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For: The Commissioners

From: James M. Taylor
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Subject: DISPOSITION OF DEPLETED URANIUM TAILS FROM ENRICHMENT PLANTS

Purpose: To inform the Commission of the expected evolution of a unique licensing issue related to uranium enrichment plants.

Summary: This paper informs the Commission of a unique licensing issue related to disposition of depleted uranium tails from enrichment plants. In the past, depleted uranium tails have been considered a resource, not a waste. Presently, there is a surplus of these tails in the Western World. The U.S. Department of Energy (DOE) now has about one billion pounds of depleted uranium hexafluoride tails in storage. The U.S. Nuclear Regulatory Commission (NRC) soon expects to start a licensing review of an enrichment facility. In accordance with newly revised legislation, this will require NRC staff to prepare an environmental impact statement (EIS). The disposition of these tails will be considered in the EIS. The NRC staff does not know yet what DOE or the private sector will decide on the disposition of depleted uranium tails. This paper discusses plausible strategies to be considered. Since this paper is for information only, it does not contain recommendations. Because the expected evolution of the tails disposition issue is apparent, the staff hopes to obtain Commission comment if the Commission wishes to redirect that evolution, or to have now a more explicit Commission action on the issue.

Background: As part of the development of atomic weapons in the early 1940's, uranium enrichment received its primary impetus from the United States (U.S.) Manhattan Engineer District Project. For many years, until the early 1970's, the U.S. was almost the sole supplier of uranium enrichment services for industrial applications and to the commercial reactor industry in the Western world. The U.S. Atomic Energy Commission (AEC), later replaced by the U.S. Energy Research and Development Administration, initially provided these services. Presently, the U.S. Department of Energy (DOE) supplies such services.

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Today, world production of enriched uranium is achieved primarily through gaseous diffusion and gas centrifuge processes. Laser techniques such as atomic vapor laser isotope separation (AVLIS) are still in the developmental stage. The readily volatile uranium hexafluoride (UF_6) is the chemical form enrichment plants use, in the present production methods, as feed material.

As a result of experiments conducted during the Manhattan Project, the centrifuge process was considered the most likely to succeed in separating uranium isotopes. However, gaseous diffusion prevailed over the centrifuge method because of the engineering problems the latter method presented at the time. Eventually, these engineering problems were resolved. Since the gas centrifuge technique is well suited for the separation of heavy isotopes, it is now one of the enrichment processes used in both Europe and the Far East (Japan). In the U.S., Louisiana Energy Services (LES) is proposing to construct a gas centrifuge facility.

After passing through an enrichment plant, natural uranium hexafluoride is separated into two fractions. The smaller of these fractions is the U-235 enriched product and the larger fraction is the U-235 depleted tails. If 3 percent U-235 enriched product with a tails assay of 0.2 percent U-235 is desired, 4.5 tonnes* of tails would be generated for every tonne of product. At a tails assay of 0.3 percent U-235, about 5.6 tonnes of tails would be generated for every tonne of product. In other terms, for these typical conditions, only 12 to 15 percent of the feed material ends up as product; the remainder becomes tails.

<u>Discussion</u>: Since the early 1940's, the U.S. Government has been enriching uranium and saving virtually all the tails as depleted UF_6 (DUF_6). These tails have been considered a resource, not a waste, because of uses for depleted uranium metal and the potential use of depleted uranium oxide as breeder reactor blanket fuel. Laser isotope separation techniques such as AVLIS, if commercialized, could also be used to recover most of the U-235 in these tails. However, there would be a tradeoff on whether to feed AVLIS with DUF_6 tails or natural uranium at current low prices. The depleted uranium metal is used in munitions, tank armor, aircraft counter-weights, and radiation shielding in transport casks for radioactive material. However, because the U.S. does not have a breeder reactor program, the demand for DUF_6 is much less than the production rate, even with military uses.

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* In the uranium enrichment industry, metric and English units are used interchangeably. The shipping cask's capacity is given in pounds, kilograms (kg) and short tons (2,000 pounds). Yet, the amount of enriched product and tails is given in kilograms and metric tons or tonnes (1,000 kg or about 2,200 pounds).

Usually, DUF_6 is stored outdoors, at the gaseous diffusion plants, in Model 48G cylinders, with about 28,000 pounds (12,700 kg) maximum fill limit. (The 48G cylinder itself weighs about 2,600 pounds). DOE now has on the order of 500 $\times 10^6$ kg of DUF_6 (500,000 tonnes or about one billion pounds) in storage, mainly in 48G cylinders. Presently, there are various sizes of cylinders used for storage. For simplicity, if all cylinders are assumed to be the 48G type, and filled to the maximum limit, the DOE inventory of cylinders is approximately 40,000. In the past, the staff was not aware that DOE had any specific plans for disposition of DUF_6. However, recent communications with DOE personnel seem to indicate that they are studying various options for disposition of this material. It should be stressed that DOE does not consider DUF_6 as waste, but as a resource material.

