UCRL-AR-124080 Vol 1 Rev 2

DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

The Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride

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FISSION ENERGY AND SYSTEMS SAFETY PROGRAM

October 16, 1997
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TO: Distribution

FROM: Robert Dann

SUBJECT: Engineering Analysis Report Transmittal Letter

Enclosed are the new cover pages for volumes 1 and 2 of the draft *Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride* which was distributed to you in May 1997. Please affix this transmittal letter and new cover pages to your existing documents.

To be consistent with normal NEPA practice, this report is being issued as a final document to coincide with the issuance of the draft PEIS. The only change that has been made to the previously distributed *Engineering Analysis Report* is the removal of the word "draft" whenever it appeared in reference to the May 1997 publication.

If you have any questions, please call me at (301) 916-7734.

Sincerely

Robert K. Dann
Project Manager
FESSP Washington Operations

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Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

1.0 Introduction

With the publication of a Request for Recommendations and Advance Notice of Intent in the November 10, 1994, *Federal Register* (59 FR 56324 and 56325), the Department of Energy (DOE) initiated a program to assess alternative strategies for the long-term management or use of depleted uranium hexafluoride (UF_6) stored in the cylinder yards at Paducah, Kentucky; Portsmouth, Ohio; and Oak Ridge, Tennessee. The current management strategy entails handling, inspection, monitoring, and maintenance activities to ensure safe storage of the depleted UF_6. The alternatives to continuing the current management strategy are strategies focusing on use, long-term storage, or disposal of the material, or some combination thereof. Complete management strategies may also involve transportation and, in many cases, conversion to another chemical form.

All alternative management strategies, including the current management strategy (the "no action alternative"), are analyzed in a Programmatic Environmental Impact Statement (PEIS) for their impacts on the natural environment and on human health.[1] In addition, an accompanying cost analysis report has been prepared to provide comparative cost data for the options analyzed in this *Engineering Analysis Report* and the alternatives analyzed in the PEIS.[2] The PEIS, the *Engineering Analysis Report*, and the *Cost Analysis Report* will be used by DOE in the decision-making process, which is expected to result in a Record of Decision in 1998. This Record of Decision will complete the first phase of the Depleted Uranium Hexafluoride Management Program, management strategy selection. During the second phase, site-specific and technology-specific issues will be determined.

The Engineering Analysis Project for the Depleted Uranium Hexafluoride Management Program consists of technology and engineering assessments. The technology assessment identified and assessed the options which were to be considered in developing management strategy alternatives. Fifty-seven responses were received to a Request for Recommendations, which asked members of the general public, industry, and other government agencies to submit suggestions for potential uses for depleted UF_6, as well as for technologies that could facilitate long-term management of the material. The results of the independent review of the

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[1]U.S. Department of Energy. *Draft Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride.* 1997.

[2]Elayat, H., J. Zoller, and L. Szytel, L. *Draft Cost Analysis Report for Alternative Strategies for the Long-Term Management of Depleted Uranium Hexafluoride.* Lawrence Livermore National Laboratory. 1997.

recommendations were presented in *The Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride*, published June 30, 1995.[3]

The goal of the Engineering Analysis Project is to perform a comprehensive technical analysis of the options and suboptions involved in the alternative strategies being considered for the long-term management of depleted UF_6, based on the technology assessment. Preconceptual, non-site-specific engineering data were developed under the Engineering Analysis Project for this purpose. Preconceptual data are developed for a project at the time of project identification. Since these data are developed prior to conceptual design, they are scoping level, order of magnitude only. As described in DOE Order 4700.1, conceptual design encompasses those efforts to develop a project scope that will satisfy program needs; assure project feasibility and attainable performance levels; develop reliable cost estimates and realistic schedules in order to provide a complete description of the project for congressional consideration; and develop project criteria and design parameters for all engineering disciplines.[4] Preliminary or Title I design continues the design effort utilizing the conceptual designs. Title I design is usually the first line-item funded design effort for a facility and the design at this point will be site-specific. In the current phase of the Depleted UF_6 Management Program, it is appropriate to consider engineering and cost data at the preconceptual level in order to determine a long-term management strategy. Following the Record of Decision, conceptual and then Title I design data would be developed for the specific technology(ies) and site(s) involved in the implementation.

The analysis of options and suboptions includes the development of facility layouts; estimates of effluents, wastes, and emissions; specification of resource requirements; preliminary hazards assessments; parametric assessments; development of accident scenario data; and the analysis of license, permit, and regulatory requirements. The *Draft Engineering Analysis Report* presents the results of the Engineering Analysis Project to date. The final *Data Requirements Report*, which established the baseline data requirements for the Cost Analysis Project and the PEIS, served as the basis for preliminary data development. The data developed in the Engineering Analysis Project supported preparation of both the PEIS and the *Cost Analysis Report*. The *Final Engineering Analysis Report* is planned to be published concurrently with the final PEIS.

The results of this analysis will assist DOE in selecting a management strategy for depleted UF_6 by providing the engineering information necessary to evaluate the environmental impacts and costs of implementing the management strategy alternatives.

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[3] Zoller, J.N., et al. *The Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride*. UCRL-AR-1203372. Lawrence Livermore National Laboratory. June 30, 1995.

[4] U.S. Department of Energy. DOE Order 4700.1, *Project Management System*, Change 1: 6-2-92.

1.1 Overview of the Depleted Uranium Hexafluoride Management Program

The Depleted UF_6 Management Program consists of two phases. The first phase is management strategy selection. Activities in this phase include an engineering analysis, an assessment of environmental impacts, and an estimate of the life-cycle costs of alternative management strategies. Selection of the preferred long-term management strategy will be documented in a Record of Decision, which is scheduled to be published in 1998.

The second phase of the Program will focus on implementation of the management strategy adopted in the Record of Decision. This phase will involve the selection of specific technologies or uses, and specific site(s) where implementation is to occur. National Environmental Policy Act (NEPA) review may result in the preparation of one or more documents to assess the site-specific impacts from transport of materials along defined routes or from the siting of facilities or the use of specific technologies.

1.2 Source of the Depleted Uranium Hexafluoride Stored at the Gaseous Diffusion Plants

Uranium is a naturally occurring radioactive element containing several different isotopes, notably uranium-238 (U-238) and uranium-235 (U-235), which is the fissionable isotope. As found in nature, uranium is about 99 percent U-238, with a U-235 concentration of only about 0.711 weight percent. To produce controlled fission in nuclear chain reactions, uranium must be "enriched" in the U-235 isotope. Enrichment is a process by which the different isotopes are separated and their relative concentrations changed. For example, in uranium for nuclear power reactors, the concentration of the U-235 isotope is typically increased from 0.711 weight percent to about 3-5 weight percent, with a corresponding decrease in the amount of U-238. "Highly enriched" uranium can have concentrations of U-235 ranging from 20 to over 95 percent.

The uranium enrichment process used in the United States is called gaseous diffusion, which was first developed on a large scale in the 1940s as part of the Manhattan Project at the DOE Oak Ridge Reservation in Tennessee. Two more plants were added at Paducah, Kentucky, and Portsmouth, Ohio, in the 1950s to help produce highly enriched uranium for defense purposes, as well as low-enriched uranium for making commercial reactor fuel. In its natural state, uranium occurs as an oxide ore (U_3O_8). This oxide ore is concentrated and then fluorinated to yield uranium hexafluoride (UF_6), the input material for the gaseous diffusion process. When heated at atmospheric pressure, UF_6 sublimes (i.e., changes from the solid to the gas phase) at 133.8°F and can be fed into the isotopic separation equipment.

The basis for enrichment by gaseous diffusion lies in the fact that lighter gas molecules move more quickly than heavier gas molecules. Thus, if both heavier and lighter molecules are present in a porous container, the lighter, faster moving molecules will strike the barrier wall more frequently and more of them will pass through the openings; the heavy molecules strike the openings less frequently and are more likely to remain behind. Applying this principle to UF_6, molecules containing the lighter uranium isotope (U-235) will diffuse, or pass through the openings, more easily than the molecules containing the heavier U-238 isotope. (Fluorine has only one isotope and therefore does not affect the weight difference.)

In a gaseous diffusion stage, a UF_6 feed stream is pumped into a porous container, or barrier tube. Aided by large gas compressors, about half the gas diffuses through the tiny holes in the barrier. This diffused stream is called the "enriched stream" because it will have a slightly higher concentration of the lighter U-235 isotope than the feed stream had. Conversely, the undiffused gas will have a slightly lower concentration of U-235 and is therefore called the "depleted stream."

Because the weights of U-235 and U-238 are so close, only a very small degree of separation occurs in a single stage. To achieve significant enrichment, gaseous diffusion plants link large numbers of stages into interconnected series known as cascades. The typical reactor fuel enrichment to 3-5 weight percent U-235, for example, requires at least 1,200 stages in series; highly enriched uranium with a U-235 concentration of over 90 percent has to go through more than 4,000 stages. At the end of each stage, the enriched stream is fed on to the next higher stage, and the depleted stream is recycled to the next lower stage. When the UF_6 is depleted to 0.2-0.4 percent U-235, it can no longer be effectively recycled and is withdrawn from the cascade. Although ratios may vary in practice, producing 1 kilogram (kg) of UF_6 enriched to 3 percent U-235 will typically result in about 5 kg of depleted UF_6 at 0.25 percent U-235. This depleted UF_6 is usually put into storage by the gaseous diffusion plants. Customers for the enriched product could take the depleted UF_6; however, most of them have chosen not to do so, and DOE has historically retained the material.

In 1985, due to a decrease in the need for enrichment services, all enrichment operations at the Oak Ridge plant ceased. In 1992, in response to the reduced requirements of the U.S. defense programs, the production of highly enriched uranium at Portsmouth was discontinued. The Department continued to operate the Portsmouth and Paducah Gaseous Diffusion Plants until July 1, 1993, when it leased them to the United States Enrichment Corporation (USEC), as required by the Energy Policy Act of 1992. Uranium is still enriched at the Paducah and Portsmouth sites by USEC. The USEC Privatization Act (P.L. 104-134), signed into law on April 26, 1996, provides for the transfer of ownership of USEC from the government to private investors. Section 3109(a)(2) of the Act provides for a Memorandum of Agreement, which will allocate liabilities among DOE, USEC, the United States government, and the new private Corporation, including those arising from the disposal of depleted UF_6 generated by USEC between July 1, 1993, and privatization. This Memorandum of Agreement is currently under discussion by the Office of Management and Budget (OMB), USEC, and DOE. The depleted UF_6 produced by USEC after July 1, 1993, will be considered once the Memorandum of

Agreement is finalized and DOE's responsibilities are clear, either in the final *Engineering Analysis Report* and PEIS or in follow-on reviews, as appropriate.

From 1945 until July 1, 1993, approximately 560,000 metric tons (MT) of depleted UF_6 accumulated at the three gaseous diffusion plant sites. This depleted UF_6 is stored as a solid in a partial vacuum in steel cylinders, each containing approximately 9 to 12 MT. The specifications for the majority of these cylinders are 3.7 m (12 ft) long and 1.22 m (4 ft) in diameter, with a wall thickness of 0.79 cm (5/16 in.). The depleted UF_6 inventory occupies 46,422 cylinders, distributed as follows: 28,351 cylinders at Paducah; 13,388 cylinders at Portsmouth; and 4,683 cylinders at Oak Ridge (K-25 Site).[5] The cylinders are stacked two high, resting on concrete or wooden storage chocks, in open gravel, asphalt, or concrete storage yards.

The Department is responsible for safely storing and managing its depleted UF_6. The activities supporting continued storage include the following:

- Routine visual and ultrasonic inspections of cylinders
- Cylinder painting
- Cylinder valve monitoring and maintenance
- General storage yard and equipment maintenance
- Yard reconstruction to improve storage conditions
- New storage yard construction
- Relocation of cylinders to new yards or to improve access for inspections
- Repair (patch welding) and contents transfer for breached cylinders
- Data tracking, systems planning and execution, and conduct of operations

The *UF_6 Cylinder Program Management Plan* is the controlling document for management and implementation of program operations.[6] Safety analysis reports were prepared for the three sites to define the safety basis for operations.

1.3 Rationale for the Depleted Uranium Hexafluoride Management Program

The goal of the Depleted Uranium Hexafluoride Management Program is to select and implement a long-term management strategy for DOE's depleted UF_6. The current DOE plan for management of the depleted UF_6 is to continue safe storage of the cylinders. If no uses for the depleted uranium are found to be feasible by about the year 2010, steps would then be taken to convert the UF_6 to triuranium octaoxide (U_3O_8). The U_3O_8 would be stored until it was

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[5]The K-25 site is now called the East Tennessee Technology Park, but is referred to as the K-25 site throughout this document.

[6]Lockheed Martin Energy Systems. *UF_6 Cylinder Program Management Plan*. K/TSO-30. July 1996.

determined that all or a portion of the depleted uranium was no longer needed. At that point, the U_3O_8 would be disposed of as low-level waste.[7] This plan was based on assumptions that supported reserving depleted UF_6 for future defense needs and other potential productive and economically viable purposes, including possible re-enrichment in an atomic vapor laser isotope separation (AVLIS) plant, conversion of UF_6 to depleted uranium metal for fabrication of penetrators (anti-tank weapons), and use as fuel in advanced liquid metal reactors.

Since the current plan was put in place, a number of developments have occurred that affect those assumptions. For example, the Energy Policy Act of 1992 assigned responsibility for the development of AVLIS to the USEC, the demand for penetrators has diminished, and the advanced liquid metal reactor program has been canceled. In addition, stakeholders near the current cylinder storage sites have expressed concern regarding potential environmental, safety, health, and regulatory issues associated with the continued storage of the depleted UF_6 inventory. The Ohio Environmental Protection Agency has issued a Notice of Violation to DOE, and the Defense Nuclear Facilities Safety Board has provided a recommendation to the Secretary of Energy regarding improvements in the management of depleted UF_6. In addition, DOE is facing increasing budget pressures with respect to the cost of continued cylinder storage.

The unique properties of depleted UF_6, as well as the large volume in storage, suggest that the evaluation, analysis, and decisions on the fate of this material be separate from those for other DOE materials which are in storage or awaiting disposition. The Department has determined that this is a major and "broad" Federal action (40 CFR 1502.4[b]) with potentially significant environmental impacts and therefore requires the preparation of a Programmatic Environmental Impact Statement (PEIS) in accordance with the National Environmental Policy Act of 1969.

1.4 Program Elements

The first phase of the Depleted Uranium Hexafluoride Management Program, management strategy selection, is composed of three elements: engineering analysis, cost analysis, and a PEIS. The relationship between these Program elements is shown in Figure 1. Lawrence Livermore National Laboratory (LLNL) and its subcontractor, Science Applications International Corporation (SAIC), have been tasked by DOE to conduct the Engineering and Cost Analysis Projects, while Argonne National Laboratory (ANL) is developing the PEIS. Bechtel National, Inc., and Lockheed Martin Energy Systems have also contributed to the Engineering Analysis Project as subcontractors to LLNL. Selection a preferred long-term management strategy will be documented in a Record of Decision, which is anticipated to be issued in 1998.

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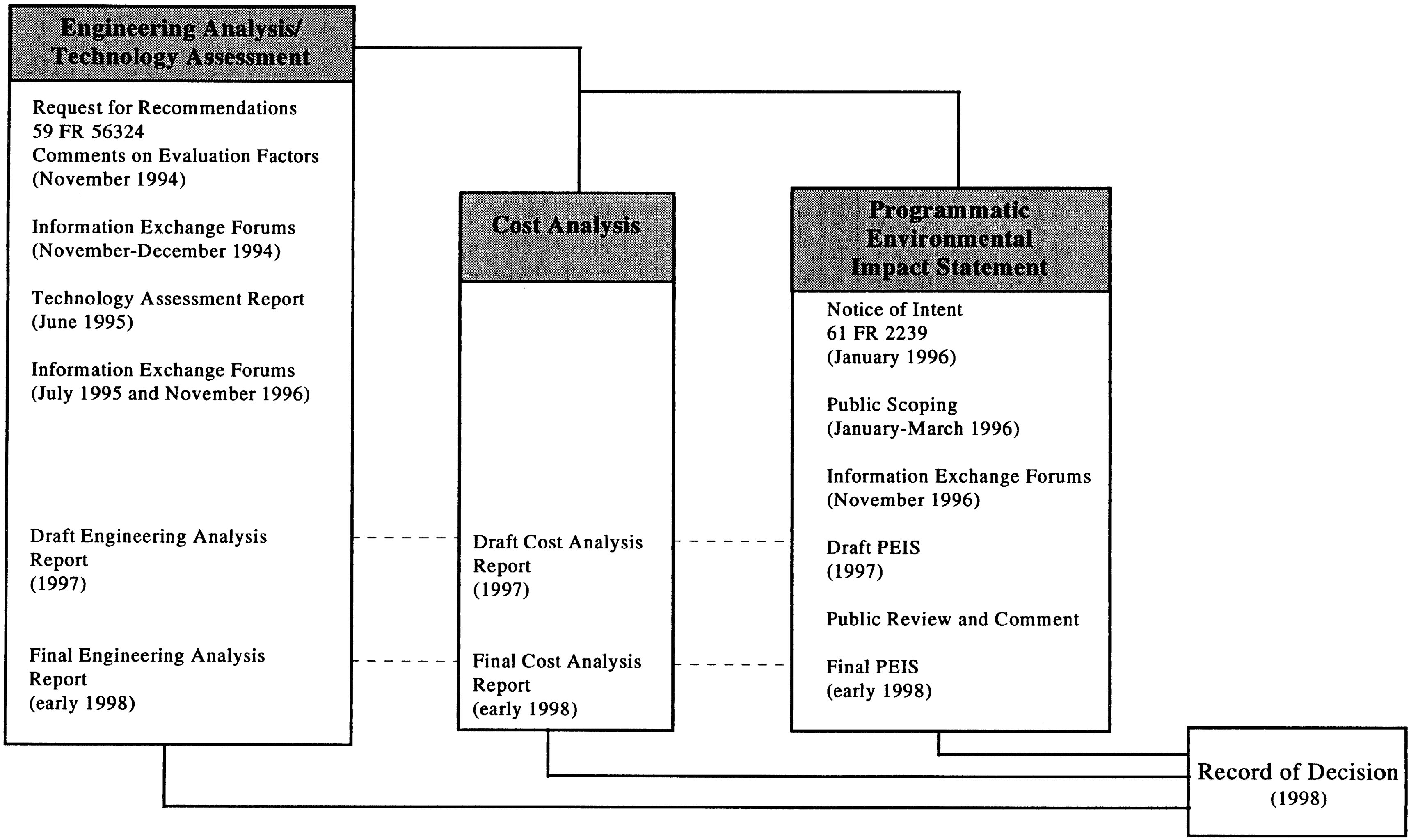
[7]Sewell, Phillip G. Memorandum to Leo P. Duffy. Subject: Plans for Ultimate Disposition of Depleted Uranium. February 20, 1992.

Public participation is an essential part of the Depleted Uranium Hexafluoride Management Program. Both NEPA and DOE policy call for public involvement in DOE decision making, and the Depleted Uranium Hexafluoride Management Program has included that involvement from its early stages. The Request for Recommendations and Advance Notice of Intent published in the *Federal Register* began the public involvement process. The factors that were used to evaluate the responses were also developed with input from the public. Public information forums were held at Portsmouth, Ohio; Oak Ridge, Tennessee; and Paducah, Kentucky, in December 1994, July 1995, and November 1996.

The Department announced that it would prepare a PEIS on selection of a strategy for the long-term management and use of depleted UF_6 on January 25, 1996, with the publication of a Notice of Intent (61 FR 2239). Public scoping meetings were held at the three sites during February 1996 to provide an opportunity for the public to comment on the proposed action, the proposed alternatives, and the range of impacts to be considered in the PEIS. The public was also invited to comment by using a mail-in or fax-in response form, a toll-free telephone number, or the e-mail link on the depleted UF_6 Management Public Scoping Homepage on the Internet. Additional public meetings are planned for the PEIS preparation process, including a workshop focused on industry and public hearings on the draft PEIS. The public will also be able to comment on the draft PEIS through the same means as were used during scoping. The intention is to provide multiple opportunities for public involvement in the DOE decision-making process and to ensure effective two-way communication between DOE and its stakeholders.

Figure 1 - Elements of the Depleted UF_6 Management Program



1.4.1 Engineering Analysis/Technology Assessment

Technology assessment was the precursor to the Engineering Analysis Project. The goal of the technology assessment was to identify and assess options that could be used in the development of alternative strategies for the long-term management of depleted UF_6. To facilitate identification of options, the Department issued a Request for Recommendations in the *Federal Register* on November 10, 1994 (FR 56324), asking individuals, industry, and other government agencies to submit suggestions for potential uses for depleted UF_6, as well as for technologies that could facilitate long-term management of the material. Fifty-seven responses were received, resulting in 70 recommendations (some responses contained more than one recommendation). The total recommendations also included five options that DOE was already considering, but that were not suggested in any of the other responses.

Using evaluation factors that were developed with input from the public, independent technical experts reviewed and evaluated the recommendations received before the submission deadline (January 9, 1995). Responses received after the submission deadline were evaluated by the Independent Technical Reviewers as time allowed, or by Lawrence Livermore National Laboratory and Science Applications International Corporation staff. The results of the review were presented in *The Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride*, published June 30, 1995.[8]

As a result of the technology assessment process, the Department's efforts to seek and consider a wide range of options have been successful. Many of the options recommended in response to the Request for Recommendations were already known, while other responses contained information on unique technologies and potential uses which had not been evaluated previously. The feasible recommendations fall into four broad categories—conversion, use, storage, and disposal—which, along with transportation, comprise the five "modules" or building blocks for constructing management strategy alternatives. The Engineering Analysis Project, discussed in detail in Section 2, has developed the engineering data for representative options in each of these modules.

1.4.2 Cost Analysis

Cost is one of the factors that has an important bearing on the selection of a long-term management strategy for depleted UF_6. The Cost Analysis Project estimated the life-cycle costs of the depleted UF_6 management strategy alternatives being considered by DOE. The *Draft Cost*

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[8]Zoller et al., 1995.

Analysis Report[9] presents life-cycle cost estimates for each of the options analyzed in the *Draft Engineering Analysis Report* and the management strategy alternatives included in the PEIS. The costs are estimated at a scoping or preconceptual design level and are intended to assist decision makers in comparing alternatives. The focus is on identifying the relative differences in the costs of alternatives for purposes of comparison, not on developing absolute costs or bid-document costs.

The technical data upon which the cost analysis is based are principally found in this *Draft Engineering Analysis Report*. Some factors that contribute to and affect the primary capital and operating costs include the following:

- Research and development
- Contingency for cost uncertainty
- Potential revenue from sales of products or by-products
- Permits, licensing, and environmental documentation
- Production rate
- Title I, II, and III engineering, design, and inspection
- Construction management
- Waste handling and disposal
- Decontamination and decommissioning

1.4.3 Programmatic Environmental Impact Statement

A PEIS is a type of Environmental Impact Statement (EIS) that deals with broad strategies and decisions, such as those that are regional or national in scope. The impacts analyzed are generic rather than site-specific. The PEIS on selection of a strategy for the long-term management or use of depleted UF_6 evaluates the impacts of reasonable alternative strategies and supports the selection of a strategy for implementation. The alternatives are analyzed for their potential impacts on the human environment, including risks to worker and public health and safety. The analysis includes the impacts of the current management activities for depleted UF_6 cylinders at the Department's three gaseous diffusion plant sites, technologies for converting the depleted UF_6 to other chemical forms, long-term storage, transportation of materials, use, and disposal. The specific process(es) and the site(s) for conversion, manufacturing, disposal, or storage facilities will be determined in the second phase of the Program. Additional NEPA documents will be prepared as necessary to consider these specific impacts.

The Advance Notice of Intent to prepare an EIS published in the *Federal Register* on November 10, 1994 (59 FR 56325), included a preliminary list of four alternatives for consideration:

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[9] Elayat et al. 1997.

(1) continuation of current storage and management practices; (2) modification of depleted UF_6 storage facilities and procedures; (3) use of depleted UF_6; and (4) disposal of depleted UF_6. These alternatives were further defined in the Notice of Intent, published in the *Federal Register* on January 25, 1996 (61 FR 2239). The preliminary management strategy alternatives, as described in the Notice of Intent, included the current management plan (the "no action alternative"), two storage alternatives, two use alternatives, and one disposal alternative. At the time of public scoping, the no action alternative was based on the course of action outlined by Sewell (1992). After public scoping and DOE internal review, the no action alternative was modified to be indefinite storage of depleted UF_6 cylinders at the three sites.

Two long-term storage alternatives are considered in the PEIS. These are storage as depleted UF_6 and storage as an oxide—either triuranium octaoxide (U_3O_8) or uranium dioxide (UO_2). Storage for up to 40 years is analyzed. The options for storage as UF_6 include (1) storage in yards, (2) storage in enclosed buildings, and (3) deep underground retrievable storage (in a mined cavity). Storage as U_3O_8 or UO_2 would involve transport of the depleted UF_6 to a conversion facility, conversion to the chosen oxide form, and transport of the oxide to a storage facility. The storage facilities analyzed for U_3O_8 or UO_2 are (1) buildings, (2) below ground cement vaults, and (3) deep underground retrievable storage (in a mined cavity).

Of the various uses for depleted UF_6 proposed in responses to the Request for Recommendations, two use alternatives are analyzed in the PEIS: the production of radiation shielding from UO_2 (DUCRETE™) and the production of radiation shielding from uranium metal.[10] The basic steps which make up a use alternative are (1) transport of the depleted UF_6 from current storage to a conversion facility, (2) conversion of the depleted UF_6 to UO_2 or uranium metal, (3) transport of this new material to a fabrication plant, (4) manufacture into radiation shielding, and (5) transport of this product to the user.

The disposal alternative for depleted UF_6 includes conversion to U_3O_8 or UO_2 and three different disposal facility configuration options. Because it is chemically stable and insoluble, the oxide form is generally regarded as the most appropriate form for permanent disposal. In this scenario, the material would be disposed of as a low-level radioactive waste. The steps in the disposal alternative are (1) transport of the depleted UF_6 from current storage to a conversion facility, (2) conversion to U_3O_8 or UO_2, (3) transport of the oxide to a disposal facility, and (4) disposal. The facility designs analyzed in the disposal alternative will include drums placed in (1) engineered trenches, (2) below ground concrete vaults, and (3) a mined cavity. Both bulk disposal and grouted disposal forms are considered. Bulk disposal consists of placing the U_3O_8 or UO_2 directly in the drums. Grouted disposal involves first fixing the oxide in a cement-type

[10]DUCRETE™ is a trademark of Lockheed Martin Idaho Technologies Company and is licensed to Nuclear Metals, Inc., Concord, MA.

medium. General facility configurations are assessed for both humid and arid hypothetical locations to provide the full range of potential impacts.

In addition to preparing the PEIS, Argonne National Laboratory is responsible for collecting and developing the data necessary to analyze the continuation of current storage and management practices (i.e., the no action alternative). Under the no action alternative, cylinder management activities (handling, inspection, monitoring, and maintenance) would continue indefinitely.

2.0 Engineering Analysis Project

2.1 Purpose

The goal of the Engineering Analysis Project is to perform a comprehensive technical analysis of the options and suboptions involved in the alternative strategies being considered for the long-term management of depleted UF_6. The data developed in this project supported preparation of both the PEIS and the *Cost Analysis Report*. This is a top-level analysis, projecting the processes, facility size, and quantities of materials which would be involved in each of the various options. The generic, non-site-specific data (preconceptual, scoping level) are being documented in a series of engineering analysis reports (EARs). The first, the *Interim Engineering Analysis Report*, was completed November 30, 1995. The data from the interim EAR were revised in response to comments from Depleted Uranium Hexafluoride Management Program personnel, and the *Predecisional Draft Engineering Analysis Report* was completed on March 22, 1996. Additional accident analyses and another option for preparing the cylinders for shipment were included in the March 22, 1996, document.

The *Predecisional Draft Engineering Analysis Report* was updated on November 15, 1996, in response to comments from Depleted Uranium Hexafluoride Management Program personnel, to maintain compatibility with the PEIS, and to incorporate new information such as the regulatory and parametric analyses. The current report reflects the latest revisions to the engineering data. The *Final Engineering Analysis Report*, incorporating comments on the draft EAR, will be made available to the public concurrently with the final PEIS.

With the exception of the no action alternative, long-term management strategy alternatives for depleted UF_6 consist of options and suboptions from two or more of the following five "modules": use, storage, disposal, conversion, and transportation. Conversion to another form, such as U_3O_8, UO_2, or metal, is needed to implement most of the alternatives. Likewise, transportation of materials is an integral part of constructing the complete pathway between the current storage sites and ultimate disposition for all alternatives except no action The analysis of options and suboptions includes the development of preconceptual designs; estimates of effluents, wastes, and emissions; specification of resource requirements; preliminary hazards assessments; parametric assessments; development of accident scenario data; and the analysis of license, permit, and regulatory requirements. The results of this analysis will assist DOE in selecting a strategy by providing the engineering information necessary to evaluate the environmental impacts and costs of implementing the management strategy alternatives.

2.2 Work Breakdown Structure

A work breakdown structure (WBS) was prepared to provide a disciplined basis for analysis and comparison of depleted UF_6 management strategies. The Engineering Analysis Project analyzed the alternative strategies by their components (modules). Figure 2 summarizes the WBS modules and the top-level options that are the building blocks for any alternative. The depleted UF_6 work breakdown elements and levels were chosen to facilitate the preparation of complete management strategy alternatives from a common database. While certain WBS elements will be alternative-specific, many are applicable to a range of alternatives. For example, those WBS elements that pertain to transportation and conversion apply to most alternatives. The WBS levels are briefly described as follows:

Level I — Depleted UF_6 Management Program (general).

Level II — Modules.
- The basic building blocks for constructing complete management strategies.

Level III — Options.
- The general options for implementing modules and global actions related to individual modules.
- Characteristic actions, material forms, applications, and end points that capture basic differences in environmental risks.

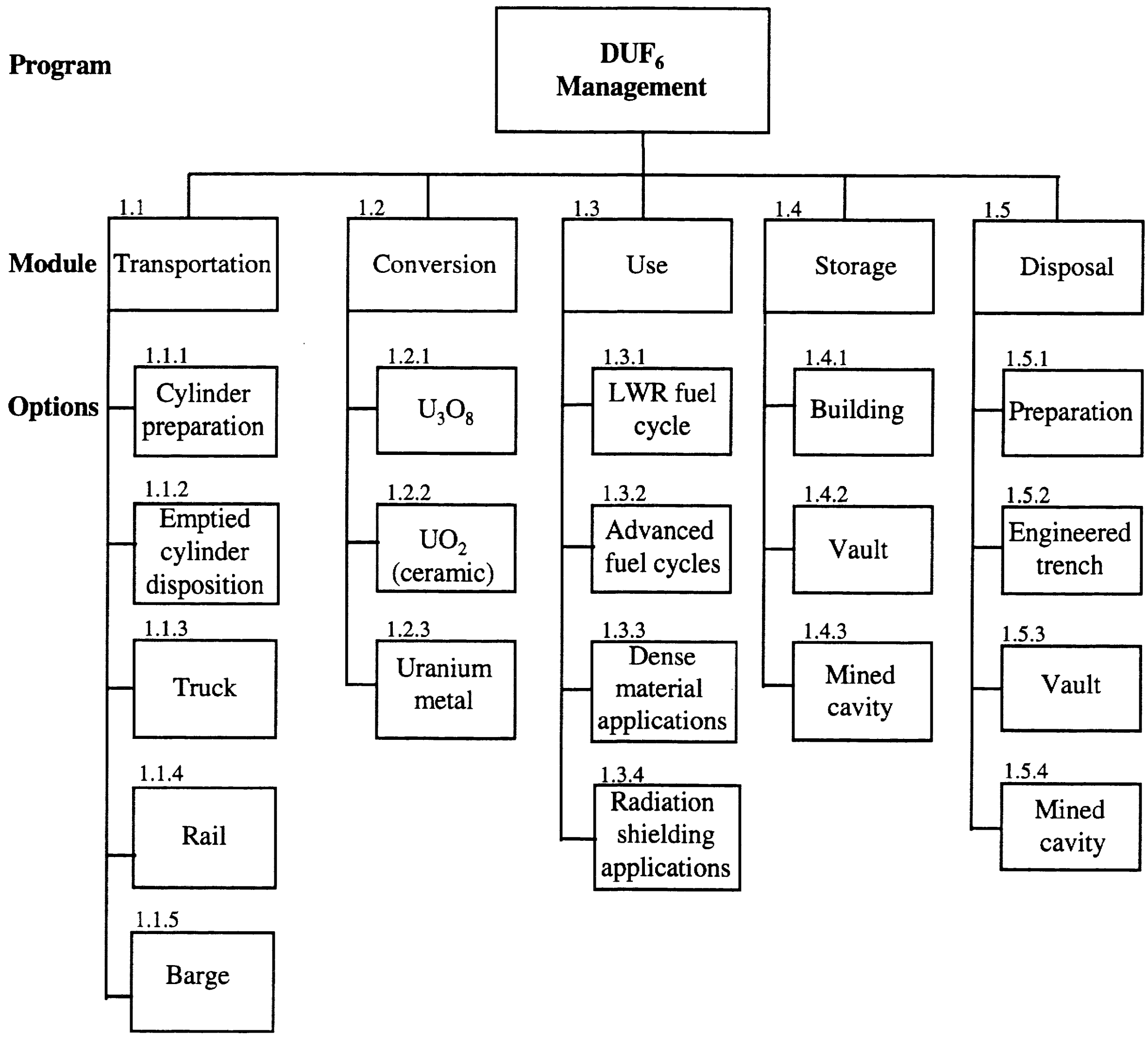
Level IV — Suboptions (e.g., technology-specific or application-specific).
- A breakdown of implementation alternatives.
- Data to support environmental risk analyses will be developed from this level, as will flowsheets.

Level V — Cost elements or accounts.
- Cost data will appear at this level.

Level VI — Cost subaccounts, where necessary.

As shown in Figure 2, there are five modules in the WBS—transportation, conversion, use, storage, and disposal. Conversion of the depleted UF_6 to another form is needed to implement most of the alternatives. Three chemical forms have been identified as options within the conversion module: U_3O_8, UO_2, and uranium metal. A number of technologies are possible for each of these conversion options, and, likewise, there are multiple possibilities under each of the

Figure 2 - Depleted UF_6 Management Work Breakdown Structure, Showing Modules (Level II) and Options (Level III)



other module options. This next level of detail in the WBS is referred to as suboptions. Suboptions provide the technology and application definition necessary for the engineering analysis and determination of environmental risks. The WBS for the U_3O_8 conversion option is graphically presented in Figure 3. Note that this figure illustrates the defluorination with anhydrous hydrogen fluoride (HF) by-product suboption, one of two representative processes for conversion to U_3O_8 examined in the engineering analysis.

2.3 Data Requirements

A document entitled *The Preliminary Depleted Uranium Hexafluoride Program Data Requirements Report* was developed jointly by the Engineering Analysis Project and PEIS teams to specify the preliminary data requirements.[11] This preliminary *Data Requirements Report* was forwarded to DOE on November 30, 1994, and signed by LLNL and ANL on December 13, 1994. *The Final Depleted Uranium Hexafluoride Program Data Requirements Report*, which was forwarded to DOE on June 15, 1995, and signed by LLNL and ANL on July 18, 1995, is the basis for data development for this *Engineering Analysis Report.*[12]

The *Data Requirements Report* established the baseline data requirements for the Cost Analysis Project and the PEIS and served as the basis for preliminary data development prior to completion of the *Technology Assessment Report* or scoping of the PEIS. The following elements are included in the final *Data Requirements Report*:

- Definition of top-level pathways. This element involves definition of the pathway between the current storage state and the end state for each option.

- Definition of technology modules. This element includes the work breakdown structure, flowsheets, process descriptions, material and energy balances, and top-level design and layouts.

- Definition of transportation requirements. This element includes identification of material quantities, characteristics, transportation packaging, transport mode, and number of shipments.

- Parametric analysis. Schedule and throughput impacts are considered in this element.

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[11]Letter from J.N. Zoller to C. Bradley. Subject: Preliminary Depleted Uranium Hexafluoride Program Data Requirements Report. UP-DUF-G-95-011. November 30, 1994.

[12]Letter from J.N. Zoller to C. Bradley. Subject: Final Depleted Uranium Hexafluoride Program Data Requirements Report. UP-DU/95-06-G-053. June 15, 1995.

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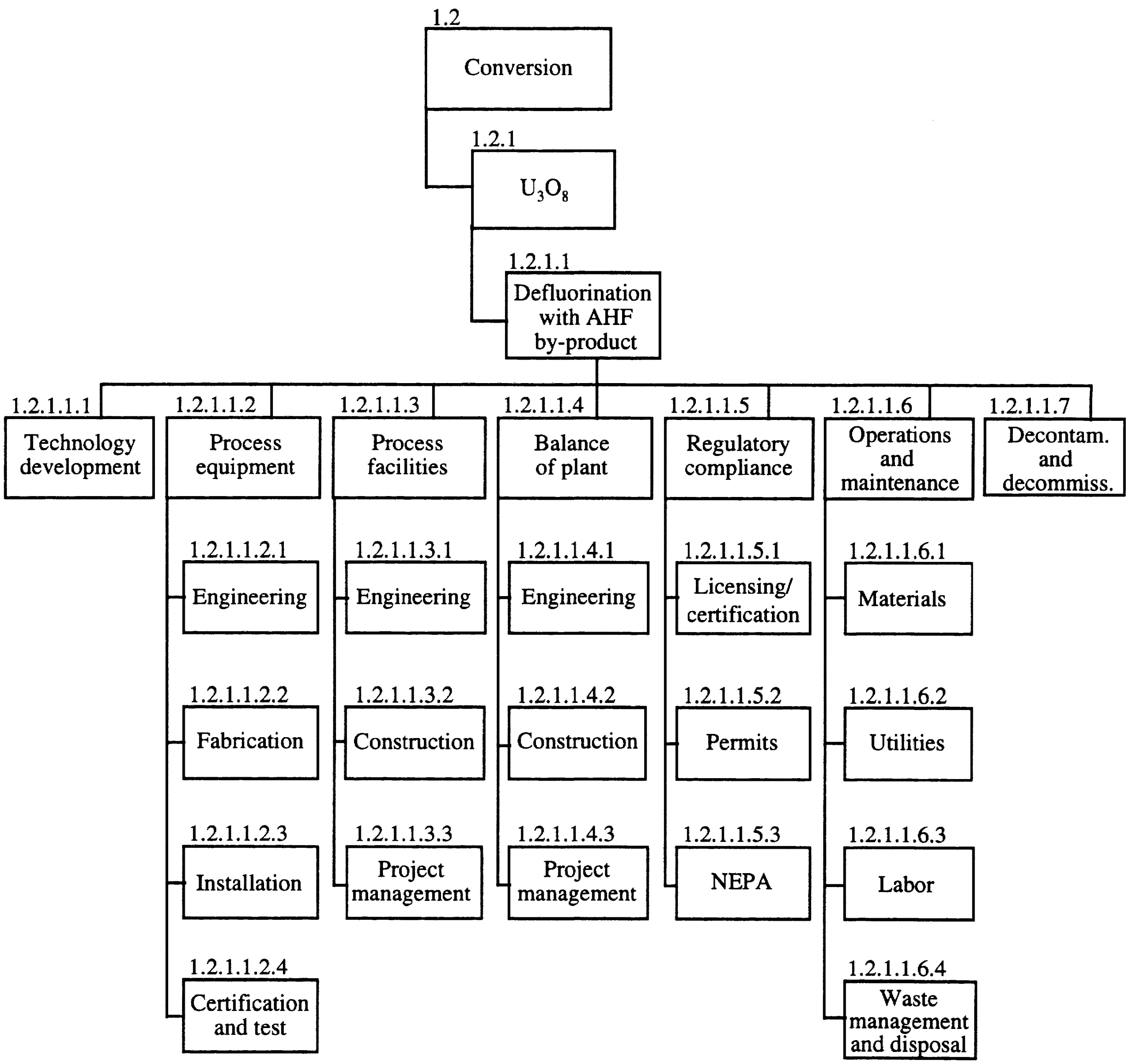
Figure 3 - Work Breakdown Structure for the U_3O_8 Conversion Option, Showing Detail to Level VI for the Defluorination with Anhydrous HF By-product Suboption



- License, permit, and regulatory analysis. This element considers regulatory impacts upon design and construction; licensing, permitting, and operations; and management of by-products and waste.

- Preliminary definition of hazards. Potential radiological, chemical, and industrial hazards from normal operations and from accident conditions are considered under this element.

- Personnel radiation exposure. This element includes estimates of the number of workers, the approximate distance of the workers from the radiation source, and the approximate thicknesses of construction materials.

2.4 Methodology

Individual Engineering Data Input Reports were developed for the various options (WBS Level III) and suboptions (WBS Level IV) that make up the depleted UF_6 management strategy alternatives. These Data Input Reports included process flowsheets, top-level facility layouts, resource requirements, emission and waste data, and preliminary hazards assessments. The basis for the selection of these options is described in Section 3, which is largely derived from the report entitled *Characterization of Options for the Depleted Uranium Hexafluoride Management Program, Basis for the Interim Engineering Analysis Report.*[13] Figure 4 shows the options and suboptions that are being analyzed in depth. Shaded blocks indicate principal options not analyzed in depth and their suboptions. Additional suboptions not analyzed in depth are discussed in Section 4.

Preliminary draft Engineering Data Input Reports were furnished to DOE and ANL for review and comment. Comments were resolved during Engineering Analysis Project team meetings and by the use of comment response documents. The Data Input Reports were revised and are included in Section 6 of this report.

[13]Dubrin, James W., and J.N. Zoller. *Characterization of Options for the Depleted Uranium Hexafluoride Management Program, Basis for the Interim Engineering Analysis Report.* November 1995.

Figure 4 - Table of Options

Transportation module	
Option	Suboptions
Cylinder preparation	• Current cylinders • Over-container • Transfer facility
Emptied cylinder disposition	• Treatment facility
Truck	• DUF_6 in current or new cylinders • DUF_6 in over-container • U_3O_8 in drums • UO_2 pellets in drums • UO_2 micro-spheres in drums • Metal billets in boxes • Metal shields • Ducrete shields
Rail	(same suboptions as Truck)
Barge	• DUF_6 in current or new cylinders • DUF_6 in over-container

Conversion module	
Option	Suboptions
U_3O_8	• Defluorination with AHF** by-product • Defluorination with HF neutralization
UO_2 (ceramic)	• Ceramic UO_2 with AHF by-product • Ceramic UO_2 with HF neutralization • Gelation
U metal	• Batch metallothermic reduction • Continuous metallothermic reduction

Use module	
Option	Suboptions
LWR fuel cycle	• Re-enrichment
Advanced fuel cycles	• Breeder and other fast neutron spectrum reactors
Dense material applications	• Existing applications: munitions, armor, counter-weights, and ballasts • New applications
Radiation shielding applications	• U metal shielding for spent nuclear fuel • UO_2 shielding for spent nuclear fuel

Storage module	
Option	Suboptions
Building	• DUF_6 • U_3O_8 • UO_2
Vault	• U_3O_8 • UO_2
Mined cavity	• DUF_6 • U_3O_8 • UO_2

Disposal module	
Option	Suboptions
Preparation	• U_3O_8 grouted • UO_2 grouted • U_3O_8 bulk • UO_2 bulk
Engineered trench	• U_3O_8 grouted • UO_2 grouted • U_3O_8 bulk • UO_2 bulk
Vault	• U_3O_8 grouted • UO_2 grouted • U_3O_8 bulk • UO_2 bulk
Mined cavity	• U_3O_8 grouted • UO_2 grouted • U_3O_8 bulk • UO_2 bulk

* Shaded areas indicate principal options not analyzed in depth and their suboptions

** Anhydrous hydrogen fluoride (HF)

In the responses to the Request for Recommendations, a significant number of conversion technologies were recommended that, with minor exceptions, are less technically mature, but potentially offer unique features in the areas of environmental and cost benefits. Because these recommendations are either in the early stages of conceptualization or development, or else contain key design aspects that are proprietary, Engineering Data Input Reports were not generated for these options and/or suboptions. These recommended options/suboptions are nonetheless preserved for later decision making during the second (implementation) phase of the Depleted UF_6 Management Program, when more narrowly focused issues such as specific siting, technology, and transportation issues will be analyzed. Section 4 of this *Engineering Analysis Report* summarizes the set of key recommendations for which Engineering Data Input Reports are not being generated.

2.5 Assumptions

For the purpose of developing engineering data, assumptions were made regarding throughput, isotopic composition, bulk density, operational availability, scheduling, packaging of materials for transportation, and lag storage of materials. These assumptions are stated in each Engineering Data Input Report and are somewhat dependent upon the option or suboption being analyzed. Following are some of the major assumptions used in the reports.

- The depleted uranium is assumed to be chemically pure, with an average isotopic composition of 0.001 percent U-234, 0.25 percent U-235, and 99.75 percent U-238 and a corresponding specific activity (alpha) of 4×10^{-7} curies per gram (Ci/g) depleted uranium (one curie equals 3.7×10^{10} nuclear disintegrations per second). In the filled UF_6 cylinders, the short-lived daughter products of U-238, thorium (Th)-234 and protactinium (Pa)-234, are in the same equilibrium with the U-238; therefore, these beta emitters each have the same activity as U-238 (i.e., 3.3×10^{-7} Ci/g)
- It is assumed that the depleted UF_6 will be transported in 14-ton cylinders like those currently used for storage and that emptied cylinders will be shipped off site for treatment, disposal, or use. Facilities provide three months' onsite storage for outgoing emptied cylinders (to allow for the decay of radioactive daughter products in the heel).
- U_3O_8 will have a final bulk density of 3.0 g/cubic centimeter (cc) and will be transported in 55-gallon (208-liter) drums.
- UO_2, in sintered pellets (0.82 in. x 0.82 in.) or microspheres (1200 micron and 300 micron), will have a final density of about 10 g/cc and will be packaged for transportation in 30-gallon (113-liter) drums.
- Metal derbies from the batch reduction process will be about 20 in. in diameter and 6.7 in. high and will be packaged in wooden boxes.
- Metal billets from the continuous reduction process will be 2 in. x 3 in. x 20 in. and will be packaged in boxes.

- It is assumed that wastes will be compacted and shipped off site for treatment and disposal. Hazardous wastes will be hauled to a commercial waste facility for treatment and disposal according to Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) guidelines.
- Depleted uranium, including depleted uranium waste forms, is subject to regulation by the Atomic Energy Act (AEA), rather than by RCRA.
- A period of 20 years is assumed to disposition the entire depleted uranium stockpile (about 560,000 MT UF_6 in 46,422 cylinders). This corresponds to an annual throughput rate of 28,000 MT of UF_6 or about 19,000 MT of uranium.
- Operations are assumed to be continuous for 24 hours/day, seven days/week, 52 weeks/year; annual operating time would be 7,000 hours, based on a plant availability factor of 0.8.
- Allowance for onsite storage space generally assumes one month's supply of incoming materials (e.g., cylinders), product, and other outgoing materials (with the exception of three months' storage for emptied cylinders).

A generic schedule was assumed for conversion (including empty cylinder treatment) and manufacturing facilities in the program. Schedules were not differentiated for DOE or privatized facilities. Beginning from the time of the Record of Decision (ROD), technology verification and piloting were assumed to take five years, including preliminary assessments. Simultaneously, design activities and the safety approval/NEPA processes would be proceeding, both of which were assumed to be completed within seven years. Site preparation, facility construction, procurement of process equipment, and testing/installation were assumed to require four years, which would have plant start-up occurring about 11 years after the ROD. Following a 20-year period of operation, decontamination and decommissioning would require three years.

All facilities were assumed to be constructed and operated at a generic green field site. The general design basis was DOE Order 6430.1A, *General Design Criteria.*[14] DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,*[15] was used as a guide to develop preliminary hazards classifications and related design features. DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities,*[16] was also used. These categories were assigned based on engineering judgment and require additional analyses before final hazards categories can be defined.

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[14]U.S. Department of Energy. DOE Order 6430.1A, *General Design Criteria.* April 6, 1989.

[15]U.S. Department of Energy. DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports.* December 1992.

[16]U.S. Department of Energy. DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities.* April 1994.

The size, number, and arrangement of facility buildings and equipment are preconceptual and can change significantly as the design progresses. Facilities and processes would require optimization during subsequent design development.

2.6 Accident Analyses

Each Engineering Data Input Report found in Section 6 includes an accident analysis. Preliminary radiological and nonradiological hazardous accident scenarios that bound and represent potential accidents for each facility are described in each report. Accident descriptions include the following elements:

- A description of the accident scenario.
- An estimate of the frequency of the scenario.
- An estimate of the effective amount of material at risk in the accident, based on the equipment sizes.
- An estimate of the fraction of the effective material at risk that becomes airborne in respirable form.
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system.

A supplemental accident analysis was prepared for externally initiated events with very low probabilities and significant hazardous or radiological material releases. Several plausible accidents in the frequency range between below 10^{-6} and above 10^{-7} are considered, and each accident is applicable to several of the options and suboptions described in the *Engineering Analysis Report.* In addition to the low-probability/high-consequence accidents, accidents involving depleted UF_6 in cylinders in temporary storage or involving onsite handling are analyzed in the Supplemental Accident Analysis. This analysis is found in Section 7.0.

