BLENDING LOW ENRICHED URANIUM WITH DEPLETED URANIUM TO CREATE A SOURCE MATERIAL ORE THAT CAN BE PROCESSED FOR THE RECOVERY OF YELLOWCAKE AT A CONVENTIONAL URANIUM MILL

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ABSTRACT

Throughout the United States Department of Energy (DOE) complex, there are a number of streams of low enriched uranium (LEU) that contain various trace contaminants. These surplus nuclear materials require processing in order to meet commercial fuel cycle specifications. To date, they have not been designated as waste for disposal at the DOE’s Nevada Test Site (NTS). Currently, with no commercial outlet available, the DOE is evaluating treatment and disposal as the ultimate disposition path for these materials. This paper will describe an innovative program that will provide a solution to DOE that will allow disposition of these materials at a cost that will be competitive with treatment and disposal at the NTS, while at the same time recycling the material to recover a valuable energy resource (yellowcake) for reintroduction into the commercial nuclear fuel cycle.

International Uranium (USA) Corporation (IUSA) and Nuclear Fuel Services, Inc. (NFS) have entered into a commercial relationship to pursue the development of this program. The
program involves the design of a process and construction of a plant at NFS’ site in Erwin, Tennessee, for the blending of contaminated LEU with depleted uranium (DU) to produce a uranium source material ore (USM Ore™). The USM Ore™ will then be further processed at IUC’s White Mesa Mill, located near Blanding, Utah, to produce conventional yellowcake, which can be delivered to conversion facilities, in the same manner as yellowcake that is produced from natural ores or other alternate feed materials. The primary source of feed for the business will be the significant sources of trace contaminated materials within the DOE complex.

NFS has developed a dry blending process (DRYSM Process) to blend the surplus LEU material with DU at its Part 70 licensed facility, to produce USM Ore™ with a U⁰²³⁵ content within the range of U⁰²³⁵ concentrations for source material. By reducing the U⁰²³⁵ content to source material levels in this manner, the material will be suitable for processing at a conventional uranium mill under its existing Part 40 license to remove contaminants and enable the product to re-enter the commercial fuel cycle. The tailings from processing the USM Ore™ at the mill will be permanently disposed of in the mill’s tailings impoundment as 11e.(2) byproduct material.

Blending LEU with DU to make a uranium source material ore that can be returned to the nuclear fuel cycle for processing to produce yellowcake, has never been accomplished before. This program will allow DOE to disposition its surplus LEU and DU in a cost effective manner, and at the same time provide for the recovery of valuable energy resources that would be lost through processing and disposal of the materials.

This paper will discuss the nature of the surplus LEU and DU materials, the manner in which the LEU will be blended with DU to form a uranium source material ore, and the legal means by which this blending can be accomplished at a facility licensed under 10 CFR Part 70 to produce ore that can be processed at a conventional uranium mill licensed under 10 CFR Part 40.

INTRODUCTION

Throughout the DOE’s nuclear complex, there are significant volumes of nuclear materials, including LEU and DU bearing materials, which are the byproducts of DOE activities. Many of these surplus materials are of no value because trace contaminants make them unfit for sale and/or use in the commercial nuclear fuel marketplace, and they cannot be directly disposed of as waste because they do not satisfy NTS waste acceptance criteria (WAC).

NFS and IUSA have devised a joint program (USM Ore™ Program) that provides DOE with an option for the final disposition of many of its surplus nuclear materials. This option will result in energy generation benefits by recycling these otherwise valueless surplus nuclear materials at a cost which IUSA and NFS can demonstrate will be competitive with the cost of treatment and/or disposal.

The USM Ore™ Program involves the development of a process and construction of a plant at NFS’ site in Erwin, Tennessee, to blend currently unusable LEU with DU to produce a licensed, refined or processed uranium source material ore. The USM Ore™ will be further processed at IUSA’s White Mesa Mill (White Mesa Mill or Mill), located near Blanding, Utah, as an alternate feed material¹, to produce conventional yellowcake, which can be delivered to conversion facilities in the same manner as yellowcake produced from natural ores or other alternate feed materials. The primary source of feed for the USM Ore™ Program will be the

¹ Alternate Feed Materials are uranium bearing materials, such as wastes or residues from other processing facilities that are not conventionally mined uranium ores.
aforementioned sources of currently unusable surplus nuclear materials within the DOE complex.

