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OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

Initial Data Report in Response to the Surplus Plutonium Disposition Environmental Impact Statement Data Call for the UO_2 Supply

V. S. White

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INITIAL DATA REPORT IN RESPONSE TO THE SURPLUS PLUTONIUM DISPOSITION ENVIRONMENTAL IMPACT STATEMENT DATA CALL FOR THE UO_2 SUPPLY

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ACRONYMS AND ABBREVIATIONS

ADU	ammonium diuranate
AHF	anhydrous hydrogen fluoride
ALARA	as low as reasonably achievable
ANSI	American National Standards Institute
ASME	American Society for Mechanical Engineers
AUC	ammonium uranyl carbonate
B&W	Babcock & Wilcox
CEDE	committed effective dose equivalent
BWR	boiling-water reactor
CFR	*Code of Federal Regulations*
Ci	curies
DCP	dry conversion process
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIS	environmental impact statement
EPA	Environmental Protection Agency
FMDP	Fissile Materials Disposition Program
GDP	gaseous diffusion plant
HaMTES	Hazardous Material Transportation Expert System Software
HazMat	hazardous materials
HEPA	high-efficiency particulate air
HF	hydrogen fluoride (hydrofluoric acid)
IDR	integral dry route
INEEL	Idaho National Engineering and Environmental Laboratory
LANL	Los Alamos National Laboratory
LEU	low-enriched uranium
LLW	low-level waste
LMES	Lockheed Martin Energy Systems, Inc.
LWR	light-water reactor
MOX	mixed oxide
mrem	millirem
MT	metric ton
MTHM	metric ton heavy metal
NRC	U.S. Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PCB	polychlorinated biphenyl
ppm	parts per million
psig	pounds per square inch gauge
PWR	pressurized-water reactor
RCRA	Resource Conservation and Recovery Act of 1976
SAR	safety analysis report
SPD	surplus plutonium disposition
TEDE	total effective dose equivalent
TRU	transuranic
USEC	United States Enrichment Corporation
WIPP	Waste Isolation Pilot Plant

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ABSTRACT

The purpose of this document is to support the U.S. Department of Energy (DOE) Fissile Materials Disposition Program's preparation of the draft Surplus Plutonium Disposition Environmental Impact Statement. This is one of several responses to data calls generated to provide background information on activities associated with the operation of the Mixed-Oxide (MOX) Fuel Fabrication Facility.

The DOE Office of Fissile Materials Disposition has developed a "dual-path" strategy for disposition of surplus weapons-grade plutonium. One path is to disposition surplus plutonium through irradiation as MOX fuel in commercial nuclear reactors. MOX fuel is composed of plutonium and uranium oxides, typically containing 95% or more of urania.

Urania feed for the MOX Fuel Fabrication Facility may be either natural or depleted. Natural uranium typically contains 0.0057 wt % ^{234}U, 0.711 wt % ^{235}U, and the majority as ^{238}U. The fissile isotope is ^{235}U, and uranium is considered depleted if the total ^{235}U content is less than 0.711 wt % as found in nature. The average composition of ^{235}U in DOE's total depleted urania inventory is 0.20 wt %. The depleted uranium assay range proposed for use in this program is 0.2500–0.2509 wt %. Approximately 30% more natural uranium would be required than depleted uranium based on the importance of maintaining a specific fissile portion in the MOX fuel blend. If the uranium component constitutes a larger quantity of fissile material, less plutonium can be dispositioned on an annual basis. The percentage composition, referred to as assay, of low-enriched uranium necessary for controlled fission in commercial light-water nuclear power reactors is 1.8–5.0 wt % ^{235}U.

This data report provides information on the schedule, acquisition, impacts, and conversion process for using uranium, derived from depleted uranium hexafluoride (UF_6), as the diluent for the weapons-grade plutonium declared as surplus. The case analyzed is use of depleted UF_6 in storage at the Portsmouth Gaseous Diffusion Plant in Piketon, Ohio, being transported to a representative UF_6 to uranium dioxide conversion facility (GE Nuclear Energy) for processing, and subsequently transported to the MOX Fuel Fabrication Facility.

1. SCHEDULE

1.1 MOX FUEL FABRICATION FACILITY URANIUM REQUIREMENTS

The U.S. Department of Energy's (DOE's) depleted uranium hexafluoride (UF_6) inventory is equivalent to ~385,000 MT (848,771,000 lb) depleted uranium dioxide (UO_2) [339,375 MTHM equivalent], which is the form required by the Mixed-Oxide (MOX) Fuel Fabrication Facility. The proposed MOX Fuel Fabrication Facility will have feed requirements of ~100 MT (220,460 lb) UO_2 [88 MTHM equivalent] per year for a 10-year period beginning in 2005. This case is based on requirements for boiling-water reactors (BWRs) and is considered bounding for dispositioning the plutonium currently identified as surplus. A case using only pressurized-water reactors (PWRs) would constitute the lower limit for requirements with ~70 MT (150,000 lb) UO_2 [62 MTHM equivalent] needed per year. The total feed requirements for the life of the MOX program, excluding testing material, will be 1,000 MT (2,204,600 lb) UO_2 [880 MTHM equivalent] based on expected operations of facility throughput. This represents a fairly high throughput on an annual basis to apply an upper bound for MOX plant size and environmental impacts. Plant size and annual impacts could be reduced if the program increased the number of years required to disposition the surplus plutonium.

Based on the current assumptions that 9.5 MT of the weapons-grade plutonium declared surplus is unacceptable for fabrication as MOX fuel, ceramic immobilization technology also has uranium requirements.[1] Assuming immobilization will take place beginning in 2005 and continue for 10 years, 8.3 MT (18,300 lb) UO_2 [7.3 MTHM equivalent] will be required annually at an ~12% plutonium level. Because of the bounding nature of the 100-MT (220,460-lb) UO_2 [88-MTHM equivalent] requirement case, it is anticipated that the immobilization uranium requirements will be available from this same estimate. No increase has been incorporated for the immobilization requirements based on the assumption that this small addition can be accommodated within the existing bounds.

The factor for converting UO_2 to equivalent UF_6 is calculated as follows (assuming no process losses):

$$\text{Conversion ratio for } UO_2 \text{ to } UF_6 = (\text{mol wt } UF_6)/(\text{mol wt } UO_2) = 352.02/270.03 = 1.3036\ .$$

The stoichiometric conversion ratio implies that for generation of each kilogram of depleted UO_2, 1.3036 kg of depleted UF_6 must be used. Applying this factor, the associated feed, net of losses, and clean-out material to be supplied to the UF_6 to UO_2 conversion facility for the MOX Fuel Fabrication Facility is 1,303.6 MT (2,873,920 lb) UF_6 [880 MTHM equivalent].

In addition to the annual requirements of 100 MT (220,460 lb) depleted UO_2 [88 MTHM equivalent], 50 MT (110,230 lb) depleted UO_2 [44 MTHM equivalent] is required by the MOX Fuel Fabrication Facility for a combination of cold and hot startup testing. This test material increases the UF_6 requirements to 1,368.8 MT UF_6 (3,017,650 lb) UF_6 [925.5 MTHM equivalent].

The schedule and duration for providing depleted UO_2 for the MOX Fuel Fabrication Facility would be based on minimizing powder inventory to 6 months at any specific point in time. Based on MOX Fuel Fabrication Facility requirements provided by the Los Alamos National Laboratory (LANL), the age of the UO_2 powder should not exceed 6 months because of the potential for exposure to moisture or air that can cause agglomeration or self-sintering (referred to as burn-back) of the powder during storage.[2] The UO_2 must be fully free-flowing for the MOX production line. The shelf life of UO_2 is discussed in the following section.

The schedule for delivering depleted UO_2 to the MOX Fuel Fabrication Facility is as follows: 25 MT (55,115 lb) UO_2 [22 MTHM equivalent] in both mid-2005 and late-2005 with 50 MT (110,130 lb) UO_2 [44 MTHM equivalent] at 6-month intervals beginning mid-2006 through the duration of the program.

1.2 CHEMICAL SHELF LIFE OF UO_2

No formal documentation could be obtained on the actual chemical shelf life of UO_2. According to "Resume of Uranium Alloy Data-XI,"[3] the shelf life depends on exposure to water and oxygen. The amount of exposure allowable is a function of the method of preparation of the powder as well as atmospheric conditions. Studies indicated that powders prepared from ammonium diuranate (ADU) were most susceptible to air; however, water was of only minor concern in all UO_2 samples regardless of conversion method. The fuel fabricators offered different time periods based on experience at their facilities. These estimates ranged from 1 year to an indefinite period if the storage container was maintained in an air- and moisture-controlled environment. The economic shelf life was of primary importance to the fabricators because of the inventory carrying costs associated with enriched uranium.

For this analysis, the effective shelf life is assumed to be 6 months based on the MOX Fuel Fabrication Facility requirements provided by LANL.[2] Therefore, it is assumed that receipt of the UO_2 should be no more than 6 months before initial feed requirements for powder blending. The UO_2 will be transported from the conversion facility to the fuel feed safeguards storage area at the MOX Fuel Fabrication Facility.

The shipments of UO_2 will be coordinated with the production schedule for the MOX facility provided in LANL's *Initial Response to the Surplus Plutonium Disposition Environment Impact Statement Data Call for a Mixed Oxide Fuel Fabrication Facility Located at the Savannah River Site.*[4] The operations phase of the MOX facility was provided as 2006–2015; thus, UO_2 will be shipped from the conversion facility no more than 6 months before feed requirements.

1.3 NUCLEAR FUEL MARKET IMPACTS

The use of depleted UO_2 in MOX may displace a small percentage of demand in the nuclear fuel market. Impacts may be felt by uranium producers, U_3O_8 to UF_6 converters, and enrichers if existing reactors are used for burning the MOX fuel because it will replace low-enriched uranium (LEU) fuel. MOX fuel using depleted UO_2 will require only the fabrication phase of the current LEU fuel cycle. Uranium production and conversion processes have already occurred for the depleted UO_2 portion of MOX fuel, and enrichment is not necessary.

The U_3O_8 displacement by use of depleted UF_6 impacts uranium mining and milling functions and U_3O_8 to UF_6 conversion services. Use of MOX fuel containing depleted UF_6 also impacts the required enrichment services to enrich UF_6 from 0.711 wt % to 1.8–5.0 wt % required by light-water reactors (LWRs). However, the fabrication, transportation, and spent fuel handling components of the fuel cycle are required for MOX as well as LEU fuel. Economic impacts on the nuclear fuel market will be temporary and on a small scale.

For the period of time the selected reactors are using MOX, the market for LEU fuel will be slightly interrupted. The depleted UO_2 will replace the natural UO_2 feed requirements of LEU fuel. The average refueling cycle requirements for an 1100+ net MW(e) LWR operating on an 18-month cycle are ~350 MT (770,000 lb) natural U_3O_8 for a PWR and ~370 MT (815,000 lb) natural U_3O_8 for a BWR. On an annualized basis, the weighted average requirement for a single LWR is ~240 MT (530,000 lb). For a one-third MOX core, the displacement averages ~80 MT (175,000 lb) natural U_3O_8 per LWR selected for use in the program. Total annual natural U_3O_8 LWR requirements in the United States will be ~20,000 MT (44,000,000 lb) in 2005 when the MOX Fuel Fabrication Facility begins startup operations. This equates to an ~750-MTHM LEU requirement for BWRs and an ~1450-MTHM LEU requirement for PWRs based on 0.30 wt % ^{235}U tails assay and up to 3.5 and 5.0 wt % ^{235}U enrichment assays for BWRs and PWRs, respectively. The displacement effect will be based on the number, capacity, and refueling schedules of the LWRs used.

