the 19.75 percent ²³⁵U requirements; however, this would decrease the amount of material available for sale to commercial nuclear power companies.

5.1.5.5.2 Active Use

There are 3.4 t of the excess HEU currently active in research reactors or in research projects in the United States and eight foreign countries, including Brookhaven Medical Research Reactor, High Flux Beam Reactor, High Flux Isotope Reactor, and National Institute of Standards and Technology. Figures 5-1-5-5-2.1 and 5-1-5-5-2.2 illustrate the active use by location and category respectively.

5.1.5.6 Materials Requiring Further Analysis

Subsequent to the determinations and exclusions which provided a scenario for the positive use of most of the HEU materials, the remaining HEU does not easily fall into such convenient groupings. Each material type in all of the forms identified must be subjected to rigorous scrutiny before it is considered for use in commercial reactor fuel or declared a waste material and prepared for disposal.

³ Letter, February 16, 1996, Mr. F. P. Gustavson from Robert J. Spence, "FY 1996 Nuclear Material Allotments for Y-12 (U)."

⁴ Draft (effective date June 24, 1996) Letter, Mr. F. P. Gustavson from Robert J. Spence, "Establishment of New Project Numbers."

Figure 5-1-5-5-2.1 Location of active use.

Figure 5-1-5-5-2.2 Active use by category.

The disposition program assumes that excess HEU materials designated for waste disposal be configured in such a manner as to preclude their unauthorized use. To accomplish this objective under current guidelines, it was assumed that such HEU would be blended down to a ²³⁵U content of about .9 percent (suggested in the EIS for this material). For this report it is assumed that the chemical processes required to achieve this state of "elemental blend down" are similar to the processes required to produce commercial fuel. In some cases, the costs of blending a specific quantity of HEU for disposal may be higher than for blending it to fuel.

A life cycle cost analysis should be completed for each lot. Such economic analysis should reveal whether some of the remaining materials can be economically processed into fuel instead of converting to waste. Statistical sampling would be required to support the economic analysis.

The outcome of the sampling and analysis may reveal some lots with unacceptable characteristics if the lots were processed one at a time. However, if a large quantity of HEU materials is taken into consideration, it may be possible to include some lower grade material in a larger quantity of HEU and meet the specification for ASTM or off-spec fuel. An integrated disposition strategy could increase the government's cost advantage for the sale or disposition of the excess HEU. Initial program plans have not investigated this potential opportunity.

5.2 GENERIC PROCESSING STEPS FOR EXCESS HEU

For each category and subcategory of the excess HEU, generic processing steps/activities were identified for processing the material into a form which could be transported to a blending site and fed into a blending process. This report focuses on the major steps with the intent to add the minor steps as required.

Of the 174.4 t of excess HEU, the data showed that 78 percent of the excess could be processed using the generic processing steps/activities. For the remaining 22 percent, additional processing steps/activities may be required. The 22 percent includes spent fuel, ²³³U, pits, irradiated material, and some miscellaneous materials. The processing steps in some cases are being decided by other program offices within DOE. In other cases, insufficient analytical information exists requiring sampling. However, the final characterization report will include, to the extent possible, the processing steps required for the other 22 percent of the excess HEU.

Also, if material is sent from one facility to another for processing or storage, and if that second facility is not also the blending facility, there will be packaging and shipping steps/activities required for the second movement of the material to the blending facility. These additional steps may be unique for each different site.

Appendix A shows details of the generic processing steps required for the categories and subcategories of excess HEU.

5.3 PROCESS FLOW DIAGRAMS (PFDs) FOR EXCESS HEU

The generic processing steps shown in Appendix A visually represent the paths forward for the categories and subcategories of excess HEU. The PFDs depict the various steps required for the categories of excess HEU to go from the existing state to a form in which it could be sent to a blending facility.

Appendix B presents the visual picture of the required processing steps. As stated in Section 3.3.2, additional processing steps may be identified, and if so, will establish a need for additional PFDs.

5.4 RANGE OF COSTS FOR THE GENERIC PROCESSING STEPS

Using the processing steps shown in the PFDs, a range of costs was estimated. The costs associated with each processing step are dependent on the process step itself as well as the material characteristics and the location of the material. For example, for metal (discrete parts) the total cost is \$23.02 per kgU for the following processing steps: receive and transfer, in-process storage, flatten/break and/or shear, and in-process storage; while the total cost is \$169.18 per kgU for receive and transfer, lathe operation, in-process storage, and transfer and receive. The characterization cost model will be able to determine the costs to prepare material for blending by category of material and/or customer order once the product specification and delivery date is known. The generic costs for the processing steps are not included in this report; they will be validated and available in the data base.