Under its Nuclear Regulatory Commission (NRC) Source Materials License (SUA-1358), the White Mesa Mill is licensed under 10 CFR Part 40 (Part 40) to receive and process conventionally mined natural uranium ores. Over 28 million pounds of yellowcake (U₃O₈) and 47 million pounds of vanadium product have been recovered from conventionally mined ores since the White Mesa Mill commenced operations in 1980. IUSA and the White Mesa Mill have been pioneers in the development of alternate feed processing at licensed uranium mills to recover valuable uranium energy resources, which would otherwise be lost to direct disposal.

Since 1994, IUSA has received 14 NRC-approved license amendments to process 17 different alternate feed materials (including DOE materials) for uranium recovery and has disposed of the resulting wastes (including tailings) in its NRC-licensed uranium mill tailings impoundments as 11e. (2) byproduct material. Since 1994, the White Mesa Mill’s alternate feed program has resulted in the recovery of over 1.1 million pounds of yellowcake that would otherwise have been lost to direct disposal.

NFS is a Category 1 nuclear fuel facility, located in Erwin, Tennessee, licensed under 10 CFR Part 70 (Part 70) to possess and maintain enriched uranium in any non-pyrophoric form at any enrichment level including, specifically, special nuclear material in the form of LEU and high enriched uranium (HEU). NFS is also licensed by the State of Tennessee to possess, store, and transfer or transport natural uranium, DU, and natural thorium (source material) in any form.

Since 1957, NFS has been a leader in the process development and production of specialty nuclear fuels for commercial power reactors, as well as research and naval reactors. NFS is the supplier of HEU fuel for the United States Navy’s fleet of nuclear submarines and aircraft carriers. NFS has also developed and implemented a process for downblending surplus HEU from nuclear weapons into fuel for nuclear power reactors.

**THE USM Ore™ PROGRAM**

**Overview of the Process**

Fluor Fernald contracted with NFS in 2000 to evaluate various methods of processing surplus nuclear materials stored at DOE’s site at Fernald, Ohio, to produce homogeneous, non-hazardous material suitable for alternate feed processing at a licensed uranium mill. For this purpose, NFS applied its technology to process LEU (0.725 to 5.0 wt% enriched U²³⁵) surplus nuclear materials. The DRY℠ Process is designed as a drypowder blending process in order to achieve economically viable throughput rates and to minimize a variety of potentially complicating factors which could arise with a wet blending process. The process is designed to size-reduce feed materials containing LEU and DU, convert these feed materials to an oxide (LEU₃O₈ and DU₃O₈), and downblend the LEU₃O₈ with DU₃O₈ and/or normal or natural U₃O₈ using a dry blending process, to create a homogeneous USM Ore™ (0.700-0.724 wt% U²³⁵), within the range of U²³⁵ concentrations of source material and suitable for processing at an NRC-licensed uranium mill under Part 40. After the downblending process is complete, the USM Ore™ (source material ore) will then be transported to the White Mesa Mill in accordance with all applicable DOT and NRC regulations and processed as an alternate feed material for the

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2 11e.(2) byproduct material is defined as, “the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.” See 42 U.S.C. § 2014(e)(2).
concentration, purification and recovery of the contained source material (U₃O₈). The resulting product from this processing operation will be yellowcake, which will be suitable for introduction into the commercial nuclear fuel cycle for conversion, enrichment and fuel fabrication.

**Description of Feed Materials**

Generally, the process is equipped to handle LEU in enrichments up to 5% and DU in any form, such as unalloyed uranium metals, clad metals, oxides and other miscellaneous non-irradiated materials with various levels of contaminants.³

As of June of 2000, DOE’s inventory of surplus LEU materials exceeded 4,700 metric tons of uranium (MTU). Most of DOE’s inventory of surplus LEU materials is in the form of alloyed and unalloyed metals and oxides. Additional excess LEU materials are designated as programmatic and held in inventory. These surplus LEU materials are considered problematic in that:

- In most cases, processing/downblending is required to meet current WAC for disposal at NTS; and
- Without further processing, trace radioactive and non-radioactive contaminants in the materials exceed current ASTM standards for re-introduction into the commercial nuclear fuel cycle.

As a result, DOE has not yet determined a final disposition path for such materials. DOE is currently analyzing the value of downblending its inventory of LEU for commercial sale under the USM Ore™ Program and will compare that value with the cost of treatment and direct disposal. Delivering such materials into the USM Ore™ Program will eliminate the need to process for disposal. The feed materials evaluated to date will provide more than four (4) years of processing with additional surplus nuclear materials within the DOE complex that may provide feed for another six (6) plus years or more of operations.

**Downblending at the NFS Site**

Feed materials destined for use in the USM Ore™ Program will be transported from various DOE sites to the NFS facility in Erwin, Tennessee in accordance with applicable DOT and NRC regulations, where they will be stored pending processing.