1.4 AVOIDED ENVIRONMENTAL IMPACTS

Substitution of uranium fuel with MOX fuel using depleted UO_2 as the diluent lessens some potential human health and environmental impacts caused by uranium production and fuel cycle services. Uranium production requires mining, milling, and conversion of U_3O_8 to UF_6; LEU fuel requires enrichment services. Current uranium enrichment services in the United States are based on gaseous diffusion technology, which is very energy intensive. These steps, potentially hazardous to human health and the environment, are not required when using UO_2 derived from depleted UF_6 that has already gone through uranium processing, and enrichment services are not required. A discussion on avoided environmental impacts is found in the *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement.*[5]

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2. PROCESS OVERVIEW: UO_2 ACQUISITION

2.1 SUMMARY OF PROCEDURES

The procedure for transferring the depleted UF_6 from the Portsmouth Gaseous Diffusion Plant (GDP) to the representative conversion facility involves the following preparatory work:

- contracting with the United States Enrichment Corporation (USEC) for autoclave emptying of the 12.7-MT (14-ton) cylinders
  - USEC, the lessee of the Portsmouth GDP, can provide the transfer service for DOE with one of the four available autoclaves. DOE or the consortium will have to negotiate a contract with USEC to perform this service.
  - The charge and timing for the service will also have to be negotiated. The current charge for this service is $2,000 per 2.28-MT (2.5-ton) cylinder (charge supplied by USEC, July 17, 1997).[6]
- purchasing 2.28-MT (2.5-ton) cylinders for use in transporting depleted UF_6 from the Portsmouth GDP to the UF_6 to the UO_2 conversion facility.

Once the contract has been reached and 2.28-MT (2.5-ton) cylinders are on-site, the actual inventory retrieval effort involves

- selecting cylinders containing depleted UF_6 which meet feed requirements from computerized printouts of inventory
- retrieving the selected 12.7-MT (14-ton) UF_6 cylinders from their storage yards with a cylinder handler (either a straddle buggy or NCH-35 transport vehicle) and moving all the cylinders to a separate location in the DOE cylinder yard
- moving cylinders on an agreed-to schedule to the transfer station located in Building X-344
- transferring the depleted UF_6 from 12.7-MT (14-ton) to 2.28-MT (2.5-ton) cylinders
  - The Portsmouth GDP is the only domestic facility capable of transferring the depleted UF_6 from the 12.7-MT (14-ton) tails cylinders to the 2.28-MT (2.5-ton) feed cylinders. The transfer facility for depleted uranium at the Paducah GDP has not operated since 1989.
  - As standard operations, the Portsmouth GDP routinely fills 2.28-MT (2.5-ton) feed cylinders with enriched UF_6. This procedure has also been used for natural and depleted UF_6.
  - UF_6 is stable up to relatively high temperatures. UF_6 can be changed from the solid state by increasing the temperature above 147.3°F (64.1°C).
  - Each 12.7-MT (14-ton) cylinder will be heated and liquefied in one of four autoclaves for UF_6 transfer to a 2.28-MT (2.5-ton) cylinder.
  - The autoclave transfer rate is 1090–1135 kg/h (2400–2500 lb/h). Four 2.28-MT (2.5-ton) cylinders can be filled in an 8-h work shift.
  - During transfer procedures, a liquid sample is extracted to determine assay.
  - A heel of ~478 kg (1054 lb) will be left in each 12.7-MT (14-ton) cylinder.
- moving the 2.28-MT (2.5-ton) cylinders to the cooling area
  - At ambient temperatures, UF_6 is a solid with a vapor pressure below atmospheric pressure.
- loading eight 2.28-MT (2.5-ton) cylinders onto a flatbed truck once cooling is complete
- transporting the cylinders by highway from the Portsmouth GDP to the conversion facility
- transferring the cylinders, and the associated materials accountability for the UF_6, to the receiving and storage facility at the conversion facility.

The primary steps involved in converting the depleted UF_6 to UO_2 can be found in Sect. 4 of this report and will not be discussed here. Following conversion, the process for transferring the UO_2 to the MOX Fuel Fabrication Facility for use as feedstock with the weapons-grade plutonium includes

- returning the 2.28-MT (2.5-ton) cylinders to the Portsmouth GDP for refilling
- filling clean 208-L (55-gal) drums with UO_2
- loading up to 72 drums on a flatbed truck

- transporting the drums to the MOX Fuel Fabrication Facility
  - — The conversion facility will have a small product storage vault for inventory awaiting transport.
- transferring the drums and associated materials accountability for the UO_2 to the fuel feed safeguards storage area at the MOX Fuel Fabrication Facility.
  - — The Hanford Reservation, Idaho National Engineering and Environmental Laboratory (INEEL), Pantex, and Savannah River sites are being considered for hosting the MOX Fuel Fabrication Facility.
- returning the drums to the conversion facility for refilling
  - — Replacement drums will be available if any drums become contaminated with plutonium.

Additional program requirements follow completion of the MOX campaign:

- transferring the used 12.7-MT (14-ton) cylinders to DOE storage yards for heels cylinders located at the Portsmouth GDP or donating the cylinders to USEC for refilling with depleted UF_6 from enrichment operations
- donating or selling used 2.28-MT (2.5-ton) cylinders to USEC or other interested parties in the commercial fuel business for cleaning and reuse in enriched UF_6 operations
- recycling or disposing of 208-L (55-gal) drums.

2.2 MATERIAL REGULATIONS (49 CFR, PARTS 173.420 AND 173.425)

Both materials, UF_6 and UO_2, are classified according to the U.S. Department of Transportation (DOT) Hazardous Materials (HazMat) Regulations. The classifications were determined through use of the Hazardous Material Transportation Expert System Software (HaMTES) developed at the Oak Ridge National Laboratory (ORNL).

2.2.1 Uranium Hexafluoride

HaMTES determined that depleted UF_6 can be shipped from the Portsmouth GDP to the representative fuel fabrication facility as follows:

- Identified as RQ, Uranium Hexafluoride, UN2978
- Classified as Primary Hazard Class 7, Container Type A
- Packaged and shipped in a cylinder designed in accordance with American National Standard for Nuclear Materials (ANSI N14.1) *Uranium Hexafluoride—Packaging for Transport*
- Regulated under Title 49 *Code of Federal Regulations* (CFR) Part 173.420
- Marked with primary hazard label as "Radioactive Yellow-II" and secondary hazard label as "Corrosive"
- Identified by primary placard as "Radioactive" and secondary placard as "Corrosive"
- Shipped by commercial carrier by highway.

2.2.2 Uranium Dioxide

HaMTES determined that the depleted UO_2 will be shipped from the representative fuel fabrication facility as follows:

- Identified as Radioactive material, low specific activity, n.o.s., UN2912
- Classified as Primary Hazard Class 7, Container Type LSA-I
- Packaged and shipped in an IP-1 Type or Strong Tight Package with exclusive use, domestic only exception. A strong, tight packaging could be an open-head drum or a fiberboard box equipped with a plastic bag liner. A gasketed, open-head, 208-L (55-gal) drum with a heavy plastic liner for contamination control is the recommended packaging method
- Regulated under 49 CFR 173.425
- No primary or secondary hazard labels required

- Identified by primary placard as "Radioactive" but no secondary placard required
- Shipped by commercial carrier by highway.

2.3 DOE UF_6 INVENTORY

DOE currently owns more than 500,000 MT (1,102,300,000 lb) of depleted UF_6 [339,375 MTHM equivalent] resulting from historical uranium enrichment activities at the gaseous diffusion complex. The gaseous diffusion enrichment process separates uranium isotopes according to atomic weight. During processing, the lighter isotopes in UF_6 are separated to increase the concentration of ^{235}U. The depleted UF_6 is stored at the two operating GDPs in Paducah, Kentucky, and Portsmouth, Ohio, and at the former Oak Ridge GDP (K-25 Site) on the Oak Ridge Reservation in Tennessee. The percentage composition of ^{235}U contained in the UF_6 ranges from ~0.1 wt % up to 0.711 wt % at all three sites. The GDPs are currently leased by USEC.

Because the Portsmouth GDP is the only facility with operating transfer autoclaves for emptying the 12.7-MT (14-ton) cylinders containing depleted UF_6, inventory from the Portsmouth GDP will be used in this analysis. The required UF_6 to be removed from inventory is ~1,390 MT (3,064,000 lb) UF_6 [940 MTHM equivalent] and is calculated as follows:

$$\text{Conversion ratio for } UF_6 \text{ to } UO_2 = (\text{mol wt } UO_2)/(\text{mol wt } UF_6) = 270.03/352.02 = 0.7671 \ .$$

A 99.5% process efficiency rate has been assumed for the representative UF_6 to UO_2 conversion facility. This loss serves to reduce the ratio as follows:

$$\text{Ratio reduced for assumed conversion efficiency rate} = 0.7671 \times 0.995 = 0.7633 \ .$$

A requirement to supply an extra 1% of UF_6 is assumed for use in system clean-out for each production run. There will be two runs per year based on requirements of the MOX Fuel Fabrication Facility. This requirement serves to reduce the ratio as follows:

$$\text{Ratio reduced for process clean-out @ } \sim 1\% \text{ each} = 0.7633 \times 0.99 = 0.7556 \ .$$

$$\text{Annual } UF_6 \text{ requirement: } 100/0.7556 \text{ MT } UO_2 = 132.345 \text{ MT } (291{,}767.8 \text{ lb}) \ .$$

$$UF_6 \text{ testing material required: } 50/0.7556 \text{ MT } UO_2 = 66.173 \text{ MT } (145{,}885 \text{ lb}) \ .$$

$$\text{10-year } UF_6 \text{ requirement: } 1{,}000/0.7556 \text{ MT } UO_2 = 1{,}390 \text{ MT } (3{,}064{,}000 \text{ lb}) \ .$$

2.4 UF_6 PACKAGING AND STORAGE

Depleted UF_6 is stored and transported in metal cylinders meeting American National Standards Institute (ANSI) requirements. Oversight of depleted UF_6 by the DOE Office of Nuclear Energy, Science, and Technology consists of complying with all applicable orders, laws, and regulations to assure that nuclear material safeguards, control, and accountability measures are followed. Regulations and policies pertinent to depleted UF_6 are listed as Appendix B. All procedures for handling and shipping cylinders, physical descriptions, and weight limits detailed in Sect. 2 can be found in *Uranium Hexafluoride: A Manual of Good Handling Practices.*[7]

The storage media for the selected depleted UF_6 stored at Portsmouth are Model 48G cylinders. These cylinders are 12.7-MT (14-ton), thin-wall (5/16-in.), carbon steel cylinders; they are 48 in. in diameter, 146 in. long, and are designed for 100-psig service pressure rating. Each cylinder has a maximum net weight of 12.701 MT (28,000 lb) of depleted UF_6 and a nominal gross weight of 13.880 MT (30,600 lb), which includes the weight of the cylinder.

Depleted UF_6 is stored in enclosed yards within security fenced areas at the Portsmouth GDP. Because consideration must be given to chemical compositions and radiological activity, storage yards are typically located a distance from human activity at the site.

2.5 PORTSMOUTH GDP SITE

The Portsmouth GDP is one of two operating enrichment facilities owned by DOE and operated by USEC. Much of the information in this section was taken from the *Portsmouth Site Annual Environmental Report Summary for 1994*[8] and the *Portsmouth Annual Environmental Report for 1995*.[9]

2.5.1 Site Mission

The primary function of the Portsmouth GDP is processing uranium isotopes through gaseous diffusion separation for use as fuel in commercial nuclear power reactors. These facilities are currently leased by USEC. Other activities at the site include environmental restoration, waste management, and high-enriched uranium suspension programs under direction of DOE.

2.5.2 Location

The Portsmouth GDP site covers ~15.5 km^2 (6 $mile^2$) near Piketon, Ohio. The two largest cities within a 45-km (28-mile) radius of the plant are Chillicothe [43.5 km (27 miles) north] and Portsmouth [43.5 km (27 miles) south]. Approximately 900,000 people live within 80 km (50 mile) of the facility. The facility has direct access to major highway systems. Figure 1 provides the relative location of cities and public facilities near the Portsmouth GDP.

2.5.3 Portsmouth GDP Facilities Required for Surplus Plutonium Disposition (SPD) Mission

Four cylinder yards are located at the Portsmouth GDP. Two of the yards, X-745-C (550,000-ft^2 area) and X-745-E (215,000-ft^2 area), contain DOE-owned cylinders of depleted UF_6. The cylinders are stacked two high to save storage space.