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6. AVAILABILITY STATUS

The availability of the material is key to the success of the excess HEU MD program. There are several ways one could determine the availability. Availability could be determined based on:

1. the customer product specifications and delivery date requirements after the customer is identified;
2. the schedule when materials become available;
3. preprocessing capabilities of the DOE sites and the private sector;
4. requirements and schedules for packaging and transportation, or requirements and availability of containers;
5. current programmatic plans, in particular, priorities for funding; or
6. choice of blend stock.

In short, each project or specific customer order would make decisions that would drive the disposition. For example, USEC's decisions are driving the schedule for disposition of the 13 t of UF_6 . The 50 t also have a tentative schedule, but it is dependent on funding, available resources for processing, USEC's choice of a blending facility, the Memorandum of Agreement between USEC and the DOE, and legislative constraints on the sale of the material.

In any case, before commitments are made with respect to delivery dates, each customer's order should be projectized to ensure that the materials are available to meet the product requirements, and that the processing can be done (capabilities and funding available) to meet the delivery dates.

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APPENDIX A

TABLES

APPENDIX A

TABLES 1-6

Table 1 Processing Steps for Excess HEU. Category: Metal	A-3*
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Table 3 Processing Steps for Excess HEU. Category: Residues	A-20
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Table 5 Processing Steps for Excess HEU. Category: Combustibles.....	A-28
Table 6 Processing Steps for Excess HEU. Category: Non-Combustibles	A-33

* Table 1, Page 1 of 13 through Page 4 of 13, describe options for processing steps if metal is shipped directly to the blender. The options are defined as follows:

Option 1: Ship as classified shapes to the blender.

Option 2: Ship after parts are flattened, broken, and/or sheared.

Option 3: Ship after declassification.

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL – Direct to Blender

Page: 1 of 13

Process Steps	Building No.	METAL FORMS							
		Subassemblies and/or Units			Discrete Parts		Broken Pieces	Right Cylinders and/or Logs	
		Options			Options			Options	
1	2	3	1	2	1	2			
Transfer and Receive	9720-5	√	√	√	√	√	√	√	√
SNM Vehicle Move	9720-5 to	9204-2E	9204-2E	9204-2E	9212	9212	9212	9212	9212
Receive and Transfer In-Process Storage	9204-2E or 9212-C.	√	√	√	---	---	---	---	---
Disassemble In-Process Storage	9204-2E	√	√	√	---	---	---	---	---
Transfer and Receive	From 9204-2E	√	√	√	---	---	---	---	---

C. = Cast
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL – Direct to Blender

Page: 2 of 13

Process Steps	Building No.	METAL FORMS							
		Subassemblies and/or Units			Discrete Parts		Broken Pieces	Right Cylinders and/or Logs	
		Options			Options			Options	
1	2	3	1	2	1	2			
SNM Vehicle Move	9204-2E to 9212-C.	√	√	√	---	---	---	---	---
Receive and Transfer In-Process Storage	9212-C. or 9212-S. P.	√	√	√	√	√	√	√	√
Flatten/Break and/or Shear In-Process Storage	9212-C.	---	√	√	---	√	---	---	√

C. = Cast
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL – Direct to Blender

Page: 3 of 13

Process Steps	Building No.	METAL FORMS							
		Subassemblies and/or Units			Discrete Parts		Broken Pieces	Right Cylinders and/or Logs	
		Options			Options			Options	
		1	2	3	1	2		1	2
Batch Preparation Casting Stack Assembly Graphite Crucible Load Furn. Load and Evacuate Furnace Operation <i>(Melt and Pour)</i> Furnace Unload Casting Stack Disass'y Mold Disassembly Cast Part Cleaning In-Process Storage	9212-C.	---	---	√	---	---	---	---	---
Transfer <i>(Inside Move)</i>	To 9212-S. P.	---	√	√	---	√	---	---	√