2.7 Parametric Analyses

A parametric analysis, considering throughput impacts, was performed for the cylinder transfer facility option before the completion of the predecisional draft EAR. The need for parametric analysis of other options being considered for the long-term management of depleted UF_6 was determined after the end of the scoping period for the PEIS (March 25, 1996). The following options were selected for parametric analyses:

- Conversion to U_3O_8: defluorination with anhydrous hydrogen fluoride (AHF)
- Conversion to UO_2: ceramic UO_2 with AHF
- Conversion to uranium metal by continuous metallothermic reduction
- Manufacture and use as shielding (metal and DUCRETE™)
- Storage in buildings as UO_2 and UF_6

- Disposal in a mined cavity as bulk U_3O_8

Data requirements and a schedule for performing these analyses were finalized in early June 1996, and the analyses were completed in October 1996. Key data elements for throughput variations that are 50 percent and 25 percent of the reference capacity case (28,000 MT/year of depleted UF_6) were evaluated. The results of the parametric analyses are presented in Section 8.0.

2.8 Regulatory Analyses

2.8.1 License, Permit, and Regulatory Analysis

A brief study was conducted to identify the major federal legislation and implementing regulations that would apply to the options discussed in the EAR, the main compliance requirements (e.g., permits, licenses, monitoring, and record keeping), and any regulatory uncertainties or potential major regulatory compliance issues. For purposes of this analysis, a "major issue" is defined as having one or more of the following characteristics: (1) there is little or no previous experience in meeting the requirement; (2) similar activities in the past have encountered problems; (3) an above-average amount of time would be required for compliance; (4) there is likely to be controversy. The license, permit, and regulatory analysis will assist in the evaluation of the different options for conversion, use, storage, disposal, and transportation, as well as in eliminating or reducing potential problems related to regulatory issues in the design for a particular option.

The following federal statutes/regulations were analyzed in the report (the order reflects the number of potential regulatory compliance issues addressed):

- Atomic Energy Act (AEA) - Nuclear Regulatory Commission (NRC) regulations
- Atomic Energy Act - DOE regulations
- Clean Air Act (CAA)
- National Environmental Policy Act
- Resource Conservation and Recovery Act (RCRA)
- Clean Water Act (CWA)
- Hazardous Materials Transportation Act (HMTA) and NRC transportation regulations
- Safe Drinking Water Act (SDWA)
- Occupational Safety and Health Act (OSHA)
- Toxic Substances Control Act (TSCA)
- Emergency Planning and Community Right-to-Know Act (EPCRA)

Additional federal laws and regulations whose provisions deal with the protection of site-specific resources (e.g., the Endangered Species Act) were not analyzed because the options in this EAR are for generic facilities only. For the same reason, state-specific laws and regulations were beyond the scope of this study. State- and site-specific regulatory issues will be addressed in the second, implementation, phase of the Program.

In addition to the assumptions used in the EAR, other assumptions were also used in analyzing the regulations and determining if major issues exist. Following are some of the major regulation-related assumptions:

- Depleted UF_6 in any form will retain its classification as "source material" and will continue to be regulated under the AEA.
- Depleted UF_6 is not considered a hazardous waste; it is considered a resource with future use applicability.
- All of the options assume green field facilities.
- For compliance under the AEA, it is assumed that all privately owned and operated facilities would be regulated by the NRC and that DOE-owned and -operated facilities would be regulated by DOE.
- All facilities that generate hazardous waste are considered small quantity generators under RCRA.
- All transportation of radioactive materials would take place within the continental United States.

The overall conclusion of the regulatory analysis is that no particular option stands out, either positively or negatively, in terms of regulatory compliance, nor do there appear to be any regulatory issues that would preclude an option from being chosen. A number of options for storage and disposal present major issues in terms of AEA licensing or compliance and NEPA compliance; options for conversion and use present major compliance issues in terms of CAA permitting and potentially for CWA permitting. The reclassification of depleted UF_6 as other than a source material could have major impacts on both RCRA and CWA compliance, affecting the permitting requirements for both regulations. Compliance at green field sites appears to be more problematic for a number of regulations in comparison with compliance at existing DOE or private facilities, where permit modifications may be all that are needed under the AEA, the CAA, the CWA, and RCRA. The time and uncertainty for such modifications is significantly less than for new permits. Ownership of materials and facilities has implications for regulatory compliance under the AEA and NEPA. In general, DOE's compliance burden is reduced whenever a private entity is the owner or operator.

2.8.1.1 Conversion

RCRA could involve some major compliance issues and uncertainties with regard to hazardous waste generation from conversion processes. Like the use and disposal facilities included in this EAR, the conversion facilities would ship mixed waste off site to a RCRA-permitted facility for treatment, storage, and disposal. However, treatment and disposal options for mixed wastes are currently limited. Because conversion, use, and disposal facilities would be considered small quantity generators under RCRA, RCRA permits would not be required. However, if onsite storage of hazardous or mixed waste becomes necessary for longer than the period allowed for a small quantity generator, a RCRA storage permit would have to be obtained.

Preparing the depleted UF_6 cylinders for transport from the current storage sites to offsite conversion facilities presents a potential major compliance issue because a number of the cylinders do not currently meet Department of Transportation (DOT) requirements for offsite shipment. Options for preparing cylinders for shipment are analyzed in Sections 6.1 and 6.2 of the EAR. Preparation of nonconforming cylinders for shipment is also addressed.

2.8.1.2 Use

Like conversion facilities, manufacturing facilities could potentially have to comply with RCRA storage and permitting requirements if adequate offsite treatment and disposal options for hazardous or mixed waste are not available.

2.8.1.3 Storage

Licensing under the AEA for private, long-term storage facilities is unprecedented and inherently controversial. Convincing regulators that storage options do not constitute disposal, especially in the case of the below ground vault or mine options, could be a major regulatory compliance issue. This would require extensive negotiations and demonstration that there is a defined term for storage and likely use of the material at the end of the storage period.

NEPA compliance represents a potential major issue because of the likelihood of controversy. Previous DOE NEPA documents on long-term storage facilities have often taken much longer than anticipated and have sometimes resulted in litigation. Options involving vault and mine storage may be perceived by both regulators and the public as disposal. Site-specific EISs for these options would take longer to develop (between three and six years) than a typical EIS.

Like the conversion options, storage as depleted UF_6 could present major regulatory compliance issues related to the shipment of existing cylinders. Many of these cylinders currently do not meet DOT requirements for offsite shipment.

2.8.1.4 Disposal

The licensing of new low-level waste (LLW) disposal facilities under the AEA would be a major compliance issue. Licensing under the AEA by NRC or authorized states may be difficult due to the extensive regulatory requirements and the inherently controversial nature of the subject.

Approvals under the AEA by DOE for new LLW disposal facilities may be difficult due to extensive performance assessment requirements. Disposal facilities could potentially be required to comply with RCRA storage and permitting requirements if offsite treatment and disposal options for mixed waste continue to be limited.

2.8.2 Transportation Regulatory Analysis

A study was made to identify recent and potential future changes in the regulatory requirements for depleted UF_6 cylinder transportation and their possible effects on activities related to the implementation of a long-term management strategy. The results of the analysis are summarized below.[17]

2.8.2.1 49 CFR and ANSI N14.1

The final rule amending the regulations in 49 CFR pertaining to the transportation of radioactive materials which was published in the *Federal Register* on September 28, 1995 (60 FR 50248), and took effect on April 1, 1996, and the 1995 revision of American National Standards Institute (ANSI) N14.1 did not significantly change the regulatory requirements for UF_6 shipments. Depleted UF_6 is still defined as a low specific activity (LSA) material, allowing it to be packaged and transported in a strong, tight or Type A packaging. The biggest change is the authorization of industrial packagings (IP-1) for use in transporting depleted UF_6.

2.8.2.2 Proposed Revisions to IAEA Safety Series No. 6

The regulatory basis for UF_6 transportation appears poised to undergo changes which could significantly impact offsite transportation options. Of several proposed changes to the International Atomic Energy Agency (IAEA) Safety Series No. 6 (*Regulations for the Safe Transport of Radioactive Material*),[18] the most significant is the thermal test, which would require UF_6 cylinders to be able to survive a 1475°F (800°C) fire for 30 minutes. The United States is not in concurrence with the necessity for this requirement, except for cylinders containing UF_6 enriched to more than 1 percent; however, 49 CFR has generally incorporated IAEA regulations in the past. It is therefore reasonable to assume that a thermal testing requirement could be in effect in this country by the time transportation activities associated with the implementation phase begin (estimated to be around 2008).

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[17] Messimore, Jason. *Depleted Uranium Hexafluoride Transportation Regulatory Analysis*, UCRL-AR-125086. Lawrence Livermore National Laboratory. August 22, 1996.

[18] International Atomic Energy Agency. Safety Series Number 6: *Regulations for the Safe Transport of Radioactive Material*, 1985 Edition (As Amended 1990). Vienna, 1990.

Thermal testing studies in France indicate that a protective covering of some sort may be necessary for all cylinders, including 5/8 in. thick-walled cylinders. It is not known whether thin-walled (5/16 in.) cylinders could pass the test even with thermal protection like that used in the studies (96 percent of the U.S. cylinder population is thin walled). These developments will need to be closely monitored, as they could potentially have a major effect on the implementation of a long-term management plan for the Department's depleted UF_6.

3.0 Summary of Options Analyzed in Depth

As stated in Section 1.4.1, the Engineering Analysis Project developed the engineering data for representative options which were determined to be feasible in *The Technology Assessment Report for the Long-Term Management of Depleted Uranium Hexafluoride.* The feasible recommendations fell into four broad categories—conversion, use, storage, and disposal—which, along with transportation, comprise the five "modules" or building blocks for constructing management strategy alternatives. The options that were analyzed in depth are summarized here. The complete data for these options are contained in Section 6, where the individual Engineering Data Input Reports are found. Other options which were considered but not analyzed in depth are summarized in Section 4.

3.1 Transportation Module

This element includes options for cylinder preparation, emptied cylinder disposition, and transport. Transport of all forms of depleted uranium by both truck and rail is included in the individual Engineering Data Input Reports for the various conversion, use, storage, and disposal options. No specific transportation technologies were described in the responses to the Request for Recommendations.

3.1.1 Cylinder Preparation Option

This element refers to the preparation of the depleted UF_6 cylinders at their current storage sites for transportation to an offsite facility, generally for conversion. A number of the cylinders currently do not meet Department of Transportation (DOT) requirements for offsite shipment. The cylinder problems are of three types: (1) overfilled cylinders, (2) overpressured cylinders, and (3) substandard cylinders (e.g., cylinders with below the minimum value wall thickness or other characteristics that render them unsafe or unserviceable according to ANSI N14.1).[19] There are no definitive data on the number of cylinders affected by any of these problems, so the basis for the engineering analysis is empirical data provided by site personnel. It is anticipated that these estimates may be revised as the issues are further examined, including additional cylinder data. It should be noted that these cylinder conditions are problems only for offsite transportation and do not restrict onsite transport or storage.

In accordance with the 49 CFR 173.420(a)(4) transportation requirements for UF_6, the volume of solid depleted uranium hexafluoride at 20°C (68°F) may not exceed 62 percent of the certified volumetric capacity of the packaging. Overfilled cylinders are those in which the amount of

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[19] American National Standards Institute. ANSI N14.1-1995, *American National Standard for Nuclear Materials - Uranium Hexafluoride - Packaging for Transport.* December 1, 1995.

depleted UF_6 exceeds the fill limit. Prior to 1987 there were no fill limits in 49 CFR—only in ORO-651 and ANSI N14.1, and these limits, with one exception, were below 61 percent. The exception was the fill limit for the 48G cylinder, which was given as 28,000 lb, or 63.4 percent of the minimum volume (139 ft^3) at 20°C. Cylinders filled before 1987 were filled up to this limit.

Overpressured cylinders are those in which the vapor space above the solid UF_6 contains excess gas (non-UF_6), causing the total pressure to be above atmospheric. These contaminants are mostly air, HF, or other light constituents (with a density less than that of UF_6) that were drawn into or became trapped within the cylinder. At ambient temperatures, these cylinders do not meet the DOT requirement that UF_6 cylinder pressures be below atmospheric pressure for shipment. When liquid depleted UF_6 was initially withdrawn from the cascades into the cylinder, this liquid contained dissolved impurities, including gases. When the depleted UF_6 solidified, these gases became trapped in the solid depleted UF_6, and as the solid continually sublimes and desublimes over the years, these gases are released. The other mechanism that can increase light gases in a cylinder is leakage of air into the cylinder through a leaking valve or plug or a breach. Moisture in the air then reacts with UF_6 to form HF in the vapor space, which subsequently increases the cylinder pressure.

Substandard cylinders are those that do not meet shipping criteria for other reasons. It is anticipated that cylinders whose wall thickness has dropped below the minimum required thickness would make up the largest component of the substandard cylinder population. Damage or defects would also put a cylinder into the substandard category. For thin-walled cylinders, which had a nominal original thickness of 312.5 mils (5/16 in.), the minimum required thickness for transportation is 250 mils (1/4 in.). Most of the cylinders in storage are thin walled. Other cylinder models have different wall thickness requirements.

Preliminary estimates of the numbers of cylinders which are overfilled, overpressured, or substandard have been made, but they are very rough and are associated with many uncertainties. For purposes of this analysis, the number of nonconforming cylinders projected for the year 2020 is used as the reference case to define the activities necessary to prepare the cylinders for shipment. It is recognized that this preliminary estimate may change over time as estimates of the number of nonconforming cylinders are refined and as cylinder conditions and regulatory requirements change. Accordingly, additional cases are considered as shown in the following table.

Table 3.1
Preliminary Estimate of the Number of Depleted UF_6 Cylinders Conforming to Off-Site Transportation Criteria

	Reference Capacity Case		Low-Capacity Case		High-Capacity Case	
	Number of Non-conforming Cylinders	Number of Conforming cylinders	Number of Non-conforming Cylinders	Number of Conforming Cylinders	Number of Non-conforming Cylinders	Number of Conforming Cylinders
Paducah	19,200	9,151	9,600	18,751	28,351	0
Portsmouth	5,200	8,188	2,600	10,788	13,388	0
K-25	4,683	0	2,342	2,341	4,683	0
Total	29,083	17,339	14,542	31,880	46,422	0

Lockheed Martin Energy Systems identified a number of methods for addressing each of these problems, including the following:

- Obtaining a DOT exemption
- Administratively raising the allowable fill limit
- Transferring excess depleted UF_6 from an overfilled cylinder into another cylinder using a transfer facility
- Venting overpressured cylinders to new or empty cylinders or through a UF_6/HF cleanup system
- Transferring the depleted UF_6 from all substandard cylinders into new cylinders using a transfer facility
- Administratively lowering the wall thickness requirements
- Shipping the cylinders as they are within a protective overcontainer

In the cylinder preparation option, two distinct suboptions are evaluated to address nonconforming cylinders: the overcontainer suboption and the transfer facility suboption. The overcontainer appears to be an optimal solution because handling is minimized, construction and operation of facilities to transfer material to new cylinders are avoided, waste is minimized, and operational risk is anticipated to be similar to current cylinder handling operations. The transfer facility suboption provides an alternative to the overcontainer. The probability of obtaining a DOT exemption or administratively lowering fill limits or wall thickness requirements is unknown.

3.1.1.1 Overcontainer Suboption

Lockheed Martin Energy Systems has developed an initial design concept for a protective overcontainer approach that would address all three problems in meeting DOT shipping requirements. The overcontainer would be suitable to contain, transport, and store the cylinder contents, regardless of cylinder condition, and could be designed as a pressure vessel enabling volatilization of the depleted UF_6 for transfer out of the cylinder. Thermal design analyses are required to establish heat transfer rates for volatilization. Wall thickness and other design details would be determined during conceptual design.

One of the technology concepts analyzed for this suboption involves placing the depleted UF_6 cylinder in a horizontal "clamshell" vessel for shipment. Two other concepts were also investigated— up-ending the depleted UF_6 cylinder and placing it into a vertical overcontainer or inserting a cradle-mounted cylinder horizontally into an overcontainer using a loading ramp and rollers. Each of these concepts would require a bolted sealing flange on one end of the overcontainer to effect closure. Handling and support equipment for onsite movement and loading the cylinder into the clamshell overcontainer would be of the same type that is currently used for cylinder management activities. This is a major advantage in terms of minimizing design and fabrication costs.

Based on the *Cost Analysis Report* and the PEIS, the overcontainer suboption appears to have the lowest potential environmental impacts and the lowest potential costs. However, it may not bound impacts if other options were implemented.

The Engineering Data Input Report for the overcontainer suboption is located in Section 6.1.

3.1.1.2 Transfer Facility Suboption

The second suboption for cylinder preparation is to transfer the depleted UF_6 from nonconforming cylinders to new cylinders. Unlike the overcontainer suboption, the transfer facility suboption would appear to bound potential environmental impacts. Not only would a building containing autoclaves be constructed (no facilities would be constructed for the overcontainer suboption), but operation of the transfer facility would involve the heating of cylinders and the movement of depleted UF_6 from nonconforming cylinders to conforming cylinders. The transfer facility could also be used to develop a long-term storage alternative for storing all the depleted UF_6 in conforming cylinders.

The reference case is designed to transfer the contents of 960 nonconforming cylinders per year, for a total of 19,200 cylinders over 20 years. As shown in Table in 3.1, this is the number of cylinders which preliminary estimates project to have problems by the year 2020 at the Paducah site. Twelve air heated autoclaves would be provided to empty the incoming, full cylinders, four in each of three parallel trains of depleted UF_6 transfer and filling equipment. Air heating would be utilized to assure safe vaporization of the depleted UF_6 because it was assumed that the use of steam heated units could result in a reaction between the depleted UF_6 and the water vapor in the steam if there were a breach (a more likely possibility for a substandard cylinder than for a conforming one). The depleted UF_6 would be transferred by sublimation rather than liquefaction, and the sublimed UF_6 gas would be compressed, liquefied in a condenser, and drained into a new, empty cylinder.

The technology feasibility for cylinder transfer of UF_6 is well established. Although domestic experience is primarily with steam heated autoclaves, there are no fundamental technical issues with air heated autoclaves. Industrial-based heat transfer coefficients were unavailable for the transfer facility engineering analysis to precisely establish the required number of autoclaves. These data and the impact of cylinder condition on the transfer rate would be established in a subsequent engineering development phase of the Program.

Two parametric cases have also been developed using substantially larger and smaller numbers of cylinders being transferred annually than in the reference case. These cases were sized by using multiples of the standard autoclave module developed in the reference case and have the following throughputs:

- Five autoclave modules transferring 1,600 cylinders per year (32,000 cylinders over a 20-year period)
- One autoclave module transferring 320 cylinders per year (6,400 cylinders over a 20-year period)

The larger facility would be capable of transferring all the cylinders at Paducah, the site with the most cylinders (28,351). The smaller facility would be appropriate for transferring all the cylinders at K-25 (4,683) or all the projected nonconforming cylinders at Portsmouth (5,200) in fewer than 20 years. These cases were developed to reflect a range of possible cylinder conditions. The high-capacity case assumes that all of the cylinders would be nonconforming and would either be placed in an overcontainer or transferred into conforming cylinders. The high-capacity case may also be used to support an option for transferring all the UF_6 from the existing cylinders into new cylinders and storing it.

The Engineering Data Input Report for this suboption is located in Section 6.2.

3.1.2 Cylinder Treatment Facility

Most of the options being considered involve removing the depleted UF_6 from the cylinders and converting it to another form. Disposition of the empty cylinders (46,422) and the residual "heel" of depleted UF_6 is addressed in the Engineering Data Input Report, *Depleted Uranium Cylinder Treatment Facility.* This report provides the initial engineering data for a stand-alone facility for removal of depleted UF_6 heels remaining in emptied cylinders. The treatment facility supports all Engineering Data Input Reports for conversion options, as well as a possible storage suboption in which the depleted UF_6 is transferred to new cylinders for long-term storage. The stand-alone facility described here would maximize the land, resource, and transportation requirements for heel removal. In practice, it is likely that this function would be integrated into other facilities at the conversion sites as a cost savings measure.

The cylinders are washed with water, and the aqueous wash solution containing uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF) is evaporated and converted to solid triuranium octaoxide (U_3O_8) and HF by pyrohydrolysis using steam and heat. The U_3O_8 is packaged and sent for either disposal or storage. The HF is neutralized with lime to calcium fluoride (CaF_2) and separately packaged. The quantity of HF produced is assumed to be too small to warrant marketing it.

This report assumes that the treated cylinders will become part of the scrap metal inventory at the gaseous diffusion plant sites. Final disposition for the cylinders, along with that for other similar materials, would be determined in other analyses. The residual radiation level is assumed to be very low; however, in the absence of a regulatory value, it is unclear that the cylinders could be released for unrestricted use.

The Engineering Data Input Report for the cylinder treatment facility is located in Section 6.3.

3.2 Conversion Module

Conversion of the depleted UF_6 to another chemical form is required for most management strategy alternatives. Triuranium octaoxide (U_3O_8), uranium dioxide (UO_2), and uranium metal (U) are the three principal uranium forms of interest. Due to their high chemical stability and low solubility, uranium oxides in general are presently the favored forms for the storage and disposal alternatives. High density UO_2 and U metal are the preferred forms for spent nuclear fuel radiation shielding applications due to their efficacy in gamma ray attenuation. Uranium metal is the required form for most dense material applications, where high density and high kinetic energy transfer are the required properties.

All conversion processes start with the volatilization of depleted UF_6, and all those being analyzed in depth involve the processing of major quantities of HF. Uranium hexafluoride and HF represent the most significant chemical hazards to the environment and the worker.

3.2.1 U_3O_8 Option

The conversion of uranium hexafluoride to U_3O_8 through the introduction of steam is often referred to as defluorination. This "dry" process is well established and is practiced on a large scale industrial basis by Cogema in France for the defluorination of depleted UF_6. The conversion process involves two steps. In the first, exothermic, step, the gaseous UF_6 is hydrolyzed with steam to produce solid uranyl fluoride (UO_2F_2) and HF. In the second, highly endothermic, step, the UO_2F_2 is pyrohydrolyzed with superheated steam (optionally containing H_2) to U_3O_8 and additional HF.

The reactions are as follows:

Step 1: $UF_6(g) + 2\ H_2O(g) \rightarrow UO_2F_2\,(s) + 4\ HF(g)$

Step 2: $UO_2F_2\,(s) + H_2O(g) \rightarrow 1/3\ U_3O_8\,(s) + 2\ HF(g) + 1/6\ O_2(g)$

or

Step 2': $UO_2F_2(s) + 2/3\ H_2O(g) + 1/3\ H_2(g) \rightarrow 1/3\ U_3O_8\,(s) + 2\ HF(g)$

Due to the large excess steam requirements for the second step, concentrated HF (typically 70 percent HF - 30 percent H_2O) is the direct process by-product. The U_3O_8 would be compacted to achieve a bulk density of about 3.0 g/cc prior to storage or disposal.

As indicated, the technology feasibility for the large scale conversion of UF_6 to U_3O_8 is well established. For the engineering analysis, there are scaling uncertainties, including residency times, associated with the conversion reactors. These and the uncertainties in materials of construction and the optimal operating conditions would be resolved in a subsequent engineering development phase of the Program. Although anhydrous HF is not produced as the by-product from the Cogema facility, distillation (the assumed process to upgrade the aqueous HF) is well established. Again, any uncertainties with the specific distillation process and its integration assumed for the engineering analysis (see 3.2.1.1) would be addressed in a subsequent engineering development phase of the Program.

Two suboptions were developed in the Engineering Analysis Project for the dry conversion of UF_6 to U_3O_8. The first process upgrades the concentrated HF to anhydrous HF (AHF < 1 percent H_2O) for sale with unrestricted usage, based on the very low uranium contamination level. The second process neutralizes the HF to calcium fluoride (CaF_2) for sale or disposal. In addition to several technologies recommended by industry, the U.S. Nuclear Regulatory Commission and the State of Tennessee Department of Environment and Conservation made general recommendations for conversion to U_3O_8.

It is considered unlikely that the presence of trace amounts of uranium would prevent the AHF from being made available for unrestricted use, and even more unlikely that this would prevent its being recycled in the nuclear fuel industry for the conversion of yellowcake (concentrated U_3O_8) to natural UF_6; however, in the unlikely event that the AHF could not be marketed, the acid would be neutralized with lime. In the absence of regulatory constraints regarding the uranium content, the CaF_2 could be sold as a fluorspar substitute for the commercial production of AHF. This would avoid the potential hazards associated with the handling, storage, and transportation of large quantities of AHF. Alternatively, the CaF_2 could be disposed of as nonhazardous solid waste in a sanitary landfill. A potential vulnerability is that disposal as low-level waste (LLW) would be necessary because of the small uranium content in the CaF_2 and the disposal costs would rise significantly.

3.2.1.1 Defluorination with Anhydrous HF Production Suboption

Defluorination with AHF production is superior to defluorination with HF neutralization in terms of waste avoidance and by-product value. This is because there is a considerable market for AHF in North America, while the market for aqueous HF is limited. However, handling, storage, and transportation of large quantities of AHF present more of a potential hazard than the suboption in which the HF is neutralized.

Based on Cogema's experience, it is anticipated that the AHF will contain only trace amounts of depleted uranium (less than 1 part per million, or 0.4 picocuries [pCi]/g). As generally recommended in the responses to the Request for Recommendations (RFR), the HF is upgraded to AHF by distillation. The HF/H_2O mixtures from the hydrolysis and pyrohydrolysis reactors are combined and then the components are separated in a distillation column to obtain an AHF stream and an azeotrope (constant boiling) stream. The azeotrope stream is vaporized and recycled to the hydrolysis reactor as the steam feed.

Distillation is a common industrial process and was the design basis for this suboption. The processing of the azeotrope and the process parameters for the conversion reactors were patterned after the General Atomics/Allied Signal response to the RFR and the Sequoyah Fuels Corp. patented process. This representative process has not been industrialized, but the initial research and development have been completed.

The Engineering Data Input Report for this suboption is located in Section 6.4.

3.2.1.2 Defluorination with HF Neutralization Suboption

As discussed in Section 3.2.1, it is reasonable to expect that, due to the very low uranium contamination level in the HF by-product stream, the AHF could be used commercially. However, in the unlikely event that the recovered HF could not be sold or even recycled in the nuclear fuel industry, the concentrated HF would be reacted with lime (CaO) to form CaF_2. In the absence of regulatory constraints regarding the uranium content, the CaF_2 could be sold as a feedstock (i.e., a high quality fluorspar substitute for the commercial production of AHF). Here, the rationale is the avoidance of the potential hazards associated with the processing, general handling, storage, and transportation of large quantities of AHF. The by-product value of CaF_2 is less than that of AHF, and major quantities of lime would be required for the neutralization. Alternatively, the CaF_2 could be sent to a disposal facility. This case would result in a large waste stream (approximately 1 kg per kg uranium) and would bound the waste generation for defluorination.

The engineering analysis for this suboption assumes the basic two-step defluorination process described above (Section 3.2.1), but with the deletion of the HF acid distillation step and the addition of a neutralization step. The specific process parameters are largely based on data from a previous report.[20] That process includes the addition of hydrogen gas to the steam pyrolysis step to reduce the external heat requirements (Step 2'). Accordingly, with the exception of HF acid neutralization, this overall process parallels the defluorination process recommended by Cogema.

Cogema operates the world's only defluorination facility for converting depleted UF_6 to U_3O_8 in Pierrelatte, France. Cogema stores the U_3O_8 in buildings on the conversion plant site and sells the aqueous HF to a ready European market. The average purity of the HF is below the 0.1 ppm uranium instrument detection levels, well within the 5 ppm specification given for aqueous HF sales (there are no regulatory limits for free release in France). The aqueous HF is viewed as very pure and highly desirable by potential purchasers, and is readily marketed to outside buyers in the glass and steel industries.

The Engineering Data Input Report for this suboption is located in Section 6.5.

3.2.2 UO_2 (Ceramic) Option

High density UO_2 is uranium dioxide with an assumed particle density of about 9.8 g/cc (90 percent of its theoretical density [10.8 g/cc]) and bulk density of about 5.9 g/cc. Depending on the particle shape, size, and size distribution, the bulk density of UO_2 will generally be two to three times that of compacted U_3O_8 powder. This higher density translates into substantially reduced space requirements for the storage and disposal alternatives. It also enables those radiation shielding applications in which depleted uranium oxide is substituted for the course aggregate material in conventional concrete.

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[20]Charles, L.D., et al. *Cost Study for the D&D of the GDPs, Depleted Uranium Management and Conversion* (Draft). K/D-5940-DF. Martin Marietta Energy Systems Central Engineering. September 1991.

The conversion of UF_6 to dense UO_2 is industrially practiced in the nuclear fuel fabrication industry. By either a "wet" or a "dry" process, the UF_6 is converted to a low density UO_2 powder under controlled conditions to assure suitable powder morphology for sintering to high density for use as nuclear power reactor fuel pellets. The wet processes are based upon precipitation of uranium from an aqueous solution, while the dry processes are based upon decomposing and reducing the UF_6 by steam and hydrogen in either fluidized bed reactors or rotary kilns. The powder is pressed into a pellet under high pressure, and the pellet is sintered at high temperatures to yield a solid which is typically 95 percent of the theoretical density. For depleted uranium, the chemical process equipment can be scaled, as there are no nuclear criticality constraints. Product morphology and other quality factors which are critical in the fabrication of nuclear fuels are relatively unimportant here.

Three suboptions were developed in the Engineering Analysis Project for the conversion of UF_6 to UO_2. A generic industrial dry process with conversion (similar to that described for U_3O_8) followed by conventional pelletizing and sintering to produce centimeter-sized pellets is the basis for the first two suboptions. The first suboption upgrades the concentrated HF to AHF (< 1 percent H_2O) for sale with unrestricted usage, based on the very low uranium contamination level. The second suboption neutralizes the HF to calcium fluoride (CaF_2) for sale or disposal. A number of respondents to the RFR recommended conversion using a dry process, including Siemens, Fluor Daniel (details are proprietary), and DOE. The third suboption, a wet process, is based on small scale studies and is referred to as the gelation process. This process was recommended by DOE. If appropriate, based upon the Record of Decision, advanced approaches for the production of dense UO_2 would be evaluated during phase two of the Program. These include concepts which would enable sintering at lower temperatures.

The technology feasibility for the large scale conversion of UF_6 to densified UO_2 using the "dry" process is well established. The nuclear fuel cycle industry produces densified UO_2 fuel pellets and Cogema operates a large scale defluorination facility. For the engineering analysis, there are scaling uncertainties, including residency times, associated with the conversion reactors. As indicated above (3.2.1), these and other uncertainties would be resolved in a subsequent engineering development phase of the program. In addition, this phase would address the design and engineering of much larger sintering furnaces compared to those used in the nuclear fuel fabrication industry.

The specific "wet" process (gelation) examined in the engineering analysis involves the initial steps of defluorination to U_3O_8 (3.2.1), followed by acid dissolution of the oxide. Both steps are well established. The subsequent aqueous processing involves significant performance and equipment scaling risks that would require an extensive research and engineering development program for resolution.

3.2.2.1 Dry Process with Anhydrous HF Production Suboption

Step one in the dry process is the same as the first step in the U_3O_8 conversion processes described in Section 3.2.1: the gaseous UF_6 is hydrolyzed with steam to produce solid UO_2F_2 and HF in an exothermic reaction. The solid UO_2F_2 from the steam hydrolysis is converted in an endothermic reaction to UO_2 powder in the second reactor by a mixture of steam and a stoichiometric quantity of hydrogen. The reactions are as follows:

Step 1: $UF_6(g) + 2H_2O(g) \rightarrow UO_2F_2(s) + 4HF(g)$

Step 2: $UO_2F_2(s) + H_2(g) \rightarrow UO_2(s) + 2HF(g)$

After standard physical treatment operations (milling, compacting, and screening) and the addition of a dry lubricant, the UO_2 powder is pressed into pellets with a density of about 50 percent of theoretical. The pellets are sintered in furnaces with a hydrogen-reducing atmosphere to achieve an assumed density of about 90 percent of the theoretical density. The HF is then upgraded to AHF as described in Section 3.2.1.1.

Due to the fact that the oxide throughput is an order of magnitude higher than that for nuclear fuel fabrication plants, the preconceptual design assumes much larger sintering furnaces than those used in commercial fuel fabrication plants. Furnaces of this size and with these performance specifications are not presently available, but furnaces with one or two of the features (high capacity, high temperature, and special gas atmosphere) are common. It is believed that sintering furnaces combining all of these features can be engineered and fabricated with moderate risks.

The Engineering Data Input Report for this suboption is located in Section 6.6.

3.2.2.2 Dry Process with HF Neutralization Suboption

The only difference between this suboption and the one described in Section 3.2.2.1 is the neutralization of the HF acid by-product. The neutralization step is the same as that described in Section 3.2.1.2.

Due to the fact that the oxide throughput is an order of magnitude higher than that for nuclear fuel fabrication plants, the preconceptual design assumes much larger sintering furnaces than those used in commercial fuel fabrication plants. Furnaces of this size and with these performance specifications are not presently available, but furnaces with one or two of the features (high capacity, high temperature, and special gas atmosphere) are common. It is believed that sintering furnaces combining all of these features can be engineered and fabricated with moderate risks.

The Engineering Data Input Report for this suboption is located in Section 6.7.

3.2.2.3 Gelation Process Suboption

In the gelation process, depleted UF_6 is processed to produce dense microspheres of UO_2 (millimeter-sized), CaF_2, and AHF. The CaF_2 and AHF are of sufficient purity to be sold commercially. The gelation process intrinsically avoids the pelletizing step and powder handling in general. The spherical, smaller-sized particles afforded by the gelation process permit higher bulk densities and can enable potential use, storage, and disposal applications requiring minimal void volumes. The chemistry is considerably more complex than in the alternative dry processes.

The initial step in the gelation process is a dry process (steam hydrolysis/steam pyrolysis) for conversion of UF_6 to U_3O_8 and AHF. In the first, exothermic, step, the gaseous UF_6 is hydrolyzed with steam in a fluidized bed reactor to produce solid uranyl fluoride (UO_2F_2) and HF. In the second, highly endothermic, step, the UO_2F_2 flows to a rotary kiln where it is pyrohydrolyzed with superheated steam to form U_3O_8, O_2, and additional HF.

The reactions are as follows:

Step 1: $UF_6(g) + 2\ H_2O(g) \rightarrow UO_2F_2\ (s) + 4\ HF(g)$

Step 2: $3UO_2F_2\ (s) + 3H_2O(g) \rightarrow U_3O_8\ (s) + 6\ HF(g) + \frac{1}{2}\ O_2(g)$

As before, the AHF is recovered using a distillation process.

After the formation of U_3O_8 and AHF, the remaining steps are as follows:

- <u>U_3O_8 dissolution:</u> U_3O_8 is dissolved in nitric acid (HNO_3) using a batch process to form an acid-deficient uranyl nitrate solution (ADUN). The acid is added in a slightly deficient stoichiometric quantity. The reaction is as follows:

  $$2U_3O_8 + 11.6HNO_3 \rightarrow 6UO_2(OH)_{0.4}(NO_3)_{1.6} + NO + NO_2 + 4.6H_2O$$

  Some nitrate is formed in the above solution by the following reaction:

  $$H_2O + NO_2 + NO \rightarrow 2HNO_2$$

  Urea (in stoichiometric excess) is added to the ADUN solution in denitriting tanks to stabilize the uranyl ion, and the solution is chilled:

  $$2HNO_2 + CH_4NO_2 \rightarrow CO_2 + 2N_2 + 3H_2O$$

- Gel solution preparation: The denitrited ADUN is cooled and mixed with a chilled hexamethylenetetramine (HMTA) solution to form a feed broth, which is fed to gelation columns. The solutions are cooled to 0°C to prevent gelation from occurring in the feed system and to control the reaction rate.

- Gel sphere formation: The ADUN/HMTA broth is fed to gelation columns through vibratory nozzles. The nozzles fragment the gel solution into droplets above a column of hot oil (trichloroethylene [TCE]). The droplets fall into the hot oil, which initiates the decomposition of the HMTA to form ammonium hydroxide and formaldehyde according to the following reaction:

  $$2\ (CH_2)N_4 + 10\ H_2O \rightarrow 4NH_4OH + 4HCHO$$

  The ammonium hydroxide then reacts with the ADUN to form UO_3 gel spheres. The gel spheres settle to the bottom of the column, where they are aged for 20 minutes to allow the reaction to go to completion. The simplified chemical reaction is as follows:

  $$UO_2(OH)_{0.4}(NO_3)_{1.6} + 1.6NH_4OH \rightarrow UO_3{*}H_2O + 1.6NH_4NO_3$$

  The gel spheres are filtered and dried with air to remove the TCE, then transferred to washing. Two sphere sizes are produced, 1200 micron and 300 micron.

- Gel sphere setting: The 1200- and 300-micron spheres are washed in a 0.5 molar ammonia solution using separate but identical equipment and processes. Heated air is used in a three zone process to dry the spheres.

- Sphere sintering and blending: The dried spheres are heated to drive off the remaining water, reduced in a hydrogen atmosphere to form UO_2, and sintered to form ceramic UO_2 spheres. The sintered UO_2 spheres are blended in a 70 weight percent 1200-micron and 30 weight percent 300-micron mixture. The final bulk density is 9.0 g/cc. The spheres are packaged in 30-gallon drums for shipment.

The technological risks associated with the gelation process are substantially greater than those associated with the dry process conversion of UF_6 to densified UO_2. In addition to the greater process performance and equipment scaling risks, the technology for the recycle of process reagents used in major quantities is uncertain. In the absence of a well-defined recycle operation, the reagents were assumed to be disposed as a sanitary waste, which significantly adds to the operating costs. The addition of a recycle operation would increase the facility capital cost, but a favorable tradeoff with operating costs (reagent and disposal) could be expected. Research and development activities are required to identify and demonstrate the optimal recycle system.

The Engineering Data Input Report for the gelation suboption is located in Section 6.8.

3.2.3 Uranium Metal Option

Two metallothermic reduction routes (batch and continuous) were analyzed in depth for the production of uranium metal. Both processes have the same chemistry: the magnesium metal (Mg) reduction of uranium tetrafluoride (UF_4) to produce uranium metal and a magnesium fluoride (MgF_2) by-product slag. The UF_4 required for either process would be generated by the hydrogen (H_2) reduction of depleted UF_6 (a standard industrial process), producing AHF as the by-product.

The reactions are as follows:

Step 1: $UF_6(g) + H_2(g) \rightarrow UF_4(g) + 2HF(s)$

Step 2: $UF_4(g) + 2Mg(s) \rightarrow U(s) + 2MgF_2(s)$

Both metal conversion processes produce MgF_2 in substantial quantities which much be disposed of as a waste. The batch metallothermic reduction process includes a decontamination step for the MgF_2 by-product, resulting in a 50 ppm uranium concentration. The by-product from the continuous metallothermic reduction process is assumed to have a low enough uranium concentration that a separate decontamination step would not be necessary. In both cases, it is assumed that the MgF_2 would be granted a free release exemption for disposal as a nonhazardous solid waste. An exemption would be required for slag disposal in a sanitary landfill since the uranium activity in the treated slag will still be large compared to that in typical soils.

Several respondents to the RFR recommended conversion to metal using batch metallothermic reduction with various MgF_2 decontamination technologies. The basis for the engineering analysis is the generic leaching process for MgF_2 decontamination. The other suboption analyzed in depth is the continuous metallothermic reduction process that is currently under development. The engineering analysis for this process is based upon the recommendations by Nuclear Metals, Inc., and DOE. The initial expectation, and the design basis, is that the level of uranium contamination in the MgF_2 by-product will be sufficiently low in the continuous process that a post-treatment step such as the acid leaching step used in the batch metallothermic process would not be necessary. The continuous metallothermic reduction process potentially offers three primary advantages: (1) higher throughput for a comparable size of reactor; (2) a lower level of uranium contamination in the by-product slag; and (3) a liquid uranium product stream for direct casting into the end product form, i.e., avoidance of a remelting step. The current continuous metallothermic reduction design produces a uranium alloy containing a small percentage of iron. This alloy is judged to be acceptable for the primary use of interest, radiation shielding.

The central issue for metallothermic reduction processes in general is the disposition of the by-product slag. There is a potential vulnerability that disposal as LLW would be necessary because of the uranium content in the MgF_2 and the disposal costs would rise significantly. Increasingly stringent requirements for sanitary disposal may necessitate alternative or additional treatment processes. Several responses to the RFR specifically addressed the treatment of the MgF_2 by-product slag (see Section 4.2.2.2).

3.2.3.1 Batch Metallothermic Reduction Suboption

In the batch metallothermic process, the UF_6 is reduced with hydrogen gas in a tower reactor. The AHF is recovered and stored for offsite shipment to a commercial customer. The UF_4 powder and a slight stoichiometric excess of Mg are contained in a sealed metal vessel and pre-heated. Once initiated, the reduction reaction is sufficiently exothermic to convert the reactants to molten uranium metal (collecting at the bottom of the reactor) and less dense molten MgF_2 (accumulating on top of the uranium metal). After solidification and further cooling, the uranium metal billet (typically 600 kg) is mechanically separated from the solid MgF_2 slag. The cycle time per batch is dominated by the heating and cooling periods (effectively about 12 hours total). A very large number of reactors are required due to the long heating and cooling periods.

The MgF_2 slag is ground and screened and any metal pellets are recovered for recycle. The highly refractory slag is then roasted and ground to facilitate leaching. After the slag is leached with nitric acid using a multistage countercurrent process, the MgF_2 is dried and drummed for disposal as appropriate. Disposal in a sanitary landfill would require an exemption, which has typically been possible for waste with activity levels below 35 pCi/g. The slag will still contain residual uranium (estimated at 50 ppm, or 20 pCi/g) that is significantly greater than the uranium activity found in soils. The nitric acid leach liquor, principally containing dissolved uranium and magnesium, is evaporated, calcined, and finally grouted with cement for LLW disposal. Alternate decontamination processes are described in Section 4.2.2.2.

The preconceptual design for the batch reduction process assumed batch sizes typically used by domestic uranium metal producers. Significantly larger batch sizes have been used by at least one non-domestic producer; however, no production information is available. Use of larger batch sizes, requiring fewer metallothermic reduction furnaces and reduced labor requirements, could result in significantly lower production costs.

The technology feasibility of the batch process for the large scale production of uranium metal is well established. The only significant uncertainties are associated with the MgF_2 by-product decontamination step, namely the exact number of leaching stages and the achievable, practical level of decontamination. If unavailable from industry, this data would be obtained in a subsequent engineering development phase of the Program. This phase would also address the tradeoffs in using reduction furnaces with larger batch sizes.

The Engineering Data Input Report for this suboption is located in Section 6.9.

3.2.3.2 Continuous Metallothermic Suboption

As in the batch metallothermic reduction process, the UF_6 is reduced with hydrogen gas in a tower reactor. The AHF is recovered and stored for offsite shipment to a commercial customer. A mixture of UF_4, magnesium (Mg), Iron (Fe), and an inert diluent salt is continuously fed into the top of a heated vertical reactor. The Fe and diluent salt reduce the melting points of the reaction product (U) and by-product (MgF_2) to improve materials compatibility and allow subatmospheric operation. Due to density differences, the U/Fe molten alloy settles to the bottom of the reactor where it is continuously withdrawn. The lower density MgF_2/diluent molten salt mixture floats on top and is withdrawn separately. The molten alloy is cast into billets or into the end product form if the manufacturing function is integrated into the conversion facility. The molten salt mixture is cooled and then ground, and the water-soluble diluent salt is dissolved. After evaporation and drying, the diluent salt is recycled to the reactor. The insoluble MgF_2 is drummed for disposal in a sanitary landfill. The annual throughput of the continuous metallothermic reduction reactor is an order of magnitude greater than that of a batch reactor (600 kg/batch); therefore the number of reactors is greatly reduced.

Based on the underlying design assumptions, the continuous process represents a lower bound on cost for producing uranium metal (alloy). However, the technological risks associated with the continuous reduction process are substantially greater than those associated with the batch process for reduction of UF_4 to uranium metal. The major uncertainty is the achievement of very low levels of uranium in the by-product salt during the reduction process. If further development indicates that such levels cannot be practically achieved, then a decontamination step would be required, at added cost. Leaching of the MgF_2, as in the case of the batch process (3.2.3.1) or in advanced processes (4.2.2.2), would be applicable.

Pilot scale testing is required to verify reactor throughputs, materials of construction, operating durations, and by-product contamination levels under production conditions. These data would be established in a subsequent engineering development phase of the Program.

The Engineering Data Input Report for this suboption is located in Section 6.10.

3.3 Use Module

There are a variety of possible uses for the conversion products of depleted UF_6. These include the light water reactor fuel cycle, advanced reactor fuel cycles, dense material applications, and radiation shielding applications. Of the various uses proposed in response to the RFR, the production of radiation shielding material provides the basis for the two suboptions that were analyzed in depth.

3.3.1 Radiation Shielding Applications Option

The engineering analysis considered two principal forms for use of depleted uranium—dense UO_2 and metal—and the approaches for manufacturing them into shielding. The first suboption uses depleted uranium as sintered UO_2 for the manufacture of depleted uranium concrete for shielding in spent nuclear fuel (SNF) storage containers. This material, which substitutes dense UO_2 for the coarse aggregate in conventional concrete, is known as DUCRETE™. As a shielding material, DUCRETE™ offers size and weight advantages over conventional concrete. Shielding made of DUCRETE™ would typically be less than half as thick as shielding made from concrete. DUCRETE™ may also be an appropriate material for overcontainers for spent nuclear fuel disposal, although this use is more speculative than its use in storage applications. Accordingly, after the spent nuclear fuel storage period, the engineering analysis assumes that the empty DUCRETE™ cask would be disposed as low-level waste. Idaho National Engineering Laboratory (INEL)[21] recommended DUCRETE™ as a potential use for depleted uranium.

The second suboption uses depleted uranium as the metal in the manufacture of annular shields for a Multi-Purpose Unit system. The Multi-Purpose Unit concept is a spent nuclear fuel package that, once loaded at the reactor, provides confinement of spent nuclear fuel assemblies during storage, transportation, and disposal. In this approach, the depleted uranium is disposed of with the spent nuclear fuel. The DOE Office of Civilian Radioactive Waste Management, industry, and members of the public recommended shielding applications using the depleted uranium as metal.

For both shielding suboptions, the shielding material would be enclosed between stainless steel (or equivalent) annular elements (shells) to provide structural integrity and avoid contact with the environment.

The Engineering Data Input Report for these suboptions is located in Section 6.11.

3.3.1.1 Shielding Application in the Oxide Form Suboption

In the DUCRETE™ shielding suboption, the manufacturing site receives the sintered UO_2 and the partially fabricated stainless steel shells and other shielding cask components for containing the DUCRETE™. The steel casks are fabricated in a nonradiological building, and the operations include welding, machining, and final assembly. The DUCRETE™, prepared in a separate (radiological) building, uses high shear mixing for combining and homogenizing the

[21]Idaho National Engineering Laboratory has recently changed its name to Idaho National Engineering and Environmental Laboratory (INEEL). This report will continue to use INEL when referring to the original submission.

DUCRETE™ constituents and subsequently casting the mixture into the annulus of the cask. After curing, final assembly of the shielding cask is carried out. The DUCRETE™ composition is nominally 74 percent UO_2, 11 percent sand, 10 percent cement and additives, and the remainder water. The annual capacity of the manufacturing plant is about 480 finished SNF vertical concrete casks, each containing about 45 MT of UO_2.

A UO_2 density of 9.8 g/cc (90 percent theoretical density) was assumed for the engineering analysis. Based on the *Conceptual Design Report for the Ducrete Spent Fuel Storage Cask System*[22], appreciably lower densities may be acceptable without a significant loss in overall shielding performance for the fixed mass of the cask. If so, this would relax the UO_2 sintering requirements and associated equipment risks.

There appear to be no major technological issues with respect to the production of DUCRETE™ shielding casks. Engineering development, including the manufacturing and testing of a prototype cask, are required. Structural, thermal, optimal compositions, and radiation attenuation evaluations are among the supporting tasks. It is noted that DUCRETE™ developmental work in several of these areas is continuing at INEEL under the sponsorship of DOE. Additionally, William J. Quapp, the former Principal Investigator for the Depleted Uranium Recycling Project at INEL, is pursuing a demonstration program for development of DUCRETE™ spent nuclear fuel storage cask systems with Nuclear Metals, Inc. Nuclear Metals is establishing a depleted uranium aggregate production capability to support the construction of DUCRETE™-shielded products.

3.3.1.2 Shielding Application in the Metal Form Suboption

In the metal shielding suboption, the manufacturing site receives uranium metal ingots (or alloy) and partially fabricated stainless steel or titanium alloy shells and other shielding cask components for containing the uranium metal. The casks are fabricated in a nonradiological building, and, as above, the operations include welding, machining, and final assembly. In a separate building, the uranium metal is vacuum melted by induction heating and directly cast into the annulus within the assembled cask. After cooling, final assembly of the shielding cask is carried out. Each finished shielding cask contains about 43 MT uranium, and about 440 casks are manufactured each year.

The engineering analysis assumes that the uranium metal shield is formed by direct casting. This and alternative fabrication methods, including casting into smaller parts and wrought fabrication, need to be further evaluated. Based on the shield size, the nature of the material, and integrity

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[22]Hopf, J. E. *Conceptual Design Report for the Ducrete Spent Fuel Storage Cask System*. INEL-95/0030. February 1995.

requirements, a significant development effort is necessary. This effort would be conducted in a subsequent engineering development phase of the Program.

3.4 Storage Module

Storage of depleted uranium is predicated on its use at some later date. In the engineering analysis, storage options are defined by the type of storage facility, and suboptions are defined by the chemical form in which the depleted uranium is stored. The types of storage facilities analyzed are (1) buildings, (2) below ground vaults, and (3) mined cavities. The three chemical forms analyzed are (1) UF_6, (2) U_3O_8, and (3) UO_2. The PEIS considers two long-term storage alternatives: storage of the depleted uranium as UF_6 and storage in an oxide form (either U_3O_8 or UO_2). In addition, the no action alternative will analyze the continued storage of UF_6 in the current yards. Yard storage of depleted uranium in the oxide form is not analyzed as it would not provide the secondary level of confinement required by DOE Order 6430.1A for new storage areas.