In contrast, at the COGEMA center located in Pierrelatte, France, the DUF_6 tails from the EURODIF enrichment plant have been partially recycled since 1984. The French Ministry of Industry limits the quantity of DUF_6 tails that can be stored onsite at the enrichment plant. For this reason, COGEMA's W Plant was commissioned to convert DUF_6 tails into U_3O_8 for safer storage and reuse in due time,* and into hydrofluoric acid (HF) aqueous solution for current commercial use. Based on information from COGEMA, and staff calculations, the cost of conversion would add to the price of product a percentage roughly equivalent to the percent of U-235 enrichment in the product, e.g., if the product were 3.7 percent enriched, the added price per kilogram of product would be about 3.7 percent.

It should be noted that HF is a very reactive and corrosive chemical that may cause unusually severe burns. Special precautions must be taken when handling it. These characteristics make manufacturing relatively expensive. Yet, it is marketable because of its wide commercial applications. HF, marketed in solution strengths of 30, 51, 60, and 80 percent, is used for etching glass and for cleaning metals, (i.e., as pickling acid in stainless-steel and non-ferrous metal manufacture).

There are large capital expenditures involved in setting up a defluorination plant similar to COGEMA's. But once this initial investment is made, this expenditure may be offset by having the uranium as U_3O_8, a more stable form than UF_6, and by potentially marketing the HF for other commercial uses. Presently, there are four major companies in the U.S.

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* The U_3O_8 might be used in France's breeder reactor program or in its developing laser enrichment program.

with a total annual production capacity of about 218,000 tons (198×10^6 kg) of HF. Anhydrous HF sells for about $1,375/ton, and for $1,000/ton if it is 70 percent HF aqueous solution.

In addition, the U.S. supply monopoly of the uranium enrichment market has changed considerably since the late 1970's. Competition has created a DOE over-capacity estimated at around 6,000 tonnes of Separative Work (SW)* per year in 1990 with no significant change forecast for the next five years.

It is likely that DUF_6 will sooner or later be treated as a waste, since there is such a surplus of depleted uranium available. If so, it is a unique form of low-level waste that would require disposal.

The development of review procedures and licensing requirements for the disposal of UF_6 tails to be generated by an enrichment facility depends on the evaluation of several factors.

These factors are:

1. Determination of whether tails are a waste or resource

2. Assessment of the production rate and the chemical and radiological characteristics of the final form of the enrichment process tails

3. Determination of the proper waste classification for tails

4. Analysis of disposal options

Each of these factors is discussed in the enclosure.

Notwithstanding these considerations, NRC soon expects to start a licensing review for an enrichment facility. In accord with newly revised legislation, this will require NRC staff to prepare an EIS. The disposition of tails will be considered in the EIS. The NRC staff does not know yet what DOE or the private sector will decide on the disposition of DUF_6.

Political and economic factors will undoubtedly have an impact on their course of action. Nevertheless, to give the Commission a general idea of plausible strategies, this paper discusses some, based on present state-of-the-art technology.

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* A Separative Work Unit (SWU) or tonne of SW is a measure of the effort necessary to enrich uranium in the U-235 isotope, and is the basis for the sale of uranium enrichment services. A typical 1,200-megawatt nuclear power plant requires about 30 tonnes of enriched uranium per year, equivalent to about 130,000 SWUs.

The plausible strategies to be considered include:

1. Maintain the current practice in the U.S. and store DUF_6 at an enrichment plant site. If a licensee were to pursue this strategy, NRC would have to impose certain conditions such as inspection, surveillance, and maintenance programs. The staff does not expect these programs to have much impact on NRC resources. Storage appears to be relatively cheap and safe. DOE has found few incidents and safety problems in storing DUF_6 over long periods. As UF_6, the material is considered a resource, and it may offer flexibility to convert to a more desirable chemical form in the future. For example, it may be cheaper to convert DUF_6 to a more suitable chemical form for AVLIS feed.

   On the other hand, this approach leaves open the questions of final disposal if DUF_6 were ultimately considered to be a waste and not a resource. If released, it may pose potential hazards, [e.g., produces toxic compounds (HF and UO_2F_2) upon reacting with moisture in ambient air]. NRC could be open to criticism for not determining final disposition of this licensed material at an early stage.