C. = Cast
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL – Direct to Blender

Page: 4 of 13

Process Steps	Building No.	METAL FORMS							
		Subassemblies and/or Units			Discrete Parts		Broken Pieces	Right Cylinders and/or Logs	
		Options			Options			Options	
		1	2	3	1	2		1	2
Pack in DOT-Approved Container In-Process Storage	9212-S.P.	√	√	√	√	√	√	√	√
Transfer and Receive	From 9212-S.P.	√	√	√	√	√	√	√	√
SNM Vehicle Move	9212-S.P. to 9720-5	√	√	√	√	√	√	√	√
Receive and Transfer Interim Storage	9720-5	√	√	√	√	√	√	√	√

C. = Cast
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 5 of 13

Process Steps	Building No.	SUBCATEGORIES									
		METAL FORMS				ALLOYS					*CLAD MATERIAL (unirradiated)
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr	
Transfer and Receive	9720-5	√	√	√	√	√	√	√	√	√	
SNM Vehicle Move	9720-5 to	9204-2E	9212-C.	9212-C.	9212-C.	9212-C.	9212-C.	9212-C.	9212-C.	9212-C.	
Receive and Transfer In-Process Storage	9204-2E or 9212-C.	√	√	√	√	√	√	√	√	√	
Disassemble In-Process Storage	9204-2E	√	---	---	---	---	---	---	---	---	
Transfer and Receive	From 9204-2E	√	---	---	---	---	---	---	---	---	

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 6 of 13

Process Steps	Building No.	SUBCATEGORIES									
		METAL FORMS				ALLOYS					*CLAD MATERIAL (unirradiated)
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr	
SNM Vehicle Move	9204-2E to	9212-C.	---	---	---	---	---	---	---	---	
Receive and Transfer In-Process Storage	9212-C.	√	---	---	---	---	---	---	---	---	
Flatten/Break and/or Shear In-Process Storage	9212-C.	√	√	---	---	√	√	√	√	√	
Batch Preparation Casting Stack Assembly Graphite Crucible Load Furn. Load and Evacuate (continued on next page)	9212-C.	√	√	√	---	---	√	√	√	√	

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 7 of 13

Process Steps	Building No.	SUBCATEGORIES									
		METAL FORMS				ALLOYS					*CLAD MATERIAL (unirradiated)
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr	
Furn. Operation (Melt and Pour) Furn. Unload Casting Stack Disass'y Mold Disassembly Cast Part Cleaning In-Process Storage	9212-C.	√	√	√	---	√	√	√	√	√	
Transfer and Receive	9212-C.	√	√	√	√	√	√	√	√	√	
SNM Vehicle Move	to 9215	√	√	√	√	√	√	√	√	√	
Receive and Transfer	9215	√	√	√	√	√	√	√	√	√	

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 8 of 13

Process Steps	Building No.	SUBCATEGORIES								
		METAL FORMS				ALLOYS				
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr
Lathe Operation (Turn to Chips) In-Process Storage	9215	√	√	√	√	√	√	√	√	√
Transfer and Receive	9215	√	√	√	√	√	√	√	√	√
SNM Vehicle Move	to 9212-C.	√	√	√	√	√	√	√	√	√
Receive and Transfer	9212-C.	√	√	√	√	√	√	√	√	√
Chip Cleaning In-Process Storage	9212-C.	√	√	√	√	√	√	√	√	√

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 9 of 13

Process Steps	Building No.	SUBCATEGORIES								
		METAL FORMS				ALLOYS				
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr
Chip Drying Can and Weigh (approved type) In-Process Storage	9212-C.	√	√	√	√	√	√	√	√	√
Transfer (Inside Move)	To 9212-S.P.	√	√	√	√	√	√	√	√	√
Burn to Oxide	9212-S.P.	√	√	√	√	---	√	√	√	√
Screen		√	√	√	√	---	√	√	√	√
Blend		√	√	√	√	---	√	√	√	√
Sample (gU/g)	9212-S.P.	---	---	---	---	---	√	√	√	√
Sample (gU/g and U ²³⁵)		√	√	√	√	---	---	---	---	---
Can and Weigh (approved type)		√	√	√	√	---	√	√	√	√
In-Process Storage		√	√	√	√	---	√	√	√	√