The 12.7-MT (14-ton) cylinders selected for this program will be moved, in entirety, to a separate location in the cylinder yard and subsequently transported, as needed, to the transfer facility located in Building X-344. These moves occur by use of a cylinder handler described in Sect. 2.9.1. Figure 2 indicates the location of the cylinder yards and Building X-344, which houses the facilities necessary for transferring the depleted UF_6 from the 12.7-MT (14-ton) cylinders to 2.28-MT (2.5-ton) cylinders. The facilities required for this program are all in close proximity and in the upper northwest quadrant of the plant site. Following transfer, the freshly filled 2.28-MT (2.5-ton) cylinders will be taken to the cooling area outside Building X-344 by forklift. After cooling, the cylinders will be loaded on truck–trailer combinations for transfer to the off-site commercial conversion facility. The trucks collect the cylinders outside Building X-344. No additional on-site transportation, except for loading activities, is required once the cylinders are placed in the cooling area.

2.6 MODEL 30B [2.28-MT (2.5-TON)] CYLINDER REQUIREMENTS

To determine the number of 2.28-MT (2.5-ton) depleted UF_6 cylinders to be shipped, an estimate of the actual useable depleted UF_6 per shipment was determined. The following conservative assumptions were used:

- The net carriage capacity of the cylinder was calculated by reducing the fill capacity by 2% (to keep from overfilling) and subtracting the maximum allowable heels for a normal UF_6 empty cylinder return

ORNL-DWG 97-2704 EFG

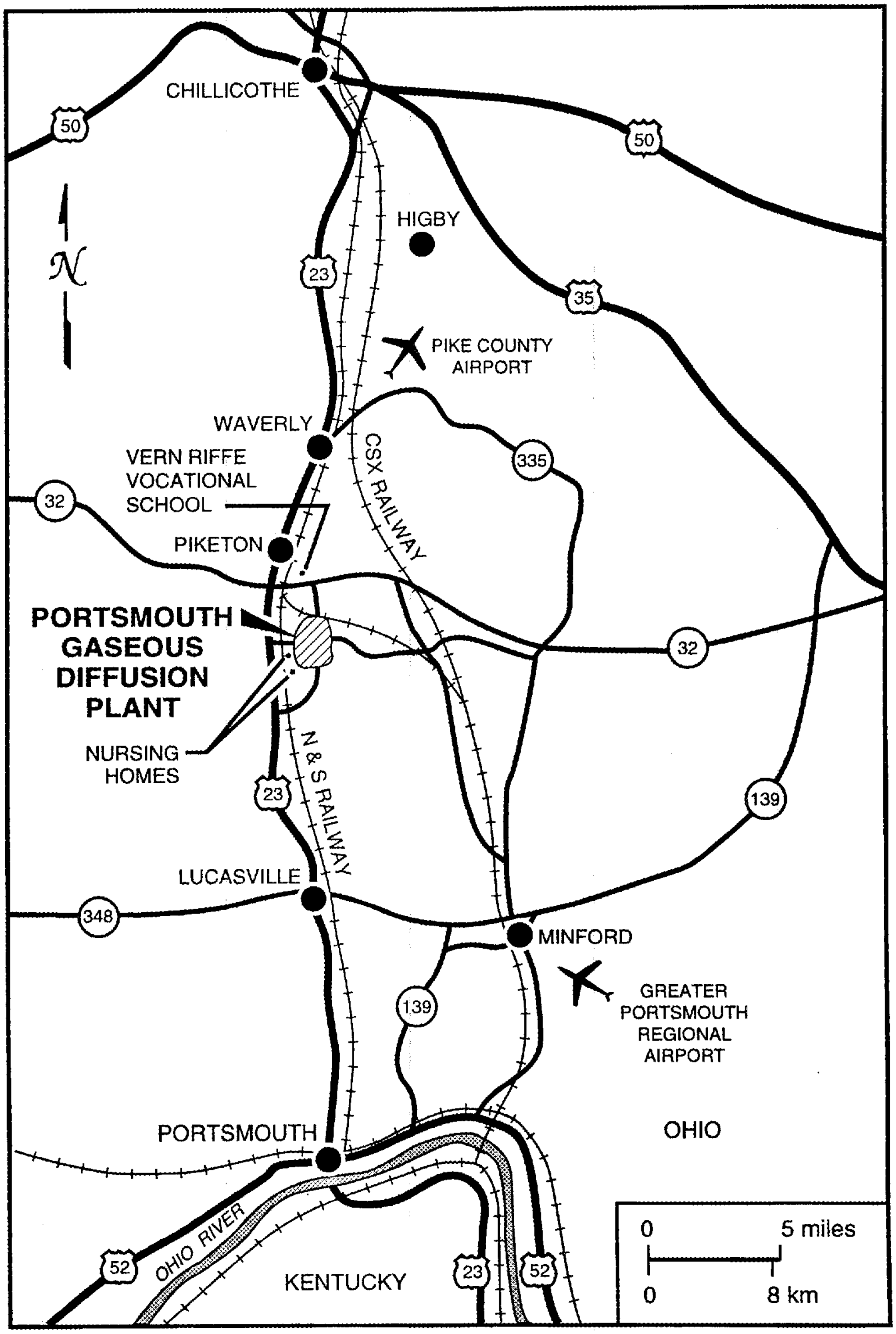

Fig. 1. Location of the Portsmouth GDP relative to geographic location.

ORNL-DWG 97-2644 EFG

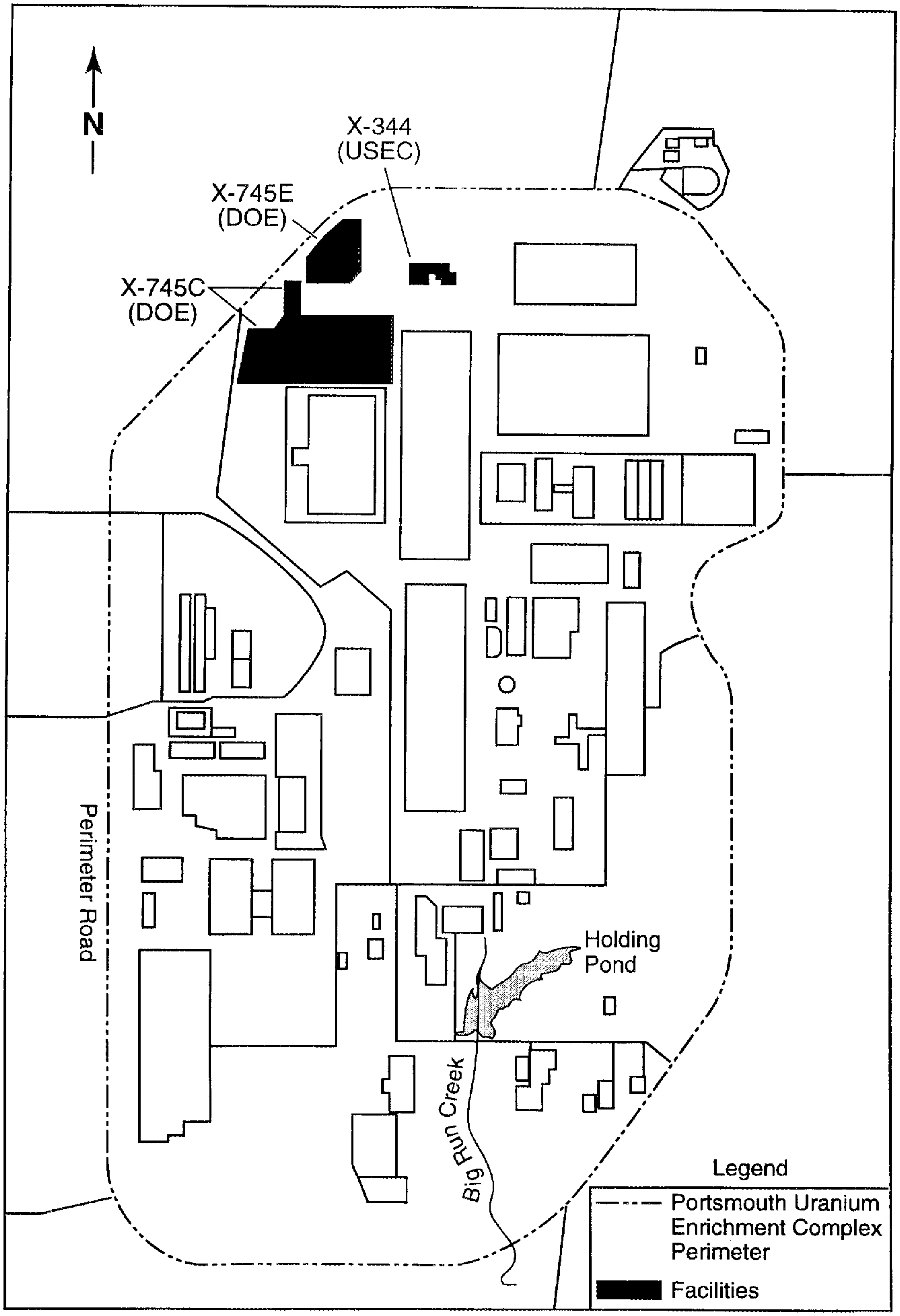

Fig. 2. Location of facilities that will be used in the SPD program at the Portsmouth GDP.

shipment. This net carriage capacity was used to calculate the number of cylinders needed to support this project.

- New Model 30B cylinders will be purchased by DOE or its consortium contractor. This is important for two reasons: (1) in general, the customers own their own UF_6 cylinders and (2) the cylinders that DOE may already own are likely to be old and have heels that contain daughter products and other impurities, which may be undesirable in the MOX fuel process.

The stoichiometric conversion rate, including process loss, was calculated in Sect. 2.3. The conversion ratio implies that for every kilogram of depleted UF_6 only 0.7556 kg of depleted UO_2 can be achieved. The conversion facility needs to receive 132.345 MT (291,767.8 lb) UF_6 [89.5 MTHM equivalent] annually or one-half the amount for each semiannual production run.

The cylinder carriage capacity limit for the Model 30B cylinders was calculated as follows:

Fill limit:	2,277.0 kg UF_6 (5,020 lb)
Less 2% net capacity:	–45.5 kg UF_6 (–100.4 lb)
Maximum heels remaining:	–11.5 kg UF_6 (–25.4 lb)
Maximum net carriage capacity:	2,220.0 kg UF_6 (4,984.2 lb)

Each 2.5-ton UF_6 cylinder can carry 2,220 kg (4,894.2 lb) of depleted UF_6; therefore, the number of cylinders shipped per year is calculated as follows:

$$
\begin{aligned}
(UF_6/\text{year})/(UF_6/\text{cylinder}) &= 132.345\ \text{kg/year}/(2{,}220\ \text{kg/cylinder}) \\
&= 59.6\ \text{cylinders/year} \\
&= 60\ \text{cylinders/year}\ .
\end{aligned}
$$

Because the annual process will be divided into two 50-MT (100,230 lb) UO_2 [44 MTHM equivalent] batches, it will be more economical to empty cylinders and return them to Portsmouth for refilling. Following each semiannual shipment to the fuel fabricator, the used cylinders will be returned to the Portsmouth GDP for servicing and refilling. If a cylinder is determined to be unsafe, it will be removed from service and a replacement cylinder purchased. Because the truck can carry up to 20 empty cylinders containing only residual heels per truckload and return to Ohio in one day from the representative conversion facility, only one-half (30 cylinders) of the annual requirements should be initially purchased for this program. It is recommended that 30 rather than 20 cylinders be purchased based on the limited processing time periods at both the Portsmouth GDP and the conversion facility.

The cost of a new Model 30B (2.5-ton) cylinder is about $2,200.00 including the valve, plugs, and valve cover. The total cost of the 30 cylinders needed is estimated at $66,000.00.

Following completion of the MOX campaign, it is expected that the Model 30B [2.28-MT (2.5-ton)] UF_6 cylinders used in this program, which remain in acceptable condition at the termination of this program, could be donated to USEC for refilling with enriched and depleted UF_6 in its ongoing production processes. Also the Model 30B cylinders could be sold for potential commercial LEU UF_6 use.