2. Continuously convert DUF_6 during the enrichment production and dispose of converted product. As mentioned previously, France is converting some of the DUF_6 to U_3O_8, which is a more stable and environmentally safe form of uranium. Yet, it is still a resource. In addition, HF, which is a byproduct of this conversion, is sold in France for other commercial uses. As U_3O_8, the material may be stacked in storage containers, saving storage space. If considered a waste, it could be disposed of by placement in a mill tailings impoundment or in a LLW facility. (See enclosure.) There are also political and economic implications involved in these possible forms of disposal. This strategy requires less complex surveillance and maintenance programs at the enrichment plant site. But the conversion process is relatively expensive. It will also involve NRC resources to license and inspect the new conversion facility.

3. Conversion of DUF_6 at end of plant life and disposition of converted material. This is a combination of Strategies 1 and 2, with similar advantages and disadvantages. Ultimate disposition of U_3O_8, or any other form of converted product, must be made in due time. This material may be used as a resource for not yet defined uses, in the future. As mentioned in Strategy 2, if U_3O_8 is considered a waste, it will require final disposal (See enclosure).

Conclusions: The need to address the final disposition of DUF_6 tails from the enrichment plant has been discussed with the prospective applicant, LES. However, LES has not indicated its choice of options. Under 10 CFR 70.25, the applicant must provide financial assurances for decommissioning. Since NRC does not regulate DOE, this will have an economic effect on LES but not on DOE. As discussed previously, defluorination of DUF_6 is currently being done in France. Annually, the major products at the COGEMA defluorination plant are 7,000 tonnes of U_3O_8, which are stored as a future fuel resource, and 4,300 tonnes of 70 percent aqueous solution of HF, which are sold for current industrial applications.

There are several factors that will influence LES' (or any other U.S. enrichment plant's) final disposition of DUF_6. There are large capital expenditures involved in setting up a defluorination plant similar to COGEMA's. But once this initial investment is made, this expenditure may be offset by having the uranium as U_3O_8, a more stable form than UF_6, and by potentially marketing the HF for other commercial use. In the future, there may be reasons to restrict or limit the amount of DUF_6 stored on site. In conclusion, disposition of tails from an enrichment plant presents a unique licensing issue. The staff anticipates that these issues will be further evaluated in the EIS for the LES plant and in the licensing process.

Coordination: The Office of the General Counsel has reviewed this paper and has no legal objection.

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Enclosure:
Factors Involved in the Disposition of Depleted Uranium Hexafluoride (DUF_6) Tails

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FACTORS INVOLVED IN THE DISPOSITION OF DEPLETED URANIUM HEXAFLUORIDE DUF_6 TAILS

Developing review procedures and licensing requirements for disposing of DUF_6 tails generated by an enrichment facility depends on evaluating the following factors:

1. Determination of whether tails are a waste or resource
2. Assessment of the production rate and the chemical and radiological characteristics of the final form of the enrichment process tails
3. Determination of the proper waste classification for uranium hexafluoride (UF_6) tails
4. Analysis of disposal options

Each of these factors is discussed in the following paragraphs. However, it should be noted that without knowing the specifics of the enrichment process, the following discussion must be generic. The amount of UF_6 tails and their activity depend on specifics such as the uranium-235 content of the feed and the efficiency of the process used for enrichment.

DETERMINATION OF WHETHER THE TAILS ARE A WASTE OR RESOURCE

The U.S. Department of Energy (DOE) has considered, in the past, that UF_6 tails were a resource for future use as blanket material for breeder reactors, for munitions, and for other purposes where the high density of uranium metal is desirable, (e.g., aircraft counterweights). DOE stores the DUF_6 in 10- to 14- ton steel cylinders at its three gaseous diffusion plant sites. About 40,000 cylinders have been used to store approximately one billion pounds of DUF_6, increasing at the rate of about 40,000,000 pounds per year.

The recently passed Defense Appropriations Bill for 1991 includes a provision for the Government to acquire, from domestic sources, for the National Defense stockpile, 36 million pounds of depleted uranium metal, over a period of 10 years. This amounts to about 5.3 million pounds of DUF_6 per year, which is only 0.5 percent of the stored DUF_6, or about 7.5 percent of the DUF_6 created per year in the United States. In other words, acquisition of depleted uranium metal for the National Defense stockpile will have little effect on the tails disposition situation and a determination of whether the tails are waste or a resource. Inasmuch as the United States has no current plans for breeder reactors, and the uses for depleted uranium metal are limited, any determination that DUF_6 tails are a resource will likely have to be made on a policy or political basis. For the purposes of this paper, the rest of the discussion assumes that DUF_6 tails are waste, requiring conversion to a chemically stable form and appropriate disposal.