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 10 of 13

Process Steps	Building No.	SUBCATEGORIES									
		METAL FORMS				ALLOYS					*CLAD MATERIAL (unirradiated)
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr	
Transfer (<i>Inside Move</i>)	To 9212-C.R.	---	---	---	---	√	√	√	√	√	
Dissolution (<i>HNO₃</i>)	9212-C.R.	---	---	---	---	√	√	---	√	---	
Dissolution [<i>HNO₃-Al(NO₃)₃-HF</i>]		---	---	---	---	---	---	√	---	√	
Dissolution (<i>Caustic Treatment</i>)		---	---	---	---	**	---	---	---	---	
Filter (<i>Solids to residue</i>)		---	---	---	---	√	√	√	√	√	
In-Process Storage		---	---	---	---	√	√	√	√	√	

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U_3O_8

Page: 11 of 13

Process Steps	Building No.	SUBCATEGORIES								
		METAL FORMS				ALLOYS				
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr
Evaporate	9212-C.R.	---	---	---	---	√	√	√	√	√
Primary Extraction		---	---	---	---	√	√	√	√	√
Strip Column		---	---	---	---	---	√	√	---	√
Evaporate		---	---	---	---	√	√	√	√	√
Secondary Extraction		---	---	---	---	√	√	√	√	√
Evaporate		---	---	---	---	√	√	√	√	√
Denitration (to UO_3)	9212-C.R.	---	---	---	---	√	√	√	√	√
Calcine (UO_3 to U_3O_8)	9212-C.R.	---	---	---	---	√	√	√	√	√
Screen										
Blend										
Sample (gU/g and U^{235})										
Can and Weigh (approved type)	9212-C.R.	---	---	---	---	√	√	√	√	√
In-Process Storage										

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 12 of 13

Process Steps	Building No.	SUBCATEGORIES									
		METAL FORMS				ALLOYS					*CLAD MATERIAL (unirradiated)
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr	
Transfer (Inside Move)	To 9212-S.P.	---	---	---	---	√	√	√	√	√	
Pack in DOT-Approved Container In-Process Storage	9212-S.P.	√	√	√	√	√	√	√	√	√	
Transfer and Receive	From 9212-S.P.	√	√	√	√	√	√	√	√	√	
SNM Vehicle Move	9212-S.P. to 9720-5	√	√	√	√	√	√	√	√	√	

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 1
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: METAL -- Converted to U₃O₈

Page: 13 of 13

Process Steps	Building No.	SUBCATEGORIES								
		METAL FORMS				ALLOYS				
		Sub-Assemblies and/or Units	Discrete Parts	Broken Pieces	Right Cylinders and/or Logs	Al	Mo	Nb	Ti	Zr
Receive and Transfer Interim Storage	9720-5	√	√	√	√	√	√	√	√	√

NOTES:

1. Assumed processing would begin with a transfer and SNM Vehicle move.
2. Assumed above subcategories would be taken to U₃O₈, pure or impure.
3. * Clad Material was not considered.
4. ** Caustic treatment is the preferred process for dissolution of Uranium Aluminum alloys. However, it is understood this process no longer exists at Y-12.
5. Oxidation of metal inside the casting furnace was considered but not included.
6. Assumed the pedigree of metal forms to be of weapons stream material, and no purification would be required.

C. = Cast
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 2
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMPOUNDS

Page: 1 of 4

Process Steps	Building No.	SUBCATEGORIES							
		Oxides (Pure)	Oxides (Impure)	Nitrates	Fluorides	Carbides	Oxides ZrO_2, ThO_2, BeO , and etc. *	Halides Other than Fluorides **	PU/EU ***
Transfer and Receive	From any MAA	√	√	√	√	√	√	√	
SNM Vehicle Move	To 9212-C.R.	√	√	√	√	√	√	√	
Receive Only In-Process Storage	9212-C.R.	√	√	√	√	√	√	√	
Calcine (to U_3O_8)	9212-C.R.	√	---	√	---	√	√		
Mill		---	---	√	√	√	√		
Screen		√	√	√	√	√	√		
Blend		√	√	√	√	√	√		
Sample (gU/g)		---	√	√	√	√	√		
Sample (gU/g and U^{235})		√	---	---	---	---	---		
Can and Weigh		√	√	√	√	√	√		
In-Process Storage		√	√	√	√	√	√		

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 2
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMPOUNDS

Page: 2 of 4

Process Steps	Building No.	SUBCATEGORIES							
		Oxides (Pure)	Oxides (Impure)	Nitrates	Fluorides	Carbides	Oxides ZrO_2, ThO_2 , BeO, and etc. *	Halides Other than Fluorides **	PU/EU ***
Dissolution (HNO_3)	9212-C.R.	---	✓	✓	---	✓	---		
Dissolution ($HNO_3 - Al(NO_3)_3 - HF$)		---	---	---	✓	---	✓		
Filter		---	✓	✓	✓	✓	✓		
In-Process Storage		---	✓	✓	✓	✓	✓		
Evaporate	9212-C.R.	---	✓	✓	✓	✓	✓		
Primary Extraction		---	✓	✓	✓	✓	✓		
Strip Column		---	---	---	✓	---	✓		
Evaporate		---	✓	✓	✓	✓	✓		
Secondary Extraction		---	✓	✓	✓	✓	✓		
Evaporate		---	✓	✓	✓	✓	✓		
Denitration (to UO_3)	9212-C.R.	---	✓	✓	✓	✓	✓		

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 2
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMPOUNDS

Page: 3 of 4

Process Steps	Building No.	SUBCATEGORIES							
		Oxides (Pure)	Oxides (Impure)	Nitrates	Fluorides	Carbides	Oxides ZrO ₂ , ThO ₂ , BeO, and etc. *	Halides Other than Fluorides **	PU/EU ***
Calcine (UO_3 to U_3O_8) Screen Blend Sample (gU/g and U^{235}) Can and Weigh In-Process Storage	9212-C.R.	---	✓	✓	✓	✓	✓		
Transfer (Inside Move)	To 9212-S.P.	✓	✓	✓	✓	✓	✓		
Pack In DOT-Approved Container In-Process Storage	9212-S.P.	✓	✓	✓	✓	✓	✓		

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 2
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMPOUNDS

Page: 4 of 4

Process Steps	Building No.	SUBCATEGORIES							
		Oxides (Pure)	Oxides (Impure)	Nitrates	Fluorides	Carbides	Oxides ZrO ₂ , ThO ₂ , BeO, and etc. *	Halides Other than Fluorides **	PU/EU ***
Transfer and Receive	From 9212-S.P.	√	√	√	√	√	√		
SNM Vehicle Move	9212-S.P. to 9720-5	√	√	√	√	√	√		
Receive and Transfer Interim Storage	9720-5	√	√	√	√	√	√		

NOTES:

1. • This material will be reviewed on receipt for appropriate type treatment required.
2. ** Same as * above.
3. ***This type material not included in this list.

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 3
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: RESIDUES

Page: 1 of 4

Process Steps	Building No.	SUBCATEGORIES				
		Dry Leachable Ash (Impure)	Wet Slurries	Reduction Residues	Discard Residues **	PU/EU Residues *
Transfer	From any MAA	√	√	√	---	
<p>NOTE: Residues are canned and run through a scanner (NDA) to determine uranium content to decide if processing is feasible.</p> <p>> 4000 PPM U^{235} and > 6000 PPM total U is processed.</p> <p>< 4000 PPM U^{235} and < 6000 PPM total U is treated as waste.</p>						
Mill Calcine Mill Screen Blend Sample (gU/g) Sample (gU/g and U^{235}) Can and Weigh In-Process Storage	9212-C.R.	--- --- --- --- √ √ --- √ √	--- √ √ √ √ √ --- √ √	√ √ √ √ √ √ --- √ √	--- --- --- --- √ --- √ √ √	

MAA = Material Access Area
 C. R. = Chemical Recovery
 S. P. = Special Processing

TABLE 3
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: RESIDUES

Page: 2 of 4

Process Steps	Building No.	SUBCATEGORIES				
		Dry Leachable Ash (Impure)	Wet Slurries	Reduction Residues	Discard Residues **	PU/EU Residues *
Dissolution (HNO_3) Filter In-Process Storage	9212-C.R.	√	√	√		
Evaporate Primary Extraction Evaporate Secondary Extraction Evaporate	9212-C.R.	√	√	√		
Denitration (to UO_3)	9212-C.R.	√	√	√		
Calcine (UO_3 to U_3O_8) Screen Blend Sample (gU/g and U^{235}) Can and Weigh In-Process Storage	9212-C.R.	√	√	√		

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 3
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: RESIDUES

Page: 3 of 4

Process Steps	Building No.	SUBCATEGORIES				
		Dry Leachable Ash (Impure)	Wet Slurries	Reduction Residues	Discard Residues **	PU/EU Residues *
Transfer (<i>Inside Move</i>)	To 9212-S.P.	√	√	√		
Pack in DOT-Approved Container In-Process Storage	9212-S.P.	√	√	√		
Transfer and Receive	From 9212-S.P.	√	√	√		
SNM Vehicle Move	9212-S.P. to 9720-5	√	√	√		

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 3
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: RESIDUES

Page: 4 of 4

Process Steps	Building No.	SUBCATEGORIES				
		Dry Leachable Ash (Impure)	Wet Slurries	Reduction Residues	Discard Residues **	PU/EU Residues *
Receive and Transfer Interim Storage	9720-5	√	√	√		

NOTES:

1. • This type material is not included in this listing.
2. ** Discard Residues will require disposition, which is unclear at this listing.