2.7 MODEL 48G [12.7-MT (14-TON)] CYLINDER SELECTION

Nominally, a single 12.7-MT (14-ton) cylinder can be used to fill five 2.28-MT (2.5-ton) cylinders. The 12.7-MT (14-ton) depleted UF_6 cylinders will be selected by assay based on MOX Fuel Fabrication Facility requirements, primarily, and by age in order to minimize the daughter products in the material. The most recently filled cylinders will be selected. Other factors that may enter into the selection will be quantity of material in each cylinder, actual cylinder condition (based on visual inspection), and retrievability of cylinder from the cylinder yard.

After the 2.28-MT (2.5-ton) cylinders are filled from a 12.7-MT (14-ton) cylinder, the 12.7-MT (14-ton) cylinder typically has 545–680 kg (1200–1500 lb) of UF_6 remaining in it. It is expected that these 12.7-MT (14-ton) cylinders would be reused and sent to the tails withdrawal station and refilled with tails material. They would subsequently be sent to the storage yard; however, cleaning of the cylinders may be required if they are not reused within a 5-year period.

In accordance with the annual requirements of 100 MT (220,460 lb) UO_2 [88 MTHM equivalent] specified to disposition 4.0 MT (7,716 lb) plutonium dioxide (PuO_2) [3.5 MTHM equivalent],[4] ~132.345 MT (291,767.8 lb) depleted UF_6 [89.5 MTHM equivalent] is required. The 10-year program would require 1,000 MT (2,204,600 lb) UO_2 [880 MTHM equivalent] plus 50 MT (110,130 lb) UO_2 [44 MTHM equivalent] for testing, equating to 1,390 MT (3,064,000 lb) UF_6 [940 MTHM equivalent] including losses. Based on a review of the fill quantities of cylinders in Portsmouth inventory, 124 Model 48G cylinders contain sufficient inventory to meet the requirements.[10] Seven additional cylinders are required to fulfill testing material requirements. To ensure adequate supply, an additional 8 Model 48G cylinders were also identified as potential replacements from a computerized printout. The assays of all selected cylinders were in the range of 0.2500 to 0.2509 wt %.

The fill dates for these cylinders were between 1980 and 1985 and were all stored in either rows 5, 6, 7, or 8 in Cylinder Yard X-745-C. Each row in the cylinder yard contains ~65 cylinders; thus, on average, only one cylinder would have to be removed to obtain the desired cylinder. The DOE inventory at Portsmouth as of February 1997 and the 131 selected cylinders identified for this program are summarized in Table 1. Less than 3% of the available depleted UF_6 in inventory at the Portsmouth GDP would be required for this program.

Table 1. UF_6 inventory with assays up to 0.30 wt % at the Portsmouth GDP

				MOX requirements	
Cylinder model	Number of cylinders	UF_6 (MT)	Equivalent UO_2 (MT)	Cylinders	UF_6 (MT)
30A	6	8	6		
48A	6	57	44		
48G	1,945	24,245	18,598	131[a]	1,390
48HI	1	12	9		
48O	85	1,077	826		
48OM	4,108	5,206	3,994		
48T	2,096	21,394	16,411		
48X	2	20	15		
Total	8,249	52,020	39,905	131	1,390

[a]Seven cylinders containing 65 MT UF_6 (50 MT UO_2), which will be used in facility startup testing, are included.

2.8 TRANSFER OF DEPLETED UF_6 FROM 12.7-MT (14-TON) TO 2.28-MT (2.5-TON) CYLINDERS

The UF_6 will be transferred from the Model 48G to the Model 30B cylinders. Model 30B cylinders are 2.28-MT (2.5-ton), thick-wall (1/2-in.), carbon steel cylinders; they are 30 in. in diameter, 81 in. long, and are designed for 200-psig service pressure rating. Each cylinder has a maximum net weight of 2.28 MT (5020 lb) of depleted UF_6 and a nominal gross weight of 2.912 MT (6420 lb).

The commercial UF_6 to UO_2 conversion facilities are set up to handle 2.5-ton cylinders. The Portsmouth plant has four liquid transfer autoclaves in Building X-344 to transfer the depleted UF_6 from the 12.7-MT (14-ton) cylinders to the 2.28-MT (2.5-ton) cylinders. As a general rule the enriched-UF_6 utility customers have a witness on site to confirm the filling and weighing of the 2.28-MT (2.5-ton) cylinders. Because these customers are charged by the pound of UF_6, this is economically advantageous. However, the depleted UF_6 is owned by DOE; it seems reasonable to assume that the charge for filling a 2.28-MT (2.5-ton) cylinder will be based on a "per 2.28-MT (2.5-ton) cylinder filled" basis rather than on an assay and unit net weight basis. Thus, the need for a witness for the depleted UF_6 transfers does not exist.

USEC has estimated the charges for transfer services as $2,000 per 2.28-MT (2.5-ton) cylinder filled. Program requirements are 60 cylinders annually for 10 years and 30 cylinders initially for testing materials, equating to 630 cylinders to be filled. The estimated total life-cycle cost for transfer services is $1,260,000.

2.9 UF_6 TRANSPORTATION REGULATIONS

Depleted UF_6 packaging, labeling, and transportation regulations are incorporated in CFR Title 49. The DOT Research and Special Program Administration is responsible for maintaining and requiring adherence to these policies. Transportation requirements were covered previously in Sects. 2.2.1 and 2.2.2.

The UF_6 cylinders are only transported after the UF_6 is solidified and the cylinder pressure is below atmospheric. A cooling time of 3 d is required for Model 30B cylinders.

2.9.1 On-Site Movement of Cylinders

The Model 48G cylinders were selected for this analysis. Cylinders must be identified by manufacturer, serial number, certified filling limit, tare weight, maximum working pressure and temperature, and date of most current hydrostatic inspection. Precise materials accountability and status are maintained for each cylinder with ongoing inspection programs. Cylinders are moved on-site through use of a cylinder handler (either a straddle buggy or NCH-35), which drives over a cylinder, picks up the cylinder, and moves it to a different location. Figures 3 and 4 are pictures of a straddle buggy and NCH-35, respectively.

Standard forklifts are used to move 2.28-MT (2.5-ton) Model 30B cylinders. The forklift tongs are set fairly close together in order to slide under a cylinder from one end. The rules for movement are "keep as low as possible" and do not exceed 30 in. at any time.

2.9.2 Off-Site Movement of Cylinders

Model 30B cylinders can be shipped to the representative facility on a truck–trailer combination. The cylinders are placed on a trailer and strapped down with heavy-duty tie-down devices. The cylinders must be fitted with a valve protector. Because these cylinders contains less than 1.0 wt % ^{235}U, no protective shipping containers are required.

It is estimated that eight or nine full depleted UF_6 cylinders could be transported on a trailer. It is assumed that each trailer will carry eight cylinders to the conversion facility. Thus, eight trailer loads of depleted UF_6 cylinders would need to be transported per year or four loads for each semiannual production run.

The types, quantity, and availability of containers used for the transport of UF_6 and the number of shipments on an annual basis are summarized in Table 2.

2.10 DEPLETED UO_2 PACKAGING AND STORAGE

The depleted UO_2 is not a fissile material and does not have a packaging limit to prevent criticality. The primary packaging consideration for the packaging for depleted UO_2 will be to protect the depleted UO_2 from moisture and air to preserve product quality and to protect the environment and personnel from inadvertent release of UO_2 powder.

This analysis is based on the assumption that the depleted UO_2 will be shipped in a drum-type package filled to the weight capacity (rather than volume capacity). A 208-L (55-gal) drum with a closed inner container or sealed heavy plastic liner and an airtight seal on the lid will be used. The weight capacity will be 250 kg (551.15 lb). Stacking of these drums will not be permitted.

Fig. 3. Straddle buggy moving a 12.7-MT (14-ton) UF_6 cylinder.

Fig. 4. NCH-35 12.7-MT (14-ton) nuclear cylinder handler.

Table 2. Annual transportation requirements for depleted UF_6 from Portsmouth GDP to GE Nuclear Energy, Wilmington, North Carolina

Annual number of shipments of depleted UF_6 to GE Nuclear Energy	Eight truck–trailer combination shipments carrying 8 cylinders for each shipment, total of 60 cylinders shipped annually	
Container types used for shipments	Model 30B [2.28-MT (2.5-ton)] cylinders	
Availability of containers	Obtainable from Columbiana Boiler Co., Columbiana, Ohio (216) 482-3373	
Average gross container weight, kg (lb)	2866.5 kg (6319.5 lb)	
Average material weight, kg (lb)	2243.0 kg (4944.9 lb)	
Average isotopic content of uranium	By isotope	Mass content (%)
	^{234}U	0.002
	^{235}U	0.250
	^{238}U	99.748
Average exposure rate[a] at 1 m for one full-time cylinder yard worker, mrem/h	0.9–1.4	
Maximum anticipated dose rate[b] at 1 m, mrem/h	3.0	

[a]The low limit for the average exposure range is based on the average of a representative random sample of 15 individual 12.7-MT (14-ton) cylinders in DOE Cylinder Yard X-745-C measured on July 1, 1997. The high limit is based on the same 15 cylinders plus 5 additional measurements giving cross-readings from 2 cylinders each. The instrument used was an Eberline RO-2, Serial No. 6256, calibration due date of July 27, 1997.[11]

[b]Maximum dose is based on the maximum measurement taken in DOE Cylinder Yard X-745-C measured on July 1, 1997.[11]

Based on the minimal cost involved and the assumption that these drums may not be returned in time for refilling twice annually, enough drums to contain the entire annual requirement of 100 MT (220,460 lb) UO_2 [88 MTHM equivalent] should be purchased. In addition, a 12% contingency overage is added to accommodate replacements for damaged drums or schedule delays.

$$(UO_2/\text{year}) / (UO_2/\text{cylinder}) = 100{,}000 \text{ kg/year} /(250 \text{ kg/drum})$$
$$= 400 \text{ drums/year} + 12\% \text{ (400 drums/year)}$$
$$= 448 \text{ drums} .$$

The cost of a new 208-L (55-gal) drum, including its plastic drum liner, is estimated at $100.00 or less per drum. The total cost of the 448 drums needed is $44,800.00.

2.11 UO_2 TRANSPORTATION

It is estimated that a standard 48-ft trailer will hold 4 drums per pallet, with 18 pallets per truckload. A truck operated by a commercial transport company can transfer up to 72 containers of UO_2 at a time on a trailer (stacking of drums is not permitted).

The number of truck–trailer combinations calculated to transport the drums of depleted UO_2 is six truckloads per year. The drums will be transported to the fuel feed safeguards storage area. The drums will be moved to the UO_2 storage area by an elevator separate from the elevator used to move PuO_2. The footprint of the UO_2 storage area was given as 1600 m^2 by LANL.[4] Assuming that each drum requires ~1 m^2, this is sufficient space for the 6-month inventory of depleted UO_2 contained in 200 of the 208-L (55-gal) drums. The types, quantity, and availability of containers used for transport of UO_2 and the number of shipments on an annual basis are summarized in Table 3.

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Following each semiannual shipment to the MOX Fuel Fabrication Facility, the used drums will be returned to the fuel fabricator for refilling unless they were inadvertently exposed to plutonium. Following completion of the MOX campaign, the 208-L (55-gal) drums used in this program will be taken to the MOX Fuel Fabrication Facility Waste Storage Facilities. The drums that have not been exposed to plutonium will be recycled as noncontaminated wastes. Those drums exposed to plutonium will be packaged for shipment to an on-site treatment facility and treated as either solid low-level waste (LLW) eventually destined for on-site burial or shipment to another DOE site or packaged as transuranic (TRU) waste and prepared for shipment to the Waste Isolation Pilot Plant (WIPP). Solid wastes will be treated by processes in compliance with the Environmental Protection Agency (EPA), Resource Conservation and Recovery Act of 1976 (RCRA), DOT, and DOE regulations.

