Affordable Cleanup?

Opportunities for cost reduction in the decontamination and decommissioning of the nation's uranium enrichment facilities

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Committee on Decontamination
and Decommissioning
of Uranium Enrichment Facilities

Board on Energy and Environmental Systems
Commission on Engineering and Technical Systems
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The present study is restricted to the D&D of the buildings and equipment comprising the GDPs. As defined by the statement of task, the study excludes consideration of environmental restoration activities, such as cleanup of soils and groundwater at the three enrichment facility sites. Also excluded are the gaseous centrifuge facilities at the Oak Ridge and Portsmouth sites that were never used for commercial production. These facilities do not represent a major part of the D&D costs at these sites, but some of this study's recommendations are pertinent to their D&D as well. The committee has considered the coordination and integration of D&D, environmental restoration, and management options for the DUF_6 for cost-effective management of the cleanup program.

THE U.S. URANIUM ENRICHMENT ENTERPRISE

Natural uranium found in ore deposits consists of the three isotopes uranium-234, uranium-235, and uranium-238 (^{234}U, ^{235}U, and ^{238}U). ^{234}U is found in trace amounts; ^{235}U and ^{238}U occur in abundances of about 0.71 and 99.28 percent, respectively. The percent by weight of ^{235}U to all uranium atoms is termed the percent enrichment of ^{235}U in uranium; thus, for natural uranium the enrichment level is 0.71 percent. Many applications require enrichment levels above 0.71 percent, typically from 2 to 5 percent for light-water power reactors and 20 percent and greater for such applications as research reactors, compact reactors for naval use, and nuclear weapons.

The U.S. uranium enrichment program was created in the 1940s to produce enriched uranium for military applications, such as nuclear weapons. The three GDPs were used primarily for this mission through the 1960s, but in 1964 Congress authorized the private ownership of enriched uranium for commercial uses. After this time, the amount of enriched material delivered to the commercial sector grew rapidly, making up 90 percent of all the separative work units (SWUs) produced in 1974.[4] Beginning in 1968, the production capacity of the three plants was increased in response to demand from the commercial nuclear power sector.

The U.S. enrichment program has relied on the gaseous diffusion process. The feed material for a GDP is uranium hexafluoride (UF_6) gas, which is produced at other industrial facilities using natural uranium and delivered to the GDPs. The enriched UF_6 product from the GDPs is sent to other plants for fabrication into uranium products such as reactor fuel. A DUF_6

[4] Enrichment capacity is typically measured in SWUs (see Glossary).

gas stream resulting from the enrichment process is collected and stored in cylinders, which are placed in outdoor storage yards at the three GDP sites (see Chapter 7).[5]

The Oak Ridge GDP was built between 1942 and 1945 under the auspices of the Manhattan Engineering District Project and began operation in 1945. The Oak Ridge GDP had the capability to enrich uranium up to 90 percent. The second plant, the Paducah GDP in Kentucky, was built between 1951 and 1955 to produce uranium to enrichment levels no greater than 2 percent. The third plant, the Portsmouth GDP in Ohio, began operation in 1956 and was designed to accept natural uranium feed, as well as the product from either the Oak Ridge or the Paducah GDP, and produce enriched uranium ranging from 2 percent to greater than 97 percent ^{235}U. When all three plants were operational, they constituted an integrated production complex (see Figure 1-1 for the geographic locations of the plants).