MAA = Material Access Area
C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 4
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: SOLUTIONS

Page: 1 of 4

Process Steps	Building No.	SUBCATEGORIES									
		UNH (Pure)	UNH (Impure)	Laboratory Solutions (1)	Oils/Organics	Chlorides (2)	Sulfates (2)	Phosphates	General Salvage (3)	Basic Caustic Pickling	PU/EU (4)
Transfer (As Required)	---	√	√	√	√	√	√	√	√	√	
N ₂ O ₄ Treatment	9212-C.R.	---	---	---	---	√	---	---	---	---	
Sr (NO ₃) ₂ Treatment		---	---	---	---	---	√	---	---	---	
Ba(NO ₃) ₂ Treatment		---	---	---	---	---	---	√	---	---	
Precipitation		---	---	---	√	---	---	---	---	---	
Filter		---	√	√	√	√	√	√	√	√	
Sample (gU/g)		---	√	√	√	√	√	√	√	√*	
Evaporate	9212-C.R.	---	√	---	---	√	√	√	√	---	
Primary Extraction		---	√	---	---	√	√	√	√	---	
Evaporate		√	√	---	---	√	√	√	√	---	
Secondary Extraction		√	√	---	---	√	√	√	√	---	
Evaporate		√	√	---	---	√	√	√	√	---	

* No uranium is expected in the caustic pickling solution.

TABLE 4
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: SOLUTIONS

Page: 2 of 4

Process Steps	Building No.	SUBCATEGORIES									
		UNH (Pure)	UNH (Impure)	Laboratory Solutions (1)	Oils/Organics	Chlorides (2)	Sulfates (2)	Phosphates	General Salvage (3)	Basic Caustic Pickling	PU/EU (4)
Denitration (to UO_2)	9212-C.R.	√	√	---	---	√	√	√	√	---	
Calcine (UO_2 to U_3O_8)	9212-C.R.	√	√	---	---	√	√	√	√	---	
Blend											
Sample (gU/g and U^{235})											
Can and Weigh											
In-Process Storage											

TABLE 4
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: SOLUTIONS

Page: 3 of 4

Process Steps	Building No.	SUBCATEGORIES									
		UNH (Pure)	UNH (Impure)	Laboratory Solutions (1)	Oils/Organics	Chlorides (2)	Sulfates (2)	Phosphates	General Salvage (3)	Basic Caustic Pickling	PU/EU (4)
Transfer (Inside Move)	To 9212-S.P.	√	√	---	---	√	√	√	√	---	
Pack in Approved DOT Container In-Process Storage	9212-S.P.	√	√	---	---	√	√	√	√	---	
Transfer and Receive	From 9212-S.P.	√	√	---	---	√	√	√	√	---	

TABLE 4
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: SOLUTIONS

Page: 4 of 4

Process Steps	Building No.	SUBCATEGORIES									
		UNH (Pure)	UNH (Impure)	Laboratory Solutions (1)	Oils/Organics	Chlorides (2)	Sulfates (2)	Phosphates	General Salvage (3)	Basic Caustic Pickling	PU/EU (4)
SNM Vehicle Move	9212-S.P. to 9720-5	√	√	---	---	√	√	√	√	---	
Receive and Transfer Interim Storage	9720-5	√	√	---	---	√	√	√	√	---	

NOTES:

1. Laboratory solutions will be processed based on chemical content.
2. The use of Chlorides and Sulfates are strongly discouraged.
3. The processing of General Salvage Solutions is costly, and solutions should be blended and sampled (gU/g) for economic consideration before processing.
4. PU/EU Solutions were not included.