Table 3. Annual transportation requirements of depleted UO_2 from GE Nuclear Energy, Wilmington, North Carolina, to the MOX Fuel Fabrication Facility

Annual number of shipments of depleted UO_2 to MOX Fuel Fabrication Facility	Six truck–trailer combination shipments carrying up to 72 drums each, total of 400 drums shipped annually	
Container types used for shipments	208-L (55-gal) open-head drums	
Availability of containers	Available from commercial vendors	
Average gross container weight, kg (lb)	275 kg (601.15 lb)	
Average material weight, kg (lb)	250 kg (551.15 lb)	
Average isotopic content of uranium	By isotope	Mass content (%)
	^{234}U	0.002
	^{235}U	0.250
	^{238}U	99.748
Average exposure rate[a] at 1 m based on data for one full-time cylinder or drum handler, mrem/h	≪0.9 (actual data not available)	
Maximum anticipated dose rate[a] at 1 m, mrem/h	≪3.0 (actual data not available)	

[a]It is expected that exposure rates would be much less for 208-L (55-gal) drums filled with depleted UO_2 than for 12.7-MT (14-ton) cylinders filled with depleted UF_6.

3. PORTSMOUTH GDP IMPACT ASSESSMENT

The retrieval of cylinders containing depleted UF_6, the transfer operations, and both on-site and off-site transportation efforts required for the SPD program are covered under routine operations at the Portsmouth GDP and by commercial transportation companies. Because no new or modified activities have been identified, it has been determined that the work required for this program poses no additional or unique threats to the environment. An in-depth impact analysis is not required. Except where noted, information provided in this section was obtained from the *Portsmouth Site Annual Environmental Report for 1994,*[12] *Portsmouth Annual Environmental Report for 1995,*[9] and *Portsmouth Annual Environmental Report for 1996.*[13]

3.1 CHEMICAL AND RADIOLOGICAL CONTAMINATION

Radiological and nonradiological emissions and discharges to the environment related to this activity are summarized in the following sections. Essentially all contamination released by the Portsmouth GDP is technetium and uranium. Radiation levels are routinely monitored both on-site and off-site at the plant. In 1994, the measurements for gamma radiation averaged 215 mrem/year inside the facility and 214 mrem annually near the boundary of the site. The annual effective-dose-equivalent rate for residents of Ohio averages 115 mrem/year. The average external gamma exposure for the United States is ~100 mrem.[8]

The SPD program's use of depleted UF_6, which has extremely low chemical and radiological activity compared to the alternative uranium feed form (natural UF_6), would notcontribute to increased levels of chemical and radiological contamination. The radiation and hazardous material protection sections of the safety analysis report for the Portsmouth GDP contain additional information on procedures, monitoring, and employee training.[14]

3.2 AIR QUALITY

Radionuclide and fluoride emissions from process vents are monitored at the site. Air sampling is also conducted in areas where airborne radiation is possible, and workers are likely to receive an annual intake of 2% or more of the annual limit (~100 mrem).[15] In 1994, 1995, and 1996, total radionuclide emissions released at the Portsmouth GDP were 0.185, 0.0343, and 0.000000002 Ci, respectively. Of these, 78% were technetium, and 22% were uranium isotopes in 1994. In 1995, 71% were technetium, and 29% were uranium isotopes. In 1996, all radionuclides released to the air consisted of uranium isotopes and short lived daughter products. Uranium emissions have decreased since 1994 and are expected to remain consistent in the future. Emissions of uranium daughters have ranged from 0.002–0.028 Ci annually since 1986. These have never shown a significant effect for the public or employees at the Portsmouth GDP.

In 1994, the highest on-site 7-d average fluoride concentration was 0.20 $\mu g/m^3$. In addition to on-site monitoring, the Ohio Environmental Protection Agency monitors ambient air quality. The primary air quality standards for Ohio are provided in Table 4.

Use of depleted UF_6, which is already stored at the Portsmouth site, for the SPD program would create no additional impact on air quality.

3.3 SOIL QUALITY

Soil is routinely sampled to ensure that no abnormal environmental contamination is present. In 1993, results for most on-site and all off-site samples were comparable to background values. One exception was Decontamination Building X-705, which was found to contain 143 pCi/g of ^{99}Tc and 45 $\mu g/g$ of uranium. It is documented that this building is contaminated from previous material spills. Also, two areas near the X-633 cooling towers contained elevated concentrations of chromium.[16]

Use of depleted UF_6 for this program wouldcontribute no incremental environmental contamination to the soil at the Portsmouth site.

Table 4. Ohio Environmental Protection Agency Primary Ambient Air Quality Standards (undated source document)

Pollutant average	Primary standard
Carbon monoxide (CO)	
1 h	35 ppm
8 h	9 ppm
Sulfur dioxide (SO_2)	
24 h	0.14 ppm
Annual	0.03 ppm
Particulate matter (PM_{10})	
24 h	150 $\mu g/m^3$
Annual (arithmetic)	50 $\mu g/m^3$
Ozone (O_3) 1 h	0.12 ppm
Nitrogen dioxide (NO_2) annual	0.053 ppm
Lead (Pb) quarterly	1.5 $\mu g/m^3$

3.4 WATER RESOURCE QUALITY

Groundwater, surface waters, and sediments are also routinely monitored to assess water quality and analyze potential radioactive and nonradioactive contamination. Monitoring programs comply with DOE orders and are designed to evaluate the effectiveness of effluent treatment and control, identify potential problems, and evaluate need for action.[14] In 1994, 3 of the 245 on-site wells were contaminated with tetrachloroethylene, trichloroethylene, freon, uranium, and technetium; in 1995 and 1996 only 1 well was found contaminated. In 1995, both uranium and technetium levels decreased from the 1994 level. In 1996, three wells in the central portion of the plume of the X-749 Contaminated Materials Disposal Facility showed slight increases from 1995. Uranium isotopes are alpha emitters, technetium is a beta emitter, and the uranium daughters (^{231}Th, ^{234}Th, and ^{234m}Pa) are beta or beta-gamma emitters.

In 1993, results of surface water monitoring indicated that radioactive, fluoride, and phosphate contamination measured less than drinking water standards. Some creek sediment samples were found to contain slightly elevated uranium and technetium levels and high concentrations of nonradioactive contamination in the form of iron, zinc, magnesium, and thallium.[16]

Use of depleted UF_6 for this program would not increase the potential impact on water resources beyond that resulting from routine operations.

3.5 HEALTH AND SAFETY OF WORKERS AND THE PUBLIC

Processing, handling, and storage of uranium at the Portsmouth GDP results in potential radiation exposure to both on-site personnel and the public in the surrounding area. In 1995 and 1996, an estimated maximum potential 50-year committed effective dose equivalent (CEDE) radiation exposure to the off-site public of 0.13 mrem/year and 0.000000262 mrem/year, respectively, resulted from operations. This exposure is small compared to the U.S. average exposure dose of 300 mrem/year resulting from natural background radiation and medical sources.

The average dose, which included background and medical sources, obtained by cylinder yard workers and uranium handlers in 1990 through 1995 ranged from 55 to 196 mrem/year. This is far below the exposure dose limit of 2000 mrem/year per person established by DOE.[15] An annual Lockheed Martin Energy Systems, Inc. (LMES) control level of 1000 mrem is established based on historical and projected exposures for current missions. Protective clothing and equipment are provided and required for all workers involved in uranium handling. In addition, administrative control limits of 500-mrem/year total effective dose equivalent (TEDE) and 10-mg/week intake of uranium per person have been set for radiological workers.[14]

The radiological standards for the Portsmouth GDP are provided in Table 5.[15]

Table 5. Summary of dose limits for the Portsmouth GDP (Exposures shall be well below the limits in this table and maintained as low as reasonably achievable.)

Type of exposure	Annual limit (rem)
Radiological worker	
Whole body (internal + external)	5
Lens of eye	15
Extremity (hands and arms below the elbow; feet and legs below the knees)	50
Any organ or tissue (other than lens of eye) and skin	50
Declared pregnant worker	
Embryo/fetus	0.5 (in 9 months)
Minors and students (under age 18)	
Whole body (internal + external)	0.1
Visitors and public	
Whole body (internal + external)	0.1

Notes:

1. Internal dose to the whole body shall be calculated as CEDE. The CEDE is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake.
2. Background, therapeutic, and diagnostic medical exposures shall not be included in either personnel radiation dose records or assessment of dose against the limits in this table.

Inventories of materials considered hazardous (toxicity, flammability, reactivity, or other causes) are maintained at the Portsmouth GDP. Gaseous fluoride emissions are monitored and sampled continuously. Personnel monitoring is done when exposures to UF_6, HF, or F_2 are anticipated. Detection limits for UF_6 are 0.25 ppm by portable detector tube, for HF are 0.5 ppm for fixed monitor and 0.25 ppm by portable detector tube, and for F_2 are 0.5 ppm for fixed monitor and 0.05 ppm by portable detector tube.[14]

The SPD program's use of depleted UF_6, which has extremely low chemical and radiological activity compared to the natural or enriched UF_6 routinely handled at Portsmouth, would not result in any additional exposure to workers or the public.

3.6 CYLINDER INCIDENTS AND ACCIDENTS

Three incidents/accidents involving UF_6 cylinders were identified at the Portsmouth GDP. In June 1997, radiologically contaminated soil was discovered in DOE Cylinder Yard X-745-C. LMES personnel determined that the contamination most likely resulted from a valve cleaning solution which had dripped onto the ground beneath the valve. This was not identified as a breached cylinder.[17]

In June 1990, two breached cylinders were detected. The damages resulted from mishandling and subsequent corrosion to the damaged areas. The UF_6 escaping from a 5.1-cm-diam (2-in.) hole in one of the cylinders was estimated at 1.8 kg (4 lb). The remaining contents were transferred to a new cylinder. The UF_6 released from a 23- by 46-cm (9- by 18-in.) hole in the second breached cylinder was estimated at 49 kg (109 lb). This cylinder required patching before the contents were transferred to a new cylinder.[18]

In March 1978, a cylinder was accidentally dropped in Cylinder Yard X-745-B. Liquid depleted UF_6 was released into the storm sewer. Following the accident, efforts were conducted to collect the material and monitor the environment for increased levels of uranium resulting from the drop. In 1994, some soil samples taken in X-745-B showed elevated uranium concentrations ranging up to 352 mg/kg. No increased levels of uranium were detected in groundwater, and contamination was limited to the yard.[19]

Use of cylinders containing depleted UF_6 stored at Portsmouth will not increase the potential for cylinder accidents at the site because these cylinders are routinely handled, moved, restacked, and inspected.

3.7 STAFFING LEVEL

The retrieval of cylinders from storage, autoclave transfer of the depleted UF_6 from 12.7-MT (14-ton) to 2.28-MT (2.5-ton) cylinders, sampling, placement in cooling area, and subsequent loading for transportation to the conversion facility can be accomplished through routine operations of the facility. Tasks associated with usage of UO_2 derived from depleted UF_6 as the diluent for the weapons-grade plutonium for MOX fuel fabrication will have no incremental impact on employment.

3.8 WASTE PROCESSING

Wastes generated from past and current operations and ongoing environmental restoration projects at the Portsmouth GDP include radioactive, hazardous chemical, and mixed wastes; polychlorinated biphenyl (PCB); asbestos; storm water runoff; and sanitary wastes. All radioactive wastes are classified as LLW or mixed waste. LLW is subsequently segregated into four classifications: burnable, scrap metal, other nonburnable, and mixed. Different storage requirements and disposal methods are in place for each type of waste.

Active waste management policies include minimization, preprocessing characterization and certification, volume reduction, on-site storage, and disposal options. DOE Order 5400.1 provides direction for environmental compliance, establishes requirements for environmental protection programs, and outlines requirements for groundwater monitoring. DOE Order 5400.5 provides guidance and standards for radiation protection for the public and the environment associated with DOE facilities. DOE Order 5820.2A sets policies, guidelines, and minimum acceptable requirements for radioactive waste management and facility contamination levels.[9]

The tasks associated with retrieving depleted UF_6 from the Portsmouth GDP cylinder yard will not generate wastes at levels greater than would be obtained in processing natural UF_6 being shipped in to the site for use in this program. The primary waste product will be in the form of used Model 48G and 30B depleted UF_6 cylinders. The 131 used 48G cylinders can be recycled on an ongoing basis to USEC for refilling with tails from the gaseous diffusion operations or sent to the DOE residual heels cylinder storage yard for subsequent disposal or reuse. Upon completion of the MOX fuel program, the 30 used Model 30B cylinders can be donated to USEC for refilling with natural, enriched, or depleted UF_6 in its routine operations or sold to a commercial entity for use in LEU UF_6 processing. These cylinders would require cleaning and inspection prior to reuse. Any Model 30B cylinders that become unusable during the MOX fuel program can be either transferred to the DOE heels cylinder storage yard for indefinite storage or decontaminated and treated as LLW through routine operations at the facility.