The overall DRYSM Process is comprised of the blending of powdered LEU with powdered DU to form a homogeneous blended powder having U²³⁵ concentrations within the range for source material uranium. The final product drums will be mixed and then analytically characterized for product quality assurance with the finished product being the USM Ore™, a high-percent uranium processed source material ore (approximately 20-90+ percent uranium, by weight), which is suitable for processing at the White Mesa Mill for the concentration/purification and recovery of its U₃O₈ content.

³ Subject only to the requirement that the ultimate USM Ore™ must meet certain specified feed acceptance criteria for the Mill.
Receipt and Processing at the White Mesa Mill

Upon receipt of the USM Ore™ at the White Mesa Mill, IUSA will perform inspections and analyses in order to confirm that the material meets the Feed Acceptance Criteria for the Mill. Under these Feed Acceptance Criteria, the USM Ore™ must be a homogeneous blend, with a particle size of less than 100 microns, that contains various levels of metal and radionuclide contaminants below certain specified limits.

Once the USM Ore™ is introduced into the White Mesa Mill’s process circuit, it will be processed in a fashion similar to other alternate feed materials and natural ores. This process will involve acid dissolution, followed by solvent extraction/ion exchange and/or precipitation, and, finally, yellowcake drying and packaging. While in the White Mesa Mill’s process circuit, any radiological or non-radiological contaminants in the USM Ore™ will be reduced to acceptable levels, and the wastes resulting from this processing operation will be discharged into the White Mesa Mill’s NRC-licensed tailings impoundments in the same fashion as the tailings and raffinate from other alternate feed processing. The resulting yellowcake product from the Mill’s process circuit will be suitable for re-introduction into the commercial nuclear fuel cycle at the conversion and, later, the enrichment stages.

Project Phases and Expected Levels of Production

Assuming receipt of all applicable NRC Part 40 regulatory approvals for the Mill and Part 70 regulatory approvals for the NFS site, the first phase of the USM Ore™ Program will be to design, construct, and operate a DRY™ processing plant. The DRY™ processing plant will be constructed and tested at NFS’ site in Erwin, Tennessee, under its Part 70 license. Upon successful completion of startup testing, the next phase of the program will involve commercial production of USM Ore™, which IUSA and NFS currently expect will last at least four (4) years, and could last longer depending on the amount of DOE surplus nuclear materials that are available for this program. Commercialization is expected to result in the production of approximately two million pounds of yellowcake per year.

OVERVIEW OF REGULATORY FRAMEWORK AND REGULATORY ISSUES TO BE ADDRESSED

The concept of downblending LEU with DU and natural or normal uranium to form a licensed, refined or processed source material ore may seem unusual, because, to the best of IUSA’s and NFS’ knowledge, it has never been conducted on a commercial basis. However, downblending, in and of itself, is not unusual. Indeed, there is significant precedent available (past and present) for downblending nuclear materials or other types of recycling to reconfigure such materials for useful purposes. The so-called “Megatons to Megawatts” program is currently a high visibility example of the feasibility and benefits of downblending. Thus, the question is not whether this downblending/recycling process can be accomplished on a technical basis, but whether or not it can be accomplished commercially in an economically viable manner. The DRY™ Process developed by NFS and IUSA under the USM Ore™ Program

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4 The Megatons to Megawatts program is the downblending of HEU to 4.95% LEU for use in conventional nuclear reactors.
allows this to be accomplished for the first time in a commercially viable manner without raising any significant, incremental threats to public health and safety or the environment.

**White Mesa Mill**

The White Mesa Mill operates under Source Material License SUA-1358 (Mill License), under which IUSA is authorized to receive and process natural uranium and natural uranium/vanadium ores primarily for the recovery of uranium (source material), alone or together with vanadium. The resulting tailings from such processing are disposed of in the White Mesa Mill’s NRC-licensed uranium mill tailings impoundments as 11e.(2) byproduct material.

IUSA’s Part 40 license allows for the possession of natural uranium as defined under 10 C.F.R. Part 40.4. NRC generally has interpreted this definition to mean natural uranium in conventional ores, because its underlying Final Generic Environmental Impact Statement on Uranium Milling (GEIS) and Part 40’s Appendix A Criteria only addressed such ores and not alternate feed materials. As a result, NRC has traditionally required that uranium recovery licensees, such as IUSA, request license amendments in order to process alternate feed materials. Therefore, IUSA will require an NRC-approved license amendment to receive and process USM Ore™.