ASSESSMENT OF THE PRODUCTION RATE AND THE CHEMICAL AND RADIOLOGICAL CHARACTERISTICS OF THE FINAL FORM OF ENRICHMENT PROCESS TAILS

As stated previously, a thorough analysis of the UF_6 product to tails ratio is not possible without a detailed description of the planned enrichment process. However, the following generic facts are known. Approximately 85 to 90 percent of the UF_6 processed through an enrichment facility are returned as tails. For example, to produce 1,000 kg of 3 percent U-235 enriched uranium, approximately 6 tonnes of uranium feed would be put through the enrichment process, and approximately 5,000 kg of 0.25 percent U-235 DUF_6 tails would be generated.* The yearly tails output from the U.S. reactor enrichment services is 20,000 tons.

UF_6 is a solid at room temperature and pressure, but it is volatile and sublimes at 56 degrees centigrade. When exposed to moisture, UF_6 will hydrolyze and produce uranyl fluoride and hydrofluoric acid. Both products are soluble in water and pose potential health hazards. Although UF_6 is not listed as a hazardous waste, both uranyl fluoride and hydrofluoric acid are Environmental Protection Agency (EPA) hazardous wastes. The chemical hazard posed by disposal of UF_6 will most certainly necessitate conversion to a more stable form before disposal. The most stable of the uranium fluorides is UF_4, to which the hexafluoride is easily reduced. However, conversion to one of the higher oxides offers even greater stability. Regardless of the conversion process, hydrogen fluoride recovery could possibly be an economic incentive for conversion. For purposes of this paper, it will be assumed that the DUF_6 will be converted to uranium oxide.

DETERMINATION OF THE PROPER WASTE CLASSIFICATION FOR UF_6 TAILS

Under 10 CFR 61.58, the Commission may authorize other provisions for the classification and characteristics of waste, on a specific basis. This will be the case if, after evaluation of the specific characteristics of the waste, disposal site, and method of disposal, the Commission finds reasonable assurance of compliance with the performance objectives of Subpart C of Part 61. Comparison of depleted uranium tails to uranium mill tailings, LLW and high-level waste (HLW) can provide insight into alternate disposal options.

* Tails from a laser enrichment process might have a very different composition and characteristics than tails from the gaseous diffusion or gas centrifuge processes.

HLW, by definition, is irradiated reactor fuel; liquid waste resulting from the operation of the first cycle solvent extraction system or equivalent; the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel; and the solids into which these liquids have been converted. These wastes contain large quantities of long and short-lived radionuclides and transuranics with very high levels of activity. For example, 10-year-old spent fuel per reactor-year of operation constitutues 35 cubic meters (m^3) of waste, with activity levels of 11,000,000 curies. In comparison, tails from the enrichment process do not reach the activity levels of HLW. For example, depleted uranium tails as U_3O_8 (if converted) have an activity level of about 0.31 μCi/g, which equates to approximately 62 curies of activity for the 200 metric tons of tails per reactor-year. This is about 2 Ci/m^3 for the uranium isotopes, or about 5 Ci/m^3, including the Th-234 and Pa-234 decay daughters. Ingrowth of other decay products is extremely slow, requiring tens of thousands of years. This discussion assumes that no recycled uranium is involved.

Uranium mill tailings result from the chemical processing of uranium ore to produce a uranium-rich U_3O_8 compound called "yellow cake." The principal radionuclides in these tailings are uranium, radium-226 and its decay products, and thorium-230. However, radium and its decay products constitute the activity of concern, since essentially all the uranium is removed in the milling process. Thus, uranium radioactivity levels in the tailings are substantially less than the radium radioactivity levels. For example, long-lived uranium activity level in mill tailings is approximately 25 pCi/g, whereas the radium-226 level averages 450 pCi/g, with a half-life of 1,600 years. However, the low uranium content of the ore processed in the mill, the extraction of the uranium, and, finally, clean-up of the mill sites, produces large quantities of waste that are comprised mainly of soil and crushed rock, plus process chemicals. The depleted uranium tails are similar to mill tailings in that they contain uranium. But they are dissimilar in that depleted uranium tails are essentially free of thorium-230 or radium-226 and its decay products, and the uranium activity level is higher (0.31 μCi/g, if converted to oxide form). Depleted uranium tails also differ from mill site wastes in that they are concentrated U_3O_8 (if converted), rather than large quantities of soil mixed with small amounts of radioactive material.