Continued storage of depleted uranium in the form of UF_6 was recommended by a number of respondents to the RFR, including the American Nuclear Society and members of the public. Preservation of options for use in the future (e.g., breeder reactor fuel) or health and safety concerns related to moving the UF_6 or converting the UF_6 to another chemical form were cited as factors in these recommendations, which included above ground storage in earthquake-resistant concrete structures. A member of the public and a member of academia also recommended storage in the oxide form. Storage as an oxide or use of the oxide was implied by all the respondents who recommended technologies for conversion to oxide forms.

3.4.1 Building Option

The engineering analysis for the storage module considered storage in a building for depleted uranium in three forms: UF_6, U_3O_8, and UO_2. In addition to storage buildings, the storage facility would include a receiving warehouse and repackaging building, a cylinder washing building (for UF_6 only), a workshop, and an administration building. The buildings would use standard concrete floors and metal wall construction on spread footings, with at-grade construction. The storage buildings would be "Butler" buildings. The number of buildings needed would depend upon the form of the depleted uranium, with U_3O_8 requiring the most.

3.4.1.1 UF_6, U_3O_8, and UO_2 Suboptions

Three chemical form suboptions—UF_6, U_3O_8, and UO_2—were considered under the building option. For long-term storage in a building, depleted UF_6 would be stored in the same containers in which it is currently stored. For the other two suboptions, depleted uranium as sintered UO_2

microspheres would be stored in 30-gallon drums on pallets, and U_3O_8 would be stored in 55-gallon drums on pallets.

The chemical form of the depleted uranium selected for storage partly depends on which of the potential use options is considered most likely. Storage as UF_6 provides maximum flexibility for future uses, and it is difficult at this point to predict what use option would be most likely in the longer term. Storage in another form, such as UO_2, would imply a specifically identified future use option. Storage as U_3O_8, a relatively benign material which is the generally recommended form for disposal, would facilitate future handling should a determination eventually be made that all or part of the depleted uranium is no longer needed.

Another consideration in evaluating the chemical form is the storage area required. Storage area is a function of the uranium bulk density, the type of storage containers, and the container configuration. Representative bulk densities for UF_6, sintered UO_2 microspheres, sintered UO_2 pellets, and U_3O_8 are 4.6, 9.0, 5.9, and 3.0 g/cc, respectively. Therefore, all other factors being equal, the sintered UO_2 microspheres would require significantly less storage area. In the analysis, storage of oxides was bounded by considering the sintered UO_2 microspheres as the lower bound (least storage volume required) and U_3O_8 powder as the upper bound (greatest storage volume required).

Environmental and cost considerations must also be evaluated in assessing storage options/suboptions. The primary concern for storage of depleted uranium is the integrity of the container to prevent potential releases to the environment as well as protecting the contents for future use. The chemical form makes relatively little difference so long as there is a continuing maintenance program that prevents water intrusion into storage areas and ensures the integrity of the storage containers. On the other hand, chemical form has a strong influence on cost, since the cost of a storage facility is proportional to its size. However, the overall cost for a particular storage alternative also includes the costs for conversion, intersite transportation, and any required repackaging. Storage as UO_2 has a higher associated conversion cost than U_3O_8, but the storage volume would be significantly less. Storage as UF_6 would have no associated conversion cost prior to storage.

3.4.2 Vault Option

The engineering analysis for the storage module considered vault storage for depleted uranium in two forms: U_3O_8, and UO_2. The vaults would be subsurface reinforced concrete structures with a steel roof supported by trusses. This design allows part of the roof to be removed for access to the vault by a mobile crane that can be relocated from vault to vault. Assuming vaults of 40 m (131 ft) by 81 m (266 ft), the engineering analysis estimated that 35 vaults (46 hectares [ha] [114 acres]) would be required to store the depleted uranium in the form of UO_2 microspheres, and 79 vaults to store the U_3O_8 form (86 ha [112 acres]). In addition to the vaults, the facility would include a receiving warehouse and repackaging building, an administration building, and a workshop.

3.4.2.1 U_3O_8 and UO_2 Suboptions

Two chemical form suboptions—U_3O_8 and UO_2—were examined under the vault option. Storage of UF_6 in the environment of a below ground vault was not considered. The sintered UO_2 microspheres would be stored in 30-gallon drums on pallets, and depleted uranium as U_3O_8 would be stored in 55-gallon drums on pallets. Evaluation of chemical form suboptions under vault storage involves essentially the same considerations of potential future use, required storage area, cost, and environmental impacts as are described above for building storage.

3.4.3 Mined Cavity Option

The engineering analysis for the storage module considered storage in a mined cavity for depleted uranium in three forms: UF_6, U_3O_8, and UO_2. In this option, the depleted uranium would be stored in drifts, or lateral extensions of below ground tunnels. Because the size of the drifts depends on the geological structure in which they are cut, the engineering analysis assumed construction in stronger, nonplastic strata which can support wide, tall drifts. Assuming drifts of 12 m (39 ft) wide by 5 m (18 ft) high by 100 m (330 ft) long, the number required for the different chemical forms of depleted uranium was estimated as follows: 180 drifts for UF_6, 105 drifts for UO_2, and 215 drifts for U_3O_8. Forced ventilation would be needed throughout the shaft, tunnel, and drift system if people are to work in the area without breathing tanks. The storage facility would also include a receiving warehouse and repackaging building, a cylinder washing building (for UF_6 only), a workshop, and an administration building.

3.4.3.1 UF_6, U_3O_8, and UO_2 Suboptions

Three chemical form suboptions—UF_6, U_3O_8, and UO_2—were considered under the mined cavity option. For long-term storage in a mined cavity, depleted UF_6 would be stored in the same containers in which it is currently stored. For the other two suboptions, depleted uranium as sintered UO_2 microspheres would be stored in 30-gallon drums on pallets, and U_3O_8 would be stored in 55-gallon drums on pallets. Evaluation of chemical form suboptions under the mined cavity option involves the same considerations of potential future use, required storage area, cost, and environmental impacts as are described in Section 3.4.1.1.

The Engineering Data Input Report for storage options is located in Section 6.12.

3.5 Disposal Module

Disposal options and suboptions are defined by the disposal facility and the nature of the waste form. The engineering analysis for this module considered three disposal facility options: (1) engineered trench, (2) below ground vault, and (3) mined cavity. Each option was evaluated for the same four waste form suboptions: (1) grouted (cemented) U_3O_8, (2) grouted UO_2, (3) bulk (i.e., not grouted) U_3O_8, and (4) bulk UO_2. The spectrum of cases reflects the differences in potential site meteorology and geology, and differences in the chemical stability, release rates, and the solubility and friability characteristics of the waste forms.

The goal is to provide a depleted uranium waste form that is both chemically and structurally stable in the disposal environment. U_3O_8 has high chemical stability and low solubility under most environmental conditions and is generally regarded as the most suitable form for disposal. However, it is difficult to control the particle size distribution of U_3O_8 and, hence, this compound is quite friable. Therefore, the base case chosen for analysis is U_3O_8 mixed with cement to form a grouted, solid product. UO_2 is also insoluble, but, at ambient temperature in air, it will slowly convert to U_3O_8. Sintered UO_2 in microspheres can, however, be stabilized with a density substantially greater than compacted U_3O_8. It was assumed that all of the depleted uranium waste forms analyzed in the EAR can be considered as Class A low-level waste (LLW) regulated by the Atomic Energy Act (AEA) and associated regulations.

Disposal as an oxide was recommended by Idaho National Engineering Laboratory and the U.S. Nuclear Regulatory Commission. PDI proposed that a mined geologic formation be considered for the long-term management of depleted uranium and offered the use of an existing underground mine as a full scale model.

3.5.1 Preparation Option

All disposal facility options include a waste form facility to serve as the interface between the UF_6 conversion facility and actual disposal. Assuming the base case of grouted U_3O_8 or the grouted UO_2 case, preparation would include mixing the incoming oxide with cement, repackaging the grouted product in new or recycled drums, and allowing it to cure. Bulk waste forms would be disposed of in the original 55- or 30-gallon shipping drums as received from the conversion facility (assuming these are undamaged), thus requiring minimal preparation and eliminating the need for cementing and curing buildings in the waste form facility.

3.5.1.1 Waste Form Suboptions (Grouted and Bulk U_3O_8, Grouted and Bulk UO_2)

The base case waste form would consist of sand, cement, and U_3O_8 in a ratio of 1:1:2. Grouting would help control the potential mobility of bulk U_3O_8 if containment were lost and would also further reduce solubility; however, because grouting increases mass, the grouted waste form would require additional drums and more storage space. Grouted UO_2 (cement and UO_2 in a 1:3 ratio) is more compact than grouted U_3O_8, but less stable. In terms of disposal volumes, this analysis considered the sintered UO_2 microspheres (ungrouted) produced by the gelation conversion process as the lower bound (requiring the least disposal volume) and grouted U_3O_8 produced by the defluorination process as the upper bound (requiring the greatest disposal volume). Disposal as UO_2 pellets such as those produced by the dry conversion processes would occupy a disposal volume in between grouted U_3O_8 and ungrouted UO_2 microspheres, and is therefore suitably bounded by these two cases.

3.5.2 Engineered Trench Option

Disposal in an engineered trench (also called a shallow earthen structure) is primarily feasible in drier areas. The trench is excavated to a depth of 8 m (26 ft) in compacted clay, which is imported into the area to replace the existing top layer of soil. Pervious sand is added to the floor to provide a firm base, improve drainage, and act as a buffer if there is a rise in the water table. The floor slopes gently to one corner, and a French drain, sumps, and monitoring pipes are used to collect and sample water. It is assumed that waste packages would be stacked three pallets high, with backfill in all void spaces. When filled, the trench is covered with a sloped cap of compacted clay, followed by a topsoil overburden and other barriers designed to direct surface water away from the disposal units and prevent intrusion.

3.5.2.1 Waste Form Suboptions (Grouted and Bulk U_3O_8, Grouted and Bulk UO_2)

The depth and basic layout of the trench are assumed to be the same for all waste forms, but the length and width are flexible. The disposal of grouted U_3O_8, the waste form with the largest volume, was modeled using a 60-m (200-ft) wide, 157-m (515-ft) long trench. Given the expectation of filling one trench per year for 20 years, the base case would require a minimum overall site size of 30.6 hectare (ha) (76 acres). Site sizes needed to accommodate 20 trenches for each of the other waste forms would be as follows: bulk U_3O_8 (16.8 ha [41.5 acres]), bulk UO_2 (9.5 ha [23.5 acres]), and grouted UO_2 (12.1 ha [29.9 acres]). All site estimates include spacing of 20 m (66 ft) between each trench.

3.5.3 Vault Option

The draft EAR analyzes a belowgrade vault design modified for depleted uranium disposal. Each vault would consist of five bays, with a total capacity per vault of either 9,000 55-gallon drums or 19,200 30-gallon drums. It is assumed that 30-gallon drum waste packages would be stacked four drums high and 55-gallon drums would be stacked six drums high. The vaults would have a reinforced concrete floor over a gravel subfloor and reinforced concrete outer walls. The design also calls for a system of drains, a sump for leachate collection and treatment as necessary, and monitoring pipes. Vaults would be filled from the top by crane and, when completely full, covered with a 3-foot thick, gently sloping concrete slab, plus additional engineered barriers and a sloping, mounded cap of excavated material.

3.5.3.1 Waste Form Suboptions (Grouted and Bulk U_3O_8, Grouted and Bulk UO_2)

Vault size was assumed to be the same regardless of the waste form. To dispose of the entire inventory of depleted uranium as grouted U_3O_8 would require about 169 vaults on 56 ha (140 acres). The other suboptions would reduce the number of vaults required as follows: ungrouted U_3O_8 - 81 vaults (28.6 ha [71 acres]), grouted UO_2 - 35 vaults (12.9 ha [32 acres]), and ungrouted UO_2 - 23 vaults (9.8ha [24 acres]).

3.5.4 Mined Cavity Option

Conceptually, a mined cavity for disposal of depleted uranium could resemble the planned Yucca Mountain repository for high-level waste. The overall design would include surface facilities, including the waste form facility; shafts and ramps for access to and ventilation of the underground portion; and underground tunnels, or drifts, for movement of material and storage of waste. It is assumed that all tunnels are lined with reinforced concrete and provided with paved roadways. Compared to Yucca Mountain, however, a depleted uranium mined repository, which would be accommodating low-level waste, would have a much denser emplacement of uranium and consequently much greater economy in use of space and tunneling.

3.5.4.1 Waste Form Suboptions (Grouted and Bulk U_3O_8, Grouted and Bulk UO_2)

The base case (grouted U_3O_8) was estimated to require 45,628 m (149,000 ft) in drift tunneling length and 187 ha (462 acres) in total underground area. Drift length and acreage for the other three suboptions are as follows:

- ungrouted U_3O_8: 21,888 m (71,813 ft) and 92.2 ha (228 acres)
- grouted UO_2: 13,452 m (44,135 ft) and 58 ha (143 acres)
- ungrouted UO_2: 8,940 m (29,332 ft) and 39.5 ha (98 acres)

The Engineering Data Input Report for the disposal options is located in Section 6.13.

4.0 Summary of Principal Options Not Analyzed in Depth

The technologies described in Section 3 are analyzed in depth in Section 6 and have a sufficient technical basis to carry out reasonably precise, preconceptual designs and meaningful estimates of the data required for the PEIS and the cost analysis. These options are primarily based upon the recommendations received in response to the Request for Recommendations. A significant number of other promising technologies were recommended, but, with minor exceptions, these are in the early stages of either conceptualization or development, entail time frames beyond that considered in the current analysis, are proprietary, or involve already existing uses of depleted uranium. These technologies are described in this section of the report. Many of these options are also discussed in the report entitled *Characterization of Options for the Depleted Uranium Hexafluoride Management Program, Basis for the Interim Engineering Analysis Report*[23].

It is noted that any technology which is not analyzed in depth during Phase I (long-term management strategy selection) is nonetheless preserved for Phase II, when specific technologies and sites will be selected. Developing technology-specific data at this time would open the scope of the analysis to an unlimited number of alternatives based on specific processes. This is not necessary, as long as representative options can be used to bound the cost and environmental impacts.

4.1 Transportation Module

This element refers to the preparation of the depleted UF_6 cylinders at their current storage sites for transportation to an offsite facility, generally for conversion. Transportation options are also considered in this module. Transportation of all forms of depleted uranium by both truck and rail is included in the individual Engineering Data Input Reports in Section 6. Transport by barge was considered, but not analyzed in detail. The locations of potential conversion, manufacturing, storage, or disposal facilities are unknown at this time and accessibility to points of entry for barge transportation is uncertain. Preliminary information about barge transportation for the three gaseous diffusion plant sites, applicable to options for moving the depleted UF_6 cylinders off the current storage sites, is summarized below. All three sites currently rely predominantly on ground transportation. With the possible exception of K-25, the capability for barge transportation would have to be developed.

<u>K-25 at Oak Ridge</u>

K-25 has a functioning barge facility, but due to weather conditions, it operates only eight or nine months a year. It is located near the old Power House and connects, through the Clinch River, to

[23]Dubrin and Zoller 1995.

major waterways. Although it does not have a permanent crane, temporary cranes can be procured, and sometimes the straddle buggies which are used for onsite movement of cylinders are able to go directly onto the barge. The barge is currently involved in an out-source leasing agreement, but would probably be available to DOE if needed. It was last used a couple of years ago to ship heavy equipment for the Navy. The barge is about one-half mile to 1 mile from the cylinder yards. The cylinders would most likely be conveyed to the barge by means of a straddle buggy-train-straddle buggy or a straddle buggy-truck-straddle buggy combination.

Portsmouth

The city of Portsmouth, on the Ohio River, has two docking facilities. McGovney's Dock is a privately-owned commercial dock for bulk goods which is currently in operation. In addition, as part of an economic development plan, the Southern Ohio Port Authority has acquired a former steel mill, which has docking facilities. This facility is not currently in operation, although it has been in the recent past. Basically, complete renovation will occur when there is a commitment for use (for example, if DOE indicated they would need it for an extended period of time). To reach the Portsmouth docks, the cylinders would have to be moved about 20-22 miles by truck. There is also rail service from the plant into Portsmouth, but it might require modifications to reach the docks. Another operating commercial dock facility, the Standard LaFarge Docks, is situated east of Portsmouth, about 30 miles from the plant.

Paducah

Although there is a thriving river shipping industry in Paducah, river transportation is not being used by the Paducah GDP. The plant is only about 6 miles away from the river, but about 20-25 miles from the existing docks area. It is uncertain whether building a road from the plant site to the river and establishing a docking facility for the plant would be feasible.

4.2 Conversion Module

In response to the Request for Recommendations, a significant number of promising conversion technologies were submitted, but, with minor exceptions, these are in the early stages of either conceptualization or development. In addition, key design aspects are proprietary for a number of these submittals. The potential advantages of these new processes include enhanced flexibility, elimination of some unit operations, lower costs, and higher revenue streams.

From an environmental perspective, all conversion routes begin with the processing of major quantities of depleted UF_6. Several conversion processes involve an HF by-product. The chemical hazard of UF_6 and HF is an issue for the storage, handling, and transportation of both these substances. One oxide conversion response not analyzed in depth avoided an HF by-product.

4.2.1 U_3O_8 Suboptions

In addition to the multiple responses recommending dry conversion with upgrading to AHF, there were several recommendations on emerging technologies or new concepts that offer unique features in the areas of environmental and cost benefits. The principal options which were considered but not analyzed in detail are summarized below.

4.2.1.1 Quantum-Catalytic Extraction Processing™

One respondent recommended a molten metal catalyzed process for single-step conversion to uranium oxides. The Quantum-Catalytic Extraction Processing™ (Q-CEP) technology was recommended by M4 Environmental Management, Inc. (limited partners: Martin Marietta Environmental Holdings, Inc., and Molten Metal Federal Holdings, Inc.). Q-CEP uses a molten metal to homogeneously catalyze the dissociation of complex feed molecules and serve as a solvent for the resulting chemical intermediates. A pilot plant using depleted UF_6 as a feed material is located in Oak Ridge, Tennessee. In addition, a commercial scale prototype unit has been operated for extended periods of time to develop process data for destruction of a wide range of heterogeneous hazardous materials.

In the Q-CEP, depleted UF_6 and other co-feeds (e.g., steam) would be fed into a molten metal reactor where they would be decomposed. Common metals such as iron and copper can be used as the working medium, and the typical operating temperature range is 1500-1600°C. Due to their density differences, the desired products (uranium oxides, anhydrous HF) can be separately withdrawn. The Q-CEP offers a more compact process than the traditional dry route for producing oxides, avoids the distillation step required to produce anhydrous HF, and does not require the mechanical grinding/compacting steps to increase the bulk density of the uranium oxide. In addition to these key features, the process intrinsically offers a broad degree of flexibility. This includes tailoring the oxide product by the addition of slag formers or fluxing agents to form a glass-like product that is dense and not friable; varying the chemical form of the by-product (e.g., aluminum trifluoride); and producing a variety of depleted uranium products, including U_3O_8, UO_2, and a uranium metal alloy (by the addition of magnesium metal). In addition, M4 promotes the process as being a lower-cost alternative. The reactions are as follows:

Hydrolysis/reduction:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$$
$$UF_6 + H_2 \rightarrow UF_4 + 2HF$$

Dissolution/recombination:

$$6UO_2F_2 + 6H_2O \rightarrow 2U_3O_8 + O_2 + 12HF$$
$$UO_2F_2 + H_2 \rightarrow UO_2 + 2HF$$
$$UF_4 + 2H_2O \rightarrow UO_2 + 4HF$$

Oxidation/reduction: $3UO_2 + O_2 \rightarrow U_3O_8$
$U_3O_8 + 2H_2 \rightarrow 3UO_2 + 2H_2O$

M4 submitted a number of communications in response to the RFR, including a January 6, 1995, proprietary response describing the Q-CEP developed and patented by Molten Metal Technologies and a restated June 5, 1995, nonproprietary technical presentation. In the June 5 communication, M4 stated that, at that time, there was

> no reported laboratory experience processing UF_6 in a molten metal bath. Further, there is no significant process information or industrial experience involving the conversion of UF_6 at the higher temperatures characteristic of the CPU [catalytic processing unit] reactor. . . . All components of the M4 Environmental Q-CEP-based process for the conversion of UF_6 have been demonstrated to some level of industrial confidence. The integrated system has not been demonstrated.[24]

It is noted that the molten metal process has, however, been successfully used for the large scale recycling of hazardous wastes.

M4 Environmental signed a contract with the United States Enrichment Corporation (USEC) to experimentally demonstrate the technical and economic viability of the Q-CEP technology for depleted uranium conversion (defluorination). A November 29, 1995, article published in the *Paducah Sun* stated that full scale testing was to begin that week and that a decision would be made on whether to build a commercial processing plant at Paducah or Portsmouth by the summer of 1996. M4 has now designed, installed, and operated the demonstration facility at their Oak Ridge Technical Center. Future efforts are unknown, but the Department has continued to track developments. Much of this information remains proprietary. Continued development of this technology will enable meaningful preconceptual designs and estimates of the environmental data in the future, perhaps on a nonproprietary basis.

4.2.1.2 Aqueous Process

Another process, the Cameco process, uses a significantly different chemistry from the dry process of steam hydrolysis/pyrolysis. This new process is based on the fact that UF_6 will react with sulfuric acid of suitable concentration to produce an insoluble uranyl sulfate complex and an aqueous solution containing uranyl sulphate and HF. Gaseous AHF is removed from the reaction vessel and recovered from a cold trap as liquid AHF. After drying, the sulfate complex is

[24]"Description of a CEP-Based Process for the Conversion of UF_6," submitted to U.S. Department of Energy by M4 Environmental L.P., June 5, 1995 (p. 7).

thermally decomposed to U_3O_8 and an off-gas of sulfur trioxide and oxygen. The acid is recovered for recycle by reacting the sulfur trioxide with water. All water and sulphuric acid involved in the process would be completely recycled; thus, no uranium-bearing effluents are expected. A principal feature of this technology (like the process described in Section 4.2.1.1) is the direct production of AHF. The possibility of producing an aqueous HF product at a lower cost is another option. Neutralization of the aqueous HF with lime for the purpose of disposal was not considered cost-effective.

The reactions are as follows:

Defluorination:	$UF_6 + 2H_2O + H_2SO_4 \rightarrow UO_2SO_4 + 6HF$
Thermal Decomposition:	$3UO_2SO_4 \rightarrow U_3O_8 + 3SO_3 + 1/2O_2$
Acid Recovery:	$SO_3 + H_2O \rightarrow H_2SO_4$

Patent applications have been filed with the U.S. and Canadian patent offices, and key features are proprietary. The technology used or developed for this process, except for the defluorination stage, is mostly state-of-the-art for the chemical industry. Further research and demonstration work is needed to optimize process parameters, confirm the low levels of AHF and U_3O_8 product contamination observed in bench scale testing, and test equipment for the liquid/solid separation and calcination stages.

4.2.1.3 Defluorination with Aluminum Trifluoride Co-product

A third defluorination process which was not analyzed in depth involves the production of a uranium oxide and the co-product, solid aluminum trifluoride (AlF_3). This process was recommended by EG&G Environmental, Inc. Aluminum trifluoride is a key material used in the manufacture of aluminum metal. The objective is to produce a valuable by-product that is easier and safer to handle and transport than HF. The inputs are depleted UF_6 and alumina (Al_2O_3) or aluminum metal (or a mixture of the two), which react in a fluidized bed to produce a combination of uranium compounds. The relative amounts of uranium oxides and uranium metal would be controlled by varying the proportion of reactants and the reaction temperature. After the exothermic reaction is complete, the solid product mixture would be transferred into a gravimetric separation system to separate the uranium oxide from the AlF_3. The system would be enclosed, and no solid, gas, or liquid discharges are envisioned.

The recommendation to produce AlF_3 is at the early stage of conceptualization, and the thermodynamic analysis is proprietary. Scientific data such as process temperatures, reaction rates, product morphologies, and separation performance are required for a suitable technical evaluation.

4.2.1.4 Defluorination with Hydrofluorocarbon and HF Co-products

Defluorination by using UF_6 as a fluorinating agent in the initial step for synthesizing hydrofluorocarbons (HFC) is another option requiring further development. Allied Signal made a specific proprietary recommendation, and Los Alamos National Laboratory made a more general recommendation for this option. Hydrofluorocarbons represent replacements for chlorofluorocarbons, which have been shown to lead to ozone degradation in the upper atmosphere. The primary incentive for HFC production appears to be economic. The much higher unit value for typical HFCs than for AHF would lead to a significantly greater revenue stream and presumably a lower net conversion cost.

Generically, the reaction is assumed to be as follows:

$$UF_6 + \text{Organic Feedstock} \rightarrow \text{HFC or HFC Intermediate} + UF_4$$

The UF_4 would then be converted by an unspecified defluorination process into U_3O_8 and AHF. Alternatively, the UF_4 could be converted into uranium metal. Like the recommendation to produce AlF_3, this technology is at the early stage of conceptualization, and scientific data such as process temperatures, reaction rates, product morphologies, and separation performance are required for a suitable technical evaluation.

4.2.2 Uranium Metal Suboptions

4.2.2.1 Plasma Dissociation Process

Plasma dissociation of UF_6 is a fundamentally different technology for metal production, offering a single-step conversion process without the generation of the MgF_2 waste stream produced by conventional processes. There were two responses recommending this technology, one from Idaho National Engineering Laboratory and one from Manufacturing Sciences Corporation (in collaboration with Los Alamos National Laboratory). In the plasma process, the UF_6-to-UF_4 conversion step is eliminated and all the original fluorine appears in the by-product AHF, i.e., 6 moles of AHF per mole uranium metal compared to 2 moles for metallothermic reduction routes. The overall reaction is as follows:

$$UF_6 + 3H_2 \rightarrow U + 6HF$$

A generic description of one of several variations of the plasma conversion process is given here. Argon (Ar) gas is injected into a plasma torch, producing an Ar plasma at temperatures exceeding 10,000°K. Gaseous UF_6 is introduced into the reactor section, downstream from the plasma torch. The high temperature causes essentially complete dissociation of the UF_6 into its atomic constituents, uranium and fluorine. The flowing gas is expanded through a nozzle to rapidly cool the mixture and to initiate the recombination of the uranium vapor into submicron-sized metal particles. A large excess of ambient temperature hydrogen gas is added to scavenge the atomic fluorine, preventing its recombination with the uranium and providing further cooling. The uranium metal powder is separated from the flowing gas stream and cast into ingots. The AHF is recovered by cryogenic condensation and stored in tanks for sale. The Ar/H_2 mixture is separated, and the Ar and H_2 are recycled to the plasma torch and the reactor, respectively.

Bench scale experiments have generated small quantities of uranium metal. Process demonstration at a larger scale is needed to resolve major design uncertainties and develop data for a more detailed analysis. This process offers a higher revenue from sales of AHF due to the complete recovery of the fluorine value. In addition, this process avoids the cost of MgF_2 disposal (either as nonhazardous solid waste or low-level waste) common to metallothermic routes.

4.2.2.2 MgF_2 Treatment Processes

The magnesium metal reduction of UF_4 to produce uranium metal generates a large MgF_2 by-product stream (see Section 3.2.3). For the industrial batch process, the MgF_2 is significantly contaminated with uranium. In the absence of subsequent processing, this stream requires disposal as a LLW. The improved batch metallothermic route described in Section 3.2.3.1 incorporates a roasting step and then an acid leaching step to decontaminate the by-product and allow its disposal in a sanitary landfill. However, because of the highly refractive nature of the MgF_2 matrix, acid leaching may not be sufficient or practical to meet increasingly stringent limits for disposal in a sanitary landfill.

Several specific responses to the Request for Recommendations dealt with the treatment of the MgF_2 by-product, including those from Advanced Recovery Systems, Cameco, Fluor Daniel, GenCorp Aerojet, and Nuclear Metals, Inc. In addition to alternative technologies for improved decontamination, these recommendations integrally addressed the recovery and beneficial use of the by-product constituents (e.g., the conversion of the MgF_2 to AHF). These advanced MgF_2 treatment technologies offer key waste minimization and economic benefits.

One example of an integrated technology for further improvements in by-product treatment is the U-metal/$MgSO_4$ process proposed by Cameco. Following the standard process for reduction to UF_4 using hydrogen in the first stage and magnesium to produce uranium metal in the second stage, the MgF_2 is reacted with concentrated sulfuric acid to produce magnesium sulfate and AHF. The reaction for this step is similar to that used in the aqueous process discussed in Section 4.2.1.2 and is as follows:

$$MgF_2 + H_2SO_4 \bullet XH_2O \rightarrow MgSO_4 + XH_2O + 2HF$$

This step effectively breaks the refractive MgF_2 matrix and simultaneously releases the fluorine as AHF for industrial use. After dissolution, the uranium would be precipitated from solution, separated, and calcined to a solid oxide. The uranium oxide could then be hydrofluorinated with AHF to UF_4 for recycle to the metallothermic reduction process. The decontaminated $MgSO_4$ solution would be evaporated, and the crystallized magnesium sulfate hydrate could potentially be sold to the fertilizer industry, depending on the uranium contamination level.

Other recommended technologies would employ a different initial step to break the MgF_2 matrix and produce a different final decontaminated product. GenCorp Aerojet would utilize batch metallothermic reduction of the depleted UF_6, followed by a decontamination system utilizing dry mill, chemical, and other unspecified technologies to remove the uranium from the MgF_2. Advanced Recovery Systems offered two potential technologies: a patented hydrometallurgical process and a thermal recovery process. The hydrometallurgical process, called DeCaF™, was developed to meet the needs of a nuclear fuel fabricator to decontaminate CaF_2 sediments. Scoping tests have been performed using the DeCaF™ process on uranium-contaminated MgF_2 samples with favorable results. In the thermal recovery process, the MgF_2 would be pretreated thermally to recover fluoride values, and this pretreatment would be followed by a hydrometallurgical process for uranium extraction and magnesium recovery. Laboratory scoping tests have been conducted. The technologies proposed by Fluor Daniels and Nuclear Metals are proprietary.

In summary, these advanced MgF_2 treatment technologies offer key waste minimization and economic benefits that may be essential for converting to uranium metal at an acceptable cost. The technologies are at an early stage of development, and process conditions and performance parameters cannot yet be reliably predicted.

4.3 Use Module (Applications)

Three use options were not analyzed in depth: (1) light water reactor fuel cycle, (2) advanced reactor fuel cycles, and (3) dense material applications. The reason for not analyzing the fuel cycle options in depth is the anticipated length of time (particularly for advanced reactors) they would require to use significant quantities of the depleted UF_6 stockpile. The possibility of pursuing these uses in the future is preserved through the analysis of the storage options being considered. The dense material applications are suitably embraced by the metal shielding suboption.

4.3.1 Light Water Reactor Fuel Cycle

Re-enrichment is the primary suboption of interest in the light water reactor fuel cycle option. The technologies for enriching natural uranium, either existing or under development, apply directly to enriching depleted uranium. The environmental impacts on a unit feed basis are essentially the same whether the uranium being enriched is natural or depleted. The viability of the re-enrichment of depleted uranium is a function of the isotopic assay of the feedstock and many uncertain factors such as the price of uranium ore, the cost of separative work, and market demand versus installed enrichment capacity.

Mixed oxide fuel applications is the other suboption in this category. In the *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement*, converting the surplus plutonium to mixed oxide fuel for use in light water and CANDU heavy water reactors is part of the preferred alternative for plutonium (Pu) disposition. Because the United States does not have a mixed oxide fuel fabrication capability, a dedicated facility would have to be constructed. The mixed oxide fuel fabrication facility would accept surplus plutonium and fabricate mixed PuO_2-UO_2 fuel by blending the PuO_2 with UO_2 containing either natural or depleted uranium.[25] This application would potentially consume a small quantity of depleted uranium.

If fully recovered, the U-235 in the depleted uranium stockpile could provide enriched nuclear fuel for the equivalent of about 1000 reactor years of operation. Re-enrichment of depleted uranium would conserve natural uranium (0.71 percent U-235) resources and reduce the environmental impacts associated with its mining and milling. Only a minor fraction of the depleted uranium is converted into the enriched product stream; therefore, the bulk of the depleted uranium (>90 percent) must subsequently be dispositioned. The two plausible technologies for the re-enrichment of depleted uranium are (1) gas centrifuge and (2) atomic vapor laser isotope separation. These were recommended by respondents to the Request for Recommendations, including Idaho National Engineering Laboratory, the Ohio Valley Regional Development Commission, and GenCorp Aerojet. Re-enrichment using gaseous diffusion technology is not generally considered to be financially attractive due to its high operating cost (it is electrical power intensive).

Uranium enrichment using gas centrifuges is a well-established industrial technology which is used in a number of other countries. Centrifuge processes have comparatively low electrical power consumption, and the operating costs are lower than those for facilities using gaseous diffusion. Urenco, a partnership established by the governments of Great Britain, Germany, and The Netherlands, operates gas centrifuge enrichment facilities at Almelo, The Netherlands; Juelich, Germany; and Capenhurst, U.K. At present, there is no domestic capacity for centrifuge enrichment. Louisiana Energy Services has proposed to build a gas centrifuge enrichment plant

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[25] U.S. Department of Energy. *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement.* DOE/EIS-0229. December 1996.

(1.5 million separative work units [SWU]/yr) in Homer, Louisiana. The Nuclear Regulatory Commission issued a final EIS for construction and operation of this facility in 1994.[26]

Atomic vapor laser isotope separation (AVLIS) is in the final stages of engineering and has been successfully tested at significant scale. At present, there are no uranium enrichment facilities utilizing this new technology, but the United States Enrichment Corporation is taking steps to commercially deploy AVLIS. Uranium metal (rather than UF_6, as used in gas centrifuge and diffusion processes) is the process feed for AVLIS. Accordingly, the depleted UF_6 would first require conversion to uranium metal.

As of July 1, 1993, the U-235 isotopic assay distribution for the total depleted uranium inventory residing in the three cylinder yards (Paducah, Portsmouth, and K-25) was as follows:[27]

Isotopic assay range (percent U-235)	Percent of inventory (6/30/92)
< 0.21	33
0.21 - 0.24	1
0.24 - 0.26	28
0.26 - 0.28	1
0.28 - 0.31	10
0.31 - 0.50	26
0.50 - < 0.71	1

Based on other isotopic data, essentially all the depleted uranium in the 0.31-0.50 percent range lies between 0.31 and 0.40 percent U-235. As of July 1, 1993 (the date when USEC began operating the gaseous diffusion plants), it was estimated that roughly 30 percent of the total inventory (0.38 million MT uranium) was in the 0.30-0.40 percent assay range.

In order for substitution of depleted uranium for natural uranium (0.71 percent U-235) to be attractive economically, the separative work cost for enriching depleted uranium to a natural uranium assay must be less than the cost for natural UF_6. The enrichment cost is the product of the number of separative work units (SWUs) to enrich the depleted uranium to a natural uranium assay and the cost ($/SWU) of separative work. The number of SWUs depends on the U-235 assay of the depleted uranium and an assumed U-235 stripping fraction (i.e., the fraction of

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[26]Nuclear Regulatory Commission. *Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center, Homer, Louisiana.* NUREG-1484. August 1994.

[27]Derived from Hertzler, T.J., and D.D. Nishimoto. *Depleted Uranium Management Alternatives.* EGG-MS-11416. August 1994.

U-235 removed), while the separative work cost is a function of the enrichment technology. Based on the estimated current cost for natural UF_6, the break-even separative work costs ($/SWU) against depleted U-235 assays (percent) are: $15 (0.2 percent), $24 (0.25 percent), $36 (0.30 percent), $54 (0.35 percent), and $83 (0.40 percent). These values are based on the arbitrary assumption that about two-thirds of the U-235 in the depleted uranium is stripped. A lower assumed stripping fraction would allow a higher separative work cost for break-even, but the amount of natural uranium assay production would be reduced proportionally. Likewise, a higher natural UF_6 cost in the future would allow a higher separative work cost for break-even and effectively enable access of lower assay depleted uranium.

For the industrial gas centrifuge process, the estimated operating cost is in the $20-$30/SWU range, which is a factor of about 2- to 3-fold lower than for gaseous diffusion. For the AVLIS process, the projected operating cost is judged to be in the same range as gas centrifugation. Therefore, for either technology, the current or projected operating costs from a break-even standpoint cover a significant portion of the depleted uranium stockpile assay distribution, i.e., the depleted uranium in the 0.30-0.40 percent assay range accounts for about 50 percent of the U-235 in the entire inventory. Accordingly, an enrichment plant with a low operating cost could use excess capacity for re-enrichment of significant quantities of depleted uranium to optimize total revenues. As indicated, there is presently no domestic capacity for either centrifuge or AVLIS enrichment. It would appear that limited inventories of depleted uranium (> 0.35 percent U-235) could be sensibly enriched using the domestic gaseous diffusion capacity.

It is useful to consider the rate of work-off (re-enrichment) for the depleted uranium inventory in the 0.30-0.40 percent assay range. The rate is proportional to the available or excess separative work capacity and to the isotopic assay of the depleted uranium. For illustrative purposes, we assume an excess separative work capacity of 1×10^6 SWU/yr (MSWU/yr). Over a 20-year period, about 90,000 MT uranium would be fed. Re-enrichment of the 90,000 MT depleted uranium would replace approximately 30,000 MT natural uranium. Though necessarily simplified, this illustration demonstrates the potential to use significant quantities of depleted uranium. However, most of the UF_6, further depleted in U-235, would remain.

In the absence of excess enrichment capacity, displacement of natural uranium with depleted uranium requires, in addition, an economic assessment of net total revenues. A given installed enrichment capacity (total SWUs annually) will give more transaction SWUs, and therefore revenues, operating on natural rather than depleted feed. A revenue analysis, including consideration of waste avoidance credits, is beyond the scope of this evaluation. Clearly, with further increases in the price for uranium ore (itself a function of the nuclear power economy), replacement of a portion of natural uranium feed with depleted uranium will become increasingly attractive.

The AVLIS technology is projected to have a substantially lower capital cost than the gas centrifuge technology. Accordingly, in the longer term when ore prices may be much higher, deployment of additional capacity dedicated to depleted uranium enrichment could be financially viable.

Due to the many uncertainties and the absence of a detailed financial analysis, one cannot precisely specify the quantities of depleted uranium or the corresponding time frames for its re-enrichment. Continued storage of the depleted uranium, and particularly material at greater than 0.30 percent U-235, preserves the option to refeed the material at some future time.

4.3.2 Advanced Reactor Fuel Cycles

One of DOE's original reasons for considering the depleted uranium a national asset was its potential future use in advanced reactor fuel cycles, most notably in a future generation of fast breeder reactors. The depleted uranium inventory represents hundreds of years of electrical power at the present U.S. generation rate. This application was recommended by members of the public and academia and by the American Nuclear Society.

The technology for fast neutron spectrum reactors is well established in general. Depending on the specific reactor, the fertile fuel would be either an oxide (fast breeder reactor) or metal (integral fast reactor). Implementation of an advanced reactor fuel cycle would require a change in national policy, which includes closing the nuclear fuel cycle. The United States currently uses a once-through fuel cycle derived from natural uranium. All fast breeder reactors (and most light water reactors outside the United States) utilize enriched uranium and/or plutonium from recycling and reprocessing spent nuclear fuel. As a result of the reactors' overall fuel efficiency, the uranium consumption rate would be very small.

Breeder reactors utilize two types of fuel: a mixed oxide driver fuel consisting of UO_2 and plutonium dioxide (PuO_2) and a blanket fuel consisting of depleted uranium. If depleted uranium were to be used in the driver fuel for fast breeder reactors, it would involve conversion to UO_2 followed by blending with uranium and plutonium oxides from reprocessed spent nuclear fuel. However, there are no breeder reactors or facilities for producing mixed oxide fuels in the United States today. Mixed oxide fuels employing natural and reprocessed uranium are used in light water reactors in Europe. In addition, prototype breeder reactors have been constructed and operated outside the United States.

Another possible advanced reactor fuel cycle option is the use of depleted uranium metal as the "make-up" uranium fuel for the integral fast reactor. This reactor also utilizes reprocessed spent nuclear fuel, and depleted uranium would be in competition with natural uranium as the make-up fuel source. This advanced reactor concept has been developed by DOE but not deployed.

Continued storage of the depleted uranium preserves the option for use in these advanced reactor fuel cycle options.

4.3.3 Dense Material Applications

This category includes the existing uses of depleted uranium (uranium metal), such as armor-piercing munitions (penetrators), vehicle armor, and industrial ballasts. Dense material applications were recommended by Idaho National Engineering Laboratory, GenCorp Aerojet, the U.S. Department of the Army, Nuclear Metals, Inc., and others (proprietary). The current demand for depleted uranium for these applications (unclassified) is roughly estimated at about 2000-3000 MT annually. Expansion in defense program requirements is uncertain.

Potential new commercial applications identified in response to the Request for Recommendations are energy storage flywheels and drill collars, well penetrators, and shape charge perforators for the petroleum industry. The future material requirements for dense material applications are uncertain. Certain proposed commercial applications could potentially use moderate quantities of depleted uranium metal as a replacement for other materials. In general, these applications would depend on a substantially lower production cost for uranium metal, regulatory changes, and changes in public perception of uranium risks.

The environmental impacts of new fabrication facilities (to accommodate expansion of existing uses or major new uses) are represented by the facility for the manufacture of uranium metal radiation shielding. The manufacturing processes would be very similar at this stage, regardless of the exact nature of the product.

4.4 Storage Module

Options for storage of depleted uranium for subsequent use or disposal are considered in Section 3.4. Storage of depleted UF_6 in buildings and a mined cavity and storage of the oxides U_3O_8 and UO_2 in buildings, vaults, and a mined cavity are analyzed in depth. The chemical forms being analyzed for storage provide planning flexibility and allow a spectrum of environmental and cost tradeoffs to be considered. Storage as elemental uranium metal and storage as uranium tetrafluoride (UF_4) were considered but not analyzed in depth. Storage as metal was recommended by GenCorp Aerojet in response to the RFR.

Storage of depleted uranium implies that there is a significant chance that it will be used at a later date. Since a use may not materialize for all or a portion of the material, consideration must be given to the form of the material with respect to its subsequent disposal. The uranium chemical form for storage depends upon a number of factors, including which of the use options is considered most likely; storage space requirements; cost; potential environmental effects; and suitability of the chemical form for eventual disposal.

Storage in the form of UF_6 provides maximum conversion flexibility for future uses. This is a key consideration, since it is difficult to predict which of the possible use options would be most likely in the longer term. Although there is no identified use for U_3O_8, storage in this chemical form is an alternative to UF_6 storage, until a determination is made that all or a portion of the depleted uranium is no longer needed. Ceramic UO_2 has a potential use in radiation shielding applications and, like U_3O_8, is considered a viable disposal form. Uranium metal also has a potential use in radiation shielding and other dense material applications.

UF_4, or green salt, is an intermediate form in the process of converting UF_6 to the metal form or converting uranium oxide to UF_6. Although green salt is more stable than UF_6, it has no identified direct use, offers no obvious advantage in required storage space, and is less stable than oxide forms. Conversion of UF_6 into uranium-bearing minerals such as soddyite and urantile for subsequent storage or disposal were not considered. These forms are highly uncertain from the standpoint of technology. Development of the chemical conversion processes, as well as an examination of the suitability of such forms for storage or disposal, would be required.

Another consideration in evaluating a chemical form for storage is the required storage space, which is a function of the bulk density. Bulk density varies with the chemical and physical form of the product and the conversion process used. Representative bulk densities for the depleted uranium forms considered are as follows:

- UF_6: 4.6 grams/cc
- UF_4: 2.0-4.5 grams/cc
- Sintered UO_2 microspheres: 9.0 grams/cc
- Sintered UO_2 pellets: 5.9 grams/cc,
- Compacted U_3O_8 powder: 3.0 grams/cc
- U metal: 19.0 grams/cc

Due to its high density, the metal would require significantly less storage space than the other forms under consideration. However, this advantage must be weighed against disadvantages such as higher conversion cost, lower chemical stability than the oxides, and uncertainty about the suitability of the metal form for eventual disposal. Among those storage forms analyzed in depth, then, the sintered oxide would require the least storage or disposal space.

Environmental and cost considerations also play a role in assessing storage options. UF_6 is highly reactive. In the presence of water, UF_6 forms uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF). Both are toxic, and the HF is a corrosive acid. In general, the chemical form of uranium makes relatively little difference as long as there is a continuing maintenance program that prevents water intrusion into storage areas and ensures the integrity of the storage containers. As has been demonstrated for 50 years, UF_6 can be safely stored as a solid.

The cost of a storage facility will be proportional to its size and, consequently, is a function of chemical form. The overall cost for a storage alternative also includes the costs for conversion, transportation, and any required repackaging. Storage as UF_6 would incur no conversion cost, but may require a costly transfer of UF_6 from existing to new cylinders to maintain cylinder integrity. Storage as the sintered dioxide would have a significantly higher associated conversion cost than that for U_3O_8, but the storage volume would be significantly less.

Long-term storage or disposal of depleted uranium in the metal form was not analyzed in depth. As indicated, one cannot reliably predict which of the use options would be most likely in the future, and it is possible that no projected beneficial use would materialize. Accordingly, if the depleted UF_6 is converted to another chemical form for storage, it is desirable that this form be acceptable for disposal, in order to avoid an additional and costly chemical conversion.

As indicated earlier, the metal, if stored as large ingots, would have at least a two-fold advantage in space requirements, as compared to oxides and UF_6. On the other hand, the conversion cost for the metal is projected to be significantly greater than conversion to U_3O_8. In addition, unless it is protected from the environment, bulk uranium metal slowly oxidizes. Metal fines or chips ignite spontaneously with a rapid energy release. Hydrogen is generated in the reaction between moisture and uranium metal, and care must be taken to avoid its accumulation in closed storage containers. These safety issues would necessitate specialized packaging and enhanced facility maintenance.

Like U metal, depleted uranium in the form of UF_4 was not analyzed in depth for long-term storage or disposal. Production of UF_4 involves a relatively simple and inexpensive conversion process, and it is less chemically reactive than UF_6. However, UF_4 has no direct use and it is more reactive than the oxide forms. In addition, its actual packing density (and hence its storage or disposal volume) is anticipated to be comparable to that of U_3O_8, and UF_4 is neither an optimal nor a generally recommended waste form (see discussion in Section 4.5). Although the conversions of UF_6 to UF_4 and to U_3O_8 are well-established industrial processes, the conversion of UF_4 to U_3O_8 is not an industrial process. Conversion to UF_4 would be considered an intermediate step toward conversion to metal, rendering later conversion to oxide forms unlikely.

In conclusion, storage in the form of UF_6 provides maximum conversion flexibility for future uses. Alternatively, conversion to an oxide provides an inert form suitable for long-term storage and disposal. In addition, sintered UO_2 has the potential for future use in radiation shielding applications. Storage and disposition of depleted UF_6 resulting from enrichment operations have also been considered by others. The French (Cogema) have been converting depleted UF_6 to U_3O_8 and storing it for more than a decade. In the *Final Environmental Impact Statement for the Construction and Operation of Claiborne Enrichment Center*, the Nuclear Regulatory

Commission limited the amount of depleted UF_6 that could be stored on site.[28] Conversion to U_3O_8 and deep geologic disposal were assumed for final disposition. Finally, the National Research Council concluded in a recent report that depleted UF_6 is not a suitable form for long-term storage of depleted uranium. Conversion to U_3O_8 for final storage was recommended unless significant new uses are identified soon.[29] The storage forms selected for in-depth analysis—UF_6 and oxide—provide planning flexibility and allow a spectrum of cost and environmental tradeoffs to be considered which are consistent with the current storage situation and other precedents.

4.5 Disposal Module

Options for disposal of depleted uranium which were analyzed in depth include disposal of the oxides U_3O_8 and UO_2 in engineered trenches, vaults, and a mined cavity. Both grouted and ungrouted (bulk) waste forms are considered for each disposal scenario. These are described in Section 3.5. Disposal as UF_6, elemental uranium metal (recommended by GenCorp Aerojet), and UF_4 were considered but not analyzed in depth. Section 4.4 includes a discussion of issues related to chemical forms for storage and some of the considerations related to subsequent disposal.

As stated in the report, *Depleted Uranium Disposal Options Evaluation,*[30] the following factors are important in determining the preferred chemical form for disposal of depleted uranium:

- Potential for release (i.e., solubility and dispersibility)
- Environmental behavior (i.e., reactivity, solubility, and binding characteristics with soil)
- Relative toxicity in drinking water

Uranium hexafluoride is soluble in water and the most reactive of the chemical forms discussed. Uranium tetrafluoride is also soluble in water and reactive, but to a lesser degree. The oxides and metal are insoluble and stable and have higher water concentration limits for radiotoxicity than the fluoride forms. In the final EIS for the Claiborne Enrichment Center, it was noted that the reaction of UF_4 with water would produce quantities of HF which could compromise the integrity

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[28] Nuclear Regulatory Commission 1994.

[29] National Research Council. *Affordable Cleanup Opportunities for Cost Reduction in the Decontamination and Decommissioning of the Nation's Uranium Enrichment Facilities.* Washington, D.C., 1996 (pp. 177-178).