4. CONVERSION PROCESS

4.1 PROCESS OVERVIEW

The MOX Fuel Fabrication Facility production line requires a free-flowing[2] depleted or natural UO_2 powder capable of being readily blended with PuO_2. The process of converting UF_6 to UO_2 powder is handled by the LEU fuel fabricator as part of its overall process and is termed the "powder preparation" step. These facilities are U.S. Nuclear Regulatory Commission (NRC)-licensed to possess and process uranium up to a level of 5 wt % ^{235}U. *Converting depleted UF_6 to UO_2 for the MOX program does not require a license amendment or modification.*

In the United States, the commercial LEU fabricators are ABB–Combustion Engineering (ABB–CE) at Hematite, Missouri; Framatome Cogema Fuels [formerly Babcock and Wilcox (B&W) Fuels] at Lynchburg, Virginia; GE Nuclear Energy at Wilmington, North Carolina; Siemens Power Corporation at Richland, Washington; and Westinghouse Electric Corporation at West Columbia, South Carolina. Framatome Cogema Fuels obtains its powder and pellet supply from another fuel fabricator.

The overall generic fuel fabrication material flow sheet consists of feed receipt, powder preparation (i.e., blending, milling, granulating, and incorporating additives), pellet fabrication (i.e., sintering, grinding, and inspection), rod fabrication, packaging, and assembling of fuel bundles required by the specific reactor's core loading requirements. The chemical conversion of the depleted UF_6 to oxide powder for subsequent blending with PuO_2 powder is an initial step for MOX fuel processing. In basic terms, depleted UF_6 conversion involves processing to obtain UO_2 with recovery of the fluoride values. The health, safety, and environmental risks involved in the conversion process and handling of materials are minimal. Preparation of powder is a routine business operation at any of the LEU fabricators.

Once converted, the depleted UO_2 would be available for transportation to the MOX Fuel Fabrication Facility for further processing. The conversion facility will have a small UO_2 product storage area for inventory awaiting transport to the MOX plant.

The proven conversion methods currently available for converting enriched UF_6 to UO_2 can be used to convert depleted UF_6 to UO_2. The representative conversion method does not involve H_2O as a liquid stream and is referred to as dry processing. A primary commercial objective in the conversion process will be recovery of the fluoride values, that is, recovery and sale of the HF by-product. The commercial viability relates to both the purity level of the HF and the market conditions. If the HF has too high a concentration of uranium remaining, it may not be considered of marketable quality and must be either processed further or treated as waste.

There are currently five commercial nuclear fuel fabricators in the United States as shown in Table 6. Appendix C contains summarized process flow diagrams for the four conversion facilities with UO_2 powder production capability.

4.2 REPRESENTATIVE FACILITY—GE NUCLEAR ENERGY

For analysis purposes only, GE Nuclear Energy in Wilmington, North Carolina, has been selected as the representative converter for the depleted UF_6. Operated by GE Nuclear Energy as a joint venture between General Electric and Japan Nuclear Fuels, the facility applies the dry conversion technology being used in France. The facility is licensed under NRC SNM-1097 and North Carolina 65-317-1 to possess nuclear materials for conversion of LEU as UF_6 to UO_2 and to fabricate LWR nuclear fuel assemblies.

The dry conversion process (DCP), deployed in 1997 by GE Nuclear Energy for conversion of enriched UF_6 to UO_2, is a more efficient process than the ammonium diuranate (ADU) wet conversion process it replaced at the GE Nuclear Energy facility. The DCP generates 90–100% less waste. The by-product, 50% HF, is captured and sold commercially if the uranium content does not exceed 3 ppm, which reduces fluoride wastes requiring treatment. Less than 400 m^3 of liquid fluoride will be shipped to the Waste Treatment Facility at the GE facility on an annual basis.[20] A summary discussion of the primary procedures follows.

Table 6. UF_6 to UO_2 powder conversion capacity in the United States

Fabricator	Location	Powder capacity (MT uranium)	Available capacity in 2006	Comments
ABB–Combustion Engineering	Hematite, Missouri	700	Yes	Capacity is from a dry conversion process (data supplied by ABB–Combustion Engineering, June 25, 1997)
Framatome Cogema Fuels (formerly B&W Fuel Company)	Lynchburg, Virginia	None	No	Powder and pellets are purchased from another fuel fabricator
GE Nuclear Energy	Wilmington, North Carolina	1000	Yes	In 1997, dry conversion lines will replace the wet (ADU) process lines (data supplied by GE Nuclear Energy, June 5, 1997)
Siemens Power Corporation	Richland, Washington	1400	Yes	Capacity includes operations from both the currently operating wet process and completion of dry process conversion scheduled to be fully operational in 1998 (data supplied by Siemens Power Corporation, June 23, 1997)
Westinghouse Electric Corporation	West Columbia, South Carolina	1150	Yes	Capacity includes operations from both integral dry route (IDR) and wet (ADU) processing lines (data supplied by Westinghouse Electric Corporation, June 26, 1997)

4.2.1 Model 30B Cylinder Emptying

The DCP has three separate processing lines with a combined annual operating capacity of 1,000 MTU (2,204,600 lb) [1,000 MTHM equivalent]. Each line is equipped with two dry electric autoclaves. The Model 30B cylinders transported from Portsmouth are unloaded from the truck and weighed following receipt at the facility. Each cylinder is placed in one of the autoclaves. Upon vaporization, the autoclaves transfer the gaseous UF_6 to the hydrolysis zone of the UO_2 kiln. The empty cylinder, containing a residual heel of less than 1 kg (2.2 lb) UF_6, is returned to the Portsmouth GDP for refilling.

4.2.2 Process Clean-Out

Before production of depleted UO_2, ~500 kg (1100 lb) depleted UF_6 must be transferred through the system to clean out enriched uranium remaining from previous processing.

4.2.3 UF_6 Conversion to UO_2 and HF Recovery

The gaseous UF_6 reacts with superheated steam to form gaseous HF and solid uranyl fluoride (UO_2F_2) powder, which is screw conveyed to the kiln for further defluorination and reduction to triuranium octaoxide (U_3O_8). This oxide is further reduced to stochiometric UO_2 through introduction of hydrogen (H_2). The three steps in the conversion process are represented by the following equations:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$$

$$3UO_2F_2 + 3H_2O \rightarrow U_3O_8 + 6HF + 1/2O_2$$

$$U_3O_8 + 2H_2 \rightarrow 3UO_2 + 2H_2O$$

Out-of-specification uranium can be sent back through the hydrolysis zone for further processing. The HF is treated to remove residual uranium and transferred to the HF recovery area in an adjacent building.

4.2.4 UO_2 Processing

The UO_2 drops into a cooling hopper that cycles approximately every 8 h. The UO_2 is cooled to room temperature with nitrogen. The powder is then transferred to a large container for short-term storage and subsequently transferred via vibrating table through a screen/magnetic separator to the homogenizer. The homogenizer contains a screw blade which rotates, blending large batches of UO_2, to ensure chemical and physical homogeneity.

The powder may then either be returned to short-term storage or sent to the blender. Isotopic blends are prepared with additions of a pore former and/or lubricant.

The powder is again either returned to short-term storage or to the precompaction press for pressing and granulating. The press includes two moveable punches with a fixed die, and the powder is pressed into a small puck approximately 1 in. in diameter and 0.25 in. thick. The pucks move to the granulator/magnetic separator where they are crushed against a screen. Granulated UO_2 is transferred to bicones for transfer to the packaging area for external shipment. A bicone is a rubber-sealed storage device consisting of two cones, one inverted on top of the other, and has the physical characteristics to allow for tumbling the powder.

4.2.5 UO_2 Packaging and Transportation

Depleted UO_2 is packaged in a heavy-plastic-lined, 208-L (55-gal) drum holding up to 400 kg (880 lb) UO_2 powder. The lining is secured with a wrapping tie and is used to prevent contamination obtained from contact with the drum. For the purpose of this analysis, we have assumed that each drum will contain 250 kg (550 lb) based on LANL's assumptions for the MOX Fuel Fabrication Facility.[4] Drums are priced at less than $100 each. The storage area houses a package refurbishment operation where drums are sandblasted and repainted following each use. GE Nuclear Energy has storage capacity sized for their European and Japanese customers for drums awaiting shipment. Storage space for UO_2 awaiting shipment to the MOX Fuel Fabrication Facility would be available subject to commitments to other customers.

4.2.6 Staffing Level

A total of five shifts are staffed. The addition of conversion of the nominal quantities of depleted UF_6 for the MOX Fuel Fabrication Facility will have no impact on employment.

4.2.7 Production Schedule

GE Nuclear Energy's preferred schedule for providing 100 MT (220,460 lb) of depleted UO_2 [88 MTHM equivalent] for the MOX Fuel Fabrication Facility would be based on an annual one-batch process. This is primarily due to economics based on the duplicate costs and extra UF_6 required for multiple system clean-outs. Due to their proprietary nature, costs are not included in this report. The time required for this annual run is calculated as follows:

$$\text{Conversion ratio for U to } UO_2 = (\text{mol wt } UO_2)/(\text{mol wt U}) = 270.03/238.03 = 1.1344 \ .$$

Annual capacity $= 1000$ MT U $\times$ 1.1344 factor $\times$ 99.5% assumed efficiency
$= 1128.728$ MT UO_2 .

Line capacity $= 1128.728$ MT $UO_2/3$ lines
$= 376.243$ MT UO_2 .

Weeks required $= 100/376.243$ MT $UO_2 \times 52$ weeks + setup/packaging
$= 15$ weeks .

Based on the MOX Fuel Fabrication Facility's requirements,[2] semiannual production runs will be made. The time required to meet each semiannual run is calculated as follows:

Weeks required $= 50/376.243$ MT $UO_2 \times 52$ weeks + setup/packaging

$= 8$ weeks .

Based on proprietary information not included in this report, GE Nuclear Energy can accommodate the annual 50 MT (110, 230 lb) UO_2 [44 MTHM equivalent] semiannual requirement of the MOX Fuel Fabrication Facility.

4.3 GE NUCLEAR ENERGY IMPACT ASSESSMENT

The GE Nuclear Energy facility at Wilmington, North Carolina, in New Hanover County, has recently completed an environmental evaluation of the DCP and their site. The impacts of handling and processing UF_6 and HF assessed in GE Nuclear Energy's evaluation were determined based on historical experience at both the Wilmington site and other uranium processing and chemical facilities. The information and data found in Sect. 4.3 were obtained from the following four referenced documents: *Safety Evaluation Report for the Renewal of Special Nuclear Material License SNM-1097 for the General Electric Company, Nuclear Energy Production, Wilmington, North Carolina*;[20] *ISA Summary—GE Wilmington Dry Conversion Process*;[21] *U.S. Nuclear Regulatory Commission Finding of No Significant Impact and Notice of Opportunity for a Hearing Renewal of Special Nuclear Materials License SNM-1097, General Electric Company, Wilmington, North Carolina, Docket 70-1113*;[22] *Environmental Assessment for Renewal of Special Nuclear Material License No. SNM-1097*;[23] and *Environmental Impact Appraisal for Renewal of Special Nuclear Material License No. SNM-1097.*[24]

Approximately 376,000 people live within a 50-mile radius of the site with 120,284 living in Wilmington, North Carolina, where the facility is located. GE Nuclear Energy employs 13.5% of people who work in manufacturing in New Hanover County.

The DCP facility has been constructed to meet industrial standards for structural integrity against wind speeds of 120 mph, seismic activity relative to Wilmington, and weather hazards. The facility is designed to prevent water from entering the building and potentially coming into contact with in-process uranium.