Since 1994, IUSA has received 14 license amendments to process alternate feed materials at the White Mesa Mill, primarily for the recovery of uranium alone or together with other metals (e.g., tantalum), with the resulting tailings being classified as 11e.(2) byproduct material. NRC has published its Interim Position and Guidance on the Use of Uranium Mill Feed Material Other than Natural Ores (Alternate Feed Guidance), which sets forth the criteria NRC will apply when considering an application from an NRC licensee for a license amendment authorizing the receipt and processing of an alternate feed material. NRC’s Alternate Feed Guidance lists four (4) requirements that must be satisfied before any alternate feed license amendment will be granted.

First, the proposed alternate feed material must qualify as a source material ore. Under the AEA, as amended, and as noted above, 11e.(2) byproduct material is defined as “the tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content.” Accordingly, if a proposed alternate feed material does not qualify as ore, wastes resulting from its processing would not be classified as 11e.(2) byproduct material for disposal in an NRC-licensed uranium mill tailings impoundment. Although UMTRCA does not specifically define what constitutes “any ore”, the Commission has developed the following definition:

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5 NRC, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, Volume 1 (September, 1980).

6 Recently, NRC has also adopted the practice of preparing an environmental assessment (EA) to evaluate the potential incremental impacts, if any, of such license amendments. Thus, this EA must be completed before a license amendment will be granted.

7 Interim Position and Guidance on the Use of Uranium Feed Material Other Than Natural Ores, Fed Reg October, 2000.
“[A] natural or native matter that may be mined and treated for the extraction of any of its constituents or any other matter from which source material is extracted in a licensed uranium or thorium mill.”

This definition is sufficiently broad so that secondary processing wastes from other mineral recovery operations (e.g., yttrium-lanthanides recovery) and wastes from the treatment of mine water having significant uranium content may qualify as ores. As in its previous version of the Alternate Feed Guidance, NRC Staff concluded that the use of the phrase any ore, rather than the phrase unrefined and unprocessed ore in the definition of 11e.(2) byproduct material, suggested that it would be consistent with Congressional intent to include a broad range of materials in the definition of ore. Thus, materials that already have been subjected to processing can qualify as refined or processed ores, and such materials, when processed primarily for their source material content, will yield wastes that are classified as 11e.(2) byproduct material.

Second, NRC’s Alternate Feed Guidance states that any material containing a listed hazardous waste subject to EPA/RCRA regulation cannot be processed as an alternate feed material. Alternate feed materials (except sludge from the treatment of wastewater) may exhibit only characteristics of hazardous waste (i.e., ignitability, toxicity, etc.)

Third, an NRC licensee must demonstrate that the ore is being processed primarily for its source material content. This fundamental requirement is also based on the definition of 11e.(2) byproduct material, which requires that the ore must be processed primarily for its source material content. This has been interpreted by the Commission to mean that the ore must, in fact, be processed at a licensed uranium mill for the recovery of uranium, and it must be, at a minimum, reasonable to expect that uranium will be recovered from the processing.

Finally, a licensee must demonstrate that the receipt and processing of the alternate feed material and the disposal of the resulting tailings will comply with the mill’s license and all Part 40 requirements and Appendix A Criteria, including any National Environmental Policy Act (NEPA) analyses that have previously been performed for the site.

In its application for approval to NRC, IUSA will demonstrate that USM Ore™ is a licensed, refined or processed source material ore that may be processed at the White Mesa Mill as an alternate feed material primarily for the recovery of its source material content, with the resulting tailings being disposed of as 11e.(2) byproduct material in the White Mesa Mill’s existing tailings impoundments. All this will be done in accordance with the White Mesa Mill’s Part 40 license, NRC’s Alternate Feed Guidance, and applicable Part 40 requirements and Appendix A Criteria. A brief listing of the various regulatory matters that must be addressed in order to arrive at this conclusion is set forth below.

9 40 CFR § 261.2(c)(3).
10 The recent IUSA alternate feed license amendment proceeding involving the receipt and processing of the Molycoorp alternate feed material provides additional support for the proposition that source material ore is expressly exempt from RCRA and, thus, may be processed as an alternate feed without jeopardizing the eventual transfer of 11e.(2) tailings impoundments to the mandatory federal long-term custodian (i.e., DOE).
Nuclear Fuel Services

The feed materials for the USM Ore™ Program, which will be comprised of LEU, DU, and natural or normal uranium will be delivered to a facility at NFS’ site, which will be operated under a Part 70 license (for LEU activities) and under a State of Tennessee license (for source material, i.e., natural uranium, normal uranium and DU, activities).