[30] Hertzler, T.J., D.D. Nishimoto, and M.D. Otis. *Depleted Uranium Disposal Options Evaluation.* EGG-MS-11297. Idaho National Engineering Laboratory. May 1994.

of a disposal facility and significantly disturb the environment.[31] Many waste disposal facilities use concrete lining material, and the HF can be expected to attack the concrete, degrading the impermeability and structural stability it is intended to provide.[32]

Regulatory criteria restrict the chemical form for disposal. Reactive waste forms such as the fluorides and metal are specifically excluded by the Nevada Test Site and Hanford waste acceptance criteria and DOE Orders. Relaxation of current waste acceptance criteria would likely be needed for disposal of fluorides or metal to occur. In limited cases, bulk depleted uranium metal has been accepted for disposal, but large scale disposal is considered speculative at this time. The oxide forms are considered more favorable for long-term disposal, and the analysis focused on U_3O_8. Uranium appears in nature as U_3O_8, and this is the generally recommended form for disposal due to its inertness and low solubility.

Bulk and grouted waste forms were considered in detail. Another waste form preparation option is vitrification. Although the basic technology is sufficiently mature (for high-level waste disposal) for this option to be feasible, it is not considered to be as desirable as the other options for several reasons. Encapsulation, either by grouting or vitrification, increases the disposal volume. Depleted uranium loading in the waste form is partly dependent on waste form stability and partly dependent on the waste acceptance criteria at the disposal facility. It is likely that vitrified waste forms would have lower uranium loading than grouted waste forms and would therefore have greater volume requirements. Engineering development is needed to determine the optimum loading levels. In addition, a vitrification facility would be more costly to build and operate than a grouting facility, due to the types of equipment and higher temperatures involved. Higher emissions and more severe accidents would also be more likely with a vitrification facility.

It is noted that Sellafield, the largest of five UK sites operated by British Nuclear Fuels, includes radioactive waste management facilities for high-level, intermediate-level, and low-level wastes. High-level waste is vitrified; intermediate-level waste is grouted; and low-level waste is compacted and grouted. Bulk or grouted disposal of low-level waste is common practice.

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[31]Nuclear Regulatory Commission 1994 (Appendix A).

[32]Kozak, Matthew, W. T.A. Feeney, C.D. Leigh, and H.W. Stockman. *Performance Assessment of the Proposed Disposal of Depleted Uranium as a Class A Low-Level Waste.* FIN A1764. Sandia National Laboratory. December 1992.

5.0 Roadmap for Integration of Engineering Data Input Reports into Long-Term Management Strategy Alternatives

As stated in Section 2.2, a work breakdown structure (WBS) was prepared to provide a disciplined basis for analyzing and comparing depleted UF_6 management strategy alternatives. Each alternative is in the form of a management strategy. A strategy is a set of activities or steps for managing the depleted UF_6 from the current storage site through use, long-term storage, or disposal. Options and suboptions from the transportation, conversion, use, storage, and/or disposal modules may be involved in a given management strategy alternative.

Figure 5 is the top-level flowchart for developing management strategy alternatives. Depleted UF_6 stored in cylinders in the yards at Paducah, Portsmouth, and Oak Ridge (K-25 Site) (the current management strategy) is shown, beginning at the left side of the figure. Moving from left to right are the transportation, conversion, use, storage, and disposal modules (WBS Level II). The options and suboptions which were analyzed in depth are shown as blocks below these module headings and are interconnected as necessary to allow development of alternatives. Offsite transportation may be required between one module and another, as indicated on the figure. Although they are not shown on this top-level figure, other activities such as construction of conversion, manufacturing, storage, or disposal facilities; transportation of input materials (e.g., reagents) and by-products; and transportation and disposal of wastes are included in the overall management strategy alternatives.

The management strategy alternatives in the PEIS include the current management strategy (no action), two storage alternatives, two use alternatives, and one disposal alternative. The two storage alternatives are long-term storage as UF_6 and long-term storage in an oxide form (U_3O_8 or UO_2). UF_6 could be stored in two of the three storage facility options: buildings and deep underground retrievable storage (such as a mine). The storage options are addressed in general in Section 3.4 and in detail in Section 6.12. Storage as an oxide would include transport of the depleted UF_6 to a conversion facility, conversion to U_3O_8 or UO_2, and transport of the oxide to a storage facility (either a building, a below ground cement vault, or a mined cavity). Storage of oxides was bounded by considering the sintered UO_2 microspheres produced by the gelation process (see Section 6.8) as the lower bound and the U_3O_8 powder produced by either defluorination process (see Sections 6.4 and 6.5) as the upper bound. The bulk densities of these forms give the maximum range of storage volume requirements. Onsite movement as well as offsite transportation would likely be required to implement either of these alternatives. Initial offsite transportation of the depleted UF_6 would be preceded by shipping preparation activities (see Sections 6.1 and 6.2). Emptied cylinders would be sent to the cylinder treatment facility (see Section 6.3).

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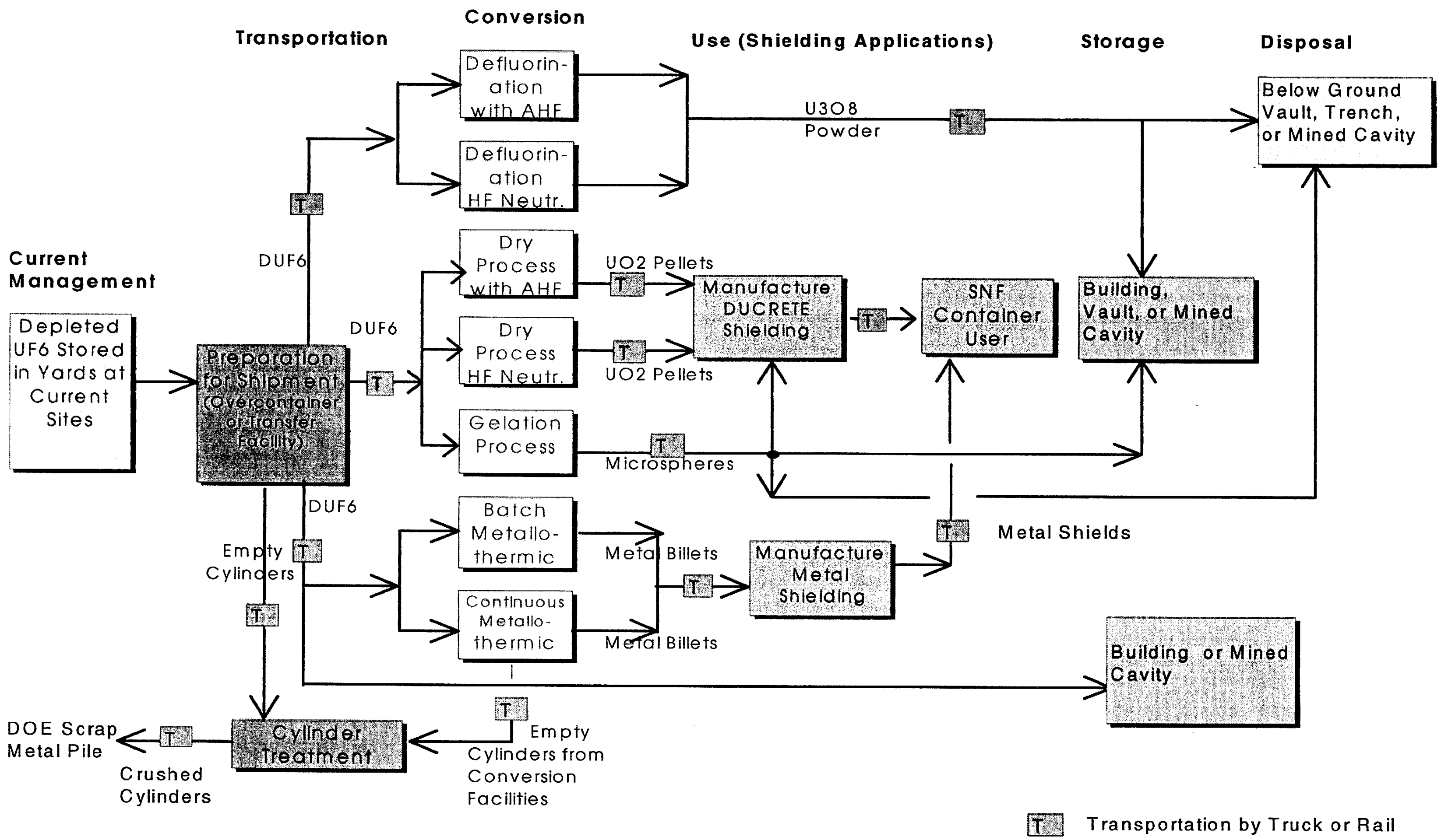
Figure 5 - Top-Level Flowchart for Developing Management Strategy Alternatives



Both of the alternatives for using the depleted uranium involve the manufacture of radiation shielding, either from dense oxide or from metal (see Section 6.11). The basic steps in either use alternative are (1) transport of the depleted UF_6 to a conversion facility, (2) conversion of the depleted UF_6 to another chemical form (either UO_2 or metal), (3) transport of the oxide or metal to a manufacturing facility, (4) fabrication of the radiation shielding, and (5) transportation of the shields to a spent nuclear fuel container user. The dense oxide could be produced in any of the three types of UO_2 conversion facility—the two dry process facilities (see Sections 6.6 and 6.7) or the gelation process facility (see Section 6.8). The metal could be produced using either the batch (see Section 6.9) or the continuous (see Section 6.10) metallothermic reduction process. Initial offsite transportation of the depleted UF_6 would be preceded by shipping preparation activities (see Sections 6.1 and 6.2). Emptied cylinders would be sent to the cylinder treatment facility (see Section 6.3).

The disposal alternative involves three potential disposal facility options: engineered trench, below ground vault, and below ground mined cavity. Each disposal method is being evaluated for four different waste forms (two bulk and two grouted). Bulk disposal would consist of placing the oxide directly in drums, while grouted disposal would involve fixing the oxide in a cementitious medium. The base case waste form is cemented (grouted) U_3O_8, and the alternatives being evaluated are bulk (not grouted) U_3O_8, grouted UO_2, and bulk UO_2. All these suboptions are described in Section 6.13. The steps in the disposal alternative are (1) transport of the depleted UF_6 to a conversion facility, (2) conversion of the depleted UF_6 to an oxide (either UO_2 or U_3O_8), (3) transport of the oxide to a disposal facility, (4) waste form preparation and packaging, and (5) disposal. As was the case for storage, disposal of oxides was bounded by considering the sintered UO_2 microspheres produced by the gelation process (see Section 6.8) as the lower bound and the U_3O_8 powder produced by either defluorination process (see Sections 6.4 and 6.5) as the upper bound.

Section 6.1

Preparation of Depleted UF_6 Cylinders for Shipment

Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

Section 6.1
Preparation of Depleted UF_6 Cylinders for Shipment
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Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

TABLES

FIGURES

ACRONYMS

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BIO	Basis of Interim Operation
CFR	Code of Federal Regulations
Ci	Curie
CX	Categorical Exclusion
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	Depleted Uranium Hexafluoride
EIS	Environmental Impact Statement
HF	Hydrogen Fluoride
IAEA	International Atomic Energy Agency
ICAO	International Civil Aeronautics Organization
K-25	K-25 Site in Oak Ridge
LLNL	Lawrence Livermore National Laboratory
LLW	Low Level Waste
LSA	Low Specific Activity
NEPA	National Environmental Policy Act
NQA	Quality Assurance Program for Nuclear Facilities
NRC	Nuclear Regulatory Commission
OR	Oak Ridge Office of DOE
PGDP	Paducah Gaseous Diffusion Plant
PORTS	Portsmouth Gaseous Diffusion Plant
PPE	Personal Protective Equipment
PSIA	Pounds per Square Inch - Absolute
QA	Quality Assurance
USAEC	United States Atomic Energy Commission
USEC	United States Enrichment Corporation
WBS	Work Breakdown Structure

1.0 INTRODUCTION AND BACKGROUND

This portion of the Engineering Analysis addresses all activities necessary to prepare the cylinders currently located at Oak Ridge, Paducah and Portsmouth for shipment to another location, either for continued storage or conversion to another chemical form. A review of these activities also considers those actions which may be implemented so that the cylinder can be emptied at the receiving facility. Table 1-1 shows the Department of Energy (DOE) inventory of depleted uranium hexafluoride (UF_6) in both cylinder quantities and metric tonnes of UF_6. Figures 1-1 through 1-3 show the site layouts and the cylinder yard locations for the three facilities.

Many of the depleted UF_6 cylinders are not expected to meet the Department of Transportation regulatory requirements for off-site shipment. These cylinders are either overpressured, overfilled, or are in substandard condition. The technology option analyzed in this report is the use of an overcontainer for shipments of all non-conforming cylinders. This appears to be an optimal solution for the following reasons:

- Handling and environmental impacts are minimized;
- Construction and operation of facilities to transfer material to new cylinders is avoided;
- Waste is minimized; and
- Operational risk is reduced to that associated with current cylinder handling operations.

Table 1-1
DOE Depleted UF_6 Cylinder Inventory

Cylinder Size	Cylinder Model No.	Portsmouth	Paducah	K-25	Total
2.5-ton	30A, 30B	15	1,782	25	1,822
10-ton thin (5/16")	48T	2,097	565	1,428	4,090
14-ton thin (5/16")	48G, 48H, 48HX	11,242	25,864	3,207	40,313
10-ton thick (5/8")	48A, 48X	9	23	2	34
14-ton thick (5/8")	48F, 48Y	56	61	1	118
Miscellaneous	5A, 5B, 8A, 12A, 12B	42	314	45	401
Total (includes heels cylinders)		13,461	28,609	4,708	46,778
Full Cylinders		13,388	28,351	4,683	46,422
Metric Tons of UF_6		162,769	338,583	54,067	555,419

Figure 1-1
K-25 Site UF_6 Cylinder Yard Locations

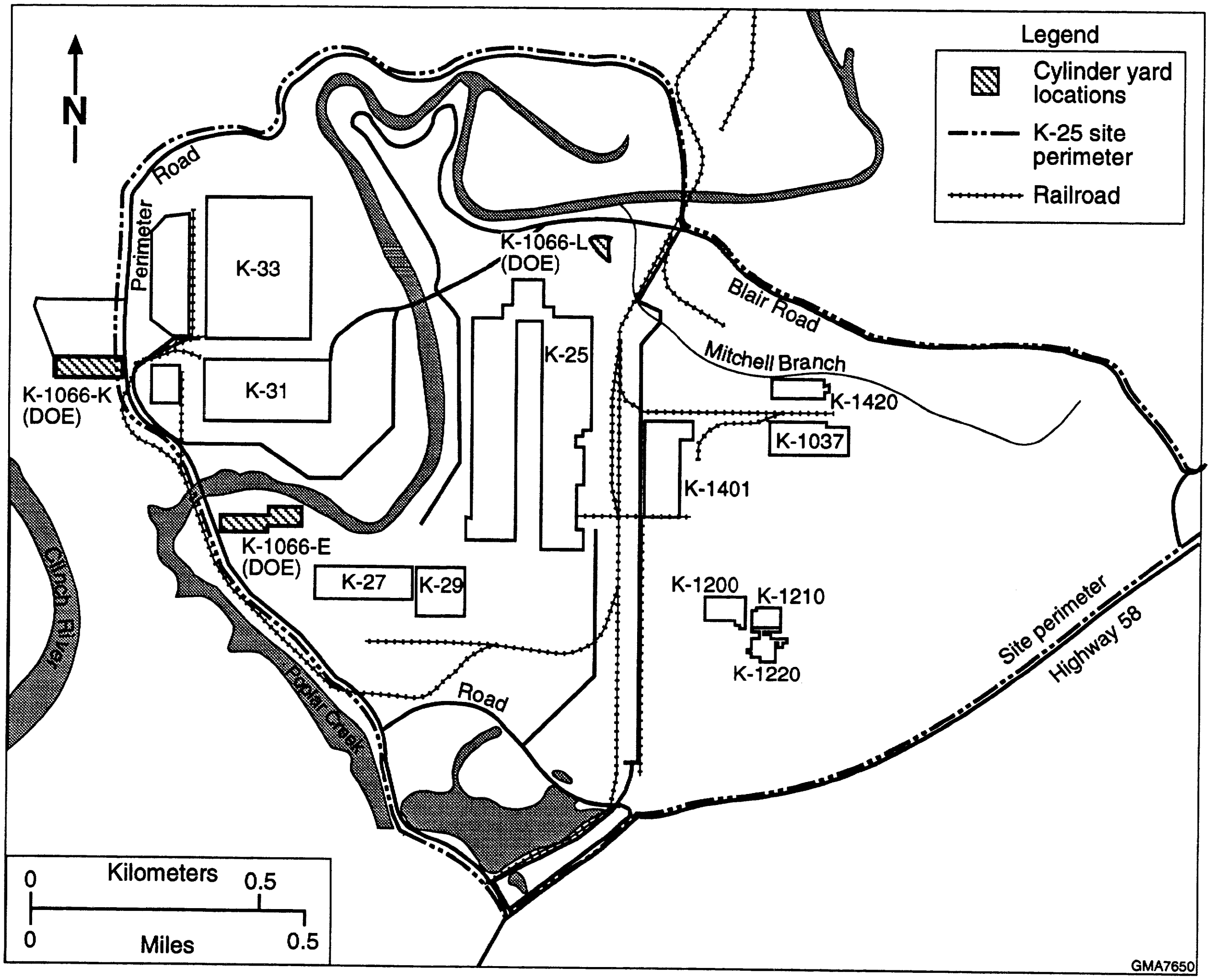


Figure 1-2
Paducah Site UF_6 Cylinder Yard Locations

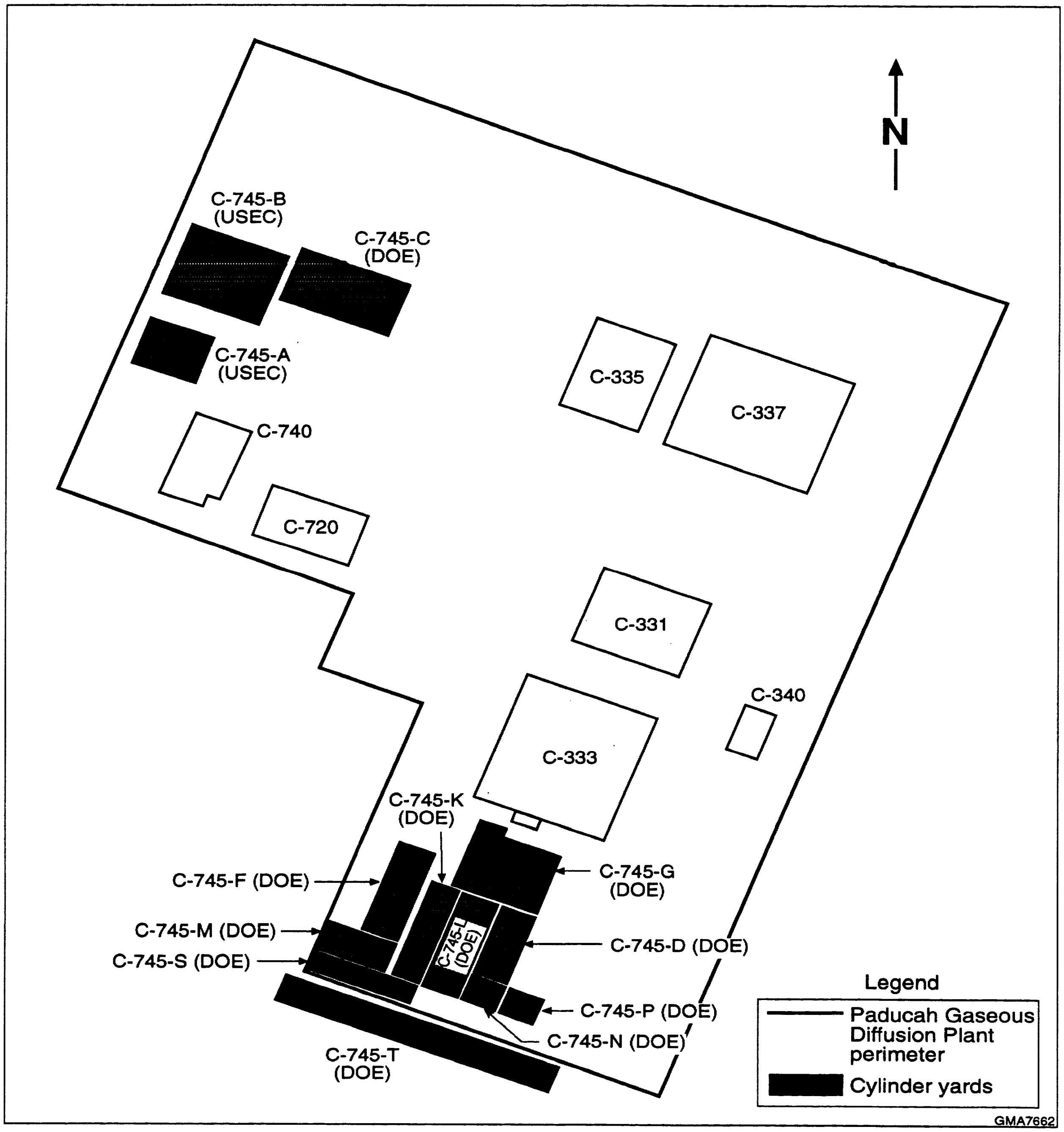
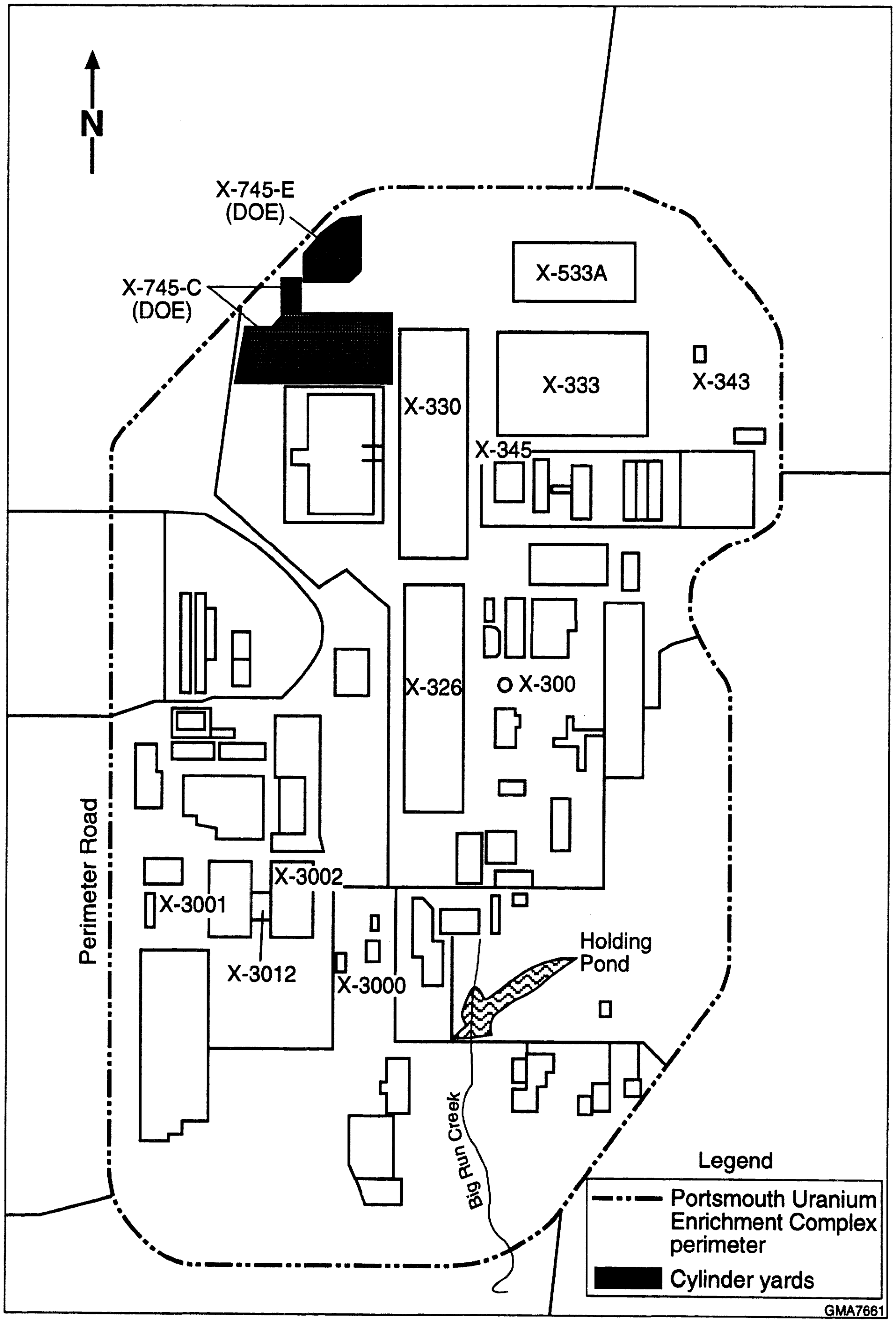


Figure 1-3
Portsmouth Site UF_6 Cylinder Yard Locations



2.0 SCOPE

This analysis identifies the activities required to prepare and load all DOE-owned depleted UF_6 cylinders at the three sites onto a conveyance for shipment to an off-site facility, in compliance with applicable Department of Transportation (DOT) and Nuclear Regulatory Commission (NRC) packaging and shipping regulations. Activities are expected to consist of cylinder retrieval from storage, on-site cylinder movement, inspections and tests, any required packaging or overpacking, and loading onto the conveyance. The scope includes any needed capital improvements (facilities and equipment) at the three sites as well as obtaining any licenses, certifications, or exemptions judged to be required to accomplish the work. Alternative modes of transportation are considered (e.g., truck and rail).

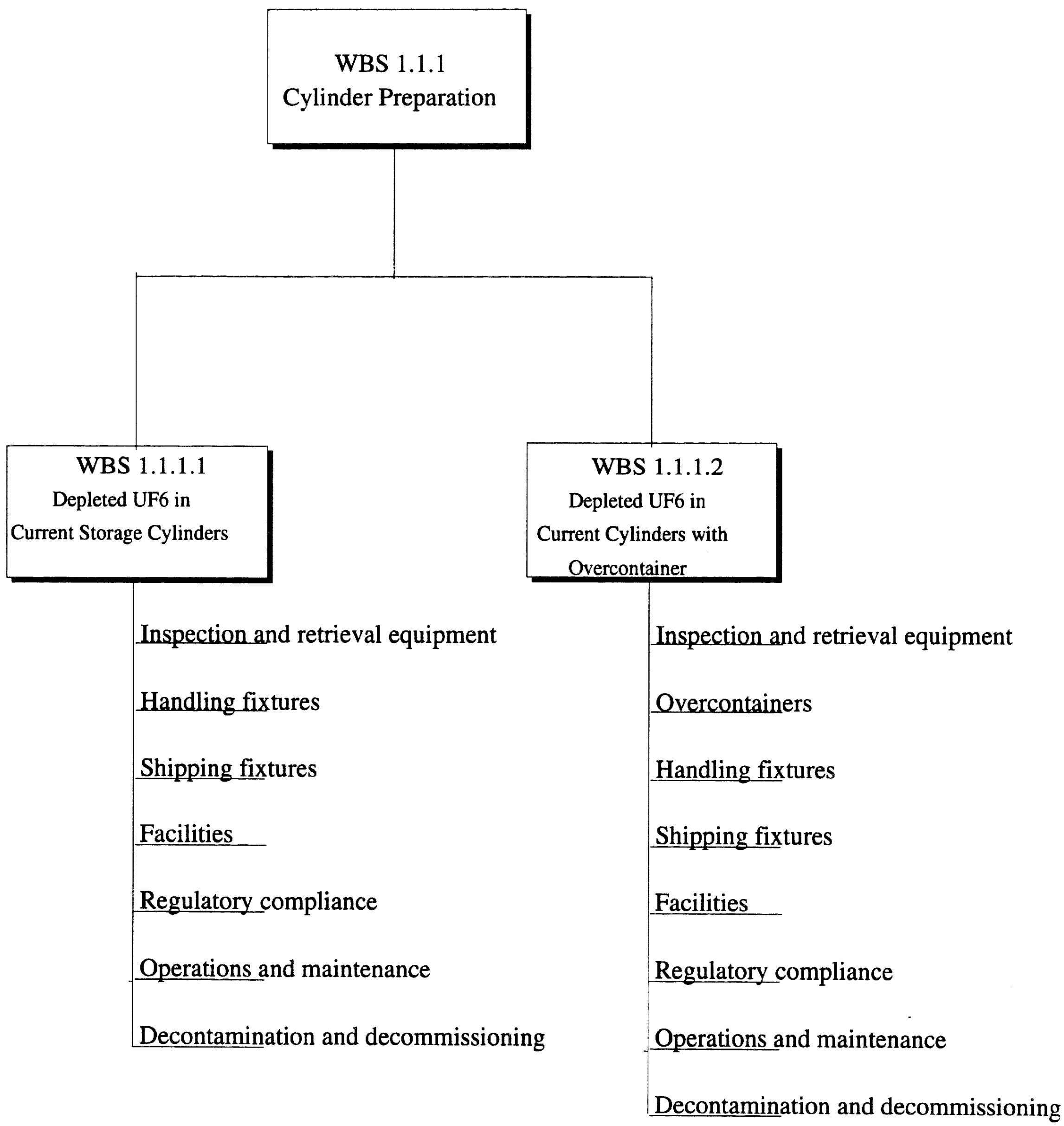
Baseline Assumptions

- Cylinder shipments will begin 11 years after the Record of Decision identifying a long-term management strategy for depleted UF_6, and continue on a steady basis for 20 years.
- The Paducah and Portsmouth gaseous diffusion plant cascades will no longer be in operation during the cylinder shipments. Thus, use of existing facilities is not considered.

Work Breakdown Structures (WBS)

Figure 2-1 shows the elements of the depleted UF_6 Management Program WBS applicable to cylinder preparation using the overcontainer. The complete WBS is included in Section 2.2 of this Engineering Analysis Report.

Figure 2-1
Depleted UF_6 Cylinder Shipment Preparation WBS



3.0 REGULATORY REQUIREMENTS

3.1 Introduction

Uranium hexafluoride is shipped between DOE facilities and to and from commercial users such as utilities, fuel fabricators, and research reactors. Essentially all of these shipments are by rail or truck using specially designed rail cars or flatbed trailers. DOE provides dedicated rail cars for transportation of UF_6 between its facilities, and commercial users provide their own dedicated flatbed trailers that are transported by commercial carriers.

Rail cars and flatbed trailers that carry UF_6 cylinders containing natural UF_6 feed material (0.711% uranium-235) to the uranium enrichment facilities are constructed with heavy tie downs and saddle devices to completely immobilize the cylinders being transported. When the UF_6 in the cylinders has a uranium-235 assay of greater than 1%, the cylinders must be transported in protective overpacks. A protective overpack is not required, however, for an empty cylinder containing a permissible heel. Ten-ton product cylinders containing solid UF_6 (assay greater than 1% uranium-235) are enclosed in specially designed overpacks called "Paducah Tigers." These are used for transporting UF_6 cylinders between the gaseous diffusion plants in Piketon, Ohio, and Paducah, Kentucky. DOE has dedicated rail cars that hold up to five Paducah Tigers, or they can be transported on dedicated trailers.

Cylinders containing depleted UF_6 do not require a protective overpack. Each UF_6 cylinder not in a protective overpack, whether empty or full, is secured for shipping with a valve protector and a numbered tamper-indicating device. In both cases the shipper provides protective seal numbers to the receiver, and the receiver verifies the seal numbers and that the seals are intact when the containers arrive.

3.2 Packaging Requirements

Section 173.420 of the Department of Transportation regulations (Title 49 of the Code of Federal Regulations (49CFR)) states that UF_6 packagings must be designed, fabricated, inspected, tested and marked in accordance with-

- American National Standard N14.1[1] (1990, 1987, 1982, 1971) in effect at the time the packaging was manufactured;
- Specifications for Class DOT-106A multi-unit tank car tanks (Sections 179.300 and 179.301 of this subchapter); or
- Section VIII, Division I of the ASME Code, provided the packaging-

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[1]American National Standards Institute. *American National Standard for Nuclear Materials - Uranium Hexafluoride - Packaging for Transport.* ANSI N14.1-1995. December 1, 1995.

(A) Was manufactured on or before June 30, 1987;
(B) Conforms to the edition of the ASME Code in effect at the time the packaging was manufactured;
(C) Is used within its original design limitations; and
(D) Has shell and head thicknesses that have not decreased below the minimum specified values

3.2.1 Packaging for Low Specific Activity UF_6

Depleted UF_6 is low specific activity (LSA) material according to 49 CFR 173.403 and depleted UF_6 cylinders have always been shipped as LSA material. With the large number of cylinders to be shipped, all shipments will be exclusive use per the definition in 49 CFR 173.403, i.e., the depleted UF_6 will be shipped in full load quantities by a single consignor and will not be shipped with other materials.

Depleted UF_6 would be shipped in conformance with 49 CFR 173.427 in cylinders that qualify as "strong, tight packages" that prevent leakage of the radioactive content under normal conditions of transport.

3.2.2 Physical Condition of UF_6

UF_6 may be shipped only as a solid when the vapor pressure of the cylinder has been measured to be below 1 atm, and the measured purity of the cylinder contents is within specification. (Solid UF_6 is a heavy crystalline mass that sublimes at room temperature). Uranium hexafluoride is a solid at ambient temperatures.

The depleted UF_6 inventory is in solid form, but in some cases the cylinder pressures are above 1 atmosphere, as discussed in Section 4.1. These overpressured cylinders contain very small amounts of light gases with low molecular weights. Due to the way UF_6 was withdrawn from the Diffusion Plant cascades, most process gas contaminants were much lighter than U-238 and went "up" in the cascades with the enriched UF_6 product rather than "down" where depleted UF_6 was withdrawn. This makes the likelihood of significant impurities in the depleted UF_6 very small. Other than isotopic assay content, characterization or sampling data on the depleted UF_6 is not readily available. However, it is anticipated that most or all of the depleted UF_6 cylinders will meet the purity specification of 99.5% required by ANSI N14.1.

3.2.3 Standard UF_6 Cylinders

Standard UF_6 cylinder data from ANSI N14.1 are shown in Table 3-1. Cylinders listed in Table 3-1 that are not specifically defined are acceptable for continued use, provided they are inspected, tested, and maintained in accordance with the intent of the standard and the requirements stated in ANSI N14.1. Most of the cylinders used to store depleted UF_6 are model number 48 series (refer to Table 1-1).

3.3 Shipping Requirements

Shipping requirements specified in ANSI N14.1 are as follows.

3.3.1 Cylinders

(1) Full cylinders to be shipped shall be packaged as specified in Section 3.2.
(2) Empty cylinders with valve protection may be shipped without outer protective packaging provided the residual quantities of UF_6 ("heels") are not exceeded as follows:

Cylinder	Heel (lb)	Maximum ^{235}U, wt%
5A or 5B	0.1	100.00
8A	0.5	12.50
12A or 12B	1.0	5.00
30B[a]	25.0	5.00
48A[b] or 48X	50.0	4.50
48F[b] or 48Y	50.0	4.50
48G or 48H	50.0	1.00
480, 480M, 480M Allied or 48T	50.0	1.00

[a]This cylinder replaces the 30A cylinder. The 30A cylinder has the same heel and maximum ^{235}U limit as the 30B.
[b]Cylinders 48A and 48F are identical to 48X and 48Y, respectively, except that the volumes are not certified.

Table 3-1
Standard UF_6 Cylinder Data - ANSI N14.1

Model Number	Nominal Diameter (in)	Material of Construction	Minimum Volume (ft^3)	Approximate Tare Weight (without valve protector) (lb)	Maximum Enrichment (wt% ^{235}U)	Maximum Fill Limit (lb UF_6)
1S	1.5	Nickel or Nickel-copper alloy[c]	0.0053	1.75	100.0	1.0[a]
2S	3.5	Nickel or Nickel-copper alloy[c]	0.0254	4.2	100.0	4.9[a]
5A	5	Nickel-copper alloy[c]	0.284	55	100.0	54.9[a]
5B	5	Nickel	0.284	55	100.0	54.9[a]
8A	8	Nickel-copper alloy[c]	1.319	120	12.5	255[a]
12A[d]	12	Nickel	2.38	185	5.0	460[a]
12B	12	Nickel-copper alloy[c]	2.38	185	5.0	460[a]
30B[g]	30	Steel	26.0	1400	5.0[e]	5020[a]
48A[b]	48	Steel	108.9	4500	4.5[e]	21030[a]
48X	48	Steel	108.9	4500	4.5[e]	21030[a]
48F[b]	48	Steel	140.0	5200	4.5[e]	27050[a]
48Y	48	Steel	142.7	5200	4.5[e]	27560[a]
48T[h]	48	Steel	107.2	2450	1.0	20700[f]
48O[h]	48	Steel	135	2650	1.0	26070[f]
48OM Allied[h]	48	Steel	140	3050	1.0	27030[f]
48OM[h]	48	Steel	135	2650	1.0	26070[f]
48H, 48HX[h]	48	Steel	140	3250	1.0	27030[f]
48G	48	Steel	139	2650	1.0	26840[f]

[a]Fill limits are based on 250°F maximum UF_6 temperature (203.3 lb UF_6 per ft^3), certified minimum internal volumes for all cylinders, and a minimum cylinder ullage of 5%. These operating limits apply to UF_6 with a minimum purity of 99.5%. More restrictive measures are required if additional impurities are present. This maximum temperature shall not be exceeded. It should be noted that initial cylinder heating may result in localized pressures above a normal UF_6 vapor pressure. This may be evidenced by an audible bumping similar to a water hammer.
[b]Cylinders 48A and 48F are identical to 48X and 48Y, respectively, except that the volumes are not certified.
[c]For example, Monel or the equivalent.
[d]This cylinder is presently in service. New procurement should be model 12B.
[e]These maximum enrichments require moderation control equivalent to a UF_6 purity of 99.5%. Without moderation control the maximum permissible enrichment is 1.0 wt% ^{235}U.
[f]Fill limits are based on 235°F maximum UF_6 temperature and minimum UF_6 purity of 99.5%. The allowable fill limit for tails UF_6 with a minimum UF_6 purity of 99.5% may be higher but shall not result in a cylinder ullage of less than 5% when heated to the cylinder design temperature of 235°F based on the actual certified volume.
[g]This cylinder replaces the Model-30A cylinder, which has a fill limit of 4950 pounds.
[h]This cylinder is similar in design to the 48G in that their design conditions are based on 100 psig at 235°F.

(3) Clean cylinders, including new cylinders, may be shipped with no special precautions other than those used in normal shipping operations, provided the shipper is confident that no residual contamination remains in the cylinder that has a specific activity that exceeds 0.002 μ curies/g, which would classify it as a radioactive material in accordance with 49 CFR 173.403. (Please see Section 3.3.7 for the definition of a curie). If this condition cannot be assured the cylinder shall be shipped in accordance with 49 CFR 173.427 or Section 2 and applicable DOT regulations. All bare cylinders shall incorporate a feature such as a seal to provide assurance that the package has not been illicitly opened.

3.3.2 Valve Protectors and Seals

Valve protectors shall be used on all cylinders (except new and cleaned ones) that are not contained in an outer protective package during shipment. All UF_6 packages when shipped shall incorporate a feature such as a seal to provide assurance that the package has not been illicitly opened.

3.3.3 Labeling

Packages shall be shipped in accordance with 3.2.1(2) (exclusive use LSA Material shipment) and information required in 49 CFR 172.403 shall be displayed on the label. The label shall be selected in accordance with the following:

(1) Radioactive White-I Label. The white-I label shall be used for radiation not exceeding 0.5 millirem per hour at any point on the external surface of the package. The white label is not authorized for Fissile Class II packages.

(2) Radioactive Yellow-II Label. The yellow-II label shall be used for packages exceeding the white-I limits but which have radiation levels not exceeding 50 millirem/hour at the package surface or a transport index exceeding 1.0.

(3) Radioactive Yellow-III Label. The yellow-III label shall be used for packages exceeding the yellow-II limits, that is, with radiation levels exceeding 50 millirem/hour at the package surface or a transport index exceeding 1.0.

(4) Corrosive Labels. Corrosive labels shall be applied to all packages containing UF_6 except those transported in accordance with 3.2.1(2) (exclusive use LSA shipments) or 3.3.1(3) (when the cylinder is sufficiently clean to be classed nonradioactive or is shipped in accordance with 49 CFR 173.427 for empty packaging).

Most depleted UF_6 cylinders are expected to be shipped with the radioactive yellow-II label due to the expected 3-5 millirem/hour dose rate in close proximity (within 6-inches) to the cylinder wall. This expected dose rate is typical of health physics monitoring data from existing cylinder yards at the K-25 Site.

3.3.4 Placarding

(1) Radioactive Placards. "Radioactive" placards shall be displayed on all conveyances transporting uranium hexafluoride (as exclusive use Low Specific Activity material) in accordance with 3.3.3, and on all conveyances transporting a package labeled "Radioactive Yellow-III."

(2) Corrosive Placards. "Corrosive" placards shall be displayed on all conveyances transporting UF_6 for which the gross weight of UF_6 plus packaging exceeds 1000 pounds.

3.3.5 Marking

Low Specific Activity UF_6 Under Exclusive Use Conditions. Cylinders transported in accordance with 3.2.1 shall stenciled or otherwise marked “Radioactive-LSA” in accordance with 49 CFR 173.427(a)(6)(vi).

3.3.6 Shipping Papers

Complete transportation documentation (shipping) papers shall accompany each shipment. All of the information required by the DOT regulations (49 CFR Part 172, Subpart C) shall be included.

3.3.7 Activity of UF_6 Shipping Cylinders

U.S. Department of Transportation and NRC regulations require that the activity of UF_6 shipments be specified. The curie (Ci) is the unit used to specify the activity of the uranium isotopes of interest and is equal to 3.7×10^{10} disintegrations per second.

Uranium hexafluoride may be produced either from unirradiated uranium or from irradiated uranium that may contain trace quantities of the ^{232}U and ^{233}U isotopes. The trace quantities of these other isotopes found in depleted UF_6 contribute insignificantly to the total radioactivity.

As a result of long-established usage in internal dose calculations (see Appendix C, of ANSI N14.1), a curie of recently extracted natural uranium has come to mean 3.7×10^{10} disintegrations per second from ^{238}U, plus 3.7×10^{10} disintegrations per second from ^{234}U, plus 9.0×10^{3} disintegrations per second from ^{235}U. Thus, when this description is applied to natural uranium, 1 curie is equal to 7.5×10^{10} disintegrations per second. Since this definition is the result of long-term usage and may not be universal, it is advisable to check the meaning of the activity, in curies, when applied to natural uranium.

There are insignificant quantities of other uranium isotopes (e.g., ^{232}U, ^{233}U and ^{234}U) in a depleted UF_6 cylinder. Therefore, it can be assumed that all depleted UF_6 cylinders will qualify as LSA material shipments, with a maximum total activity of the full depleted UF_6 cylinders being in the range of 2-3 curies. More detailed discussion of the above dose calculations can be found in ANSI N14.1.

Additional discussion of the curie unit and activity determinations relative to UF_6 shipping cylinders may be found in USAEC Report K-L-6252.

3.4 Quality Assurance

The licensee-user shall have a documented quality assurance (QA) program that meets the applicable criteria of Subpart H, Title 10, CFR, Part 71 [3] or ANSI/ASME NQA-1-1986 and ANSI/ASME NQA-1c-1988, at least for those quality-related activities associated with protective packaging. The licensee-user shall ensure that all applicable QA requirements in Subpart H, Title 10, CFR, Part 71, for all parties are met to ensure that the product or service supplied meets the requirements stated herein.

3.5 Regulations and Other Reference Information

The packaging and transportation of radioactive materials are regulated by various organizations including DOE, DOT, Nuclear Regulatory Commission (NRC), U.S. Postal Service, and state and local governments. Radioactive materials are also regulated by the International Civil Aeronautics Organization (ICAO), the International Atomic Energy Agency (IAEA), and the International Air Transport Association.

Table 3-2 is a list of DOE Orders; NRC and DOT regulations; and certificates, standards, and resource material pertaining to UF_6 handling and transport. For the present inventory of DUF_6 cylinders shown in Table 1, most cylinders have valid ASME "U" code stamps for pressure vessels.

DOT regulations for transportation of radioactive materials have been recently revised. These revisions were published in the Federal Register on September 28, 1995, and took effect April 1, 1996 (60 FR 50292). The latest revisions of applicable rules and regulations will need to be reviewed prior to actual shipment of cylinders to address potential impacts of changes to the rules and regulations. Although the definition of and transport requirements for Low Specific Activity materials were modified in the April 1996 revision to 49 CFR, there does not appear to be any significant impact on shipping the depleted UF_6.

Potential future changes which could result in a requirement for cylinders to withstand an 800°C fire for 30 minutes would have a profound impact on off-site transportation. It is anticipated that none of the current storage cylinders could meet this requirements. All preparation for shipment activities would need to be reevaluated if this change took effect.

Table 3-2
Depleted UF_6 Handling and Transport Reference Material

DOE ORDERS

1540.1	Materials Transportation and Traffic Management
1540.2	Hazardous Material Packaging for Transport—Administrative Procedures
1540.3	Base Technology for Radioactive Material Transportation Packaging Systems
5480.3	Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes
5700.6C	Quality Assurance

REGULATIONS

Nuclear Regulatory Commission

10 CFR 71	Packaging and Transportation of Radioactive Material

Department of Transportation

49 CFR 171	General Information, Regulations, and Definitions
49 CFR 172	Hazardous Materials Tables and Hazardous Materials Communications Regulations
49 CFR 173	Shippers--General Requirements for Shipments and Packaging (Subpart I--Radioactive Materials)
49 CFR 174	Carriage by Rail
49 CFR 177	Carriage by Public Highway

International Atomic Energy Agency

Safety Series #6 and Supplement	Regulations for the Safe Transport of Radioactive Material—1985 Edition (As Amended 1990)

American National Standards (in effect at time of cylinder manufacture)

ANSI N14.1	Uranium Hexafluoride—Packaging for Transport
ANSI/ASME NQA-1	Quality Assurance Program Requirement for Nuclear Facilities

Other

USEC-651	Uranium Hexafluoride: A Manual of Good Handling Practices, Revision 7, January 1995.

4.0 IDENTIFICATION AND COMPARISON OF OPTIONS

In order to assess the costs and potential environmental impacts associated with this project, estimates must be made on problems a cylinder may have that would prevent a normal shipment, the number of cylinders having these problems, and the actions necessary to correct or mitigate these problems so that the cylinders may then be shipped. In most cases there are multiple options available for correcting cylinder problems so that they may be shipped and emptied. These options will be listed for each of the identified problem areas and briefly discussed before the preferred option is recommended.

Review of 49 CFR, ANSI N14.1, and USEC-651 along with other documents listed in Table 3-2 has helped identify cylinder problems which can be categorized into three areas, overpressured, overfilled and substandard. Overpressured cylinders do not meet the requirement that they be shipped at subatmospheric pressures. Overfilled cylinders contain excess inventory of UF_6 which exceeds allowable fill limits for shipping and/or feeding in an autoclave. Substandard cylinders do not meet the "strong, tight" requirements for cylinder shipments and include those cylinders with corrosion sufficient for the wall thickness to be below allowable minimums, and all other nonconformances that prevent shipment of the cylinder "as-is". These include damaged cylinders, cylinders with plug or valve threading problems and any other cylinders that don't meet minimum shipping requirements. It is noteworthy that these cylinder conditions are problems only for offsite transportation and do not restrict onsite transport or storage.

Table 4-1 lists the estimated number of cylinders at each site which would fall under each of these problem areas. These data points are preliminary estimates based on limited testing of cylinder pressures in the yards, review of accountability records and historical information, and a small number of cylinders which have been inspected for wall thinning using an ultrasonics monitoring program. Mathematical and statistical modeling have also been used to analyze the data from the inspections and monitoring program. The results were used to help generate Table 4-2 which lists projected number of non-conforming cylinders in the year 2020, which is the reference case for this analysis. More detailed information on this modeling can be obtained from a report by B.F. Lyon of the Center for Risk Management at Oak Ridge National Laboratory titled "Prediction of External Corrosion for UF_6 Cylinders: Preliminary Results of an Empirical Method" report number ORNL/TM-13012, published in June 1995. Efforts to estimate the extent of corrosion of the depleted UF_6 cylinders are ongoing, and other reports on this subject have been produced. Rather than analyzing ongoing changes to the data, a parametric approach which considers a range of possible cylinder conditions was used. The results are presented in Appendix A.

Cylinder problem areas overlap. Many of the substandard cylinders are overfilled or overpressured or both. In other words, cylinder problems are not mutually exclusive. The substandard cylinders are mostly older cylinders that have been in poor storage conditions for a longer period of time. These same cylinders are more likely to have been overfilled and/or overpressured. There is no data to support an estimate of the number of cylinders which have more than one problem. A conservative estimate of the total number of non-conforming cylinders was made by assuming the problems are mutually exclusive. It should also be noted that these figures are very rough estimates with high tolerances associated with many unknowns.

For purposes of this analysis, the number of non-conforming cylinders projected for the year 2020 is used as the reference case to define the activities necessary to prepare the cylinders for shipments. It is recognized that this preliminary estimate may change over time as estimates of the number of non-conforming cylinders are refined and as cylinder conditions and regulatory requirements change. Accordingly, a parametric analysis was performed to consider a range of possible cylinder conditions (see Appendix A).