The GE Nuclear Energy facility was issued License No. SNM-1097 on January 1, 1967. The NRC's safety review for license renewal in June 1997 concluded that activities at the GE Nuclear Energy facility in Wilmington, North Carolina, posed minimal risk to employees or public health and safety. Processing of depleted UF_6 for this program would not increase environmental risks beyond those generated in processing natural UF_6.

4.3.1 Chemical and Radiological Contamination

The GE Nuclear Energy production processes and operations release low-level radioactive and non-radioactive materials, which include uranium, fluoride, nitrates, and ammonia (NH_3). Controls, environmental monitoring devices, and administrative procedures are in place to maintain effluent releases within prescribed limits. Operating procedures require that investigation of unusual concentrations and corrective action be performed. The program is reviewed and updated when changes occur in operations.

The DCP is designed to prevent inadvertent release of airborne uranium into parts of the facility where personnel could be unprotected from such releases. Processing areas are ventilated and equipped with high-efficiency particulate air (HEPA) filters. The air flow design is such that air is drawn downward and away from personnel work areas. In areas where UO_2 powder is handled, vented hoods and glove boxes are used.

Treatment systems and retention basins are used to reduce the concentration of liquid effluents discharged through the release channel of the Northeast Cape Fear River. Analyses on liquid effluents from operations are performed daily for uranium, weekly for alpha and beta activity, and semiannually for ^{99}Tc.

Solid effluent streams are processed, recycled, incinerated, or sent for disposal.

4.3.1.1 Cylinder handling and autoclave operation

Operators are trained in proper cylinder handling procedures, and movement of UF_6 cylinders complies with procedures outlined in Ref. 7. Additional administrative controls are in place to preclude processing of overweight UF_6 cylinders.

Electric autoclaves are used in the DCPs vaporization step. The autoclaves are manufactured to meet the ASME specifications for pressure vessels and are pressure-tested annually. The autoclaves are also equipped with UF_6 leak detectors. Upon detection of a leak, the UF_6 can be fed safely by the introduction of nitrogen at high pressure to suppress leakage.

Employees wear protective equipment when installing or disconnecting the UF_6 line to cylinders. Mechanical and administrative controls are in place to prevent overpressurizing cylinders. If a leak occurs into the autoclave room, the DCP design allows for the ventilation system to be shut down to avoid UF_6 release.

4.3.1.2 Conversion process

The conversion process includes both conversion of UF_6 to UO_2 powder and recycle of powder too high in fluoride content. Loss of H_2 containment in the kiln is the primary concern during processing. The kiln is controlled by a pressure check system, which includes monitors and alarms. In the event of an H_2 leak into the kiln room, detectors alert operators to shut down H_2 and UF_6 being fed to the reactor. Operators wear protective equipment when engaging or disengaging feed connections.

Filters are installed in the reactor top and off-gas lines to prevent particulate uranium from entering the off-gas system. The kiln filters are periodically cleaned during operation to avoid excess powder accumulation. Guards and interlocks are installed on kiln drive units, the reactor, and screw conveyor motors to prevent personnel injury caused by moving parts. Lock-out/tag-out procedures are instituted as standard practice.

4.3.1.3 UO_2 powder

Moisture can be introduced to UO_2 through excess quantities of pore former, lubricants, water, or slug press oils. Valve locks, moisture and weight interlocks, and computerized fill-level controls are in place to prevent moisture or condensation on UO_2. Small quantities of lubricants for mechanical parts, which have minimal opportunity to come in contact with processed powder, are not considered to cause a significant hazard.

Interlocks and containment guards are installed on the blender, slug press, granulator, and powder packer to prevent personnel injury caused by moving parts. In addition, the powder tumbler can only be operated when the tumbler room door is in the locked position to prevent potential injury to personnel.

Powder-packing operating procedures for filling UO_2 shipment containers are instituted to further protect employees from inadvertent contact with airborne uranium. Container handling equipment is covered by site-wide safety procedures, and operators attend required training in proper use of equipment.

4.3.1.4 Hydrogen fluoride

The HF area produces aqueous HF from the HF off-gas from the conversion process. The HF product is loaded into tankers for subsequent shipment. Criticality incidents or accidents can occur if particulate enriched uranium enters the off-gas system. Filters, installed in the top of the reactor and off-gas line downstream from the reactor in the DCP, are continuously monitored for pressure fluctuations. Each HF line is equipped with a uranium detector to divert unacceptable streams to a separate tank, and an additional detector is installed in the combined line subsequent to the merger of the individual lines. An air blower dilutes off-gas to a level lower than the H_2 explosive limit.

The HF facility also processes the kiln off-gas to remove residual HF and fluorides before airborne release to the environment. Diluted, aqueous HF is sent to the site waste treatment facility to remove the HF content. HF storage tanks and the tanker-loading bay drain into a concrete dike designed to contain spills.

Personal protection equipment is worn by operators, and safety showers are available for use by personnel in case of exposure to aqueous HF. The HF area is equipped with an HF scrubber should room air become contaminated.

4.3.2 Air Quality

Six sampling stations perform continuous air monitoring for gross alpha activity at the GE Nuclear Energy Wilmington facility. These samples are analyzed daily or weekly and showed no elevated gaseous levels from 1989 to 1995. GE Nuclear Energy estimates airborne uranium effluents will decrease by 50% when the DCP becomes fully operational.

Several stations also monitor releases of fluoride. HF is the most significant airborne contamination from the DCP facility. From 1989 to 1995, fluoride concentrations averaged 2 $\mu g/m^3$ (0.01 lb/d). The reference exposure limits are 2500 $\mu g/m^3$ for fluoride and 2000 $\mu g/m^3$ for occupational exposure to HF. GE Nuclear Energy expects HF releases to increase to ~0.12 lb/d when the DCP is fully operational. The State of North Carolina set an emission limit of 0.63 lb/d for the facility.

4.3.3 Soil Quality

To monitor and observe potential long-term buildup of uranium deposits, GE Nuclear Energy samples soil on-site and from the effluent channel annually. Uranium concentrations found in the on-site samples are slightly higher than samples taken at off-site locations. In 1989–1995, the average on-site concentration was 560 ppm uranium compared to 280 ppm found in off-site samples.

Semiannual sampling of fluoride content in trees and grasses near the facility is also conducted. From 1989 to 1995, fluoride measurements ranged from below 10 ppm up to 41.5 ppm at the northeast sampling station.

4.3.4 Water Resource Quality

Liquid effluents are released into the Northeast Cape Fear River, which is not used as a supply of drinking water for the area. Samples are taken both upstream and downstream of the liquid effluent discharge point from the DCP. In addition, storm water runs into the Prince George Creek on the eastern part of the facility. Surface water radiological and nonradiological analyses are performed weekly to quarterly. Recent results conclude that discharged effluents are indistinguishable from background levels.

Groundwater monitoring is required by the NRC and the State of North Carolina and is conducted to provide warning of containment failure or inadvertent releases of material. Monitoring wells are sampled monthly or quarterly depending on their location. Wells near the waste treatment or sludge storage facilities are sampled monthly; those in the final process basis that have relatively limited risk are sampled quarterly.

Levels of gross alpha activity were observed in wells near the final process basins between 1989 and 1995. One final process basin well and one waste treatment facility well contained uranium contamination in addition to elevated gross alpha activity. GE Nuclear Energy is analyzing the impact of this contamination in the final process basin and thinks that the waste treatment facility well was contaminated in 1986 from an ammonium fluoride wastewater leak in the overhead piping.

GE Nuclear Energy estimates uranium concentration in liquid effluents will decrease by as much as 85% when the DCP replaces the ADU process. Also because GE Nuclear Energy only processes UF_6 inside site buildings, the likelihood of a liquid UF_6 release outside the buildings is small.

4.3.5 Health and Safety of Workers and the Public

GE Nuclear Energy's radiation protection program is established to protect both employees and the general public from hazards associated with operations. GE management has committed to maintain exposure as low as reasonably achievable (ALARA). Engineering controls, procedures, radiation checks, ventilation systems, protective equipment, emergency planning, and other systems have been instituted to monitor and control potential exposure. To prevent airborne contamination of personnel, seals are purged with nitrogen, and ventilation containment systems are in place. Controls, alarms, and computerized systems are installed throughout the DCP for monitoring, process shutdown, and personnel notification purposes.

Possible radiological accidents could include hairline cracks in cylinders resulting from accidental drops, which would not cause a major UF_6 leakage; UO_2 powder spills, which would be primarily contained to the interior of the buildings where processing occurs; and UF_6 cylinder rupture caused by fire, which then causes the UF_6 to react with moisture to form HF and UO_2F_2. These scenarios would not pose significant threat to the general public.

Facility accidents include explosion, fires, criticality events, and HF or hydrogen leakage accidents. Impacts from these scenarios would be primarily contained to individuals in the area at the time of the accident. Reference 23 provides details relating to potential accidents and their environmental impacts.

In 1994 and 1995, approximately 1000 workers were involved in activities where potential exists for exposure to radioactive materials. Average dose rates for the 1000 workers monitored in 1994 and 1995 are provided in Table 7. The maximum level exposure doses at the GE Nuclear Energy facility were below the NRC limit of 5,000 mrem/year detailed in 10 CFR 20.1201.

Table 7. Exposure rates for workers at the GE Nuclear Energy Facility in Wilmington, North Carolina[20]

Exposure dose	Exposure rate (mrem/year)
External skin dose	
Average (1994)	43
Average (1995)	30
Highest (1994)	890
Highest (1995)	1110
External deep dose	
Average (1994)	27
Average (1995)	18
Highest (1994)	480
Highest (1995)	300
Total effective dose equivalent (TEDE)	
Average (1994–1995)	390
Highest (1994)	2100
Highest (1995)	2400
Internal exposure—committed effective dose equivalent (CEDE)	
Highest (1994)	2080
Highest (1995)	2420

4.3.6 Waste Processing

Liquid wastes generated at the DCP include fluoride, radioactive, nitrate, low-level, storm water runoff, and sanitary waste. Fluoride waste streams containing low concentrations of uranium are treated in the process area through an ion exchange process to remove excess uranium before being piped to the GE Nuclear Energy's Waste Treatment Facility. The liquid is treated by adding lime to raise the pH. The result, calcium fluoride (CaF_2), can be sent to the on-site disposal dike.

Radioactive and nitrate waste steams are generated by the production processes, scrubbers, and general cleaning procedures. These liquids are treated to remove solids, which are sent to scrap uranium recovery. Uranium-free liquid wastes are combined and treated before being released to the environment. Sanitary waste is treated, dried, and shipped off-site. The NRC liquid effluent limit for uranium at the facility boundary is 300 pCi/L. From 1991–1995, average discharges at the Wilmington facility remained below the NRC limit.

Solid wastes include both uranium-contaminated and uncontaminated materials in the form of tools, equipment, filters, protective clothing, other production articles, and uranium and fluoride sludges. Non-combustible uranium-contaminated waste is decontaminated before processing further or shipping off-site to an NRC-licensed disposal site. Combustible waste is sent for decontamination, placed in proper containers, and incinerated on-site. The ash is sent through a uranium recovery process or sent to off-site disposal.

Processing of depleted UF_6 for this program would not generate waste levels greater than those generated in processing natural or enriched UF_6.