The Oak Ridge GDP ceased production of highly enriched uranium (with enrichment levels greater than or equal to 20 percent) in 1964 because of insufficient demand. Low-enriched uranium (with enrichment levels less than 20 percent) was produced until 1985, when the plant was placed in a standby mode because of declining demand for low-enriched uranium from the commercial nuclear power sector; the plant was permanently closed in 1987. Since cessation of enrichment operations at the Oak Ridge GDP in 1985, the two plants at Portsmouth and Paducah have constituted a two-site complex. Both plants receive natural and partially enriched feed. The Portsmouth high-enrichment section has been closed since November 1992. The enrichment level capacity of certain parts of the Paducah plant was increased to 2.75 percent in 1995.[6]

The cost estimate prepared by Ebasco Environmental (Ebasco) assumes both operating plants would close in 2005, at which time other lower cost enrichment technologies would be expected to be used in the United States. The time of closure of the plants is uncertain, depending on the world uranium enrichment market and competitive forces. The Ebasco estimate assumed a sequential cleanup, Oak Ridge followed by Paducah, with Portsmouth last. The Ebasco cost estimate assumed the physical decommissioning to occur from 2002 to 2030 (DOE, 1991a). If either the Paducah or Portsmouth plant were to close sooner, there might be cost or other incentives to change the sequence or schedule of D&D activities for the three plants.

THE UNITED STATES ENRICHMENT CORPORATION

EPACT restructured the government-owned uranium enrichment enterprise, which was under the management of DOE, by creating the USEC. The corporation was established as of

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[5] This depleted UF_6 is sometimes referred to as "tails," although that term is not universally favored (Lemons et al., 1990).

[6] Personal communication from Michael Buckner, Lockheed Martin Utility Services, Paducah, Kentucky, to James Zucchetto, NRC, June 1, 1995. The USEC has contingent approval from its current regulator, DOE, to operate at this enrichment level, but as of January, 1996 no uranium has been enriched at this plant above 2 percent. Modifications to the plant required to satisfy the contingent approval are expected to be in place by the time the Nuclear Regulatory Commission assumes regulatory authority over the plant, sometime in 1996.

American market requirements for HF annually. In contrast, a 5-year operation would generate about 8 percent of North American HF requirements each year with resulting repercussions on the market. An appropriate choice of plant size and schedule would reduce conversion costs.

Uranium Oxide Density

The normal conversion product is U_3O_8 of very small particle size (a large fraction less than 10 microns) and low density (3 g/cm^3 after compaction). Both properties are undesirable for final storage. Fine material will require special handling and possibly grouting. Low density is costly because unit storage cost is normally quoted in terms of volume stored. The storage costs shown in Table 7-4 of $156 million to $305 million could be reduced by increasing the density.

One method suggested for increasing density is a low-temperature sintering with a small amount of a sintering aid—in effect, a brickmaking process (Quapp, 1995). Work at the Idaho National Engineering Laboratory with cerium oxide has demonstrated densities as high as 90 percent of theoretical density. Application of this approach could achieve U_3O_8 densities as high as 6 g/cm^3. The costs of the process are believed to be low (on the order of a few cents per kg U), and the additive would result in only small uranium dilution. Storage cost savings of $100 million or more might be possible. Research and development on this or other processes for increasing density could yield significant cost savings.

An effective process for converting U_3O_8 to high-density bricks might offer another possible saving: it would yield a very stable product of extremely low radioactivity. Such a product would be a good candidate for on-site or near-site storage if a low-level waste repository near the diffusion plant sites were deemed acceptable.

HF Production and Marketing

The committee has included in its analysis a small credit for the HF produced (see Table 7-5). The credit shown could be much larger if the material gains general acceptance in the market. Much more important is avoiding the alternative, namely, neutralization with lime and storage of the CaF_2 produced as waste, possibly low-level radioactive waste. The additional cost of neutralization (capital and operating costs) scaled from the estimate given by MMES (Charles et al., 1991) is approximately $600 million; the storage cost for the CaF_2 could be $800 million. (The storage cost is again scaled from an estimate given by MMES and must be considered approximate, inasmuch as long-term storage costs are uncertain at this time. The figure of $800 million appears to be at the high end of the range.)

These costs for making and storing CaF_2 translate to an additional cost for disposal of the DUF_6 of approximately $4/kg U. There is therefore a large incentive to avoid such costs by marketing the HF produced instead. The French experience in marketing HF has been excellent, and product purity has been acceptable. It will be important to establish the same level of industrial and public acceptance in the United States.