4.1 Overpressured Cylinders

In accordance with 49CFR173.420(a)(5) transportation requirements for UF_6, the pressure in the package at 20 degs. C (68 degs. F) must be less than 101.3 kPa (14.8 psia). Overpressured cylinders are those in which the vapor space above the solid UF_6 contains excess contaminant gas (non-UF_6 or "lights") causing its pressure to be above atmospheric (i.e., cylinder pressure is greater than 14.7 psia). This condition might have developed due to small leaks in or around the valves. These contaminant gases are mostly air, HF, and other light constituents (density less than UF_6) that were withdrawn into or became trapped within the cylinder. Other cylinders may be overpressured as a result of filling processes used in the past that employed noncondensible gases (nitrogen and dry air). At ambient temperatures, the quantities and vapor pressures of these gases cause the cylinder to violate the requirement that UF_6 be shipped at cylinder pressures below atmospheric (See 3.2.2). Depending upon the ambient temperature and the vapor pressure of UF_6 at that temperature, this vapor space contains 2-20 pounds of UF_6.

As can be seen from Tables 4-1 and 4-2, the number of overpressured cylinders is expected to increase from 2600 to 5000 over time due to two mechanisms. One mechanism is the off-gassing of impurities from the solid UF_6 in the cylinder. When liquid depleted UF_6 was initially withdrawn from the cascades into the cylinder, this DUF_6 liquid contained dissolved impurities including gases. When the DUF_6 solidified, these gases became trapped in the solid DUF_6 and as the solid continually sublimes and desublimes over the years, these gases are released. The other mechanism that can increase lights in a cylinder is in leakage of air into the cylinder through a leaking valve, plug, or a breach. Moisture in the air then reacts with UF_6 to form HF in the vapor space, which subsequently increase the cylinder pressure. Although these gases may increase the cylinder pressure above atmospheric they do not significantly impact purity. No data exists regarding the partial pressures of each of the constituents in the gas space, but the total pressure is expected to be less than 10 psig for the great majority of cylinders.

The estimated number of cylinders which are currently estimated to be overpressured (2,600) and which are projected to be overpressured in the year 2020 (5,000) is based upon engineering judgment. Very little information exists in this area because pressure checks are not part of current cylinder management activities. This is primarily due to the difficulty and risk of opening valves (a significant percentage of which may be frozen after years in storage) versus the utility of the information which would be obtained to the current management program. Even if a cylinder had below atmospheric pressure today, another pressure check would be required immediately prior to shipment. Positive internal cylinder pressure is not an issue for storage, and pressure measurements have been taken in the past to assure cylinders shipped offsite met the requirement that they be shipped below atmospheric pressure. A cylinder was rejected for shipment if it was found to be overpressured; however, data was not collected on these non-conforming cylinders.

The overpressured cylinders are anticipated to be the smallest component of the non-conforming cylinder population. Despite the lack of firm data regarding the number of overpressured cylinders, revisions to the prediction would have minimal impact on the total number of non-conforming cylinders.

Options for dealing with overpressured cylinders which will be discussed here include (1) obtaining a DOT exemption; (2) transferring depleted UF_6 to evacuated new or empty UF_6 cylinders; (3) shipping the cylinder as-is within a protective overcontainer; and (4) controlled venting of the light gases to the atmosphere through a UF_6/HF clean-up system. The recommended option is Option 3.

Obtaining a DOT exemption for shipping cylinders above atmospheric pressure may be possible but the probability of success is unknown at this time. This option needs to be explored further but was not considered a suitable option for recommendation in this study.

Transferring depleted UF_6 to evacuated cylinders would generate additional cylinders which would have to be handled due to the volume necessary to equalize pressures between the cylinders and end up with all cylinders below atmospheric. This option would be more expensive than option 3.

Table 4-1
Non-conforming Depleted UF_6 Cylinders - Present (Preliminary Estimate)

	Portsmouth	Paducah	K-25	Total
Total Cylinders	13,388	28,351	4,683	46,422
Overpressured[1]	1,000	1,000	600	2,600
Overfilled[2]	1,000	5,000	1,500	7,500
Substandard[3]	800	10,500	1,500	12,800
Total Non-conforming Cylinders	2,800	16,500	3,600	22,900

[1]Cylinder pressure over atmospheric
[2]Cylinder inventory over 49 CFR allowable fill limits, 62% by volume at 20°C for depleted UF_6
[3]Cylinder fails to meet minimum wall thickness (250 mils) required by 49 CFR and ANSI N14.1 for transporting cylinders or cylinders with characteristics that render it unsafe or unserviceable according to ANSI N14.1

Table 4-2
Non-conforming Depleted UF_6 Cylinders- 2020 (Preliminary Projection for Reference Case)

	Portsmouth	Paducah	K-25	Total
Total Cylinders	13,388	28,351	4,683	46,422
Overpressured[1]	1,500	2,500	1,000	5,000
Overfilled[2]	1,000	5,000	1,500	7,500
Substandard[3]	2,700	11,700	2,600	17,000
Total Non-conforming Cylinders	5,200	19,200	4,683	29,083

[1]Cylinder pressure over atmospheric
[2]Cylinder inventory over 49 CFR allowable fill limits, 62% by volume at 20°C for depleted UF_6
[3]Cylinder fails to meet minimum wall thickness (250 mils) required by 49 CFR and ANSI N14.1 for transporting cylinders or characteristics that render it unsafe or unserviceable according to ANSI N14.1

Option 4 involves controlled venting of the light gases through a clean-up system so that the air and other inert gases can be released to the atmosphere. A mobile cart would be designed and built for this purpose, with one or more carts located at each site. The cart would include a UF_6/HF cold trap, chemical traps for secondary trapping and a HEPA-filtered vacuum source. Instrumentation and controls along with a power source (portable generator) would also be provided. Trapped UF_6 would be collected in smaller cylinders as a solid so that very few additional cylinders would be generated with this operation. Option 4 is not recommended due to the increased environmental and safety risks associated with the operation of the carts. Additional cylinders and wastes would be created leading to increased costs over Option 3.

The recommended option is option 3, shipping the cylinders as-is within a protective overcontainer. Shipping in the protective overcontainer would meet the requirement to ship below atmospheric pressure because the annulus between the cylinder and the overcontainer would be evacuated such that even if the cylinder breached during shipment, the release of the cylinder's excess pressure would not raise the annulus pressure above atmospheric. See Sections 4.4 and 4.5 for details on the protective overcontainer and cylinder packaging operations.

4.2 Overfilled Cylinders

Regulations governing offsite shipment of uranium hexafluoride (UF_6) are found in 49 CFR and in ANSI N14.1 and ORO-651, which are incorporated by reference into 49 CFR. In accordance with 49CFR173.420(a)(4) transportation requirements for UF_6, the volume of solid depleted uranium hexafluoride at 20 degs. C (68 degs. F) may not exceed 62% of the certified volumetric capacity of the packaging. After the 1986 accident in Gore, Oklahoma, where an overfilled UF_6 cylinder ruptured while being heated, there were a series of rulemakings modifying 49 CFR to include fill limits for cylinders in transportation. Prior to that time there were no fill limits in 49 CFR - only in ORO-651 and ANSI N14.1. Revision 4 of ORO-651 (in effect at the time of the rulemakings) gave fill limits for each cylinder model which, with one exception, were below 61%. The exception was the fill limit for the 48G cylinder, which was given as 28,000 lb, or 63.4% of the minimum volume (139 ft^3) at 20 degs. Cylinders filled before 1987 were filled up to this limit.

The regulations were later amended to permit the transport of depleted UF_6 in packaging filled 62% full by volume at ambient temperatures, in accordance with a revision to ANSI N14.1 published in 1987. This fill limit is in effect today, leaving an estimated 7,500 cylinders overfilled by current standards.

It should be noted that being overfilled is not an issue for cylinder storage: there are no regulations which prohibit it and no safety concerns at ambient temperature. By regulation, fill limits must be met for transportation, but there are no apparent safety concerns associated with having overfilled cylinders at ambient temperature in transport. It is essential, however, that fill weight and maximum safe temperature be determined before a cylinder is heated to preclude hydraulic rupture.

Options for dealing with overfilled cylinders which will be discussed here include (1) obtaining a DOT exemption; (2) shipping the cylinder as-is within a protective overcontainer; (3) administratively raising the allowable fill limit; and (4) transferring excess inventory into another cylinder (new or used) using a Transfer Facility. The recommended option is option 2.

Option 1, obtaining a DOT exemption for shipping overfilled cylinders, may be possible but the probability of success is unknown at this time. This option needs to be explored further but was not considered a suitable option for recommendation in this study. The same applies to Option 3, administratively raising the allowable fill limit. This would require a revision to ANSI N14.1 and the likelihood of this happening is judged to be remote because such a change would reduce the safety basis.

Option 4, transferring excess inventory to another cylinder using a Transfer Facility, is not as desirable due to its high cost. Environmental and safety risks would be higher, and waste management issues would also make this option less desirable. This option is analyzed in Section 6.2 of the *Engineering Analysis Report.*

The recommended option is option 2, shipping the cylinders as-is within a protective overcontainer. Shipping in the protective overcontainer would meet the ANSI N14.1 allowable fill limits due to the additional available volume of the annulus between the cylinder and the overcontainer. See Sections 4.4 and 4.5 for details on the protective overcontainer and cylinder packaging operations.

4.3 Substandard Cylinders

Substandard cylinders are those that do not meet shipping criteria for reasons other than being overpressured or overfilled. The largest percentage of these are the corroded cylinders in which the wall thickness has dropped below the minimum required of 250 mils (1/4-inch) for thin-walled cylinders which had an original wall thickness of 312.5 mils (5/16-inch). See Table 4-3 for minimum acceptable wall thicknesses by cylinder models. Other damage or defects would also put a cylinder into the substandard classification.

Table 4-3
Minimum Acceptable Cylinder Wall Thickness

Cylinder Model	Minimum Thickness (in.)
1S	1/16
2S	1/16
5A	1/8
5B	1/8
8A	1/8
12A and B	3/16
30B	5/16
48A, F, X and Y	½
48T, O, OM, OM Allied HX, H and G	1/4

Options for dealing with substandard cylinders which will be discussed here include (1) obtaining a DOT exemption; (2) shipping the cylinder as-is within a protective overcontainer; (3) administratively lower the minimum allowable wall thickness; and (4) transferring all cylinder inventory into another cylinder (new or used) using a Transfer Facility. The recommended option is option 2.

Option 1, obtaining a DOT exemption for shipping substandard cylinders, may be possible. The probability of success is unknown at this time, but judged to be low. This option needs to be explored further but was not considered a suitable option for recommendation in this study. The same applies to Option 3, administratively lowering the minimum allowable wall thickness. This would require a revision to ANSI N14.1 and the likelihood of this happening is judged to be remote because such a change would reduce the safety basis.

Option 4, transferring cylinder contents to another cylinder using a Transfer Facility, is not the preferred option due to its high cost. Environmental and safety risks would be higher, and waste management issues would also make this option less desirable. This option is analyzed in Section 6.2 of the *Engineering Analysis Report.*

The recommended option is option 2, shipping the cylinders as-is within a protective overcontainer. Shipping in the protective overcontainer would meet the requirement to ship in "strong, tight" containers and provides sufficient wall thickness to meet or exceed allowable minimum wall thickness per ANSI N14.1. See Sections 4.4 and 4.5 for details on the protective overcontainer and cylinder packaging operations.

4.4 Protective Overcontainer

A preconceptual design for a protective overcontainer was developed. This overcontainer would provide a cost effective method to safely contain, transport, store and, if desired, autoclave transfer the contents of UF_6 cylinders which don't meet shipping requirements, regardless of their condition.

Three fundamentally different approaches were evaluated for the design of the protective overcontainer for these cylinders. The performance criterion for all three concepts was that the overcontainer must equal or exceed all capabilities of the original UF_6 cylinders in pristine condition.

One of the candidate concepts (Figure 4-1) investigated the up-ending of the UF_6 cylinder, enclosed in a constraining, dedicated custom sling, and the vertical lowering of this assembly into an open-ended, upright pressure vessel. Another, (Figure 4-2) was the horizontal insertion of a cradle-mounted UF_6 cylinder into a horizontal cylindrical pressure vessel using a loading ramp and rollers. Each of these concepts required a bolted sealing flange on one end of the pressure vessel overcontainer to effect closure.

The recommended concept (Figures 4-3, 4-4, and 4-5) is a horizontal clamshell pressure vessel into which a level UF_6 cylinder, supported by dedicated metal chain slings, is lowered by a crane. Closure of the overcontainer cylinder is achieved by bolting the two halves together at the midpoint sealing flange. Handling and support equipment for on-site movement and loading the cylinder into the overcontainer would be the same type currently used for cylinder management activities. Although additional equipment may be required (e.g., Raygo-Wagners and cranes to pick up the cylinders from the stacks or straddle buggies for on-site movement), design of new specialized equipment would not be required.

4.4.1 Overcontainer Design Requirements

Three fundamentally different configurations of the proposed protective UF_6 cylinder overcontainer were investigated. The design requirements imposed on all three of these configurations were that the overcontainer vessel, when loaded with a damaged, deteriorated or breached UF_6 cylinder, could safely be subjected to the same handling, storage, transportation, pressure, temperature and operational requirements as new Model 48G cylinders.

The overcontainer design shall permit the removal of UF_6 from standard cylinders contained within the overcontainer using a standard 72 inch internal diameter feed autoclave or heater and steam heat. It is anticipated that heat will be controlled such that the depleted UF_6 sublimes and is transferred as a gas rather than a liquid. This will avoid additional stress on the non-conforming cylinders caused by increasing the interior pressure on the cylinder and is consistent with plans for transferring the depleted UF_6 from "normal" cylinders at generic conversion facilities. It is anticipated that the cylinder would remain inside the overcontainer while the contents are being transferred in order to avoid a potential for contact between the depleted UF_6 and steam in the unusual case where the cylinder breaches as a result of its substandard condition. The design would be optimized for heat transfer from the autoclave through the overcontainer to the interior cylinder. In addition, a separate nozzle with a different style valve fitting shall also permit the removal of material contained within the annulus between the overcontainer and a leaking or breached UF_6 cylinder contained within.

The overcontainer shall be a pressure vessel that is hydrotested at 200 pounds per square inch internal pressure per ANSI N14.1, the same as the Model 48G thin-wall cylinder. Design, fabrication, testing and marking shall be in accordance with ASME Boiler and Pressure Vessel Code Section VIII, Division 1, and ANSI N14.1 as required in 49CFR173.420. The vessel shall be U stamped. Material of construction is proposed to be carbon steel per ASTM A516. Table 4-4 describes the preliminary preconceptual design characteristics for the depleted UF_6 cylinder overcontainer. It is anticipated that the design of the overcontainer would be coordinated with the ANSI N14.1 committee as well as the Department of Transportation and that some revisions to ANSI N14.1 and 49 CFR may be necessary. Since the objective is to design an overcontainer which could meet the same requirements as new cylinders, such revisions are judged to be feasible.

Table 4-4
Preconceptual Design Characteristics for the Depleted UF_6 Cylinder Overcontainer

Design Parameter	Standard
Material of Construction	ASTM A516 Steel
Approximate Weight	8,000 pounds[2]
Nominal Wall Thickness	5/8 inches
Internal Design Pressure	100 psig
External Design Pressure	25 psig
Hydrostatic Test Pressure	200 psig

4.4.2 Alternate Design Concepts

The design basis for the overcontainer is to provide a container that could safely be subjected to the same handling, storage, transportation, pressure, temperature and operational requirements as new Model 48G cylinders. These requirements are described in ANSI N14.1, the American National Standard entitled *Uranium Hexafluoride--Packaging for Transport.* This standard includes design pressure specifications for transportation that must be met whether or not the cylinder contents are ever liquefied in an autoclave. Should an exception be obtained for the pressure vessel requirement, an alternate design would potentially involve a much thinner walled overcontainer design. Since it is anticipated that warm or cold feeding could be used, the 100 psig rating and 200 psig hydrotest for the overcontainer could possibly be much lower leading to a lower wall thickness. The thickness would be specified for shipping protection only and not be based on pressure vessel requirements necessary for liquefying the cylinder contents. This is a case where the design requirements must be developed integrating those necessary to meet shipping rules and regulations, and those for the feed system of the processing (or conversion) facility. If a future regulatory change requires that depleted UF_6 packages withstand accident conditions, a more rigorous design would be necessary.

The total weight of the overcontainer, containing a filled UF_6 cylinder, would not exceed DOT unrestricted highway transportation limits. The weight is estimated to be approximately 8,000 pounds for a wall thickness assumed to be 5/8" thick. Actual wall thickness would be determined during detailed design.

[2]Based upon the tare weight of a 14 ton thick wall (5/8") cylinder, Model 48Y (5,200 lb).

Figure 4-1
Vertical Overcontainer Concept

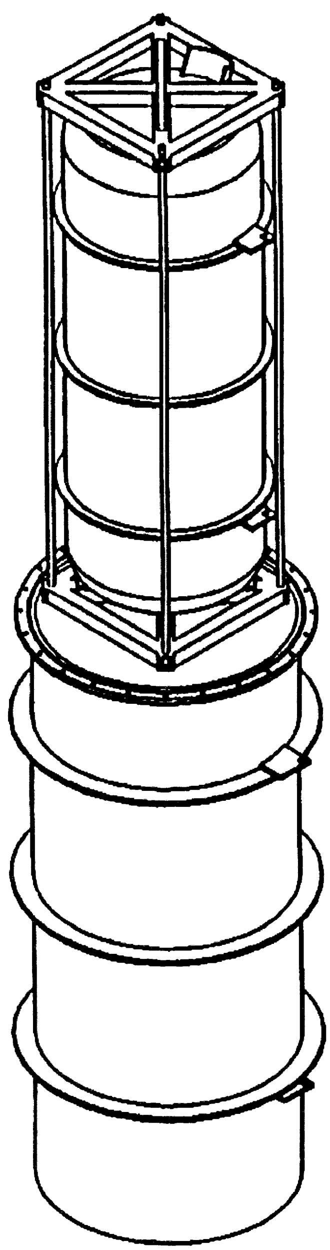


Figure 4-2
Horizontal End-Loading Overcontainer Concept

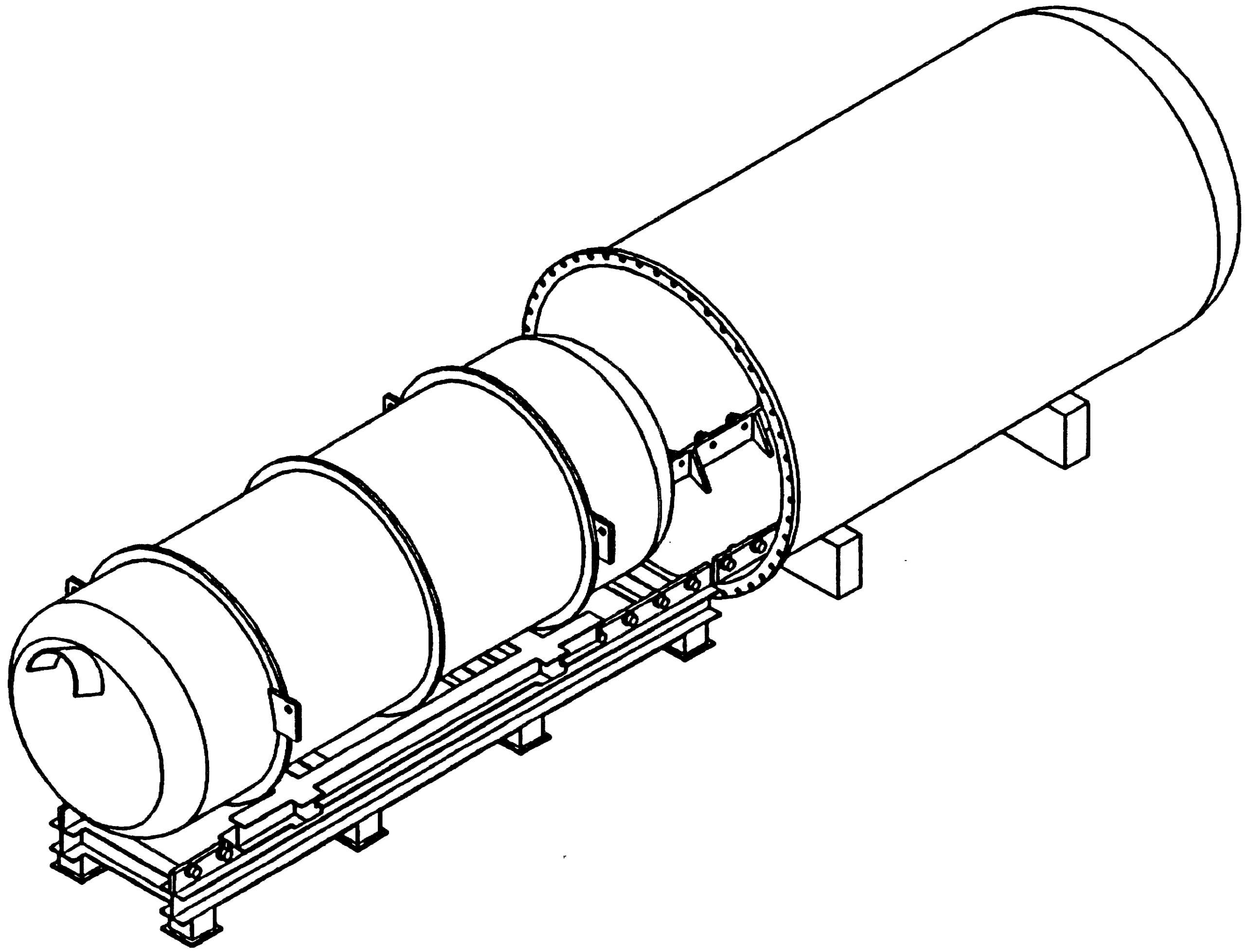


Figure 4-3
Horizontal Clamshell Overcontainer Concept

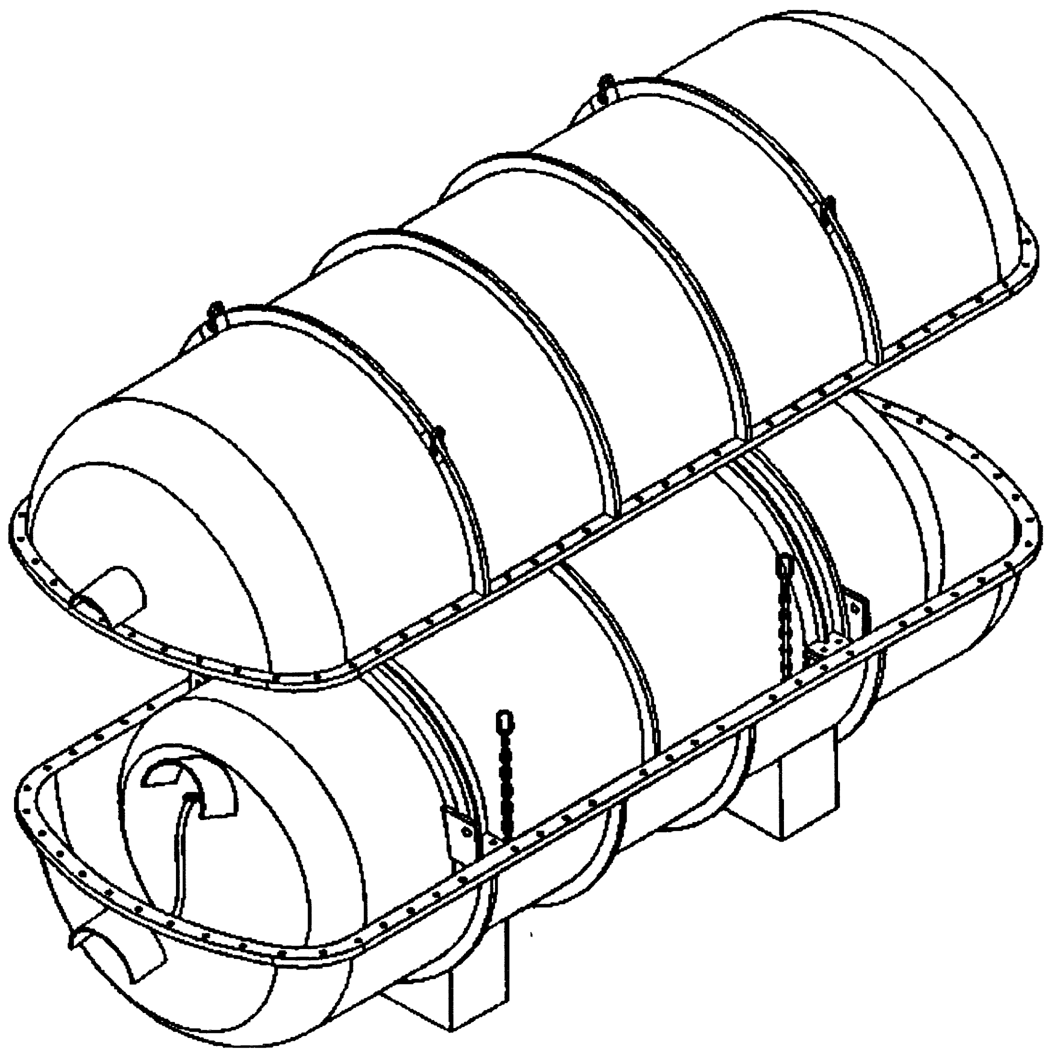
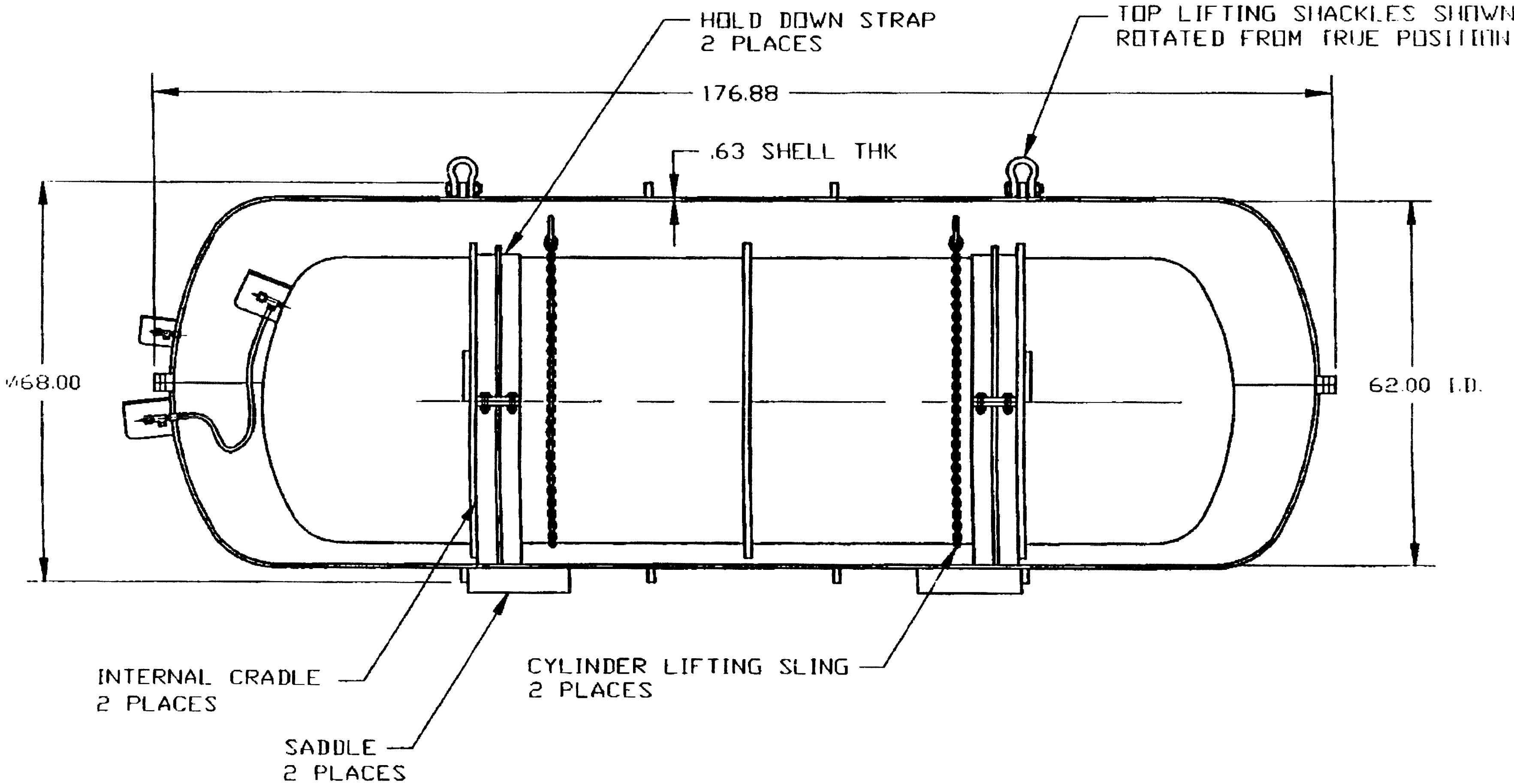
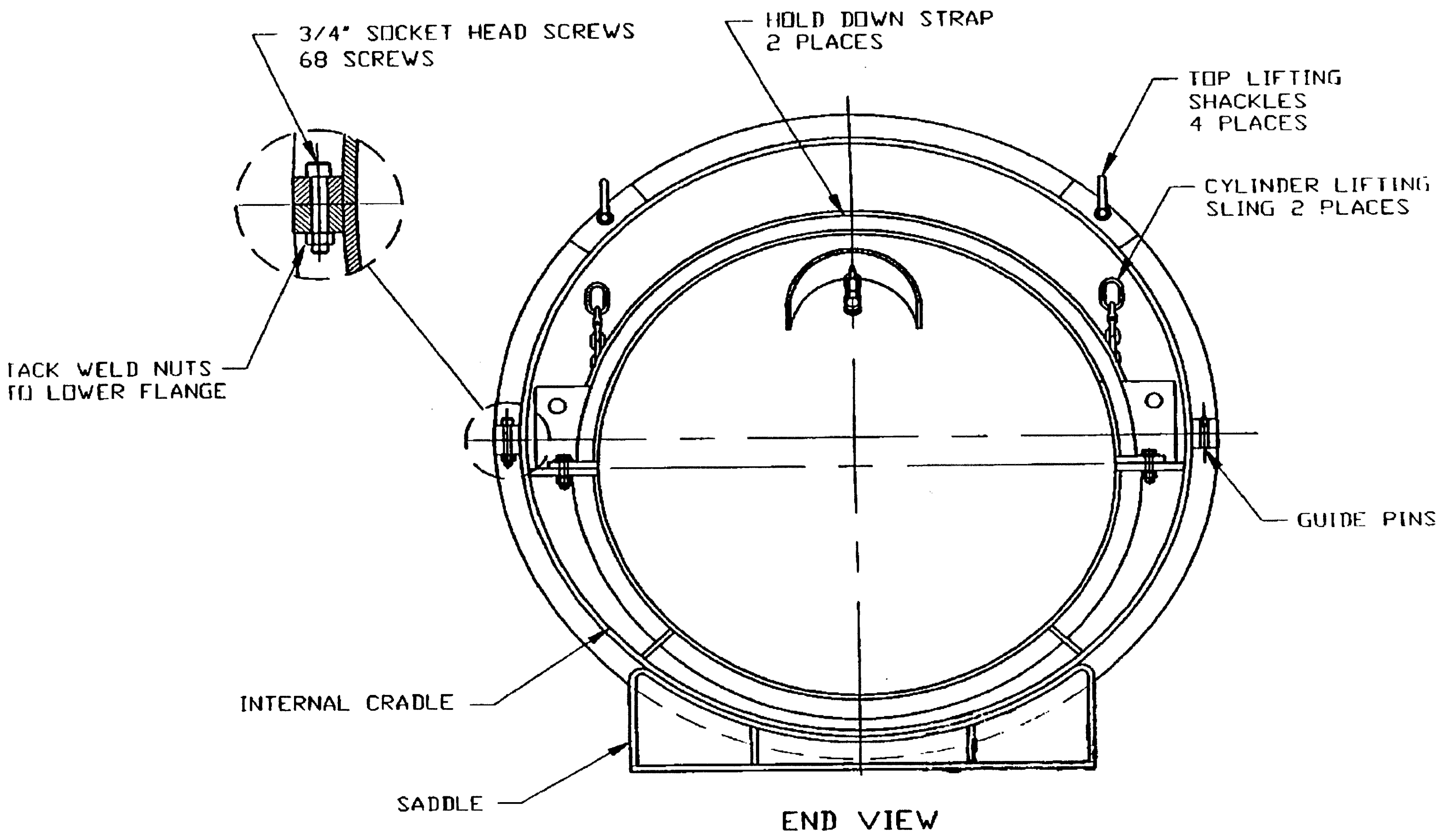


Figure 4-4
Cylinder Loaded into Overcontainer



CYLINDER LOADED INTO OVER PACK

Figure 4-5
End View of Cylinder Loaded into Overcontainer



4.4.3 Number of Overcontainers Required

Table 4-5 shows the estimated number of cylinders at each site which would require overcontainers. Since the overcontainers would be reusable, fewer overcontainers than non-conforming cylinders would need to be procured for the project. Using the number of cylinders requiring protective overcontainers from Table 4-5, and a 17-week turnaround from loading to return to the site, the 20 year shipping schedule leads to the number of overcontainers required. This 17-week turnaround time is based upon the following assumptions:

- 2 days for preparing the full cylinder and overcontainer for shipment and loading it onto the conveyance
- 7 days for transportation to the conversion facility
- 21 days in storage at the conversion facility as a full cylinder (average time in lag storage)
- 2 days in the conversion facility for processing
- 76 days in storage at the conversion facility as an empty cylinder and overcontainer[1]
- 2 days for preparing the overcontainer for shipment and loading it onto the conveyance
- 7 days for transportation to the site of origin to be reused
- 2 days for unloading the overcontainer and returning it for reuse

There would be about 1,454 truck shipments per year of non-conforming cylinders (260 from Portsmouth, 960 from Paducah, and 234 from Oak Ridge), as shown in Table 4-6. Based on a 50 week work year, about 6 cylinders would leave Portsmouth every week, 20 would leave Paducah, and 5 would leave Oak Ridge. It is estimated that Portsmouth will need about 113 overcontainers, Paducah about 374 and K-25 about 94, assuming a 10% contingency for spares, unforeseen delays, and the few overcontainers which may need to go to the cylinder treatment facility to be washed out. The emptied cylinders would go to the cylinder treatment facility, as described in Section 6.3 of the *Draft Engineering Analysis Report.*

[1]Preliminary estimates have indicated possible dose rates in the range of 1 rem/hr at the lower surface of emptied cylinders. This 76 day period allows for the daughter products in this heel to decay to acceptable levels.

Table 4-5
Depleted UF_6 Cylinder Cylinders Requiring Protective Overcontainer for Shipping (Estimated)

	Portsmouth	Paducah	K-25	Total
Total Cylinders	13,388	28,351	4,683	46,422
Cylinders Requiring Overcontainer	5,200	19,200	4,683	29,083
% Inventory Requiring Overcontainer	39%	68%	100%	63%
Number of Overcontainers Needed	113	374	94	581

Table 4-6

Number of Depleted UF_6 Cylinders Shipped

	Portsmouth	Paducah	K-25	Total
Total Cylinders	13,388	28,351	4683	46422
Conforming Cylinders per year	410	458	0	868
Cylinders in Overcontainers per year	260	960	234	1,454
Total Cylinders Shipped per year	670	1,418	234	2,322

4.5 Cylinder Packaging Operations

This recommended approach is illustrated in Figure 4-3. Figures 4-4 and 4-5 show additional details of the concept. This approach features a horizontal clamshell pressure vessel into which a level UF_6 cylinder, supported by dedicated metal chain slings, is lowered by a crane. Closure of the overcontainer is achieved by bolting the two halves together at the midpoint sealing flange.

Before any cylinder is moved, an inspection would be performed. This inspection would include:

- Cylinder record review to determine if a cylinder is overfilled
- Visual observation
- A cold pressure check to determine if the cylinder is overpressured
- Ultrasonic wall thickness measurements (if warranted based on the visual inspection) to determine if the cylinder is substandard
- Preparation of documentation
- Contamination surveys and decontamination as necessary

Personnel protective equipment consisting of anti-contamination gloves, shoes and overalls, plus safety glasses and hard hat would be worn while preparing cylinders for movement.

A major advantage of this concept is that no special handling or support equipment is needed. Design and fabrication costs are therefore significantly reduced.

In addition, the loading of the UF_6 cylinder into the overcontainer is made safer and is greatly simplified by only handling the UF_6 cylinder once during loading operations, (i.e., the UF_6 cylinder, supported by dedicated chain slings, is lifted with a crane and is placed directly into the overcontainer). The chain slings are then retained within the overcontainer and remain attached to the UF_6 cylinder in order to be readily available for later removal and/or disposal of the UF_6 cylinder. The overcontainer is then sealed. The hoisting and placement of the overcontainer cover is also simplified since only vertical precision hoisting motions are required.

Once the shipping container is loaded, sealed and the annulus evacuated and leak-tested, it would be handled like regular cylinders during loading/unloading activities discussed below or the overcontainer bottom could be previously mounted on a truck or railcar. A minimal work crew of 3-4 persons would be required for these activities and personal protective equipment would also be kept to a minimum due to the small amount of hands-on work. Personal protective equipment would be that required for the work area where the cylinders are located, i.e., contamination area or radioactive material storage area. It is not anticipated that respirators would be required for any of these operations.

4.6 Cylinder Transport

Loading/Unloading Activities: A crane would be used to load/unload cylinders and shipping containers to/from semi-trailers and, more likely, railcars. Again, a minimal crew of 3-4 persons would be required wearing minimal personal protective equipment. Once the cylinder is loaded onto chocks on the railcar, it is strapped down and then it is ready for travel. Unloading at the processing facility would simply reverse the process.

Transportation Activities: On-site transfer/movement of the cylinders is performed using a Raygo-Wagner for stacking/destacking and cylinder movement, a straddle buggy for cylinder movement and a crane for lifting/loading activities. Transportation of cylinders between sites is done by semi-trailers or railcars. Railcars are the most likely mode because truck shipments can handle only 1 cylinder at a time while railcars can hold multiple cylinders per car and multiple cars can be conveyed at a time.

It is assumed that four depleted UF_6 cylinders (either "normal" or in overcontainers) could be placed on a rail car, and that twelve rail cars would be loaded for each shipment. There do not seem to be any weight- or dimension-based constraints which would prohibit this approach. According to *Uranium Hexafluoride: A Manual of Good Handling Practices*, up to five Paducah tigers (overpacks) with 10 ton UF_6 product cylinders may be shipped (end-to-end) per dedicated rail car. The package gross weight (Paducah tiger overpack plus the contents) is 37,500 pounds according to the NRC Certificate of Complicate number 6553. Thus, a single rail car loaded with five Paducah tigers would bear a 187,500 pound load while the weight of four depleted UF_6 cylinders with overcontainers is estimated to be approximately 150,600 pounds. The overall dimensions of the 48G cylinder are approximately 4 feet by 12 feet and the dimensions of the overcontainer are estimated to be approximately 5-2/3 feet by 14-3/4 feet. The dimensions of the Paducah tiger are 6-1/3 feet by 12-3/4 feet. Five Paducah tigers would occupy at least 63-3/4 linear feet while four cylinders in overcontainers are estimated to occupy about 59 linear feet.

It is also assumed that conforming and non-conforming cylinders could be mixed on the same railcar and railcars of conforming cylinders and railcars of non-conforming cylinders could be part of the same shipment. The number of shipments of conforming and non-conforming cylinders per year is approximate. Based on 48 cylinders per rail shipment, 49 total shipments would be required to ship the 2,322 cylinders each year. Some of these shipments would have fewer than 4 cylinders on a railcar or fewer than 12 railcars per shipment because the total number of cylinders is not a multiple of 48. Using trucks would require one driver per cylinder, while using railcars would require one engineer, one brake person, and one conductor per shipment by rail for 48 cylinders.

Table 4-7
Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Material	Material	Material
Transported Material			
Type	Depleted UF_6	Depleted UF_6	Low Level Waste
Physical Form/Treatability Category (for waste)	Solid	Solid	Combustible Solid
Chemical Composition/ Pressure/Temperature	UF_6/ ambient	UF_6/ ambient	Gloves, wipes, rags, PPE, etc./ambient
Packaging			
Size	14 ton	14 ton in over-container	55 gallon drum
Certified by	DOT	DOT	DOT
Model	48 G or similar	TBD	Varies
Container Weight	2,650 lb.	2,650 lb. + 8,000 lb.	50 lb.
Material Weight per container	27,000 lb.	27,000 lb.	300 lb.
Chemical/Isotopic Content	100% UF_6/ 99.75% U-238, 0.001%U-234, 0.25% U-235	100% UF_6 99.75% U-238, 0.001%U-234, 0.25% U-235	< 1 g. UO_2F_2/drum 99.75% U-238, 0.001%U-234, 0.25% U-235
Shipments			
Average Volume/yr	131,000 ft^3	219,000 ft^3	800 ft^3
Packages/year	867	1,455	109
Total Packages	17,339	29,083	2,180
Packages/Shipment	1/truck 48/rail (4/railcar)	1/truck 48/rail (4/railcar)	55
Shipments/year	867 by truck/ 18 by rail	1,455 by truck/ 31 by rail	2
Shipments/life of project	17,339 by truck/ 362 by rail	29,083 by truck/ 606 by rail	40
Form of Transport/Routing			
Mode	Truck/rail	Truck/rail	Truck
Destination	Conversion or Storage	Conversion or Storage	LLW Disposal Facility

5.0 PRELIMINARY ASSESSMENTS

5.1 Waste Management

Waste streams generated by activities associated with cylinder preparation and shipping are, in general, small for cylinder operations and the emptied cylinders themselves. Various wastes are generated in cylinder handling, loading of cylinders into packages (overcontainers) and testing and surveying of the cylinders. Most of these streams are small and will be kept to a minimum by using the most efficient designs and operating scenarios.

All major aspects of the cylinder shipment project would have Waste Management Plans written which will document how to minimize and handle all waste streams generated by any particular activity. See section 7.0 for further emissions data.

5.2 Safety

Prior to moving/handling DUF_6 cylinders designated for processing, it will be necessary to perform a comprehensive safety evaluation of all operations/activities leading up to and including off-site shipment. This safety analysis will meet all requirements of DOE Order 5480.23. This evaluation will take into account the fact that DUF_6 cylinders have been stored in an outdoor environment and may have experienced accelerated corrosion. Moreover, the initial protective coatings on some of the cylinders have not been efficiently maintained. Thus, DUF_6 cylinder integrity will be comprehensively evaluated to ensure that adequate controls are in place prior to initiating large scale off-site shipments.

The types of operations/activities that will be considered are as follows:

1. Applicability and completeness of existing safety documentation.
2. Adequacy of cylinder inspection/handling/moving procedures.
3. Adequacy of proposed cylinder readiness testing procedures.
4. The need for overcontainers and the adequacy of any new overcontainer designs (or any other packaging methods used)
5. The need for and applicability of any other special requirements to ensure safe cylinder handling and shipping.

This safety evaluation will be prepared and submitted to DOE for approval as part of an anticipated Operational Readiness Review conducted in accordance with DOE Order 5480.31, or equivalent.

5.3 Environmental

National Environmental Policy Act requirements will be satisfied for each phase and aspect of the project. A categorical exclusion (CX) will probably be sufficient for cylinder handling activities. These types of operations fall under each sites' general CX for maintenance activities.

5.4 Risk

Risk assessments, as required, will be prepared for all cylinder shipping activities. Risk assessments, properly performed early in the project, can help identify the best method of accomplishment with the least levels of risk, for all necessary project requirements.

6.0 EMPLOYMENT NEEDS

This section provides preliminary estimates of the employment needs during cylinder shipment operations.

6.1 Employment Needs During Operation

Table 6-1, On-Site Employment During Operation, provides labor category descriptions and the estimated numbers of employees required for cylinder shipment operations. The figures are by site and assume security is still present at the facilities. An FTE is a full-time equivalent employee. Operators belong to the labor category responsible for preparing the cylinders for shipment. A 5-day work week, one shift operation is assumed with the operators working about 40% of the available time in the yards preparing the cylinders for shipment (~850 hours per year).

Table 6-1

On-Site Employment During Operation

K-25

Labor Category	Number of FTEs
Managers and Staff	2
Professionals	2
Technicians	4
Office and Clerical	2
Craft Workers (Maintenance)	4
Operators/Line Supervision	8/2
Total Employees (for all on-site operations)	24

PORTSMOUTH

Labor Category	Number of Employees
Managers and Staff	3
Professionals	3
Technicians	6
Office and Clerical	3
Craft Workers (Maintenance)	6
Operators/Line Supervision	16/3
Total Employees (for all on-site operations)	40

PADUCAH

Labor Category	Number of Employees
Managers and Staff	6
Professionals	6
Technicians	12
Office and Clerical	6
Craft Workers (Maintenance)	12
Operators/Line Supervision	40/6
Total Employees (for all on-site operations)	88

6.2 Badged Employees at Risk of Radiological Exposure

Table 6-2 provides a tabular breakdown of the subset of employees from Table 6-1 which are expected to be at risk of radiological exposure, and their total effective dose equivalent on average and maximum as seen from Paducah Exposure Data, 1989-1994.

Table 6-2

Employees at Risk of Radiological Exposure

Labor Category	Total Effective Dose Equivalent (mrem/yr)		Number at Risk K-25	Number at Risk Portsmouth	Number at Risk Paducah
	Avg.	Max.			
Operators	100	315	8	16	40
Craft Workers (Maintenance)	*	*	2	3	6
Technicians	30	144	4	6	12
Managers and Staff	*	*	2	3	6
Total			16	28	64

*Data not available--expected to be much lower than that for operators or technicians due to minimal time close to cylinders.

6.3 Personnel Exposure

The number of workers required for cylinder shipment operations whose work may require close proximity to the cylinders is shown in Table 6-2. Close proximity is defined as within 6-inch of the cylinder wall which is assumed to be 1/4" thick (a few cylinders may have up to 5/8" walls) carbon steel ASTM A-516. Preliminary measurements have shown the exposure rate to be 3-5 mr/hr.

Table 6-3 shows the average annual exposure data per cylinder yard worker over the six year period beginning in 1990. The average worker at Portsmouth received a higher exposure because they performed more diverse tasks in other areas of plant operation, such as work in feed and withdrawal areas at the enrichment plant.

Table 6-3

Average Annual Exposure Data for Cylinder Yard Workers[1]

(mrem/year)

Year	Oak Ridge	Portsmouth	Paducah
1990	<1	114	16
1991	32	55	17
1992	75	114	45
1993	40	196	27
1994	92	170	34
1995	67	117	56

Table 6-4 shows the operational activities required to prepare the cylinders for shipment. It is assumed that the material of construction (i.e., the steel cylinder wall) is nominally 1/4 in. thick on average. The workers at risk of radiological exposure shown in Table 6-2 would be performing these operations as well as many other activities (both radiological and non-radiological) on the sites involved in the current management of the cylinders. Thus, only a fraction of their time is expected to be spent on the specific activities involved in preparing this cylinders for shipment.

[1]Data provided January 23, 1996, to Christopher R. Kline, United States Senate Committee on Governmental Affairs.

Table 6-4

Operational Activities Required to Prepare Cylinders for Shipment

Operation	Number of Workers/ Operation	Operations/ yr	Duration of Operation (hours)	Distance from Source (feet)	Person-hours
Pre-shipment Inspections/Testing/ Surveying	4	2,322	2	2 persons @ 1' 2 persons > 15'	18,576
Destacking (Raygo-Wagner)	4	2,322	½	2 persons @ 1' 2 persons > 15'	4,644
On-site transportation (straddle buggy)	2	2,322	1	1 persons @ 1' 1 person > 5'	4,644
Packaging Operations - Loading non-conforming cylinders into overcontainers[1]	4	1,455	4	3 persons @ 1' 1 persons > 15'	23,280
Loading cylinder or cylinder/overcontaine r onto truck or train	4	867	1	2 persons @ 1' 2 persons > 15'	3,468
Total					54,612

[1]When non-conforming cylinders are loaded into overcontainers, the overcontainer would first be placed on the conveyance so that only one lift of the UF_6 cylinder is needed.

7.0 WASTES AND EMISSIONS FROM PREPARATION FOR SHIPMENT

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emissions estimates from cylinder shipment operations. In general, the numbers are based on engineering judgement due to the pre-conceptual nature of the project.

7.1 Emissions

Assuming fuel consumption of 3-gal for loading a "normal" cylinder for shipment and 4-gal for loading and placing a "non-conforming" cylinder into overcontainers for shipment leads to the diesel fuel requirements as shown in Table 7-1.

Table 7-1

Annual Diesel Fuel Requirements (gal/yr)

Portsmouth	2,270
Paducah	5,214
K-25	940

Annual Air Emissions during Operation

Criteria Pollutants	Annual Emissions (lbs)		
	K-25	Paducah	Portsmouth
Sulfur Dioxide	30.0	160.0	70.0
Nitrogen Dioxide	12.4	68.9	30.0
Hydrocarbons	8.3	45.9	20.0
Carbon Monoxide	103.5	574.2	250.0
Particulate Matter	2.7	14.9	6.5

7.2 Solid and Liquid Wastes

No liquid wastes would be generated at the sites as a result of cylinder shipment activities. The only solid waste generated will be personal protective equipment (PPE) and wipes and rags which would be used to remove any surface contamination on cylinders before shipment. The treatability category for this low level waste would be combustible solid. It is assumed that bulk density for this material, when compacted, would be approximately 40 lb/ft^3.

Stress analysis indicates that a corroded cylinder with 1/3 of the body having an average wall thickness of 0.063 inches with the remainder of the cylinder having a wall thickness equal to or greater than 0.250 inches can be lifted safely.[1] It is assumed that very few cylinders would breach inside the overcontainer. Cylinders which are able to be lifted safely are expected to maintain containment in transportation. The depleted UF_6 contained within the annulus between the overcontainer and a leaking or breached UF_6 cylinder would be removed at the conversion facility using the separate nozzle, which has been included in the overcontainer preliminary design for this purpose. The overcontainer with the cylinder inside would then be shipped to the cylinder treatment facility for decontamination after being stored in the empty cylinder yard at the conversion facility. It is anticipated that the overcontainer would be reused after decontamination, and that the same amount of wash water would be adequate. Thus, the wash water volume at the cylinder treatment facility during the decontamination of the overcontainer would not increase. The U_3O_8 generated after the drying and pyrohydrolisis steps at the cylinder treatment facility is not expected to noticeably increase the total volume of this waste stream.