TABLE 5
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMBUSTIBLES

Page: 1 of 5

Process Steps	Building No.	SUBCATEGORIES				
		Miscellaneous (Paper, Rags, Gloves, Wipes, Mop Heads, and etc.)	Bag Filters and Other Combustible Filters	Carbon and Graphite Scrap from Casting	Embedded EU in Plastic	PU/EU *
Transfer and Receive (As Required)	---	√	√	√	√	
SNM Vehicle Move	To 9212-C.R.	√	√	√	√	
Receive Only In-Process Storage	9212-C.R.	√	√	√	√	
Pre-Sorting (Remove Non-Combustibles)	9212-C.R.	√	√	---	---	
Gamma Scan (Remove Non-Contaminated)	9212-C.R.	√	√	√	√	

C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 5
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMBUSTIBLES

Page: 2 of 5

Process Steps	Building No.	SUBCATEGORIES				
		Miscellaneous (Paper, Rags, Gloves, Wipes, Mop Heads, and etc.)	Bag Filters and Other Combustible Filters	Carbon and Graphite Scrap from Casting	Embedded EU in Plastic	PU/EU *
Bag for Burning Incinerate Screen Mill (<i>Crush/Grind</i>) Blend Sample (<i>gU/g</i>) Can and Weigh In-Process Storage	9212-C.R.	√	√	√	√	
Dissolution (<i>HNO₃</i>) Filter In-Process Storage	9212-C.R.	√	√	√	√	

C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 5
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMBUSTIBLES

Page: 3 of 5

Process Steps	Building No.	SUBCATEGORIES				
		Miscellaneous (Paper, Rags, Gloves, Wipes, Mop Heads, and etc.)	Bag Filters and Other Combustible Filters	Carbon and Graphite Scrap from Casting	Embedded EU in Plastic	PU/EU *
Evaporate Primary Extraction Evaporate Secondary Extraction Evaporate	9212-C.R.	√	√	√	√	
Denitration (to UO_3)	9212-C.R.	√	√	√	√	
Calcine Screen Blend Sample (gU/g and U^{235}) Can and Weigh In-Process Storage	9212-C.R.	√	√	√	√	

C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 5
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMBUSTIBLES

Page: 4 of 5

Process Steps	Building No.	SUBCATEGORIES				
		Miscellaneous (Paper, Rags, Gloves, Wipes, Mop Heads, and etc.)	Bag Filters and Other Combustible Filters	Carbon and Graphite Scrap from Casting	Embedded EU in Plastic	PU/EU *
Transfer <i>(Inside Move)</i>	From 9212-C.R.	√	√	√	√	
Pack in DOT-Approved Container In-Process Storage	9212-S.P.	√	√	√	√	
Transfer and Receive	From 9212-S.P.	√	√	√	√	
SNM Vehicle Move	To 9720-5	√	√	√	√	
Receive and Transfer Interim Storage	9720-5	√	√	√	√	

C. R. = Chemical Recovery
S. P. = Special Processing

TABLE 5
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: COMBUSTIBLES

Page: 5 of 5

NOTES:

1. Combustibles are checked by a Gamma Scanner (NDA) to determine uranium content and if processing is feasible.

Combustible drums limited to 350 Grams U.

> 5 Grams U^{235} /Drum are to be processed.

< 5 Grams U^{235} /Drum are to be treated as waste.

2. PU/EU Combustibles are not included.

3. Combustibles could be processed through incineration, milled, screened, blended, sampled (gU/g and U^{235} Isotope), canned, weighed, and handled as residues or as a waste product.

TABLE 6
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: NON-COMBUSTIBLES

Page: 1 of 2

Process Steps	Building No.	SUBCATEGORIES			
		Filters (Metallic, Ceramics, and Other Non-Combustible Filters)	Metal Scrap (Piping, Hardware, Tools, and Etc.)	Glass	Plastics
Transfer and Receive (as required)	---	√	√	√	√
SNM Vehicle Move	To 9212 Chemical Recovery	√	√	√	√
Receive Only In-Process Storage	9212 Chemical Recovery	√	√	√	√
Gamma Scan (Remove Non- Contaminated Material)	9212 Chemical Recovery	√	√	√	√
Disassemble (Filters, Valves, and etc.)	9212 Chemical Recovery	√	√	---	---