The Part 70 license at the Erwin, Tennessee site will contain all of the relevant terms, conditions and safeguards applicable to a Part 70 facility of this nature. A condition of this Part 70 license will be that all nuclear safety issues associated with handling LEU will be adequately and safely dealt with on-site, and that there can be no nuclear safety issues associated with USM Ore™ once it leaves the purview of the Part 70 license.

Regulatory Matters to be Addressed

In order for the USM Ore™ to be processed at the White Mesa Mill as an alternate feed material under NRC’s Alternate Feed Guidance, IUSA must obtain an amendment to its Part 40 license. The application, which includes an Environmental Report under NEPA and a White Paper which addresses all related regulatory and legal matters, is expected to be submitted to the NRC in the first quarter of 2003. The application will demonstrate the following to the NRC:

- It is possible to downblend LEU with DU and/or natural or normal uranium to create a source material ore. As mentioned above, there is ample technical and regulatory precedent for this type of activity. The question is whether or not it can be accomplished on a commercial basis. IUSA and NFS believe that the USM Ore™ Program will accomplish this on a commercially viable basis, and in a manner that is cost-competitive with direct disposal;

- In order to be considered source material and, hence, source material ore, the USM Ore™ will be blended such as to contain between 0.700 and 0.724 weight percent U^{235}. This is the range for normal uranium, which both NRC and DOE have classified as source material.

- If blended to the specifications detailed in the previous paragraph, the USM Ore™ will be an ore within the meaning of the NRC’s Alternate Feed Guidance.

- The USM Ore™ will not contain any listed hazardous waste subject to EPA (or state) jurisdiction under RCRA. The USM Ore™ will be a product (i.e., an ore) and not a waste. Moreover, as a source material ore it will be exempt from RCRA, regardless of its chemical or metal composition.

- The White Mesa Mill will be processing the USM Ore™ primarily for its source material content, with the result that the tailings will be 11e.(2) byproduct material that can be disposed of in the White Mesa Mill’s existing tailings impoundments. Even though the USM Ore™ will contain high levels of uranium prior to processing at the Mill, the Mill will nevertheless be extracting or concentrating/purifying uranium from the ore, within the meaning of NRC’s Alternate Feed Guidance.
• Processing the USM Ore™ at the White Mesa Mill will comply with Part 40 and Appendix A thereto, and will be consistent with previous NEPA evaluations for the Mill. IUSA is preparing a detailed Environmental Report under NEPA, which arrives at the conclusion that a Finding of No Significant Impact (FONSI) would be appropriate. In fact, as the quantity of tailings will be only a very small fraction of the tailings that would normally be produced from milling natural mined ores, and as the tailings will contain virtually no radium, and hence will emit virtually no radon, the potential environmental impacts will be less than those for milling natural ores; and

• There are no regulatory or environmental, health and safety concerns at the conversion, enrichment, fuel fabrication or other stages of the nuclear fuel cycle.

CONCLUSION

Under the USM Ore™ Program LEU can be downblended with DU and/or natural or normal uranium to form a source material ore, for the first time on a commercially viable basis. Moreover, the USM Ore™ Program allows the USM Ore™ to be re-introduced at the milling and conversion stages of the nuclear fuel cycle, thereby promoting the on-going viability of these facilities while uranium prices are too low to justify production at conventional uranium mills from natural ores. Successful initiation of the USM Ore™ Program will result in the production of approximately two (2) million pounds of uranium per year for four (4) years or longer. This uranium will be used to provide electricity, rather than create a waste liability that requires shallow-land burial with associated long-term custodial requirements and costs.

DOE will also benefit because it will no longer have to expend the financial resources necessary to manage its inventory of surplus nuclear materials, and long-term management of the wastes generated from processing the USM Ore™ will be returned to DOE upon closure of the White Mesa Mill at no cost to the government. Further, DOE will also be following the mandate of Congress “to support a domestic uranium enrichment industry in the short and long-term…including the domestic conversion and mining industries.”¹¹ As noted in its Report to Congress on Maintenance of Viable Domestic Uranium, Conversion and Enrichment Industries, DOE stated, “[a] key portion of the Secretary [of Energy’s]…plan is the demonstration of U.S. origin technology in order to satisfy national security objectives.” This is a rare situation wherein NRC can: (1) develop domestic-based technology; (2) promote the recycling and preservation of valuable energy resources (yellowcake); (3) expedite safe and efficient waste disposal; (4) support and maintain the front end of the domestic nuclear fuel cycle; (5) reduce costs to DOE and the American public; and (6) assure adequate protection of public health, safety and the environment.