Table 7-2

LLW PPE Generated (FT^3/YR)	
Portsmouth	250
Paducah	450
K-25	100

No other mixed, hazardous, non-hazardous or recyclable wastes will be generated due to cylinder shipment operations.

[1]ERWM Programs Intersite Procedures Manual Number ERWM/EF-P2400, Subject: DOE 48 Inch Diameter UF_6 Cylinder Handling and Inspection

8.0 ACCIDENT ANALYSIS

Accidents related to the storage, transportation, and handling of depleted UF_6 in cylinders are found in the Supplemental Accident Analyses, Section 7 of the *Draft Engineering Analysis Report.*

9.0 SCHEDULE

Table 9-1 shows the preliminary project schedule. The schedule was developed to have the overcontainers delivered by the time a conversion facility would begin operations according to the preliminary project schedule for conversion facilities. It is anticipated that the overcontainer would be purchased from a commercial firm using a competitive bid process. The project schedule is subject to modification.

Table 9-1

Preliminary Project Schedule for Preparing Depleted UF_6 Cylinders for Shipment

Activity	Years After ROD
PEIS ROD - Long Term Management Strategy Selected	0
Depleted UF_6 Management Strategy Phase II - Site/Technology Selected	0-2
Preliminary Design of Overcontainer	2-4
Final Design of Overcontainer	4-5
Coordination of overcontainer concept and design with regulators	2-5
Revision of Applicable Transportation Regulations (e.g., ANSI N14.1, 49 CFR)	5-7
Procurement Process: Request for Proposals to Build Overcontainer Issued and Contract Awarded	7-9
Construction and Delivery of Overcontainers	9-11
Use Overcontainers to Ship Cylinders to Conversion or Storage Locations	11-31

APPENDIX A - Parametric Analysis

The following methodology was developed for defining changes in key parameters if the number of non-conforming cylinders (and hence the number of overcontainers) changes. In order to assess the costs and potential environmental impacts associated with preparing the depleted UF_6 cylinders for offsite shipment, estimates were made of the number of cylinders which may not meet transportation requirements over the shipping time frame. Review of 49 CFR, ANSI N14.1, and USEC-651 helped identify problems which may prevent offsite transportation. These problems fall into three categories: overfilled, overpressured, and substandard (below minimum wall thickness or other non-conformances).

Empirical estimates have been made of the number of cylinders which would not meet Department of Transportation regulations because they are either overpressured, overfilled, or substandard. These data points are preliminary estimates based on limited testing of cylinder pressures in the yards, review of accountability records and historical information, and a small number of cylinders which have been inspected for wall thinning using an ultrasonics monitoring program. Mathematical and statistical modeling have also been used to analyze the data from the inspections and monitoring program. The estimated number of non-conforming cylinders presented as the reference case below is used in the engineering and cost analyses, both for the overcontainer option presented in this section of the *Draft Engineering Analysis Report* (DEAR) and for the transfer facility option presented in Section 6.2. It is recognized that this preliminary estimate may change over time as estimates of the number of overpressured, overfilled, and substandard cylinders are refined and as cylinder conditions and regulatory requirements change.

The proposed low and high capacity cases were developed to reflect a range of possible cylinder conditions. The high capacity case assumes that none of the cylinders would meet the transportation requirements at the time of shipment and would either be placed in an overcontainer or transferred into other cylinders. The high capacity case may also be used to support an option for transferring all the UF_6 from the existing cylinders into new cylinders and storing it. The low capacity case is assumed to be half the base case.

	Reference Capacity Case		Low Capacity Case		High Capacity Case	
	Number of Non-conforming Cylinders	Number of Conformin g Cylinders	Number of Non-conforming Cylinders	Number of Conforming Cylinders	Number of Non-conforming Cylinders	Number of Conforming Cylinders
Paducah	19,200	9,151	9,600	18,751	28,351	0
Portsmouth	5,200	8,188	2,600	10,788	13,388	0
K-25	4,683	0	2,342	2,341	4,683	0
Total	29,083	17,339	14,542	31,880	46,422	0

As part of a parametric analysis, the impact and cost of a lower and a higher design throughput transfer facility was studied. The lower design throughput facility is based on a total capacity of 6,400 substandard cylinders, which is 1/3 of the reference case (19,200 substandard cylinders). The higher design throughput facility is based on a total capacity of 32,000 substandard cylinders, which is 5/3 of the reference case. In addition to the parametric analysis for the transfer facility, a methodology for defining changes in key parameters if the number of non-conforming cylinders (and hence the number of overcontainers) changes was developed.

The number of non-conforming cylinders presented in Section 6.1 (see Table 4-2) of the DEAR represents the reference case for preparing conforming cylinders and non-conforming cylinders for shipment using an overcontainer. The following methodology is used to derive the desired parametric cases:

1. Let N = Number of non-conforming cylinders at a particular site

   N_{base} = Number of non-conforming cylinders for the base case at a particular site, where N_{base} = 5,200 for Portsmouth, 19,200 for Paducah, and 4,683 for K-25.

   T = Total number of cylinders at a particular site

   O = Number of overcontainers for the base case at a particular site, where O = 113 for Portsmouth, 374 for Paducah, and 94 for K-25.

2. Number of overcontainers required at a particular site = $O + 0.02(N-N_{base})$

therefore, the number of overcontainer required at each site becomes:

Portsmouth = 9 + 0.02N

Paducah = 0.02N - 10

K-25 = 0.02N

Overcontainers at PORTS	Problem Cylinders at PGDP	Overcontainers at PGDP	Problem Cylinders at K-25	Overcontainers at K-25	Total Problem Cylinders	Total Number of Overcontainers
36	2,835	47	468	9	4,642	92
63	5,670	103	937	19	9,284	185
89	8,505	160	1,405	28	13,927	278
116	11,340	217	1,873	37	18,569	370
143	14,176	274	2,342	47	23,211	463
170	17,011	330	2,810	56	27,853	556
196	19,846	387	3,278	66	32,495	649
223	22,681	444	3,746	75	37,138	742
250	25,516	500	4,215	84	41,780	835
277	28,351	557	4,683	94	46,422	927

The number of non-conforming cylinders vs the number of overcontainers using 10% increments and assuming between 10 and 100% of the cylinders had non-conforming features is given in the table above.

3. Assuming a fuel consumption of 3-gal for loading a "normal" cylinder and 4-gal for loading a "non-conforming" cylinder, the annual diesel fuel requirements may be estimated by the following formula:

Total diesel fuel required (gal) = 4N + 3(T-N) = N + 3T

Annual diesel fuel required (gal/yr) = 0.05N + 0.15T

4. Annual air emissions as given in Table 7-1 of Section 6.1 of the DEAR are as follows:

Criteria Pollutants	Annual Emissions (lbs)		
	K-25	Paducah	Portsmouth
Sulfur Dioxide	30.0	160.0	70.0
Nitrogen Dioxide	12.4	68.9	30.0
Hydrocarbons	8.3	45.9	20.0
Carbon Monoxide	103.5	574.2	250.0
Particulate Matter	2.7	14.9	6.5

These values can be scaled by multiplying the base case given above by the following factors:

Portsmouth air emissions = (0.05N + 0.15T)/2,270

Paducah air emissions = (0.05N + 0.15T)/5,214

K-25 air emissions = (0.05N + 0.15T)/940

5. The only waste generated will be personal protective equipment (P.P.E.) and wipes and rags which would be used to remove any surface contamination on cylinders before shipment. This surface contamination removal may be necessary whether or not the cylinders are placed in an overcontainer and is assumed to be independent of the number of non-conforming cylinders. The values in Table 7-2 of Section 6.1 of the DEAR are therefore constant.

6. Table 6-4 has been modified as follows to show operational activities required to prepare cylinders for shipment as a function of the number of non-conforming cylinders. Only the packaging and loading operations are affected.

Operational Activities Required to Prepare Cylinders for Shipment

Operation	Number of Workers/ Operation	Operations/ yr	Duration of Operation (hours)	Distance from Source (feet)	Person-hours
Pre-shipment Inspections/Testing/ Surveying	4	2,322	2	2 persons @ 1' 2 persons > 15'	18,576
Destacking (Raygo-Wagner)	4	2,322	½	2 persons @ 1' 2 persons > 15'	4,644
On-site transportation (straddle buggy)	2	2,322	1	1 persons @ 1' 1 person > 5'	4,644
Packaging Operations - Loading non-conforming cylinders into overcontainers[1]	4	N*	4	3 persons @ 1' 1 persons > 15'	16N
Loading cylinder onto truck or train	4	2,322-N	1	2 persons @ 1' 2 persons > 15'	9,288 - 4N
Total					37,152+12N

*N=1,455 for the base case.

[1]When non-conforming cylinders are loaded into overcontainers, the overcontainers would first be placed on the conveyance so that only one lift of the UF_6 cylinder is needed.

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Section 6.2

Depleted Uranium Hexafluoride Transfer Facility

Draft Engineering Analysis Report
Depleted Uranium Hexafluoride Management Program

Section 6.2
Depleted Uranium Hexafluoride Transfer Facility

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Preface

This report provides the EIS data input for a facility to transfer UF_6 to new cylinders from existing "problem" cylinders, which do not meet DOT regulations for off-site shipment. The problem areas are overpressured cylinders, overfilled cylinders, and otherwise substandard cylinders (in particular, cylinders having a below minimum wall thickness). The facility is designed to transfer UF_6 from 19,200 cylinders over 20 years. This projected number of problem cylinders, estimated by the Oak Ridge National Laboratory, is what would exist at the Paducah, Kentucky Gaseous Diffusion site in 2020. Cylinder problem areas overlap and, for conservatism, the facility is designed to transfer the entire contents of all problem cylinders to new cylinders. The cylinders are heated by forced hot air in an autoclave. The sublimed UF_6 gas is compressed, liquefied in a condenser, and drained into a new, empty cylinder.

Process Summary

The facility described in this report is used to transfer depleted uranium hexafluoride (UF_6) from existing cylinders to new cylinders. The facility is based on a total capacity of 19,200 substandard, existing cylinders. Of these, 5,000 are overfilled, 2,500 are over-pressure, and 11,700 are otherwise substandard. The facility is designed to transfer the UF_6 over 20 years for a rate of 960 cylinders per year.

A one month supply of filled existing cylinders is stored on site. These are transferred by truck to the Process Building, where they are loaded into autoclaves and emptied by vaporization of the contents. The UF_6 is condensed and loaded into new cylinders in the Process Building. A one-month supply of empty cylinders and newly filled cylinders are maintained on site. The empty, waste cylinders are transferred to an Outgoing Empty Cylinder Storage Building, with a three month capacity, for subsequent transfer and disposition.

1.0 DUF_6 Transfer Facility - Missions, Assumptions and Design Basis

1.1 MISSION

The Depleted Uranium Hexafluoride (DUF_6) Transfer Facility transfers depleted UF_6 from the existing, substandard storage cylinders to new storage cylinders for further processing at other facilities.

1.2 ASSUMPTIONS & DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The transfer facility is assumed to be a stand-alone, "greenfield" facility. For purposes of the parametric and environmental data for this PDEIS, this site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3. However, it is also assumed that this facility or a similar facility will ultimately be located and operated at one or all of the existing gaseous diffusion plants.
- The facility will receive existing, incoming 14 ton DUF_6 cylinders by truck or rail car. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of: incoming (over-filled, over-pressured, or substandard), full cylinders; incoming (new), empty cylinders; and outgoing (new), full cylinders is provided. Three months storage of outgoing, empty cylinders is also provided.
- The DUF_6 transferred to the new cylinders is assumed to be chemically pure, and the assumed average isotopic composition is: 0.001% U-234, 0.25% U-235, and 99. 75% U-238. The corresponding specific activity (alpha) is $4x10^{-7}$ Ci/g DU. In the UF_6 filled cylinder, the short lived daughter products of U-238, Th-234 and Pa-234 are in the same equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is assumed to be 7,000 hours based on a plant availability factor of 0.8.
- Twelve air heated autoclaves are provided to empty the incoming, full cylinders. There are three parallel trains of UF_6 transfer and filling equipment.

- Of the total 19,200 incoming, full cylinders assumed to be processed through the facility, 11,700 are assumed to be substandard, 5,000 are assumed to be overfilled and 2,500 are assumed to be over-pressured. For the purposes of this PDEIS, it is assumed that all cylinders will have their entire contents transferred, leaving a maximum of 10 kg of heel in the cylinder.
- An overfilled cylinder is assumed to contain 400 lb of excess UF_6. The vapor space of overfilled or substandard cylinders is assumed to contain 0.17 atm UF_6, 0.1 atm HF, and 0.2 atm air. The vapor space of overpressured cylinders is assumed to contain 0.17 atm UF_6, 0.5 atm HF, and 1.0 atm air.
- For this study, it is assumed that the outgoing, empty DUF_6 cylinders are shipped to an off-site cylinder treatment facility for the removal of the residual UF_6 (heels).
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- Outgoing, full cylinders will be shipped to another facility for DUF_6 processing.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities" as defined in DOE Order 6430. 1A and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- Outgoing Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility including the following:

- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 960 cylinders annually. The DUF_6 inventory of 19,200 cylinders would be transferred within a 20 year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

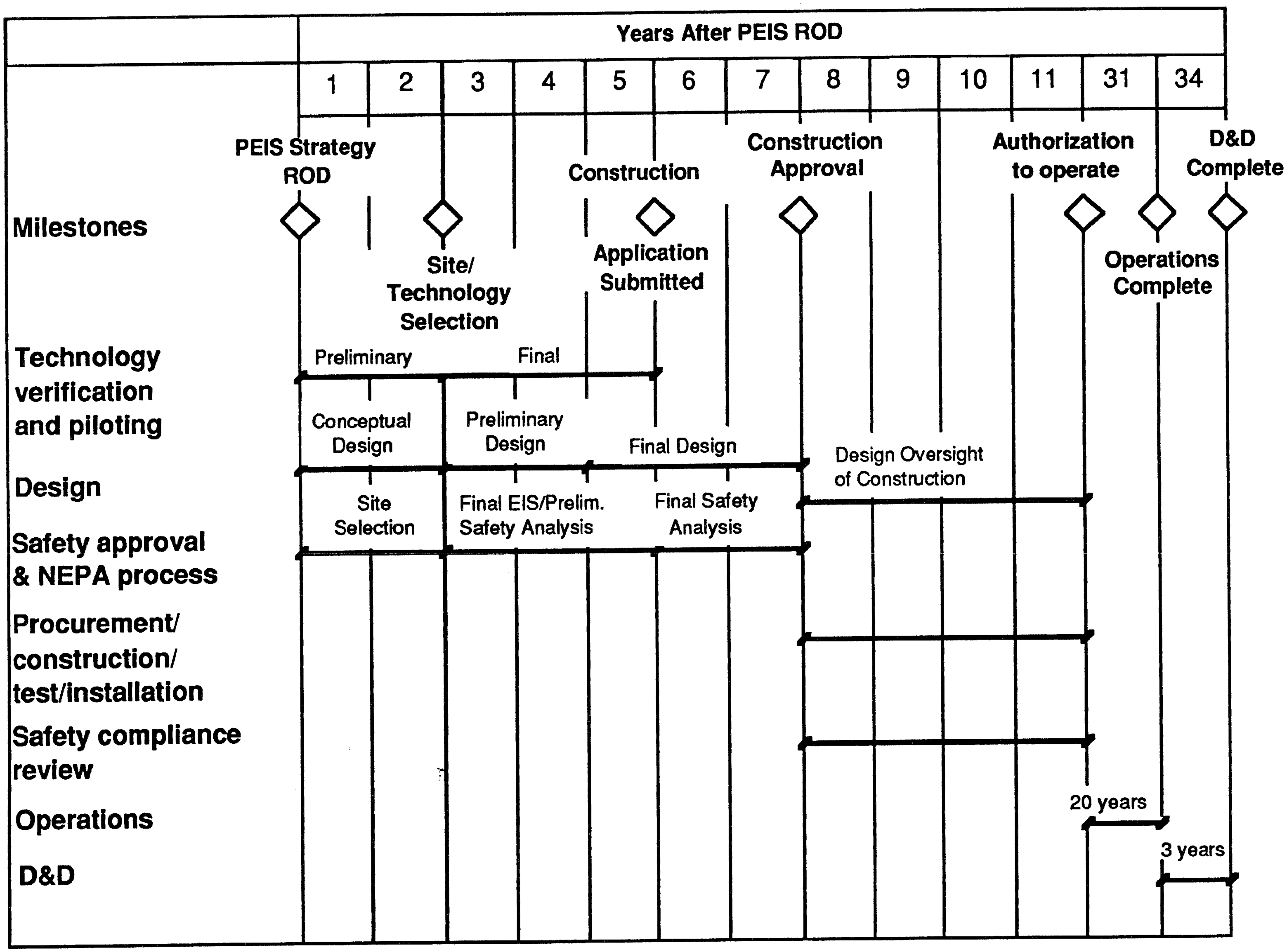

Figure 1-1 Preliminary Project Schedule

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502, *Environmental Impact Statement,* 10 CFR 1021, *National Environmental Policy Act Implementing Procedures* (for DOE) and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program.*

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria.* Applicable codes, standards, guidelines, etc. as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable NRC regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards;* DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations;* and DOE Order 5440.1C, *National Environmental Policy Act.* Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection.*

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements;* the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and non radioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Non radioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process and facilities design include the following:

- The total number of substandard existing cylinders in the DOE stockpile has not been determined at this time. The assumed total number of 19,200 cylinders to be processed in the facility requires verification to finalize the required facility throughput.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- Air heated autoclaves have been utilized to assure safe vaporization of the UF_6 from the incoming substandard cylinders. It was assumed that use of steam heated units could result in a steam/UF_6 reaction due to inleakage of steam in a substandard cylinder. Since design of these air heated units is preliminary, the number required for the design throughput may change during later design phases.
- Due to the pre-conceptual nature of the facility design, development of process and support system equipment and component design details as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment/system/facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.

2.0 DUF_6 Transfer Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The facility described in this report is used to transfer depleted uranium hexafluoride (UF_6) from existing cylinders to new cylinders. An overall cylinder transfer diagram is shown on Figure 2-1.

The facility is based on a total capacity of 19,200 incoming, full cylinders. Of these, 5,000 are overfilled, 2,500 are over-pressure, and 11,700 are otherwise substandard. All cylinders are assumed to be DOT-approved containers (Model 48G or equivalent) with a nominal capacity of 14 tons, containing 13.42 tons each except for the overfilled. Overfilled cylinders are assumed to each contain an excess of 400 pounds, so that 75 cylinders are required to contain the transferred overfill. The facility is designed to transfer the UF_6 over 20 years for a rate of 960 cylinders per year.

A one month supply of incoming, filled existing cylinders is stored on site. These are transferred by truck to the Process Building, where they are loaded in autoclaves by crane. These autoclaves are closed and the cylinders are emptied of the UF_6 by vaporization. The UF_6 is condensed and loaded into new cylinders. A one-month supply of incoming, empty cylinders and outgoing, filled cylinders are maintained on site. The empty, outgoing cylinders are transferred by a straddle carrier to an Outgoing, Empty Cylinder Storage Building, with a three month capacity, for subsequent transfer and disposition.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings, including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

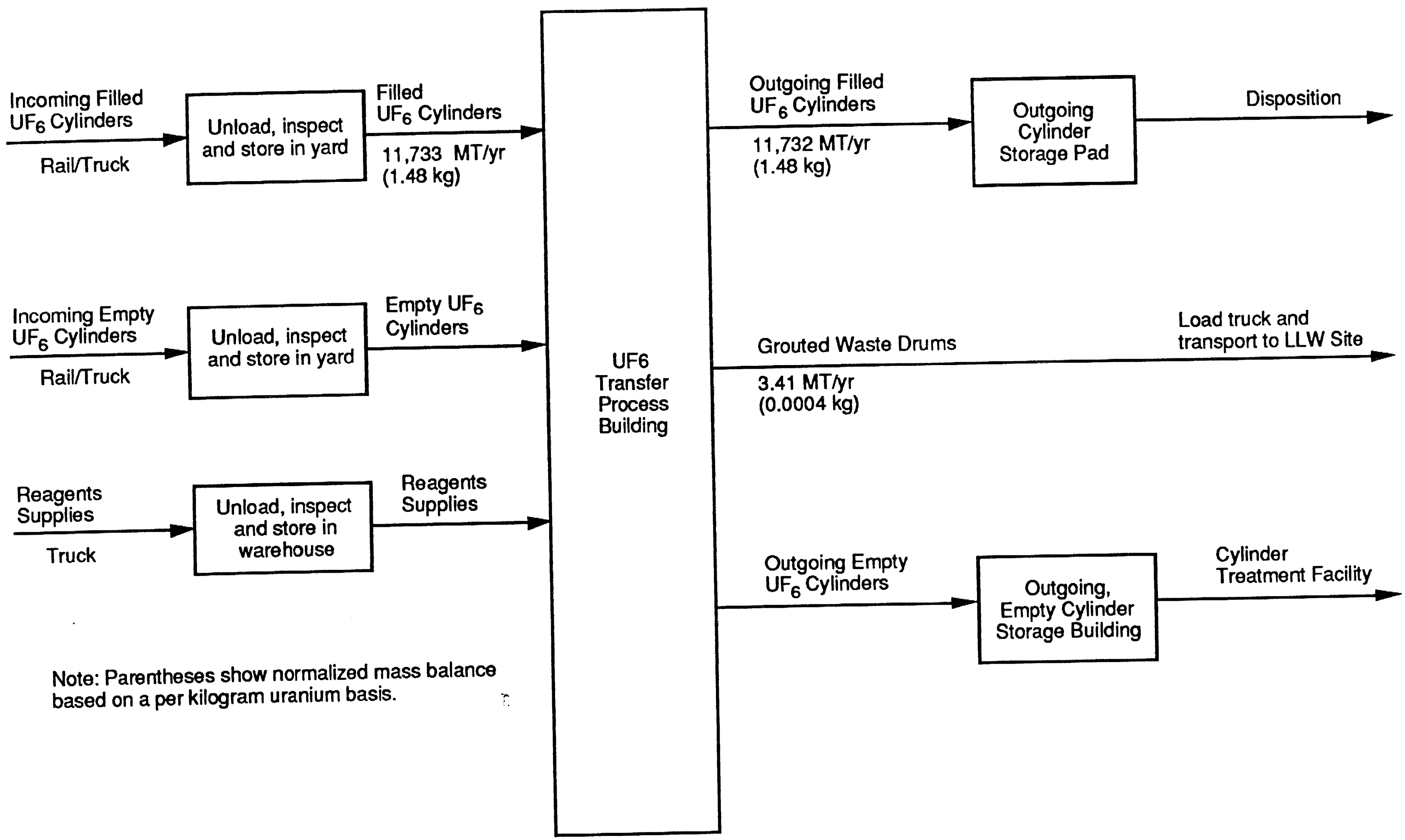

Figure 2-1 UF6 Transfer Material Flow Diagram

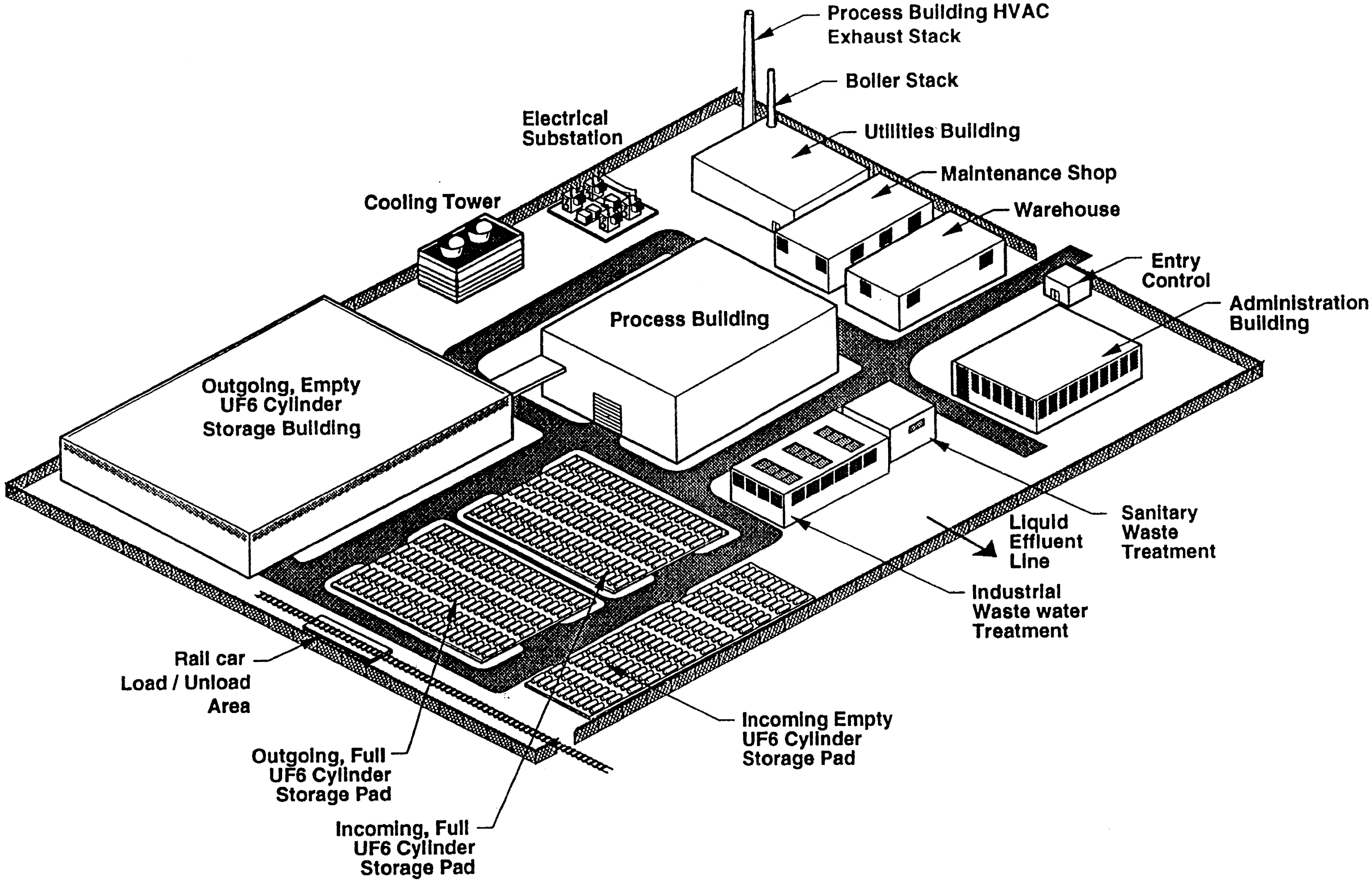

Figure 2-2 Plot Plan
DUF6 Transfer Facility

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	35,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
Outgoing Empty Cylinder Storage Building	51,000	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	6,000	1	No	Yes	General	Metal Frame
Administration Building	8,000	1	No	No	General	Metal Frame
Maintenance Shop	5,000	1	No	Yes	General	Metal Frame
Warehouse	5,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	1,500	1	No	No	General	Metal Frame
Cooling Tower	4,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The Process Building layout, section and equipment arrangement is shown in Figures 2-3, 2-4 and 2-5. The building is comprised of two parallel high bays bordered on three sides by a two story section of support facilities

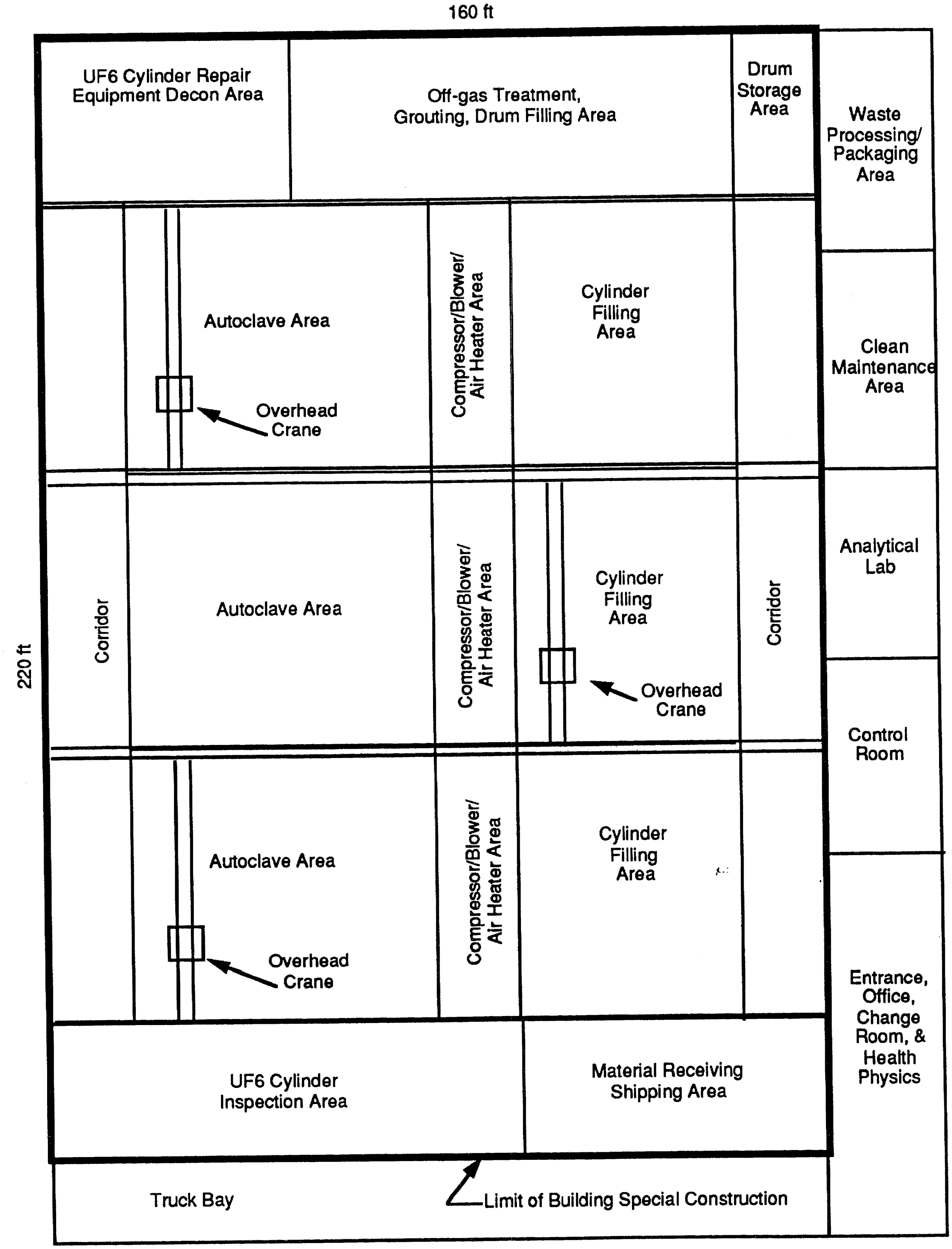

FIGURE 2-3
PROCESS BUILDING LAYOUT
UF6 TRANSFER FACILITY

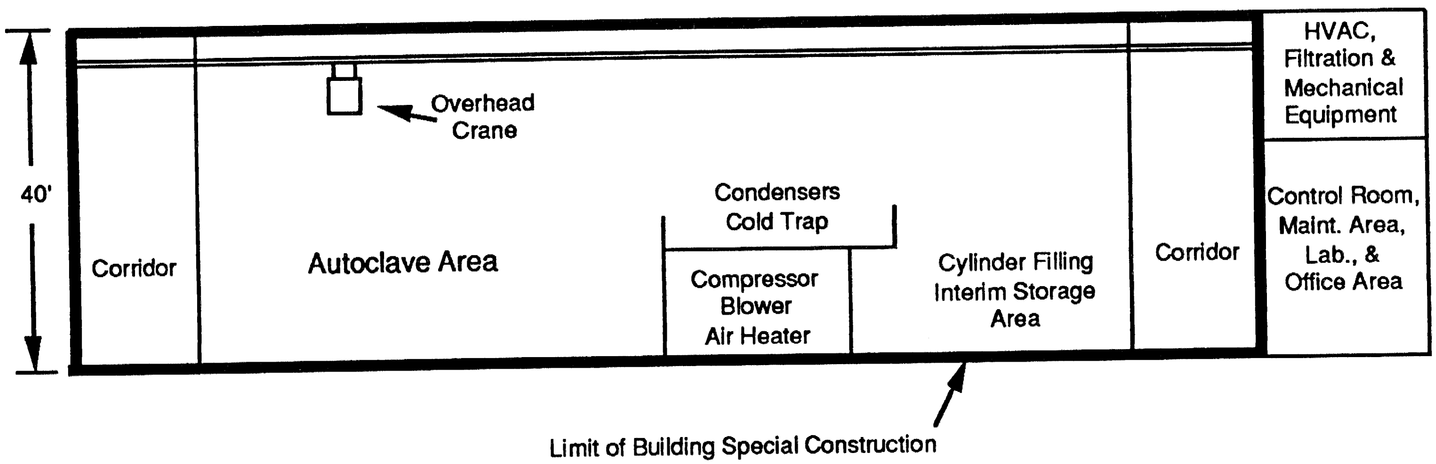

FIGURE 2-4 PROCESS BUILDING SECTION
UF6 CYLINDER TRANSFER FACILITY

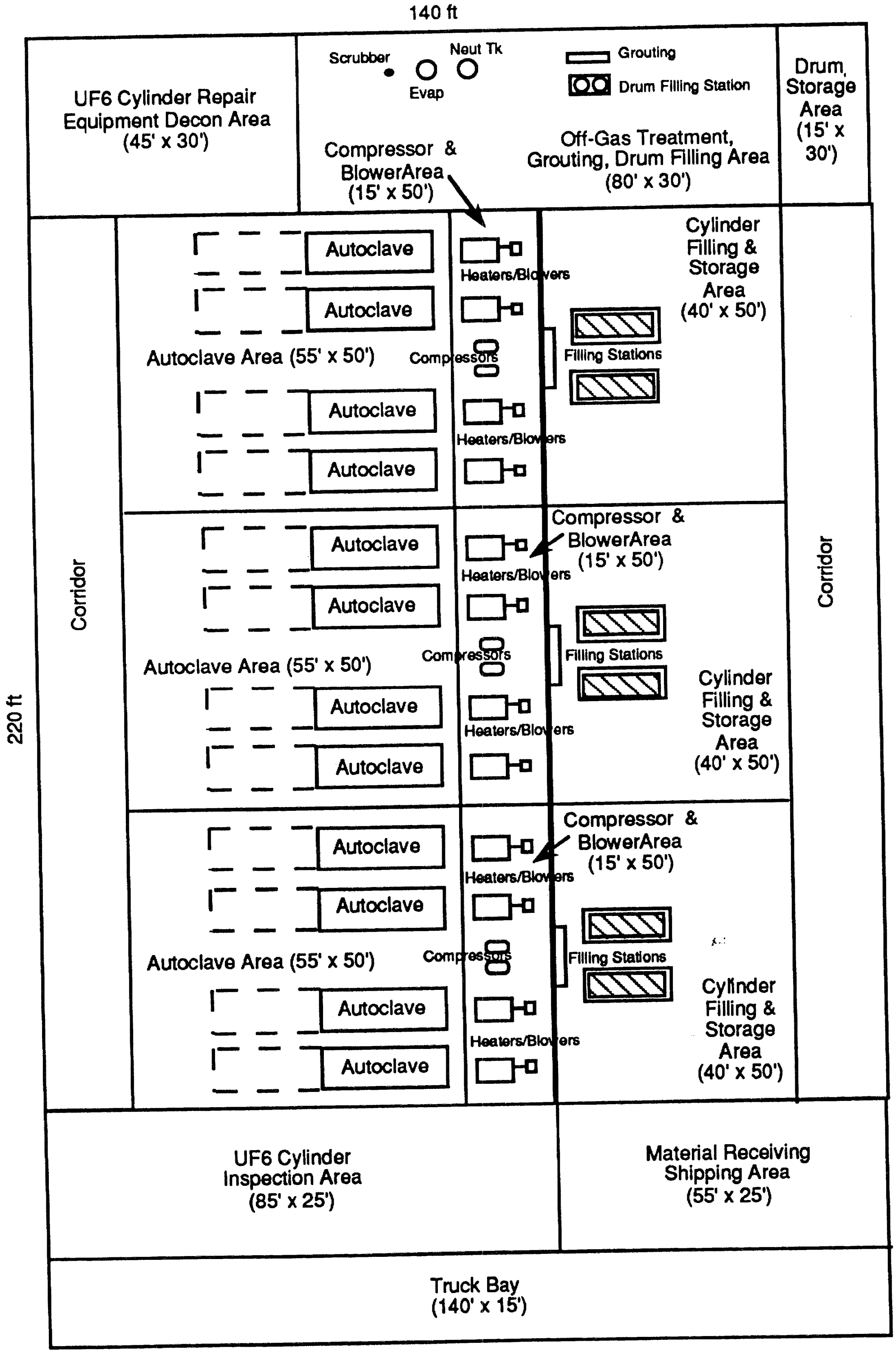

FIGURE 2-5
PROCESS EQUIPMENT ARRANGEMENT
UF6 TRANSFER FACILITY

and utility areas. The building is constructed of reinforced concrete and classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of UF_6 are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The high bay areas contain the main processing functions with three autoclave bays which feed the parallel high bay which contains the cylinder filling equipment. The remaining support facilities portion of the building contains the shipping / receiving areas, the cylinder inspection area, the cylinder repair area, the off-gas treatment area, personnel entry control, change rooms, offices and health physics areas, an analytical laboratory and facility control room, and a maintenance area. The second floor primarily contains mechanical support systems such as the heating, ventilating and air conditioning systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

The autoclave and cylinder fill areas are large bays in the Process Building. Each of the three bays contain a stand alone train for the transfer of the UF_6. Each of the bays can be isolated from the other two bays in an upset condition without disrupting operations in the unaffected bays. Sufficient room has been provided for in each bay to do minor repair of cylinders or as a laydown area for equipment for major recovery operations.

2.1.3.2 Outgoing Empty Cylinder Storage Building

The Outgoing Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.3 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the Transfer Facility includes the following facilities and systems: (Facilities are shown on Site Map Fig. 3-1.)

A metal frame general use Utilities Building housing raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal frame or masonry Administration Building to house the facility support personnel.

A metal framed general use Maintenance Shops Building for housing clean maintenance and repair shops.

An 6.1 MM BTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 610 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility for the receipt, treatment and disposal of non-radiological contaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility with a capacity of approximately 3,000 gpd.

Compressed air systems including plant air, instrument air and breathing air. A single set of two redundant 300 cfm reciprocating air compressors provide compressed air to both systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in desiccant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

Building heating, ventilating and air conditioning (HVAC) systems use a central chilled water system for building cooling. Three 50% capacity, 220 ton centrifugal water chillers, and three 350 gpm circulating pumps are provided.

A steel stack serving the Process Building HVAC exhaust systems is provided. The steam plant boiler vents through a dedicated steel stack. (See Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 9,200 lb/hr of 50 psig steam which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration and chlorination. The demineralized water is used in the process and for steam boiler feedwater (See also Figure 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a design capacity of 1,400 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 300 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas which require special lighting for nightime operation include the UF_6 cylinder storage pad areas, the rail car spur area, the utility area and the site entry control area.

Site security fencing as shown on Site Map, Figure 3-1, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventive systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSC's) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety class systems, structures, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Transfer Areas
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1.2 Tornadoes

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Floods

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480.7. This criteria requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

2.2.3 Materials Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the DUF_6 cylinders, piping, and the facility ventilation systems. Autoclaves which contain the cylinders during the vaporization and transfer process are also a confinement barrier.

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will utilize a combination of dividing the buildings into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breached or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing autoclaves, and other uranium processing areas. The ventilation system for these rooms utilize once-through air flow to prevent recirculation of contaminants, double filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard.

The remainder of the Process Building will be zone 3, including grouting areas, waste processing areas, and support system areas. These rooms will be maintained at a positive pressure with respect to the rest of the building, but slightly negative with respect to the outside. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on the Site Map, Figure 3-1. This figure also shows the effluent air release point ventilation and boiler stacks.

Table 2-3 summarizes the facility effluent air release points.

Table 2-3 Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Process Building Exhaust	100	85	80	60
Boiler	100	18	500	60

3.0 Site Map and Land Use Requirements

3.1 Site Map

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to and from the facility. Air emission points from the Process Building exhaust stack and the facility's boiler stack are shown. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 Land Area Requirements During Operation

As shown in Figure 3-1, the total land area required during operations is approximately 437,000 ft^2 or about 10 acres.

3.3 Land Area Requirements During Construction

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 14.3 acres. Construction areas required in addition to the site structures and facilities include:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

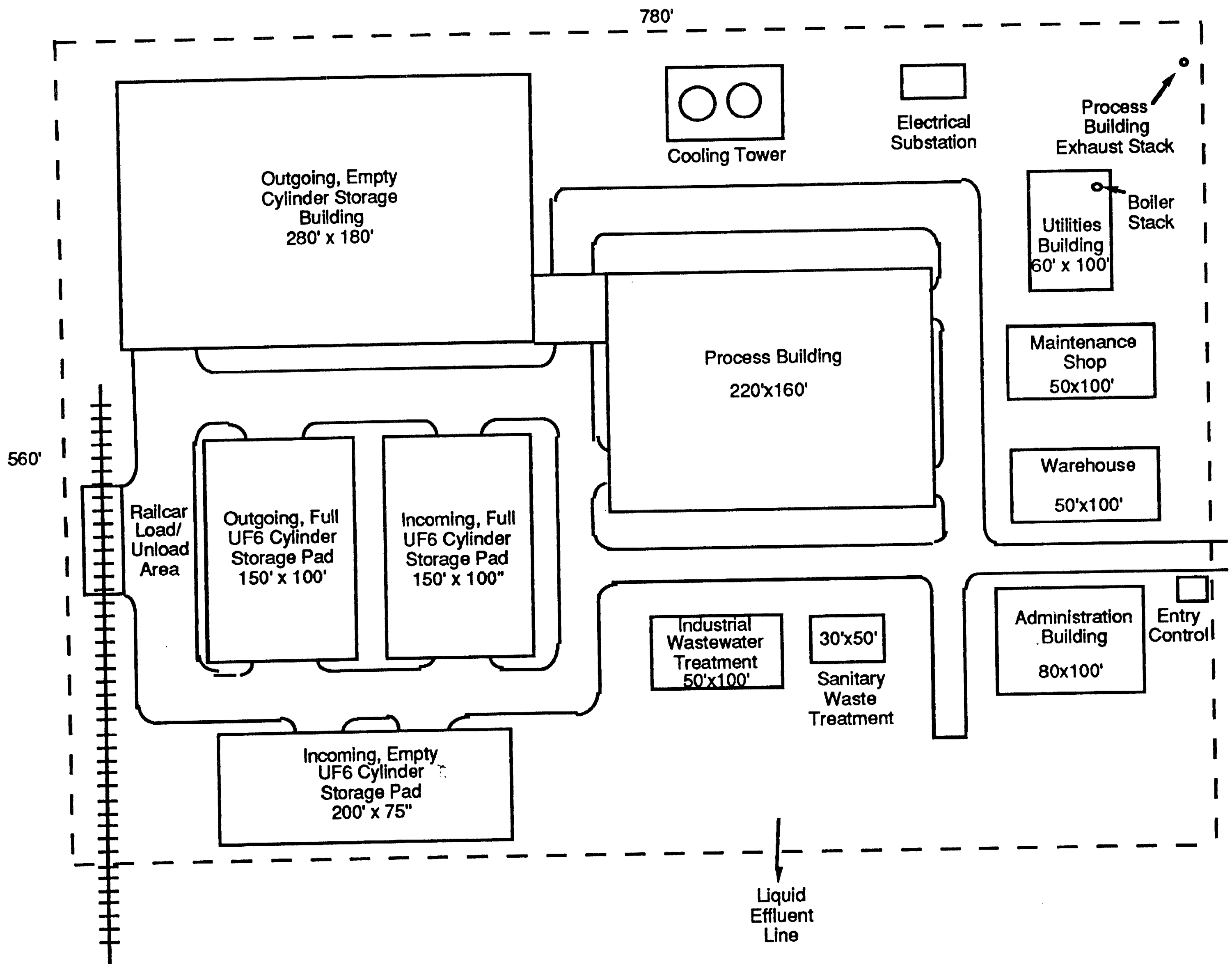

FIGURE 3-1 SITE MAP
DUF_6 TRANSFER FACILITY

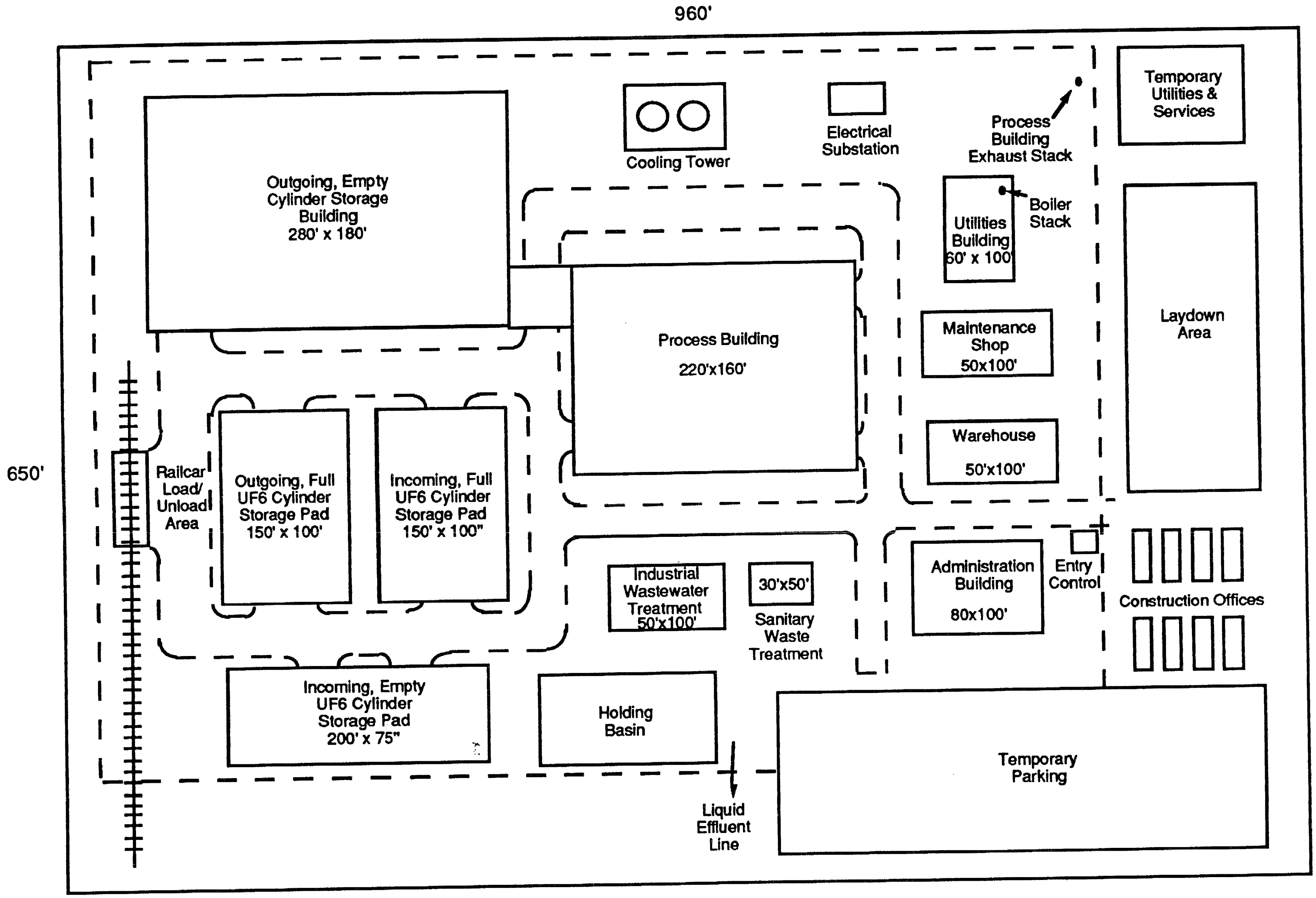

FIGURE 3-2 SITE MAP DURING CONSTRUCTION
DUF_6 TRANSFER FACILITY

4.0 Process Description

Depleted uranium hexafluoride (UF_6) in incoming, full cylinders is transferred into new, incoming, empty cylinders for transport. The UF_6 transfer process is shown in Figures 4-1 and 4-2. Annual and hourly material balances are given in Appendix A.

The UF_6 to be transferred is contained in cylinders that are either substandard, overfilled or overpressured. The cylinders are loaded into autoclaves and heated to sublime UF_6 gas from the solid. The UF_6 gas is compressed and flows to a condenser, which condenses most of the UF_6. The liquid UF_6 drains into a new, empty cylinder. The condenser off-gas flows to a cold trap, which desublimes additional UF_6. When a cold trap is full, it is heated to melt the UF_6, which drains into the cylinder.

The cold trap off-gas, which includes HF, air and UF_6, is contacted with a potassium hydroxide (KOH) solution in a scrubber to remove HF and remaining traces of UF_6. The off-gas is then filtered and discharged to atmosphere.