TABLE 6
PROCESSING STEPS FOR EXCESS HEU

CATEGORY: NON-COMBUSTIBLES

Page: 2 of 2

Process Steps	Building No.	SUBCATEGORIES			
		Filters (Metallic, Ceramics, and Other Non-Combustible Filters)	Metal Scrap (Piping, Hardware, Tools, and Etc.)	Glass	Plastics
Vacuum Clean and Collect Dry Solids	9212 Chemical Recovery	√	---	---	---
Decontaminate using Water, Steam, HNO ₃ as required.	9212 Chemical Recovery	√	√	√	√
Filter Solutions	9212 Chemical Recovery	√	√	√	√
Burn (wet solids) Mill Screen Blend Sample (gU/g) Can and Weigh In-Process Storage	9212 Chemical Recovery	√	√	√	√

NOTES:

1. Solids are processed as Residues.
2. Solutions are processed as Solutions.

APPENDIX B

FIGURES

PROCESS FLOW DIAGRAMS (PFDs)

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APPENDIX B **FIGURES** **PROCESS FLOW DIAGRAMS (PFDs)**

Figure 1	Process Flow Diagram Category: Metal—Direct to Blender; Subcategory: Subassemblies and Units	B-3
Figure 2	Process Flow Diagram Category: Metal—Direct to Blender; Subcategories: Discrete Parts, Broken Pieces, and Right Cylinders/Logs	B-4
Figure 3	Process Flow Diagram Category: Metal—Converted to U_3O_8 ; Subcategory: Subassemblies and Units	B-5
Figure 4	Process Flow Diagram Category: Metal—Converted to U_3O_8 ; Subcategory: Discrete Parts	B-6
Figure 5	Process Flow Diagram Category: Metal—Converted to U_3O_8 ; Subcategory: Broken Pieces	B-7
Figure 6	Process Flow Diagram Category: Metal—Converted to U_3O_8 ; Subcategory: Right Cylinders/Logs	B-8
Figure 7	Process Flow Diagram Category: Metal—Converted to U_3O_8 ; Subcategory: Alloys	B-9
Figure 8	Process Flow Diagram Category: Compounds; Subcategory: All Types Except PU/EU	B-10
Figure 9	Process Flow Diagram Category: Residues; Subcategory: All Types Except Discards and PU/EU	B-11
Figure 10	Process Flow Diagram Category: Solutions; Subcategory: All Types Except PU/EU	B-12
Figure 11	Process Flow Diagram Category: Combustibles; Subcategory: All Types Except PU/EU	B-13
Figure 12	Process Flow Diagram Category: Non-Combustibles; Subcategory: All Types	B-14

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- DIRECT TO BLENDER
SUBCATEGORY: SUBASSEMBLIES AND UNITS

[1] OPTION 1 Ship as classified shapes to blender.

[2] OPTION 2 Ship after parts are flattened, broken, and/or sheared.

[3] OPTION 3 Ship after declassification.

Figure 1

PROCESS FLOW DIAGRAM
CATEGORY: METAL - DIRECT TO BLENDER
SUBCATEGORY: DISCRETE PARTS, BROKEN PIECES, AND RIGHT CYLINDERS/LOGS

Figure 2

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- CONVERTED TO U_3O_8
SUBCATEGORY: SUBASSEMBLIES AND UNITS

Figure 3

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- CONVERTED TO U_3O_8
SUBCATEGORY: DISCRETE PARTS

Figure 4

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- CONVERTED TO U₃O₈
SUBCATEGORY: BROKEN PIECES

Figure 5

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- CONVERTED TO U_3O_8
SUBCATEGORY: RIGHT CYLINDERS/LOGS

Figure 6

PROCESS FLOW DIAGRAM
CATEGORY: METAL -- CONVERTED TO U_3O_8
SUBCATEGORY: ALLOYS

Figure 7

PROCESS FLOW DIAGRAM
CATEGORY: COMPOUNDS
SUBCATEGORY: ALL TYPES EXCEPT PU/EU

Figure 8

PROCESS FLOW DIAGRAM
CATEGORY: RESIDUES
SUBCATEGORY: ALL TYPES EXCEPT DISCARDS AND PU/EU

Figure 9

PROCESS FLOW DIAGRAM
CATEGORY: SOLUTIONS
SUBCATEGORY: ALL TYPES EXCEPT PU/EU

Figure 10

PROCESS FLOW DIAGRAM
CATEGORY: COMBUSTIBLES
SUBCATEGORY: ALL TYPES EXCEPT PU/EU

Figure 11

PROCESS FLOW DIAGRAM
CATEGORY: NON-COMBUSTIBLES
SUBCATEGORY: ALL TYPES

Figure 12