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Appendix A
ASSUMPTIONS

- Urania feed for the MOX Fuel Fabrication Facility will be depleted UO_2.
- 50 MT (110,230 lb) depleted UO_2 [44 MTHM equivalent] will be required for startup testing.
- 100 MT (220,460 lb) depleted UO_2 [88 MTHM equivalent] will be required annually.
- Assay range for depleted UF_6 selected for use is 0.2500–0.2509 wt %.
- Depleted UF_6 is stored in 12.7-MT (14-ton) Model 48G cylinders.
- Each 12.7-MT (14-ton) cylinder contains up to 12 MT (26,455.2 lb) depleted UF_6.
- Depleted UF_6 will be shipped from the Portsmouth GDP to GE Nuclear Energy in 2.28-MT (2.5-ton) cylinders.
- The Portsmouth GDP has four autoclaves for transferring UF_6 from any 48-in. cylinder to 2.28-MT (2.5-ton) cylinders.
- Cost for transferring depleted UF_6 is $2,000 per 2.28-MT (2.5-ton) cylinder filled.
- Each 2.28-MT (2.5-ton) cylinder will contain ~2.2 MT (4850 lb) depleted UF_6.
- Cost per 2.28-MT (2.5-ton) cylinder is $2,200.
- A maximum of 9 of the 2.28-MT (2.5-ton) cylinders can be transported in each shipment.
- Depleted UO_2 will be shipped from GE Nuclear Energy to the MOX Fuel Fabrication Facility in 208-L (55-gal) drums.
- Each 208-L (55-gal) drum will contain ~250 kg (550 lb) depleted UO_2.
- Cost per 208-L (55-gal) drum is $100.
- A maximum of 72 of the 208-L (55-gal) drums will be transported in each shipment.
- UO_2 storage at the MOX Fuel Fabrication Facility will be capable of housing the 208-L(55-gal) drums.
- Lead time for UO_2 arrival at the MOX Fuel Fabrication Facility is a maximum of 6 months before it is needed.

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Appendix B
REGULATIONS

Policies and regulations relating to UF_6 cylinders are as follows:

Document	Description of Document
ANSI N14.1	*American National Standard for Nuclear Materials—Uranium Hexafluoride Packaging for Transport*, American National Standards Institute (1990)
ASME NQA-1	*Quality Assurance Program Requirements for Nuclear Facilities*, American Society for Mechanical Engineers
DOE 1270.2	*Safeguards Agreement with the International Atomic Energy Agency*, U.S. Department of Energy (June 1992)
DOE 1540.1	*Materials Transportation/Traffic Management*, U.S. Department of Energy (July 1992)
DOE 1540.2	*Hazardous Material Packaging for Transport—Administrative Procedures*, U.S. Department of Energy (September 1986)
DOE 5480.3	*Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes*, U.S. Department of Energy (July 1985)
DOE 5630.11	*Safeguards and Security Program*, U.S. Department of Energy (August 1994)
IAEA	*Regulations for the Safe Transport of Radioactive Material*, IAEA Safety Standards Series 6, International Atomic Energy Agency, [1996 (effective date is 2001)]
ORO-651, Rev. 6	*Uranium Hexafluoride: A Manual of Good Handling Practices*, U.S. Department of Energy, prepared by Martin Marietta Energy Systems, Inc.
USPS Pub. 52	*Acceptance of Hazardous or Perishable Articles*, U.S. Postal Service, Publication 52
10 CFR	Parts 40.4, 50.34, 70, and 71(H), and Appendix B to Part 50, *Code of Federal Regulations*, U.S. Nuclear Regulatory Commission
42 USC 2296b-5	*Energy Policy Act (EPACT) of 1992*, Public Law 102-486, Section 1016—Uranium Inventory Study, (October 24, 1992)
49 CFR	Parts 171, 172, 173.420, 173.425, 173.474, 173.475, 174, 175, 176, 177, 178.188, 178.120, 178.121, and 178.350, *Code of Federal Regulations*, U.S. Department of Transportation, Research and Special Program Administration

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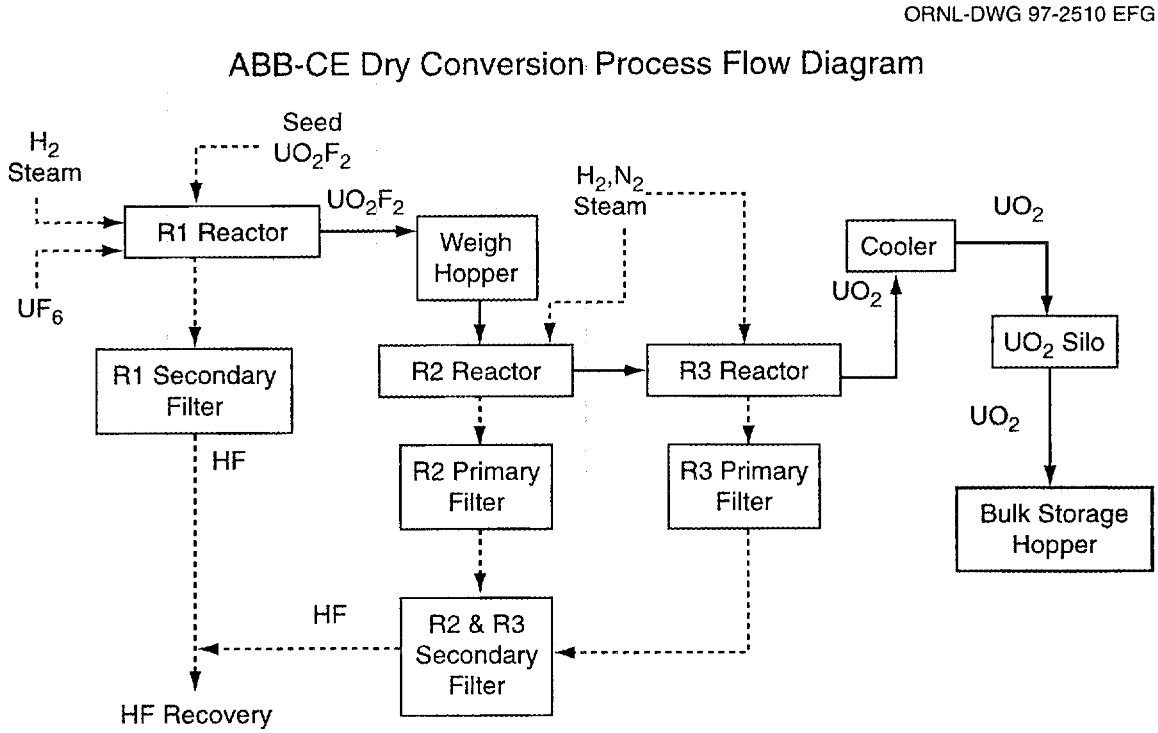
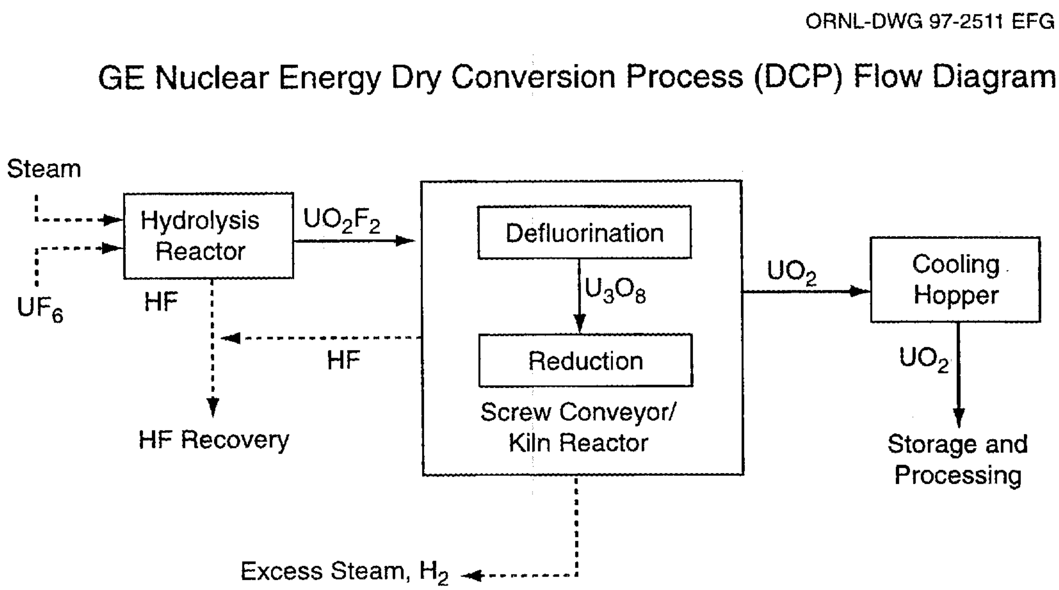
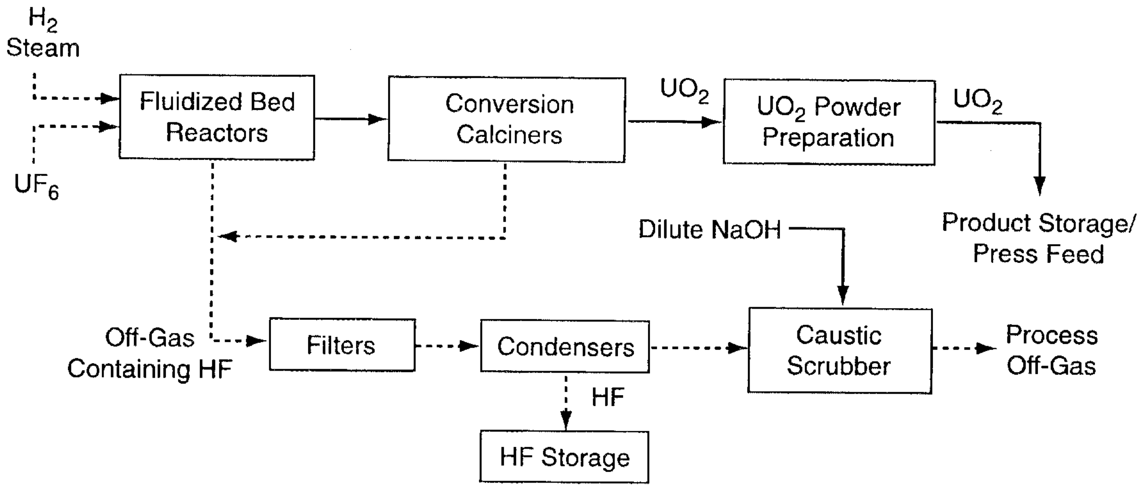
Appendix C
FLOW DIAGRAMS OF U.S. UF_6 TO UO_2 CONVERSION PROCESSES





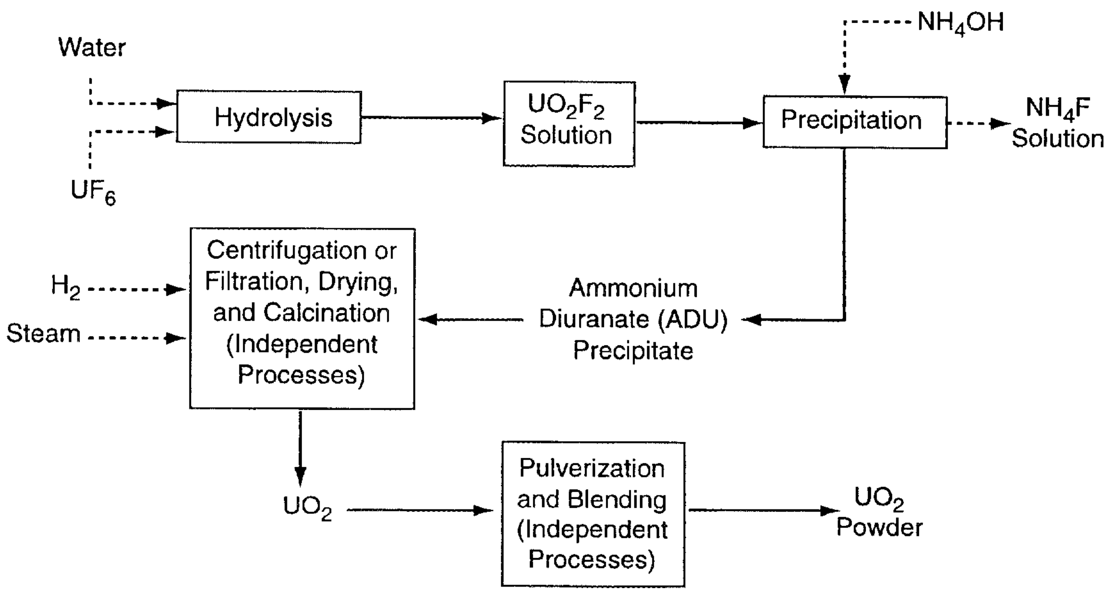
ORNL-DWG 97-2512 EFG

Siemens Dry Conversion Process Flow Diagram



ORNL-DWG 97-2513 EFG

Westinghouse Wet Conversion Process (ADU) Flow Diagram



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