Periodically, the scrub solution is discharged and replaced with fresh KOH solution. The spent scrub solution is neutralized with sulfuric acid and evaporated to remove excess water. The slurry is mixed with cement in a drum to form a grout, which is disposed of as low level waste.

There are three parallel trains of UF_6 transfer equipment, which include the autoclaves, compressors, condensers, cold traps and cylinder fill stations. One off-gas scrubbing system treats the off-gas from the three trains. The UF_6 transfer process is based on practices in gaseous diffusion plants and UF_6 production facilities.

4.1 UF_6 Transfer System

Autoclaves and compressors are used to vaporize the UF_6 and to empty the existing, incoming cylinders. Condensers and cold traps are used to collect the UF_6, which is drained as a liquid into empty cylinders. The system is shown in Figure 4-3.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported to the Process Building, where they are inspected and repaired if necessary. The cylinder is placed in an electrically-heated, hot air autoclave and connected to a compressor suction line. Hot air at 140°F heats the cylinder and the compressor maintains a vacuum inside the cylinder, which causes the UF_6 to sublime at about 123°F and 10 psia. Assuming an emptying rate of the cylinders of 370 lb/hr, ten autoclaves feed simultaneously to provide the required plant capacity.

The sublimation process avoids pressurization of the cylinders and formation of liquid UF_6 inside cylinders. This reduces the possibility of a

Note: Parentheses show normalized mass balance based on a per kilogram uranium basis.

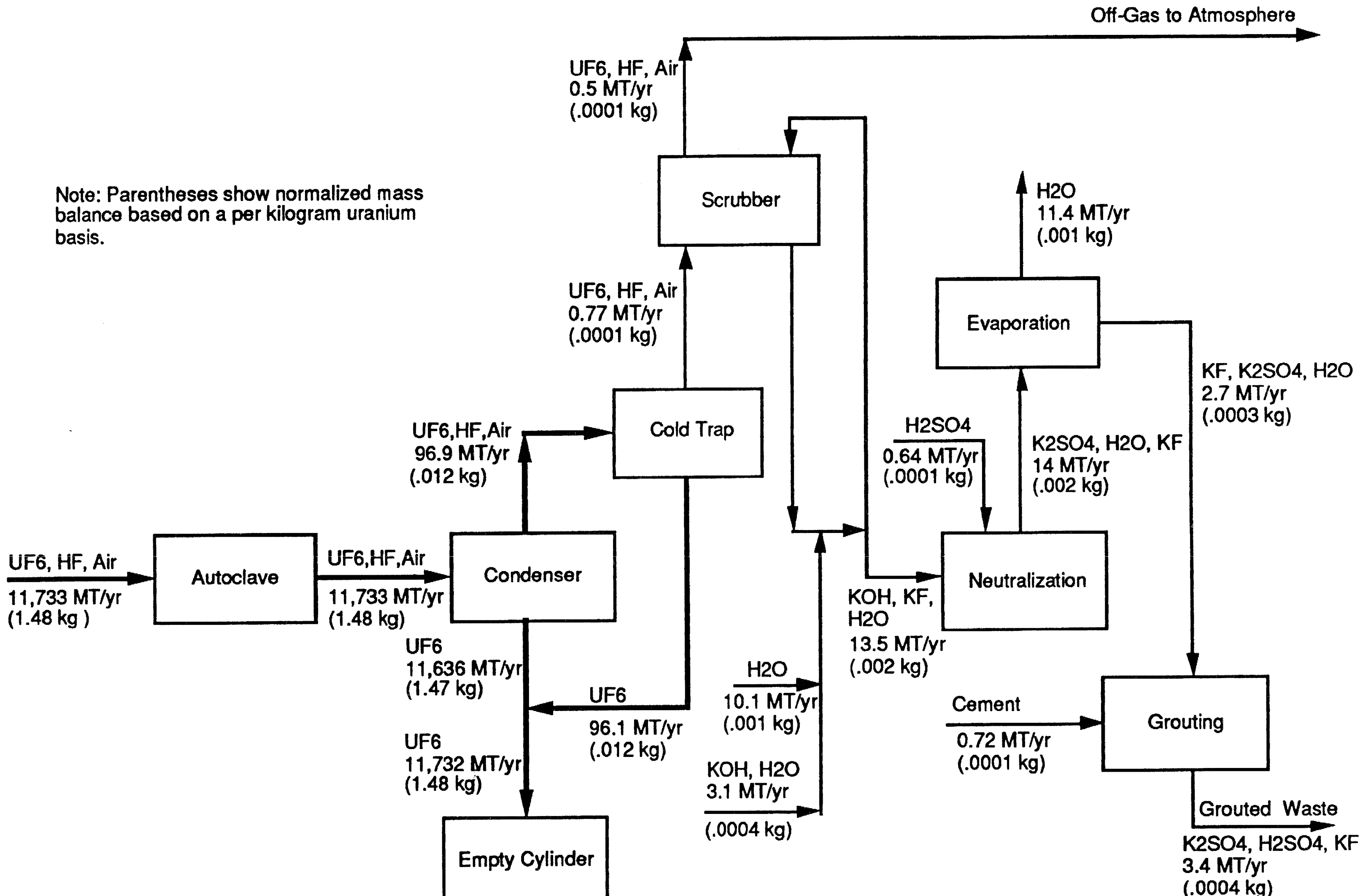

Figure 4-1 UF6 Transfer Block Flow Diagram

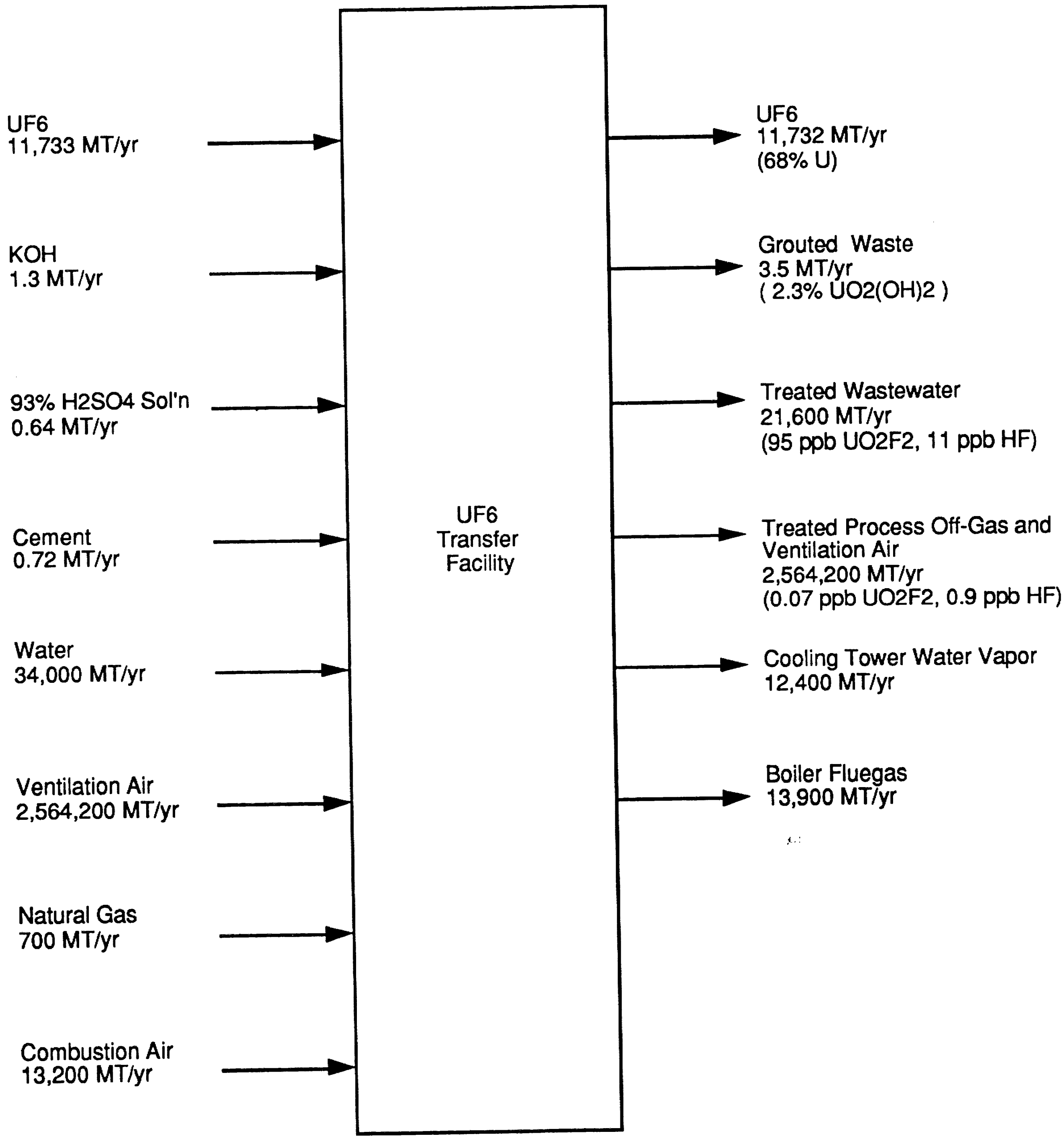

Figure 4-2 UF6 Transfer Facility Input / Output Diagram

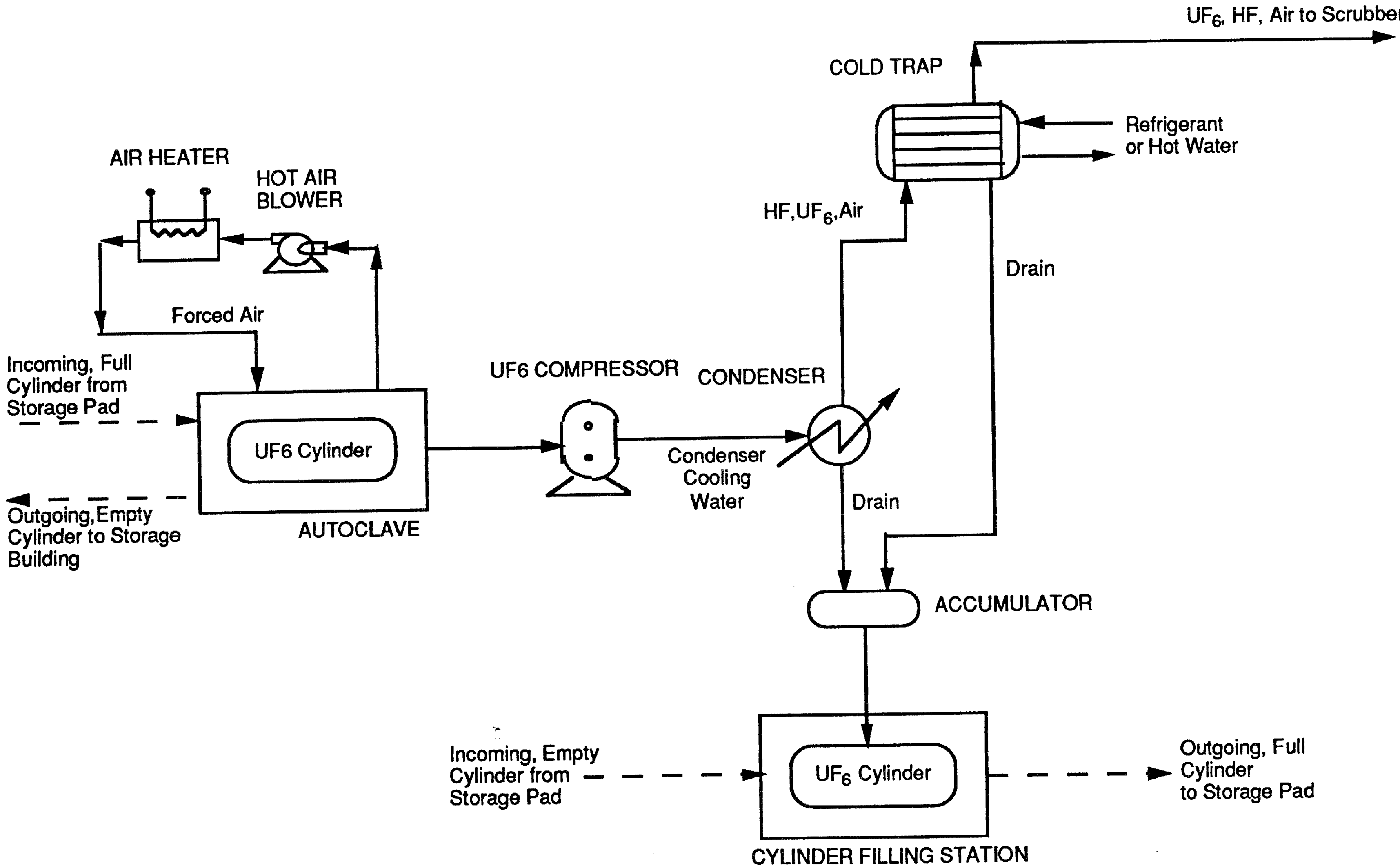

Figure 4-3 UF6 Transfer Process Flow Diagram

cylinder rupturing and should a leak occur, the amount of UF_6 leaked into the autoclave would be small. In the unlikely event of a cylinder rupture, an HF sensor that monitors the autoclave air would alarm. The autoclave would be shut down and the cylinder would be removed and repaired. The autoclave would then be decontaminated.

When the cylinder is nearly empty, a backing compressor evacuates the cylinder to 1 psia to minimize the heel in the cylinder. The backing compressor discharges at 10 psia to the main compressor inlet.

The empty cylinder is transported to the Outgoing Empty Cylinder Storage Building. The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site. Special handling equipment and procedures are used to reduce radiation exposure to workers.

The UF_6 gas is compressed to about 50 psia and flows to a condenser operating at 160°F. The majority of the UF_6 condenses and drains to an accumulator, which discharges to the cylinder filling station.

The remaining UF_6 and uncondensed gases, primarily air and HF, flow to a cold trap operating at -55°F, where the UF_6 desublimes and is collected as a solid. The exhaust from the cold trap is routed to the off-gas treatment system. The cold traps are operated in pairs, with one trap on-line while the other is being regenerated off-line. When a cold trap is full, it is taken off-line and heated to 160°F. The trap pressurizes, the solid UF_6 melts, and liquid UF_6 flows to the accumulator, which drains to the cylinder filling station. The traps are sized to be regenerated once every 24 hours.

The cylinder filling station has positions for two 14-ton cylinders. One cylinder is being filled, while the other is being connected or disconnected. The fill stations have load cells to determine when cylinder filling is complete. The cylinders are evacuated prior to filling, and the fill lines are purged and evacuated after filling. After filling, the cylinders are disconnected and stored in the fill area for five days to allow the UF_6 to cool and solidify. The filled cylinders are then moved to the outdoor storage pad for shipment off-site.

There are three parallel trains of UF_6 transfer equipment. Each train consists of four autoclaves, two compressors (one is a spare), two backing compressors (one is a spare), one condenser, two cold traps, one accumulator and one cylinder fill station.

Preliminary major equipment includes 12 autoclaves, six 5 hp compressors, two 0.5 hp backing compressors, three 10 in. diameter by 6 ft long Monel condensers, six 1 ft diameter by 8 ft long Monel cold traps and 3 cylinder filling stations.

4.2 Off-Gas Scrubbing System

Off-gas from the cold traps is treated in a scrubber to reduce atmospheric release of HF and UF_6 to acceptable levels. The system is shown in Figure 4-4.

The off-gas enters a packed column, where it is scrubbed with a 10 wt% potassium hydroxide (KOH) solution. The HF is removed by the reaction HF + KOH ---> KF + H_2O. The remaining traces of UF_6 are removed by the reaction UF_6 + 6KOH ---> $UO_2(OH)_2$ + 6KF + $2H_2O$. The off-gas is then filtered and discharged to atmosphere.

Periodically, the scrub solution is discharged and replaced with fresh KOH solution. The spent scrub solution, containing 5 wt% KOH, is transferred to a neutralization tank, where sulfuric acid (H_2SO_4) is added. The chemical reaction is 2KOH + H_2SO_4 ---> K_2SO_4 + $2H_2O$. The neutralized solution is transferred to the evaporation system.

Major equipment includes a 1 ft diameter by 10 ft high Monel HF scrubber with plastic packing, a 3 ft diameter by 3 ft high 100 gallon Monel neutralization tank and associated pumps.

4.3 Evaporation and Grouting System

The neutralized scrubber solution is evaporated and grouted. The system is shown in Figure 4-5.

The neutralized scrubber solution is transferred to a steam-heated evaporator, where it is concentrated to remove excess water. The condensate from evaporation is collected and sent to waste treatment. The evaporated slurry is mixed with cement in a drum filling station. The drum is sealed and mixed by tumbling to form a grout. The composition of the grout is 30.5% K_2SO_4, 29% H_2O, 21% cement, 17.2% KF and 2.3% $UO_2(OH)_2$. After solidification, the waste drums are stored for shipment to a low level waste disposal site.

Major equipment includes a 3 ft diameter by 3 ft high (100 gallon) carbon steel evaporator with heating coil, a drum filling station, and a drum tumbling station.

4.4 UF_6 Cylinder Handling Systems

Incoming DUF_6 cylinders (both empty and full) will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into the storage position. When the cylinders are transported to the Process Building, the yard crane will again load the cylinder on a cart, which is transported to the Process Building. Once the cylinders are in the autoclave or cylinder fill areas of the Process Building, the cylinders will be handled by an overhead bridge crane located in each of the autoclave-fill bays of the Process Building.

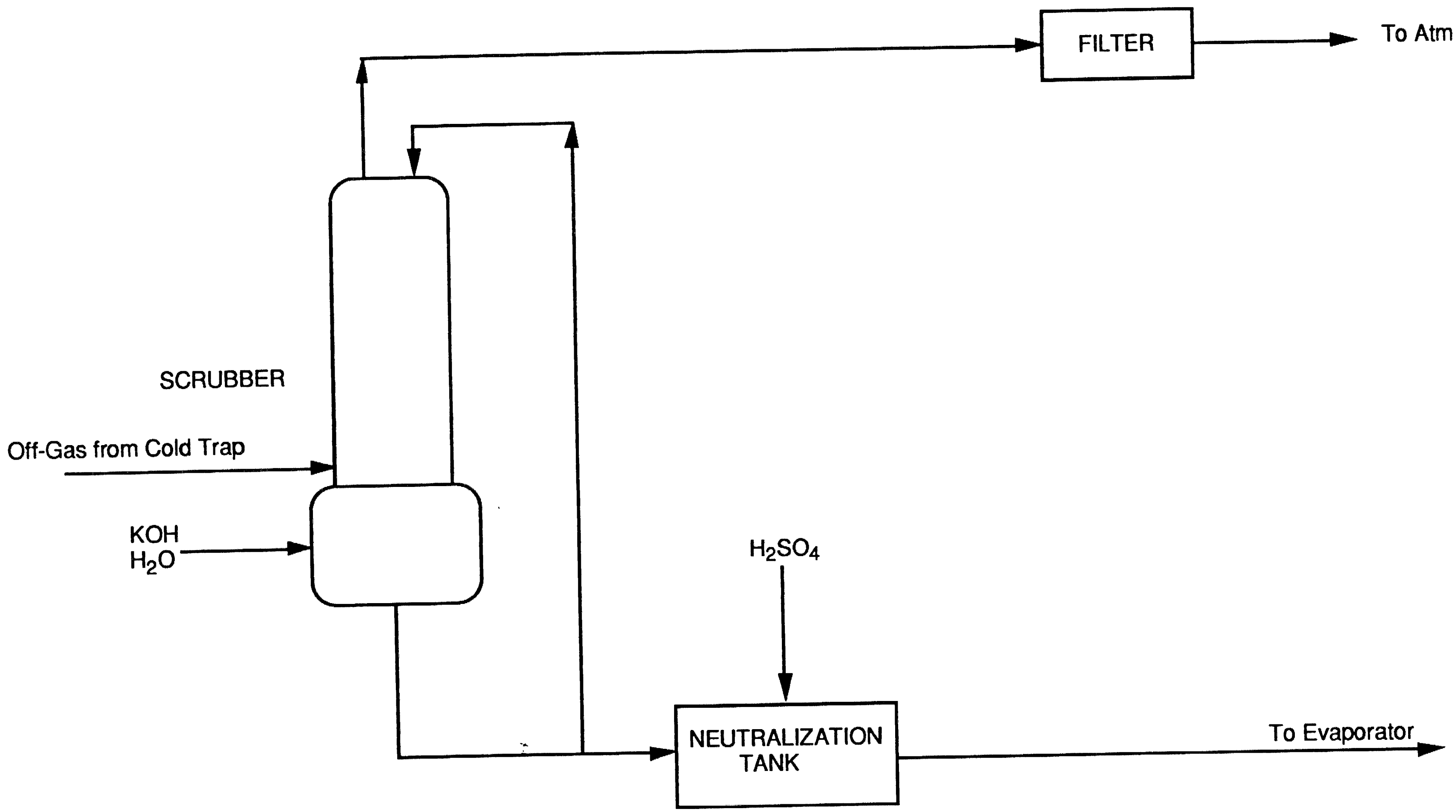

Figure 4-4 Off-Gas Scrubber Process Flow Diagram

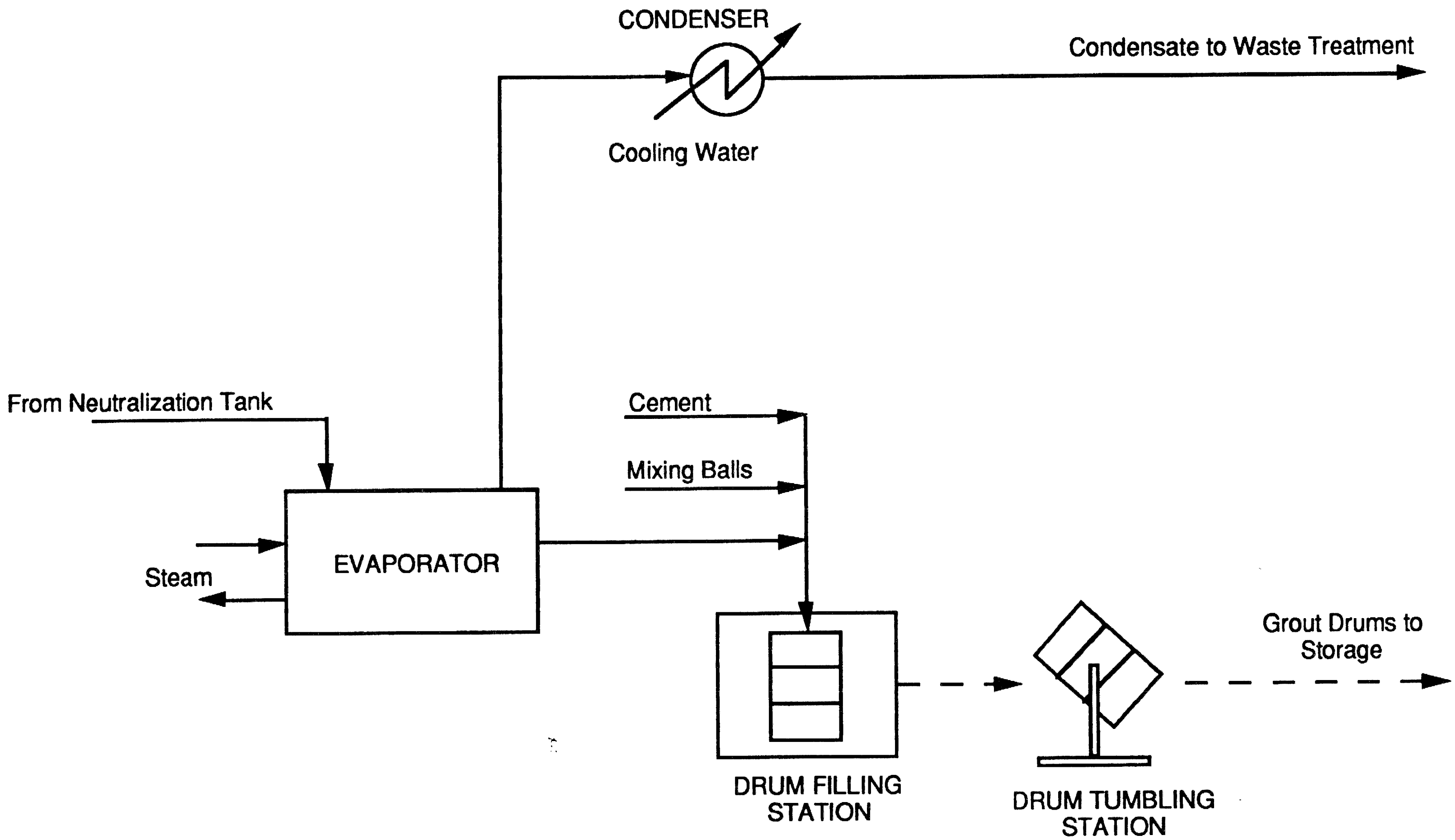

Figure 4-5 Evaporation and Grouting Process Flow Diagram

For outgoing full cylinders, the cylinder handling is essentially the same as for incoming full cylinders. Cylinders will be removed from the fill stations by the overhead cranes and will be placed on a cart for transport to storage for cooldown. Once in the yard, the cylinder will again be handled by the mobile yard cranes and carts.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead cranes. The overhead cranes will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to storage in the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.5 Waste Management

The primary wastes produced by the process are empty UF_6 cylinders and grouted waste drums. For this study, it is assumed that the empty cylinders are shipped off-site for treatment and disposal.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	10.8 GWh	1.4 MW
Liquid Fuel	5,500 gals	NA
Natural Gas[2]	35×10^6 scf	NA
Raw Water	9.0×10^6 gals	NA

[1] Peak demand is the maximum rate expected during any hour.
[2] Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance. This balance is based on the greenfield generic midwestern U. S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

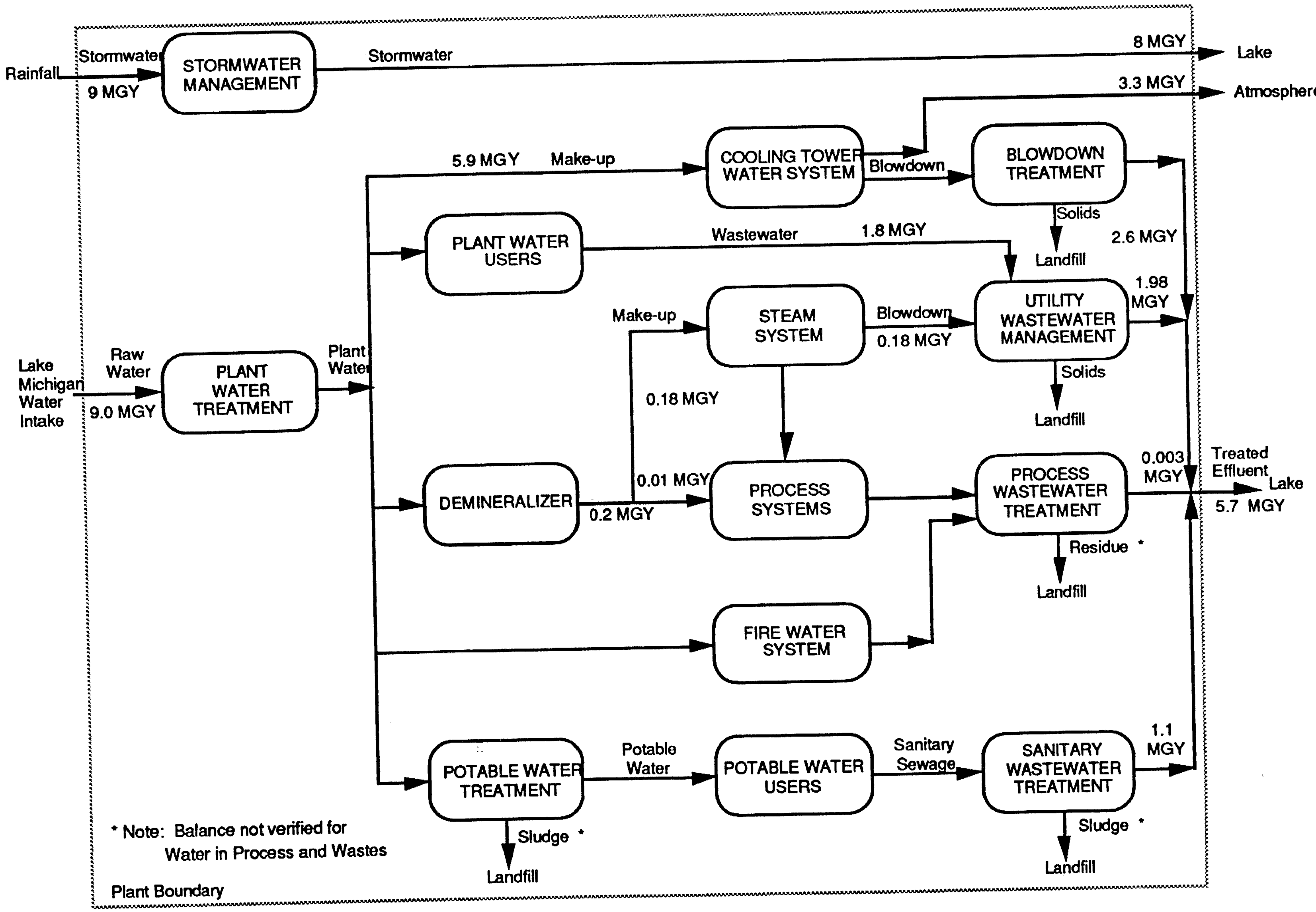

Figure 5-1 Preliminary Water Balance Uranium Hexafluoride Transfer

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Cement	1,600
Potassium Hydroxide	2,700
Detergent	500
Liquid	
Sulfuric Acid (93% H_2SO_4)	1,400
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	1,300
Sodium Hydroxide (50% NaOH)	1,100
Sodium Hypochlorite	1,100
Copolymers	1,100
Phosphates	110
Phosphonates	110
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 4x2x7 ft boxes - see also Table 9-1)	365 drums 10 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium hexafluoride (DUF_6) which is, in turn, shipped off site.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5-3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	35,000 MWh	1.5 MW
Water	8.0×10^6 gal	700 gal
Solids		NA
Concrete	20,000 yd^3	
Steel (carbon or mild)	8,000 tons	
Electrical raceway	20,000 yd	
Electrical wire and cable	50,000 yd	
Piping	20,000 yd	
Steel decking	25,000 yd^2	
Steel siding	10,000 yd^2	
Built-up roof	10,000 yd^2	
Interior partitions	1,500 yd^2	
Lumber	5,400 yd^3	
HVAC ductwork	100 tons	
Asphalt paving	220 tons	
Liquids		
Fuel [2]	1.5×10^6 gals	
Gases		
Industrial Gases (propane)	4,400 gal	

1 Peak demand is the maximum rate expected during any hour.

2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel, etc.) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 5 tons of Monel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 EMPLOYMENT NEEDS DURING OPERATION

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	6
Professionals	6
Technicians	15
Office and Clerical	20
Craft Workers (Maintenance)	10
Operators / Line Supervision	62/18
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	163

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 EMPLOYEES AT RISK OF RADIOLOGICAL EXPOSURE

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4 [1]
Process Building	17	13	13	13
Cylinder Storage Pads & Building	7	3	3	3
Utilities/Services/Admin Areas	40	17	17	17
TOTAL EMPLOYEES	64	33	33	33

1 The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	250	420	170
Construction Management and Support Staff	30	50	80	30
TOTAL EMPLOYEES	200	300	500	200

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	21/44
Nitrogen Dioxide	Boiler Stack / Grade	2,900/350
Hydrocarbons	Boiler Stack / Grade	60/300
Carbon Monoxide	Boiler Stack / Grade	1,400/2,200
Particulate Matter PM-10	Boiler Stack / Grade	110/70
OTHER POLLUTANTS		
HF	Proc. Bldg. Exhaust Stack	5
UO_2F_2	Proc. Bldg. Exhaust Stack	0.36
Copolymers	Cooling Tower	220
Phosphonates	Cooling Tower	20
Phosphates	Cooling Tower	20
Calcium	Cooling Tower	400
Magnesium	Cooling Tower	110
Sodium and Potassium	Cooling Tower	40
Chloride	Cooling Tower	80
Dissolved Solids	Cooling Tower	2,300

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg Exhaust Stack	5.0×10^{-5}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	6.3×10^{-4}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Quantity Packages
Low Level Waste					
Combustible Solids	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	176,000	81	23 lb UO_2F_2	301 55-gal drums
Metal, surface contaminated	Failed equipment	16,000	10	21 lb UO_2F_2	37 55-gal drums
Noncombustible, compactible solids	HEPA filters	3,600	21	72 lb UO_2F_2	10 4x2x7 ft boxes (3/4" plywood)
Noncombustible, noncompactible solids	Grouted Waste See Sec. 4.3	7,600	2.5	180 lb $UO_2(OH)_2$	9 55-gal drums
Other	LabPack (chemicals plus absorbent)	800	0.5	1 lb UO_2F_2	2 55-gal drums
Hazardous Waste					
Organic Liquids	Solvents, oil, paint, thinner	1,100	0.7 (150 gal)	See description	3 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	1,600	1	2 lb HF 2 lb NaOH	4 55-gal drums
Combustible debris	Wipes, etc. (plastic, paper, cloth)	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	410	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Inorganic process debris	Failed equipment (metal, glass)	400	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Combustible debris	Wipes, etc. (plastic, paper, cloth)	135	0.25	0.1 lb UO_2F_2 0.1 lb Acetone	1 55-gal drum

[1] All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.1×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	410	4.6×10^6
Recyclable Wastes	160	-

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 Wastes and Emissions Generated During Construction

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2
Nitrogen Dioxide	28
Hydrocarbons	8
Carbon Monoxide	190
Particulate Matter PM-10	40

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the facility since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	50 yd^3
Hazardous Liquids	20,000 gals
Nonhazardous Solids	
Concrete	100 yd^3
Steel	30 tons
Other	800 yd^3
Nonhazardous Liquids	
Sanitary	3.0×10^6 gals
Other	1.0×10^6 gals

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 Bounding Accidents

The facility includes areas with hazard categories of chemically high hazard (HH) and radiologically moderate hazard (HC2) for buildings containing UF_6 and radioactive decay products. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment (because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques)
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following structures, systems, and components (SSCs) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of gaseous or liquid UF_6 because their rupture could release UF_6 with unacceptable consequences.
- The Process Building structure because it houses large inventories of gaseous or liquid UF_6, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	0.018 lb UO_2F_2 4.7 lb HF
Tornado	Extremely Unlikely	No Release
Flood	Incredible	No Release
UF_6 Vapor Leak	Anticipated	9.0×10^{-3} lb UO_2F_2 2.4 lb HF
UF_6 Liquid Leak	Anticipated	4.5×10^{-3} lb UO_2F_2 1.2 lb HF
UF_6 Cold Trap Rupture	Unlikely	0.13 lb UO_2F_2 34 lb HF
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	9.0×10^{-3} lb UO_2F_2 2.4 lb HF

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	18 lb UO_2F_2 4.7 lb HF	1	1×10^{-3} 1	30 min
Tornado	No Release	NA	NA	NA
Flood	No Release	NA	NA	NA
UF_6 Vapor Leak	9 lb UO_2F_2 2.4 lb HF	1	1×10^{-3} 1	30 min
UF_6 Liquid Leak	9 lb UO_2F_2 2.4 lb HF	.5 (a)	1×10^{-3} 1	30 min
UF_6 Cold Trap Rupture	262 lb UO_2F_2 68 lb HF	.5 (a)	1×10^{-3} 1	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	9 lb UO_2F_2 2.4 lb HF	1	1×10^{-3} 1	2 min

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).
2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).
3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Fraction airborne is .5 based on flashing of 160°F UF6 liquid at 1 atm. Fraction in respirable range is 1.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234, Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 transfer process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium and hydrofluoric acid (a reaction product from UF_6 release) are the primary hazardous materials handled in this facility. Uranium is toxic and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where liquid or gaseous UF_6 is present. Therefore, it would be incredible that these structures fail in the event of the DBE.

In the extremely unlikely event that an earthquake exceeding the PC-3 DBE or failure of PC-3 SSCs in the Process Building occurs, it is postulated that a UF_6 compressor discharge pipe is cleanly sheared off. There are three compressors running simultaneously, each with a flow of 1,232 lb/hr. It is assumed that one UF_6 transfer line leaks 100% of its flowing contents for 1 minute, thus releasing 20.5 lb of UF_6 into the Process Building. After the leak is detected by a low compressor pressure and air monitoring instruments, the autoclave and compressor are shut down to stop the leak. The HVAC system can be shut down if required to contain the release in the building. If functional, the building water spray system can also be activated to absorb HF vapor in the area.

The UF_6 vapor reacts with moisture in the air to form 18 lb of solid UO_2F_2 and 4.7 lb of gaseous HF. The Process Building ventilation system has HEPA filters that remove 99.9% of the UO_2F_2. The HEPA filters do not remove any HF. Thus 4.7 lb of HF and 0.018 lb of UO_2F_2 are released to atmosphere through the Process Building Exhaust stack. This accident is judged to be extremely unlikely.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Structures in high hazard areas of the Process Building are designed for the performance category PC-4 DBT. Therefore failure of these structures in the event of the DBT is incredible. A tornado results in no significant release.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF_6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 UF_6 Vapor Leak

Gaseous UF_6 flows from the autoclaves and compressors. There are three lines, each with a flow of 1,232 lb/hr. Possible accidents are compressor or pipe leakage.

It is postulated that a UF_6 transfer line leaks 5% of its flowing contents for 10 minutes, thus releasing 10.3 lb of UF_6 into the Process Building. After the leak is detected by air monitoring instruments, the autoclave and compressor are shut down to stop the leak. The HVAC system can be shut down if required to contain the release in the building. The building water spray system can also be activated to absorb HF vapor in the area.

The UF_6 vapor reacts with moisture in the air to form 9.0 lb of solid UO_2F_2 and 2.4 lb of gaseous HF. The Process Building ventilation system has HEPA filters that remove 99.9% of the UO_2F_2. The HEPA filters do not remove any HF. Thus 2.4 lb of HF and 9×10^{-3} lb of UO_2F_2 are released to atmosphere through the Process Building Exhaust stack. This accident is judged to be anticipated.

8.1.3.3 UF_6 Liquid Leak

Liquid UF_6 drains from the condensers during normal operation. There are three condensers, each with a UF_6 liquid flow of 1,222 lb/hr. Possible accidents are condenser or pipe leakage.

It is postulated that a UF_6 drain line leaks 5% of its flowing contents for 10 minutes, thus releasing 10.2 lb of UF_6 into the Process Building. After the leak is detected by air monitoring instruments, the autoclave and compressor are shut down to stop the leak. The HVAC system can be shut down if required to contain the release in the building. The building water spray system can also be activated to absorb HF vapor in the area.

The 160°F UF_6 liquid flashes at 1 atm and 147°F, and about 50% freezes and settles on the floor based on the enthalpy balance. The rest of the UF_6 (5.1 lb) vaporizes and reacts with moisture in the air to form 4.5 lb of solid UO_2F_2 and 1.2 lb of gaseous HF. The Process Building ventilation system has HEPA filters that remove 99.9% of the UO_2F_2. The HEPA filters do not remove any HF. Thus 1.2 lb of HF and 4.5×10^{-3} lb of UO_2F_2 are released to atmosphere through the Process Building Exhaust stack. This accident is judged to be anticipated.

8.1.3.4 Cold Trap Rupture

UF_6 is desublimed in cold traps and collected as a solid. To remove the UF_6, the trap is heated and pressurized to convert the solid into a liquid, which is drained into an accumulator that discharges into a cylinder. If a cold trap was overfilled with UF_6, the pressure in the trap would be significantly higher during heating. It is assumed that the overpressure is sufficient to rupture the trap and release UF_6 into the room. The traps have high weight alarms and interlocks to prevent overfilling. They also have high pressure alarms and interlocks that stop heating of the trap. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

There are three cold traps running simultaneously, each collecting about 10 lb/hr UF_6. A trap is regenerated once every 24 hours, so it will contain up to 240 lb of UF_6. It is postulated that a trap is overfilled by 25%, ruptures during heating, and releases its entire contents of 300 lb of liquid UF_6 in a 5 minute period. The 160°F UF_6 liquid flashes at 1 atm and 147°F, and about 50% freezes and settles on the floor based on the enthalpy balance. The rest of the UF_6 (150 lb) vaporizes and reacts with moisture in the air to form 131 lb of solid UO_2F_2 and 34 lb of gaseous HF. The Process Building ventilation system has HEPA filters that remove 99.9% of the UO_2F_2. The HEPA filters do not remove any HF. Thus 34 lb of HF and 0.13 lb of UO_2F_2 are released to atmosphere through the Process Building Exhaust stack. This accident is judged to be unlikely.

8.1.3.5 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a significant release to the environment.

The UF_6 compressors would stop and the condensers would depressurize. The UF_6 gas in the condenser and piping would not condense at atmospheric pressure and would flow to the cold trap. The cold trap would remove most of the UF_6, and the rest would be removed by the scrubber.

8.1.3.6 Loss of Cooling Water

Loss of cooling water to the condenser would result in UF_6 not being condensed. The cold trap and scrubber would remove a portion of the UF_6, with the remainder released to atmosphere through the Process Building Exhaust stack. High temperature alarms and interlocks would shut down the autoclaves and compressors to prevent the release.

It is postulated that water flow to the condenser is lost and UF_6 flow continues for 1 minute before interlocks stop the flow. There are three condensers, each with a flow of 1,232 lb/hr. During the 1 minute period, a total of 20.5 lb of UF_6 would flow from the condenser to the scrubber. It is assumed that the scrubber removes 50% of the UF_6. The remaining UF_6 (10.3 lb) is converted to 9.0 lb UO_2F_2 and 2.4 lb HF and is assumed to be discharged from the scrubber. The Process Building ventilation system has HEPA filters that remove 99.9% of the UO_2F_2. The HEPA filters do not remove any HF. Thus 2.4 lb of HF and 9×10^{-3} lb of UO_2F_2 are released to atmosphere through the Process Building Exhaust stack. This accident has been judged to be anticipated.

9. 0 Transportation

9. 1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming, filled 14-ton DUF_6 cylinders to the Process Building, newly filled DUF_6 cylinders from the Process Building to the Outgoing, Full Cylinder Storage Pad, and low level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of truck transport of UF_6 to the plant boundary. Hazardous waste materials such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, laboratory wastes, etc. requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary for shipment to off-site hazardous waste treatment, storage and disposal facilities.

9. 2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product and waste materials is shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), potassium hydroxide (KOH), hydrochloric acid (HCl), and sulfuric acid (H_2SO_4). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output depleted uranium hexafluoride (DUF_6), low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Input Material #5
Transported Materials					
Type	UF_6	HCl	NaOH	H_2SO_4	KOH
Physical Form	Solid	Liquid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	H_2SO_4/ ambient	KOH/ ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	TBD	TBD
Container Weight (lb)	2,600	50	50	50	50
Material Weight (lb)	27,000	540	660	840	500
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	93% H_2SO_4	100% KOH
Shipments					
Average Volume (ft^3)/Year	134,000	22	15	15	44
Packages/Year	960	3	2	2	6
Packages/Life of Project	19,200	60	40	40	120
Packages/Shipment	1 (truck) or 4 (rail car), 12cars/train	3	2	2	6
Shipments/Year	960 (truck) or 20 (rail)	1	1	1	1
Shipments/Life of Project	19,200 (truck) or 400 (rail)	20	20	20	20
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck
Destination - Facility Type	NA	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	UF_6	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	Varies	Varies	Varies	48G
Container Weight (lb)	2,600	50/300	50	50	2,600
Material Weight (lb)	27,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% UF_6	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 Note 1
Shipments					
Average Volume (ft^3)/Year	134,000	3,100	100	20	134,000
Packages/Year	964	349/10	13	3	960
Packages/Life of Project	19,280	6,980/200	260	60	19,200
Packages/Shipment	1 (truck) or 4 (railcar) 12cars/train	40/10	13	3	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	964 (truck) or 20 (rail)	9/1	1	1	960 (truck) or 20 (rail)
Shipments/Life of Project	19,280 (truck) or 400 (rail)	180/20	20	20	19,200 (truck) or 400 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	TBD	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci of Th-234 and 0.16 Ci of Pa-234.