LLW, which refers to all radioactive waste other than HLW, uranium mill tailings, and TRU waste, constitutes the majority of waste generated by the fuel cycle. However, LLW contains a relatively small portion of radioactivity. Although the long-lived isotopes of uranium, thorium, and low concentrations of TRU and other long-lived radionuclides can be present in LLW, the bulk of the radioactivity results from cobalt-60, cesium-134, cesium-137, and other lower-yield fission and activation products with maximum half-lives of approximately 30 years. LLW decays to low radioactivity levels in tens to hundreds of years, but it requires isolation during that time. The depleted uranium tails from the enrichment process are different from most LLW, in that they contain solely the long-lived isotopes of uranium in concentrated form, plus Th-234 and Pa-234. However, in accordance with 10 CFR Parts 40 and 61, depleted uranium tails from the enrichment process are source material and, if waste, are included within the definition of LLW, and could be disposed of in a LLW disposal facility licensed under 10 CFR Part 61, if in proper waste form. Review of the Environmental Impact Statement supporting 10 CFR Part 61 shows that although NRC considered the disposal of uranium and UF_6 conversion facility source terms in the analysis supporting Part 61, NRC did not consider disposal of large quantities of depleted uranium from an enrichment facility in the waste streams analyzed because there was no commercial source at that time. Therefore, analysis of the disposal of depleted uranium tails from an enrichment facility at a Part 61 LLW disposal facility should be conducted similar to the pathway analyses conducted in support of Part 61. Under 10 CFR 61.55(a), DUF_6 tails are Class A wastes. However, if stored or disposed of in 48G casks, they would not meet the minimum waste form requirements in 10 CFR 61.56(a).

It is customary for the provider of the enrichment service to offer the depleted uranium tails, together with the enriched product, to its customer. The general expectation is that the customer will decline to accept the depleted uranium tails. In the present competitive market, it is also likely that the enrichment plant would agree to keep these tails. Then, there are several possible scenarios concerning the responsible entity that would regulate the offsite disposal of the depleted uranium tails.

One scenario is to assume LES to be the enrichment plant accepting the depleted uranium tails and converting them to a proper waste form for final disposal. Classification of these converted tails as LLW, under the current provisions of the Low Level Radioactive Waste Policy Amendments Act of 1985, therefore, makes the State of Louisiana, an Agreement State, the entity that would regulate the offsite disposal of depleted uranium tails. Depending on the details of the central compact of which Louisiana is a member, classification of these tails as LLW could automatically require the compact facility to accept the tails for disposal. But conversion of these tails on the LES site would change the nature of the enrichment plant license, and the NRC would have to address the issue.

Another scenario could be for the enrichment plant to send the depleted tails to be converted to a proper waste form to a processing plant in another State, with access to a LLW disposal facility, therefore, likely providing a route for final disposal. If the processing plant is, however, in a State that does not have access to a LLW disposal facility, final disposition of the tails may be cumbersome.

If we compare the radiological characteristics of depleted uranium tails with the radiological characteristics of uranium mill tailings, and with LLW and HLW, the depleted uranium tails from the enrichment process appear to more closely resemble uranium mill tailings. However, the differences are sufficient to consider them a unique waste form.

ANALYSIS OF DISPOSAL OPTIONS

If DUF_6 tails are determined to be waste, there appear to be three options that might be considered for disposal of the tails after conversion to a more chemically stable form of uranium. The options would need additional investigation by an applicant and the staff to determine their acceptability.

1. Legally, the tails are considered source material and can be disposed of as LLW waste under the requirements of 10 CFR Part 61. As stated previously, detailed pathway analysis of depleted uranium, as conducted in the development of 10 CFR Part 61, should be conducted following the provisions of 10 CFR 61.58. Section 61.58 states: "The Commission may, upon request or on its own initiative, authorize other provisions for the classification and characteristics of waste, on a specific basis, if, after evaluation, of the specific characteristics of the waste, disposal site, and method of disposal, it finds reasonable assurance of compliance with the performance objectives in Subpart C of this part."

2. The second option is to dispose of the depleted uranium in an existing uranium mill tailings impoundment and apply the regulatory provisions of Appendix A to 10 CFR Part 40. Once again, pathway analysis should be conducted to ensure protection of the public health and safety from the addition of concentrated U_3O_8 to the impoundments. In addition, the disposal of the tails in this manner ultimately will involve land transfer of tailings disposal areas to the Federal Government.

3. The third option is to dispose of the depleted uranium in a separate facility licensed under Part 61, also applying the provisions of 10 CFR 61.58.