10.0 References

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
atm	atmosphere
CaF_2	calcium fluoride
CaO	calicum oxide
CAR	Cost Analysis Report
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	Environmental Safety and Health
ft^2	square feet
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt ($1x10^6$ kW) hour(s)
HCl	hydrochloric acid
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
H_2SO_4	sulfuric acid
KF	potassium fluoride
KOH	potassium hydroxide
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MT	metric tonne(s)
MW	megawatt(s)

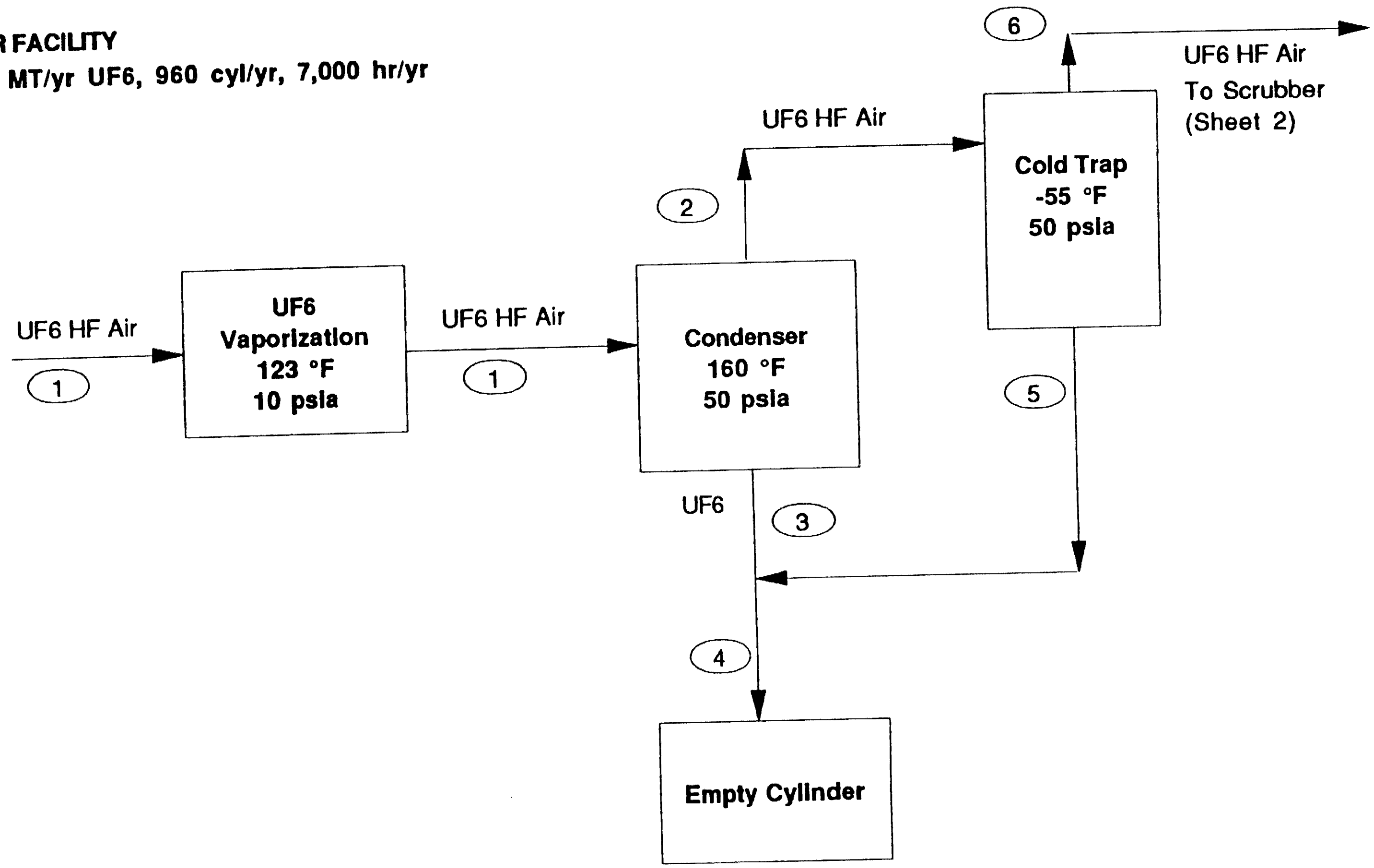
MWh	megawatt hour(s)
NaOH	sodium hydroxide
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
RFP	request for proposal
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
Th	thorium
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UO_2	uranium oxide
UO_2F_2	uranyl fluoride
$UO_2(OH)_2$	uranyl hydroxide
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
wt%	weight percent
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

7-Mass Bal MT/yr

UF6 TRANSFER FACILITY
Basis: 11,732 MT/yr UF6, 960 cyl/yr, 7,000 hr/yr
UF6 Transfer



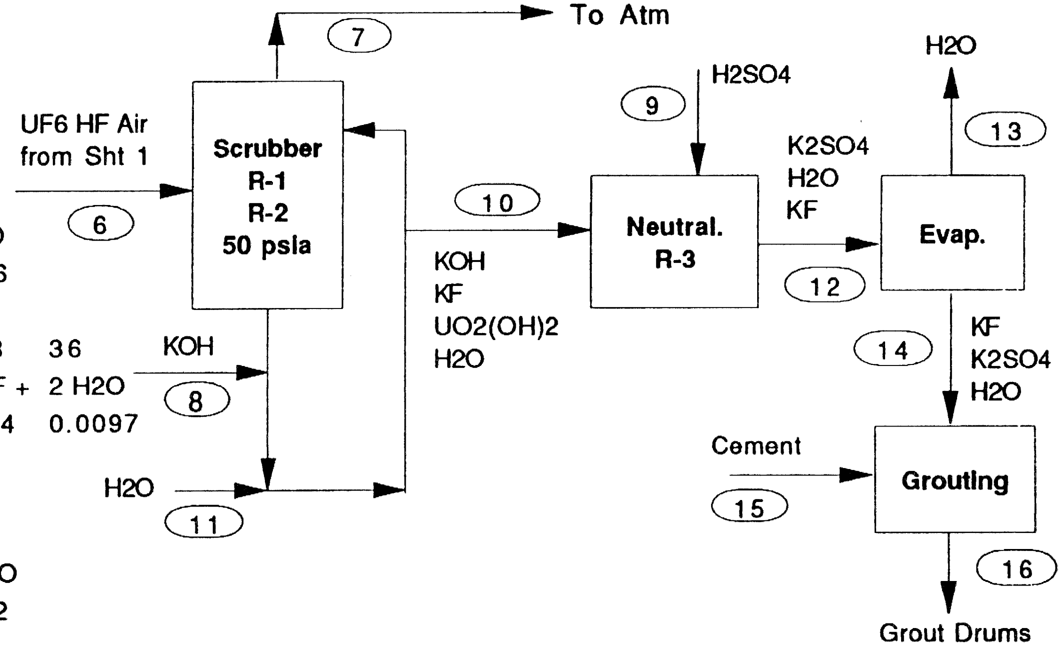
	Mol Wt	1	2	3	4	5	6
UF6	352	11,732	96.20	11,636	11,732	96.11	0.096
HF	20	0.174	0.174				0.174
Air	29	0.50	0.50				0.50
Total MT/yr		11,733	96.88	11,636	11,732	96.11	0.77
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

11/5/96

7-Mass Bal MT/yr

UF6 TRANSFER FACILITY
Basis: 11,732 MT/yr UF6, 960 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

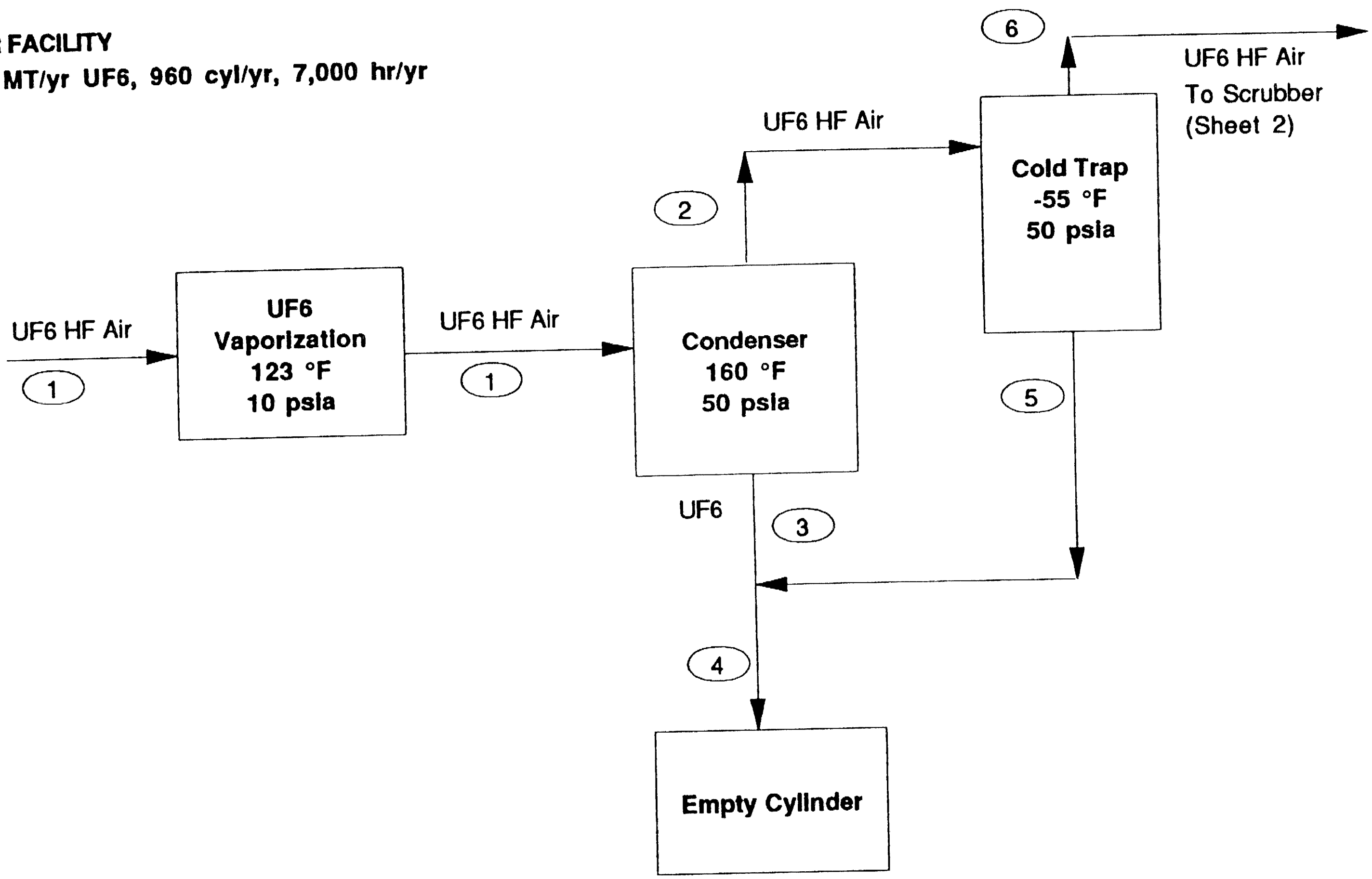
	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.17	0.48	0.50	0.16	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.095	0.091	0.082	0.094	0.0097
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	0.68	0.59	1.05	0.22	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.00096									
HF	20	0.00174									
Air	29	0.50									
KOH	56		1.25		0.68						
H2O	18		1.87	0.045	12.17	10.13	12.43	11.43	1.00		1.00
UO2(OH)2	304				0.082		0.082		0.082		0.082
KF	58				0.59		0.59		0.59		0.59
K2SO4	174						1.05		1.05		1.05
H2SO4	98			0.59							
Cement										0.72	0.72
Total MT/yr		0.50	3.12	0.64	13.52	10.13	14.16	11.43	2.73	0.72	3.45
kg/kg U		0.00006	0.0004	0.00008	0.0017	0.0013	0.0018	0.0014	0.0003	0.00009	0.0004

7-Mass Bal lb/hr

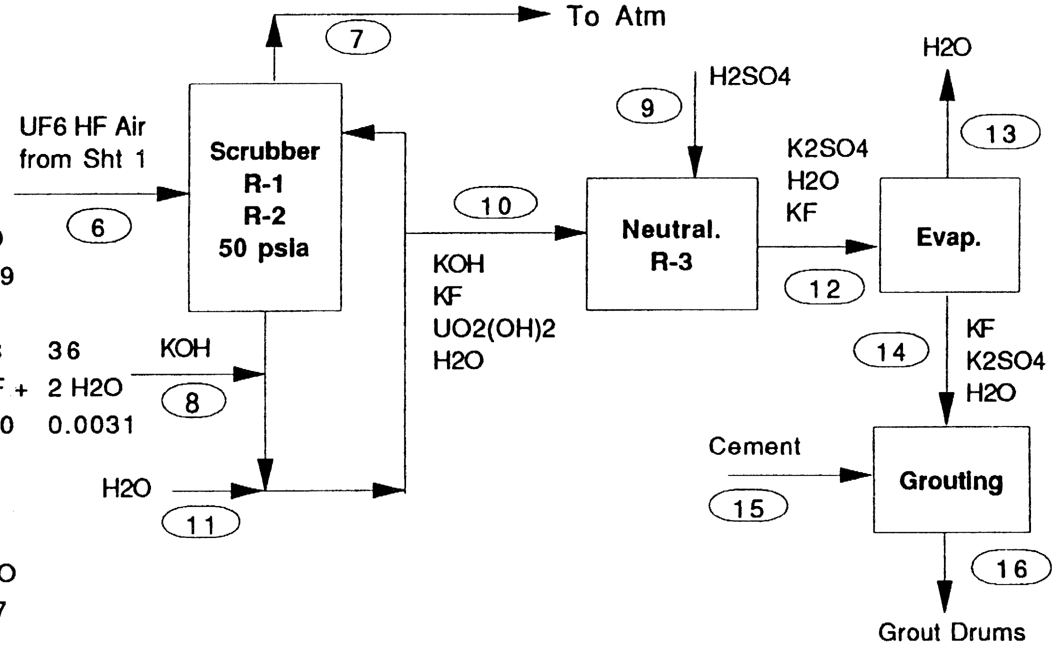
UF6 TRANSFER FACILITY
Basis: 11,732 MT/yr UF6, 960 cyl/yr, 7,000 hr/yr
UF6 Transfer



	Mol Wt	1	2	3	4	5	6
UF6	352	3,695	30.30	3,665	3,695	30.27	0.030
HF	20	0.055	0.055				0.055
Air	29	0.16	0.16				0.16
Total lb/hr		3,695	30.51	3,665	3,695	30.27	0.25
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

UF6 TRANSFER FACILITY
Basis: 11,732 MT/yr UF6, 960 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.054	0.152	0.158	0.049	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.030	0.029	0.026	0.030	0.0031
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	0.21	0.19	0.33	0.07	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.00030									
HF	20	0.00055									
Air	29	0.160									
KOH	56		0.39		0.21						
H2O	18		0.59	0.014	3.84	3.20	3.93	3.61	0.32		0.32
UO2(OH)2	304				0.026		0.026		0.026		0.026
KF	58				0.19		0.19		0.19		0.19
K2SO4	174						0.33		0.33		0.33
H2SO4	98			0.19							
Cement										0.23	0.23
Total lb/hr		0.16	0.99	0.20	4.27	3.20	4.47	3.61	0.86	0.23	1.09
kg/kg U		0.00006	0.0004	0.00008	0.0017	0.0013	0.0018	0.0014	0.0003	0.00009	0.0004

Appendix B

Equipment List

MAJOR EQUIPMENT LIST
UF6 Transfer Facility

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (12)	7'Dx23'Lx 5/8" wall, carbon steel. A fixed head w/ movable shell section. 12-1/2 hp fans attached to shell inside	Proc. Bldg
Forced Air Blower (12)	3000 scfm, 15 hp	Proc. Bldg
Air Heater (12)	Electric type, 20 kw	Proc. Bldg
UF6 Compressor (6)	1400 lb/hr UF6 (45 cfm) at 10 psia inlet, 50 psia discharge, 5 hp	Proc. Bldg
Backing Compressor (6)	5 cfm, 1 psia inlet, 10 psia discharge, 0.5 hp	Proc. Bldg
Condenser (3)	10" dia x 6' L, Monel shell with U tubes.	Proc. Bldg
Cold Trap (6)	12" dia x 8' H Monel shell with finned tubes.	Proc. Bldg
UF6 Accumulator (3)	2' dia x 3' L, Monel, 70 gal	Proc. Bldg
UF6 Filling Station (3)	Two(2)- 20 ton scales	Proc. Bldg
Off-Gas Scrubber	1'dia x10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	6" dia pipe x 5' L, steam jacketed	Proc. Bldg
Off-Gas HEPA Filter (2)	8"x8"x12"	Proc. Bldg
KOH Storage Tank	3' dia x 3' H, carbon steel	Proc. Bldg
KOH Pump	1 gpm	Proc. Bldg
Scrubber Pump	5 gpm, Monel	Proc. Bldg
Neutralization Tank (1)	3' dia x 3' H, Monel, with cooling coils	Proc. Bldg
Neutralization Pump (1)	5 gpm, Monel	Proc. Bldg
Evaporator	3' dia x 3' H, carbon steel with heating coils	Proc. Bldg
Slurry Pump	5 gpm, carbon steel	Proc. Bldg
Drum Filling Station	0.03 drum per day (avg.)	Proc. Bldg
Dry Tumbling Station	0.03 drums/day, carbon steel	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Condenser Cooling Water System	129,000 BTU/hr, 140 °F, w/ heat exchanger tank and pump.	Proc. Bldg
Cold Trap Cooling System	2700 Btu/hr, -75 °F, w/ tank, chiller & pump	Proc. Bldg
Cold Trap Heating System	1600 Btu/hr, 185 °F, w/ tank, heater & pump	Proc. Bldg
Material Handling Systems	Two (2) flatbed trucks	Yard
	Three (3) 20-ton cranes	Proc. Bldg
	Two (2) 20-ton yard cranes	Yard
	Two (2) forklift trucks	Proc. Bldg/Yard
	Two (2) 20-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets Three (3) storage racks each for 80 cylinders	Proc. Bldg/ Storage Areas
DUF_6 Cylinder Vacuum System	Two (2) vacuum systems with cold traps, NaF traps and vacuum pumps	Proc. Bldg
Decontamination & Maintenance Systems	Four (4) decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations w/ tanks.	Proc. Bldg
Process Control / Monitoring System	Dstributed Control System(DCS) with centralized monitoring stations. Closed circuit TV monitoring system	Proc. Bldg
Sampling / Analytical Systems	Two (2) local sampling glove boxes with laboratory liquid / powder sample hardware. Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazard-ous Waste Management System	Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Low Level Radioactive & Hazardous Waste Management System (continued)	• bar code reader / computerized • accountability system • 1-radwaste drum assay device	
Material Accountability System	•Computerized material control and accountability system (hardware & software).	Proc. Bldg
	•2 accountability scales for incoming and outgoing DUF_6 cylinders & waste drums	Proc. Bldg
	•2 bar code readers for DUF_6 cylinder and waste drums.	Proc. Bldg/Yard
	•Process uranium monitors and sampling stations for approx. 20 sampling points	Proc,Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF and UF_6,) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Utility /Services Systems	Boiler - 9200 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing Air Compressors-2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, -40°F dew point	Util. Bldg
	Demineralized water system - 600 gpd	Util. Bldg
	Sanitary water treatment system - 3,000 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 13,000 gpd	Wastewater Treatment area
	Electrical substation - 1400 kW	Substation
	Emergency generators - 2 @ 300kW	Substation
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 6 MM Btu/hr, 610 gpm	Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-2000 cfm, 5 H,P exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-30,000 cfm, 120 HP exhaust fans, 2-30,000 cfm 40 HP supply air units	DUF6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 25 HP supply air units, 2-15,000 cfm, 10 HP exhaust fans, 2-15,000 cfm, 15 HP supply air units	Waste Process'g Control Room Support Areas
HVAC Chillers	3-220 ton chillers	Proc. Bldg
Circulating Pumps	3-350 gpm, 10 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

TRANSFER FACILITY - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Unload arriving full incoming UF6 cylinder	3	0.50	960	1	3	Steel	1/4"	1440.0
Inspect arriving full incoming UF6 cylinders	1	0.50	960	1	3	Steel	1/4"	480.0
Transfer full incoming UF6 cylinder to storage pad	2	0.50	960	1	6	Steel	1/4"	960.0
Unload full incoming UF6 cylinder at storage pad	2	0.50	960	1,7	3,3	Steel	1/4"	960.0
Load full incoming UF6 cylinder onto cart	2	0.50	960	1,7	3,3	Steel	1/4"	960.0
Transfer full incoming UF6 cylinder from storage to process building	2	0.50	960	1	6	Steel	1/4"	960.0
Inspect full incoming UF6 cylinders	2	0.50	960	1	3	Steel	1/4"	960.0
Load full incoming cylinder into autoclave from cart	3	0.50	960	1,5	3,3	Steel	1/4"	1440.0
Autoclave pressure test	2	1.00	960	1	15	Steel	1/4"+1/4"	1920.0
Unload autoclave	1	0.30	960	2	3	Steel	1/4"	288.0
Transfer empty outgoing UF6 cylinder to pallet	2	0.25	960	2	20	Steel	1/4"	480.0
Transfer empty outgoing UF6 cylinder to Storage Building	1	0.25	960	2	3	Steel	1/4"+1.25"	240.0
Store empty outgoing UF6 cylinder in Storage Building	1	0.25	960	2	3	Steel	1/4"	240.0
Move empty incoming UF6 cylinder to filling area	2	0.50	964	4,6	10	Steel	1/4"	964.0
Move full outgoing UF6 cylinder to storage area	3	0.50	964	4	6	Steel	1/4"	1446.0
Transfer full outgoing UF6 cylinder to storage yard	2	0.50	964	4	6	Steel	1/4"	964.0
Prepare empty outgoing UF6 cylinder for shipment	2	0.50	960	3	3	Steel	1/4"	960.0
Load empty outgoing UF6 cylinder for shipment	3	0.50	960	3	6	Steel	1/4"	1440.0
Load full outgoing UF6 cylinder for shipment	3	0.50	964	4	6	Steel	1/4"	1446.0
Full incoming UF6 cylinder storage surveillance	1	0.50	2190	1,7	3	Steel	1/4"	1095.0
Autoclave, compressor, condenser surveillance	1	0.25	1752	1,4,5,6	3	Steel	1/4"	438.0
Full outgoing UF6 cylinder surveillance	1	0.50	2190	4,9	3	Steel	1/4"	1095.0
Cylinder Repair	2	4.00	100	1	2	Steel	1/4"	800.0
Off-gas Scrubbing / Process Liquid Treat. surveillance	1	0.50	1752	1,2	25	Steel	1/4"	876.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Waste grouting	2	2.00	44	10	3	Steel	0.06"	176.0
Transfer grouted drums to storage area	2	0.50	44	10	3	Steel	0.06"	44.0
Load grouted drums for shipment offsite	2	1.00	2	10	3	Steel	0.06"	4.0
Supervision	4	8.00	1100	1,2,3	15	Steel	1/4"	35200.0
Process control room operations	3	8.00	1100	4,6	25	Steel	1/4"	26400.0
Laboratory operations	1	8.00	1100	4,6	25	Steel	1/4"	8800.0
HP	2	8.00	1100	4,6	25	Steel	1/4"	17600.0
Management / Professionals	12	8.00	250	4,6	25	Steel	1/4"	24000.0
Accountability	2	2.00	1100	1,2	3	Steel	1/4"	4400.0
Industrial and sanitary waste treatment	2	8.00	1100	4,6	140	Steel	1/4"	17600.0
Utilities operations	2	8.00	1100	1,2	140	Steel	1/4"	17600.0
Warehouse	2	8.00	250	4,6	140	Steel	1/4"	4000.0
Administration	20	8.00	250	4,6	190	Steel	1/4"	40000.0
Guardhouses / Process Bldg.	6	8.00	1100	4;6	250;25	Steel	1/4"	52800.0
Maintenance								12416.0
								283892.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in a Cylinder Filling & Storage Area. There are 3 Cylinder Filling & Storage Areas.
7) There are up to 80 full incoming UF6 cylinders in the storage area.
8) There are up to 250 empty outgoing UF6 cylinders in the storage building.
9) There are up to 80 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) 960 incoming UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    44 grouted waste drums/yr
    44 grouted waste drums/yr /25 drums per shipment = 2 transfers per year
12) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

TRANSFER FACILITY - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (12)	2	26	12	1,5,2	3	Steel	1/4"+1/4"	624
Forced Air Blower (12)	2	52	12	1,5;4	8	Steel	1/4"+1/4";1/4	1248
Air Heater (12)	2	26	12	1,5;4	8	Steel	1/4"+1/4";1/4	624
UF6 compressors (6)	2	52	6	1,5;4	8	Steel	1/4"+1/4";1/4	624
Backing Compressor (6)	2	52	6	1,5;4	8	Steel	1/4"+1/4";1/4	624
Condenser (3)	2	26	3	14	6	Monel	1/4"	156
Cold Trap (6)	2	26	6	14	3	Monel	1/4"	312
Off-gas scrubber (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas heater (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas HEPA filters (2)	2	4	2	1,2	25	Steel	1/4"+1/4"	16
KOH pump (1)	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Scrubber Pump	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Neutralization pump (2)	2	52	2	1,2	25	Steel	1/4"+1/4"	208
Evaporator (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Slurry pump (1)	2	52	1	1,2	30	Steel	1/4"+1/4"	104
Grout mixing / drum tumbling station (1)	2	26	1	1,2	35	Steel	1/4"+1/4"	52
DUF6 Cylinder Vacuum System	2	26	2	1,2;4	10	Steel	1/4"+1/4";1/4	104
20 Ton Crane	2	52	3	1,2,5	35	Steel	1/4"+1/4"	312
Air Compressor, Water Systems in Process Bldg.	1	52	4	4,6	40	Steel	1/4"	208
HVAC equipment	2	520	1	4,6	40	Steel	1/4"	1040

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Boiler, Water Systems, Compressed Air, other Utilities	2	52	4	1;2	140	Steel	1/4"+1/4";1/4	416
Waste water treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Admin building	1	1000	1	4,6	190	Steel	1/4"	1000
								12416

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in a Cylinder Filling & Storage Area. There are 3 Cylinder Filling & Storage Areas.
7) There are up to 80 full incoming UF6 cylinders in the storage area.
8) There are up to 250 empty outgoing UF6 cylinders in the storage building.
9) There are up to 80 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) Loaded filter/bag.
12) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HVAC components
    6 hours per day on waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
13) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
14) Inventory in Cold Trap

Appendix D

DUF_6 Transfer Facility
(Low Capacity Case)

Summary

As part of a parametric analysis, the impact of a lower design throughput on the Depleted Uranium Hexafluoride Transfer Facility was studied. The facility described in this appendix is based on a total capacity of 6,400 substandard, existing cylinders, which is 1/3 of the baseline case. The facility is designed to transfer the UF_6 over 20 years at a rate of 320 cylinders per year. To accomodate an even lower total capacity, such as 2,500 substandard cylinders, the facility could be operated for 8 years rather than 20 years.

There is one train of UF_6 transfer equipment, consisting of four autoclaves, two compressors (one is a spare), two backing compressors (one is a spare), one condenser, two cold traps, one accumulator and one cylinder fill station. An off-gas scrubbing system treats the off-gas from the transfer equipment.

Major changes due to the reduced throughput are shown in this report. Assumptions, design bases, facility and process descriptions, and accident analyses have not changed and can be found in the report for the baseline case.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	22,200	2	Yes	Yes	HC2 / HH	Reinforced Concrete
Outgoing Empty Cylinder Storage Building	21,000	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	5,100	1	No	Yes	General	Metal Frame
Administration Building	6,400	1	No	No	General	Metal Frame
Maintenance Shop	4,000	1	No	Yes	General	Metal Frame
Warehouse	4,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	4,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	1,250	1	No	No	General	Metal Frame
Cooling Tower	4,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

Table 2-3 Facility Air Release Points

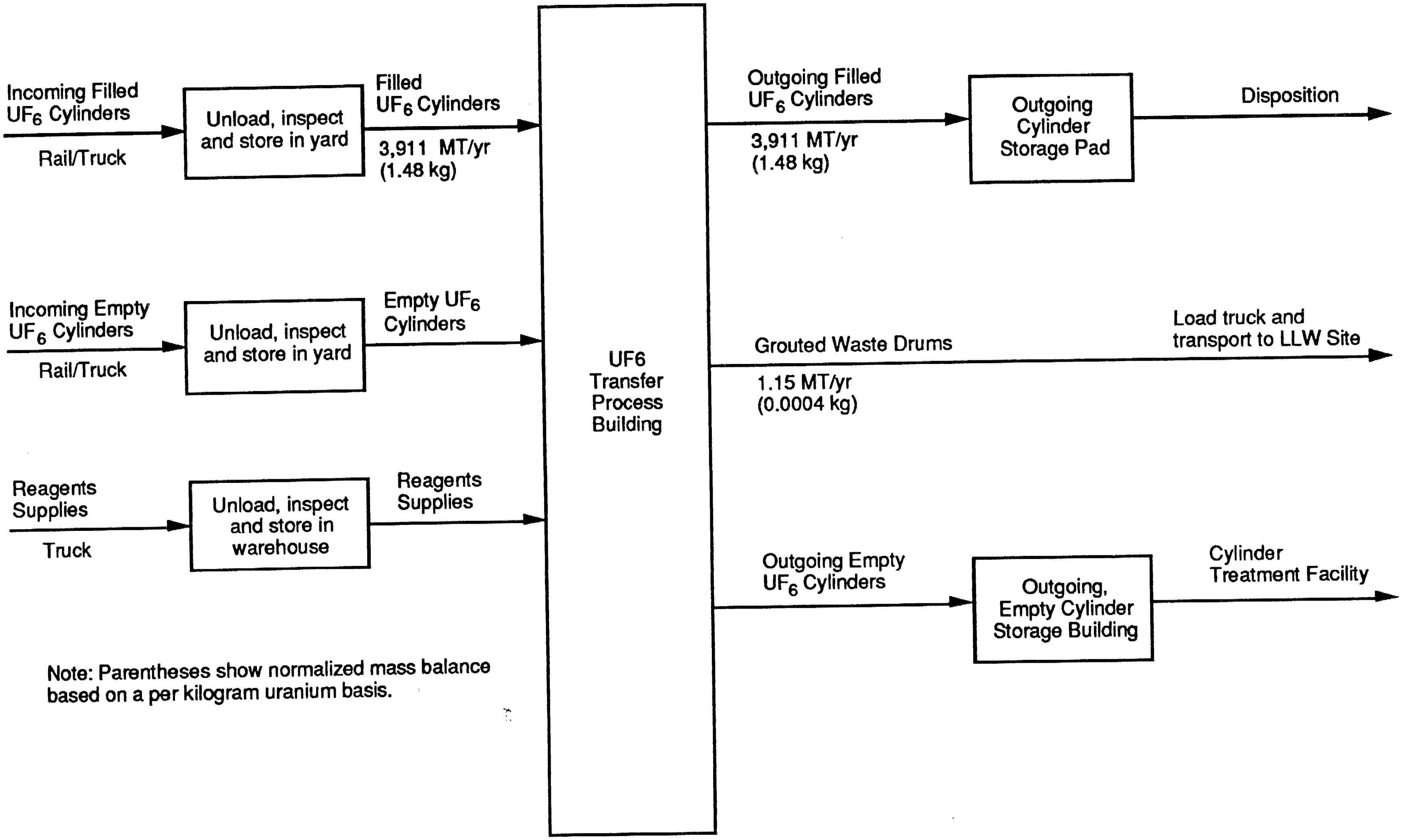
Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Process Building Exhaust	100	73	80	60
Boiler	100	15	500	60

The total land area required during operations is approximately 350,000 ft^2 or about 8 acres. Land area requirements during construction are approximately 12 acres.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	7.1 GWh	0.9 MW
Liquid Fuel	4,800 gals	NA
Natural Gas[2]	26×10^6 scf	NA
Raw Water	6.8×10^6 gals	NA

[1] Peak demand is the maximum rate expected during any hour.
[2] Standard cubic feet measured at 14.7 psia and 60 °F.



Note: Parentheses show normalized mass balance based on a per kilogram uranium basis.

Figure 2-1 UF6 Transfer (Low Capacity Case) Material Flow Diagram

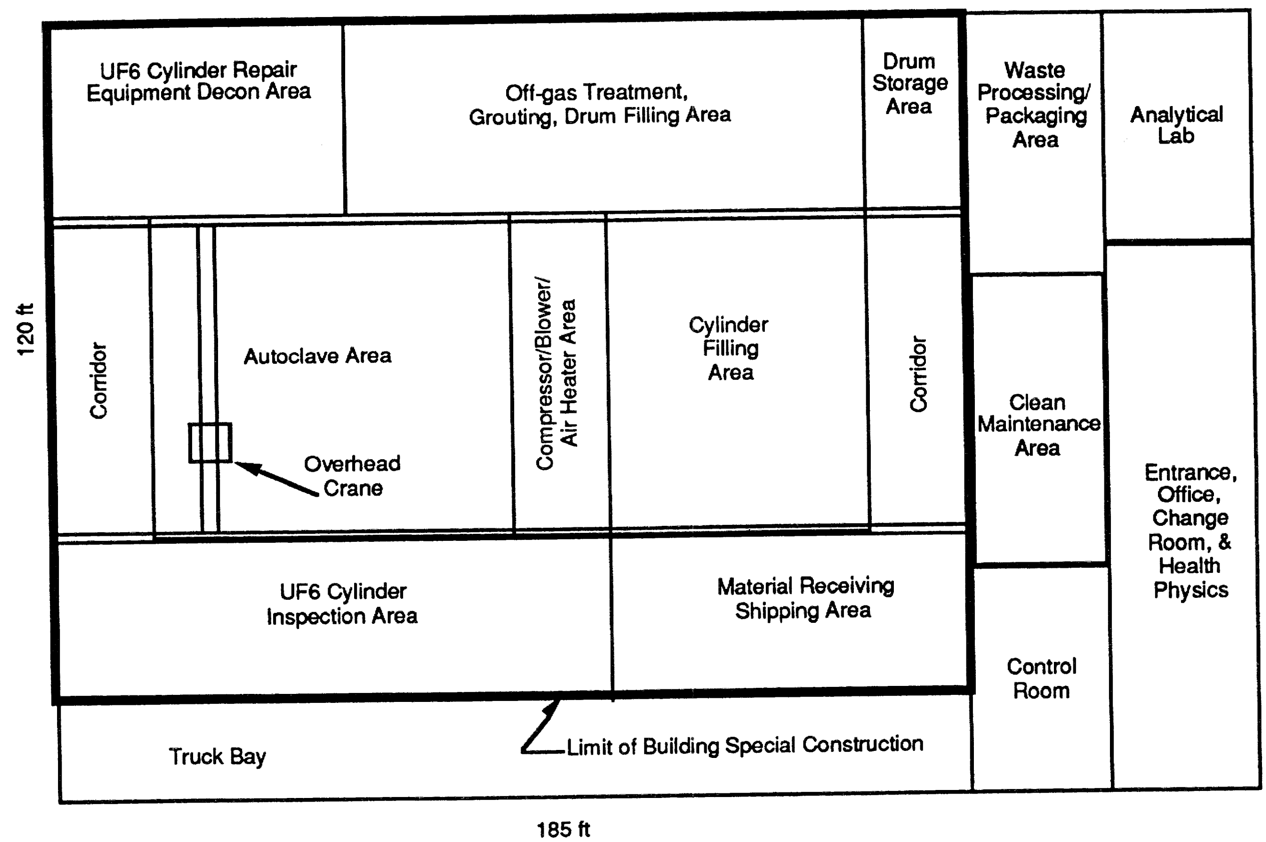


FIGURE 2-3
PROCESS BUILDING LAYOUT
UF6 TRANSFER FACILITY - LOW CASE

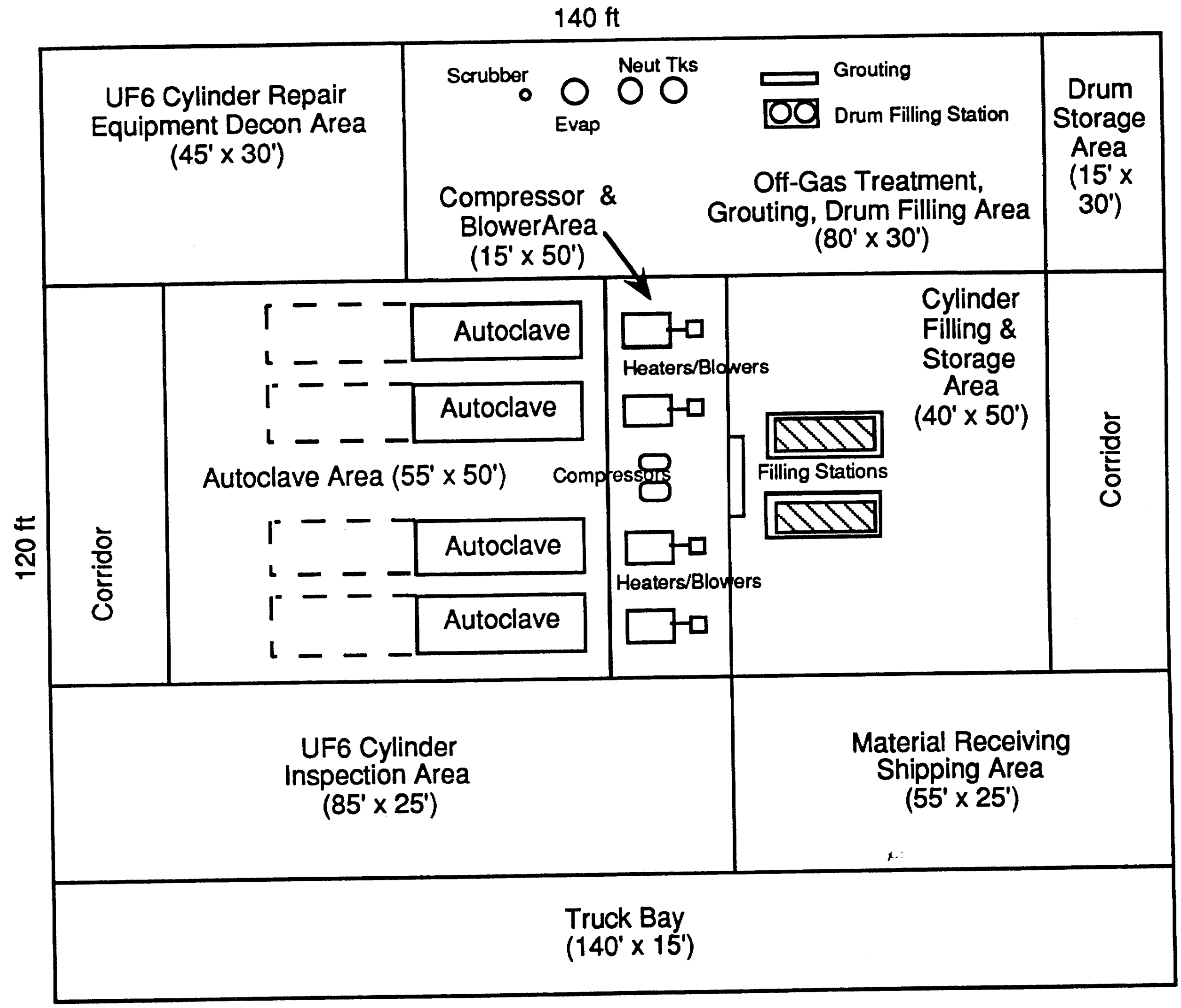


FIGURE 2-5
PROCESS EQUIPMENT ARRANGEMENT
UF6 TRANSFER FACILITY - LOW CASE

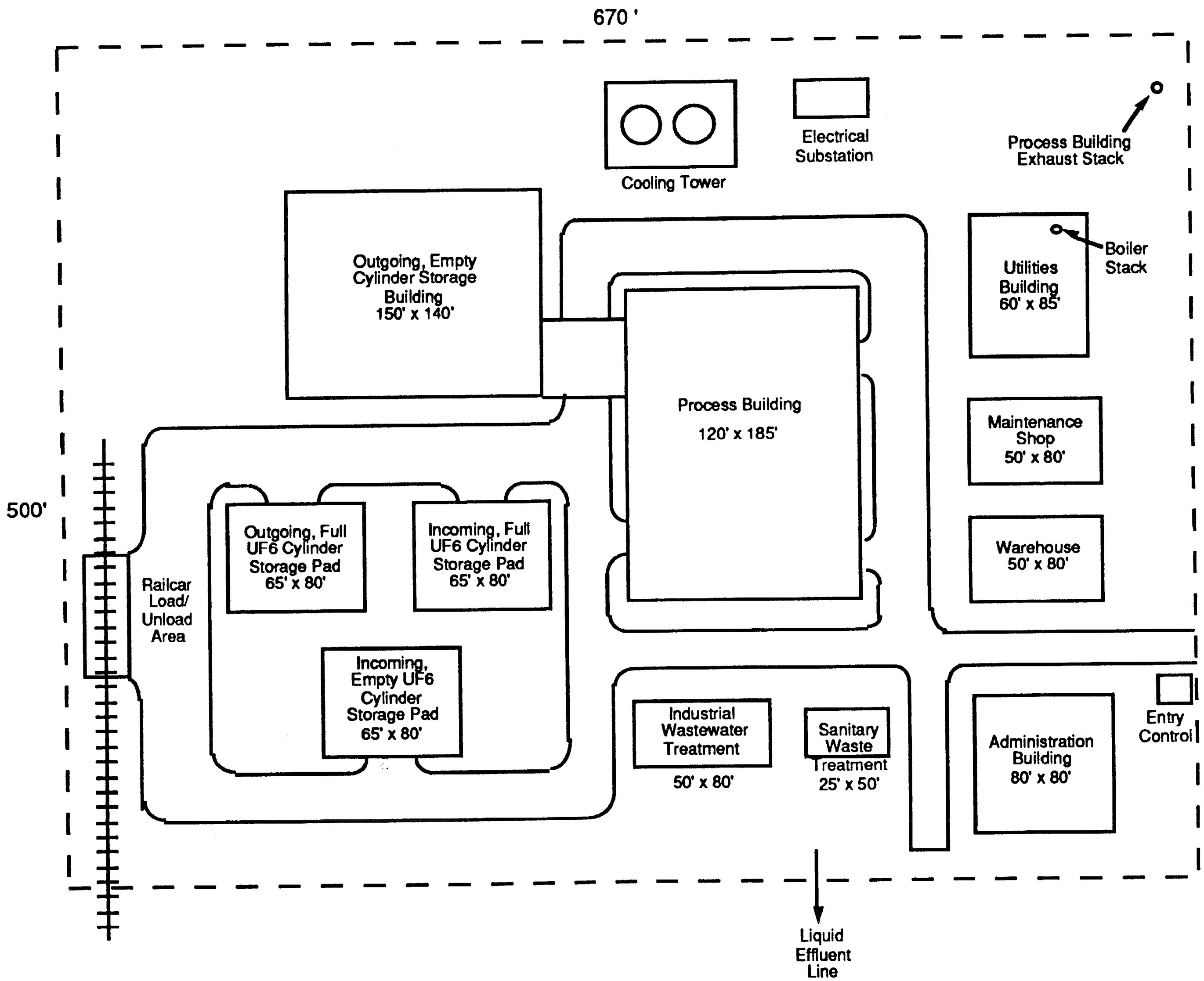


FIGURE 3-1 SITE MAP
DUF_6 TRANSFER FACILITY - LOW CASE

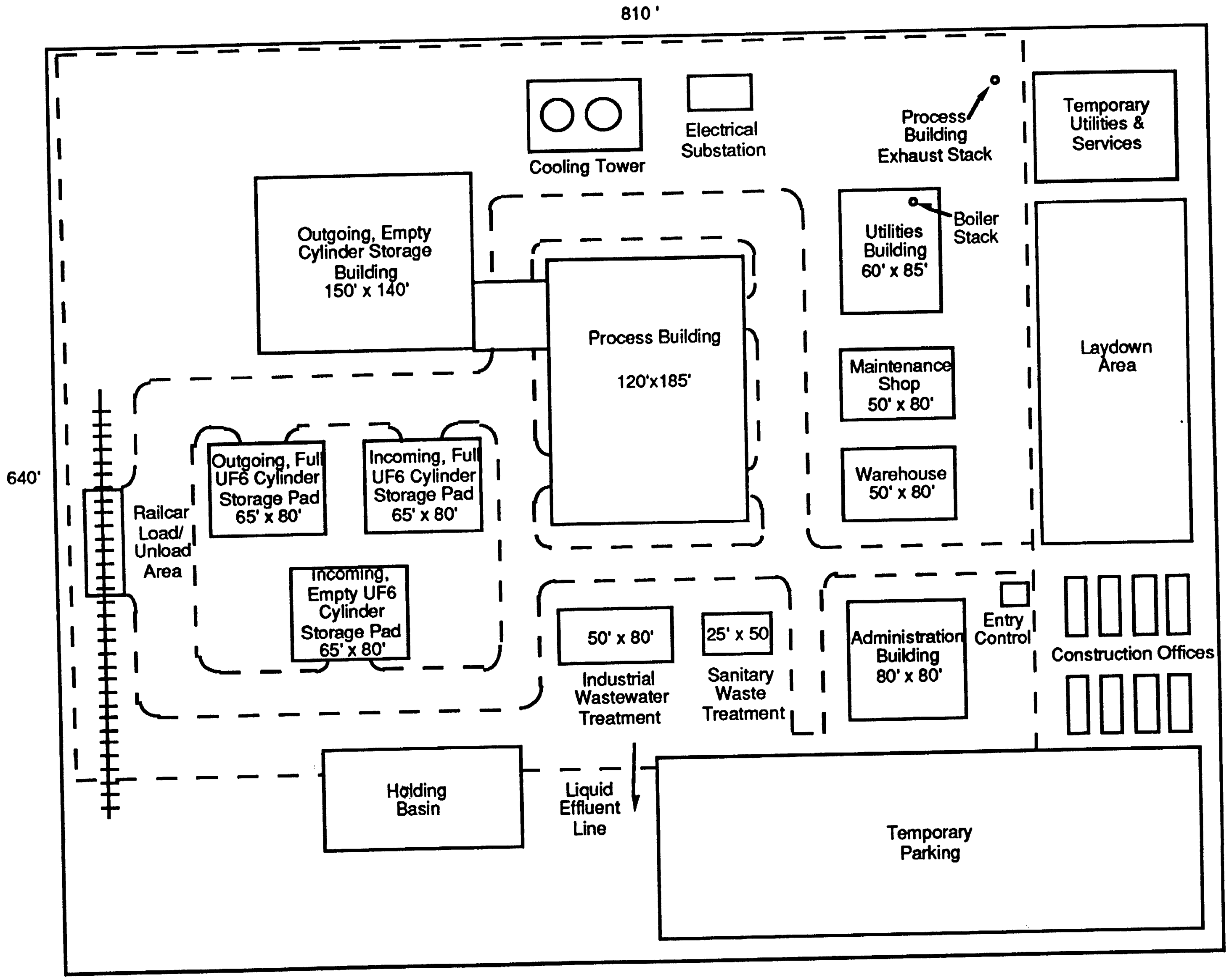


FIGURE 3-2, SITE MAP DURING CONSTRUCTION
DUF_6 TRANSFER FACILITY - LOW CASE

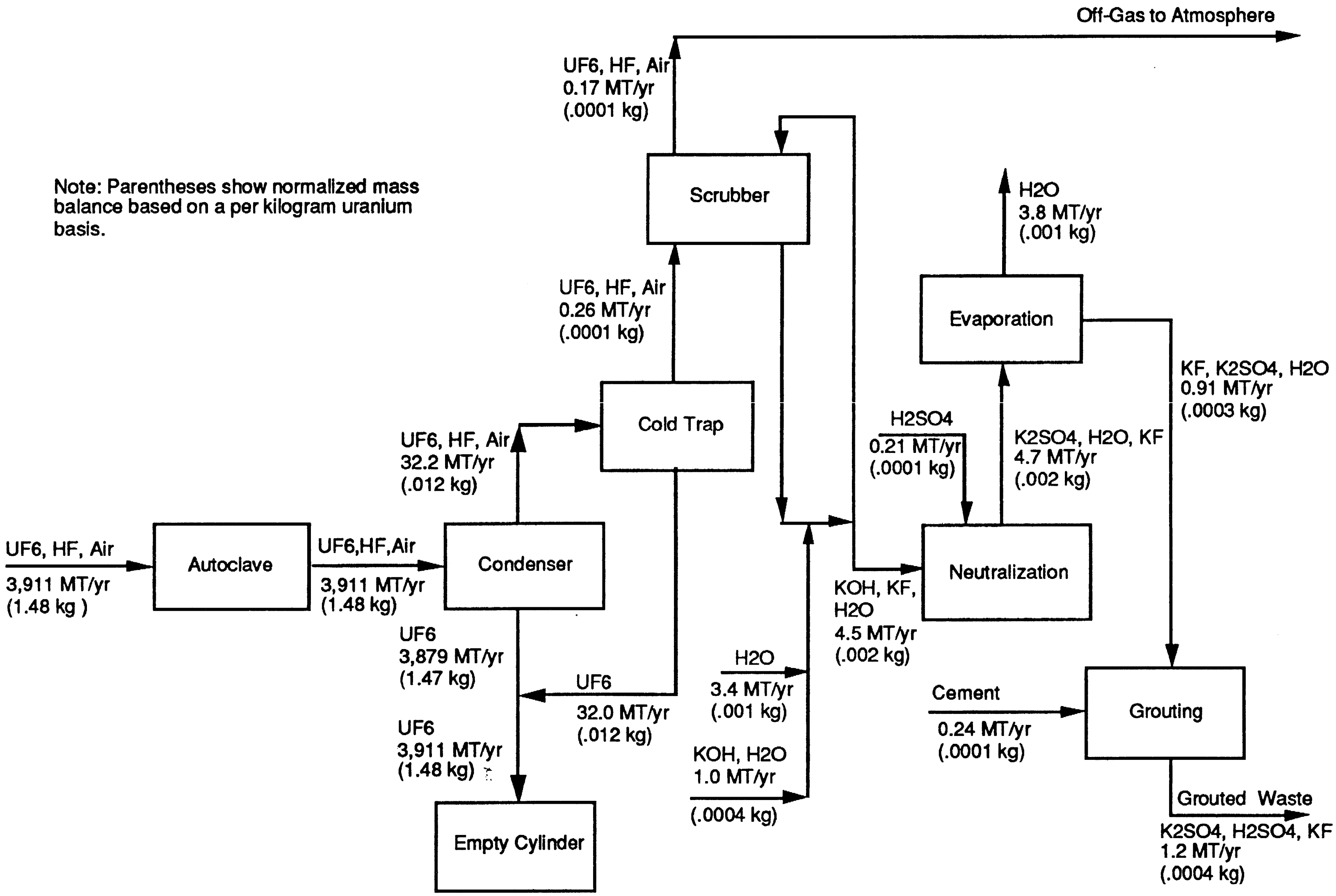


Figure 4-1 UF6 Transfer (Low Capacity Case) Block Flow Diagram

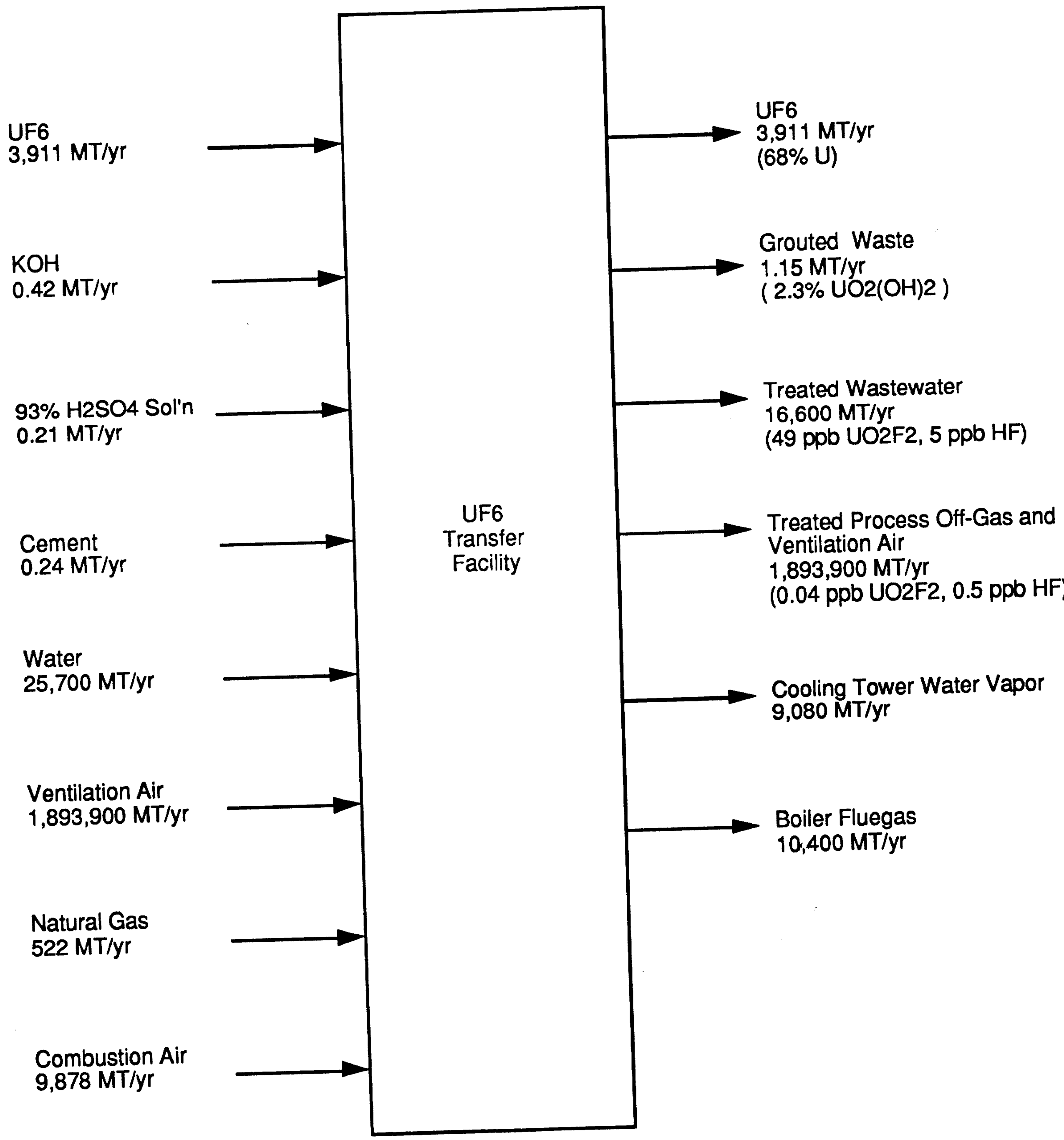


Figure 4-2 UF6 Transfer (Low Capacity Case) Input / Output Diagram

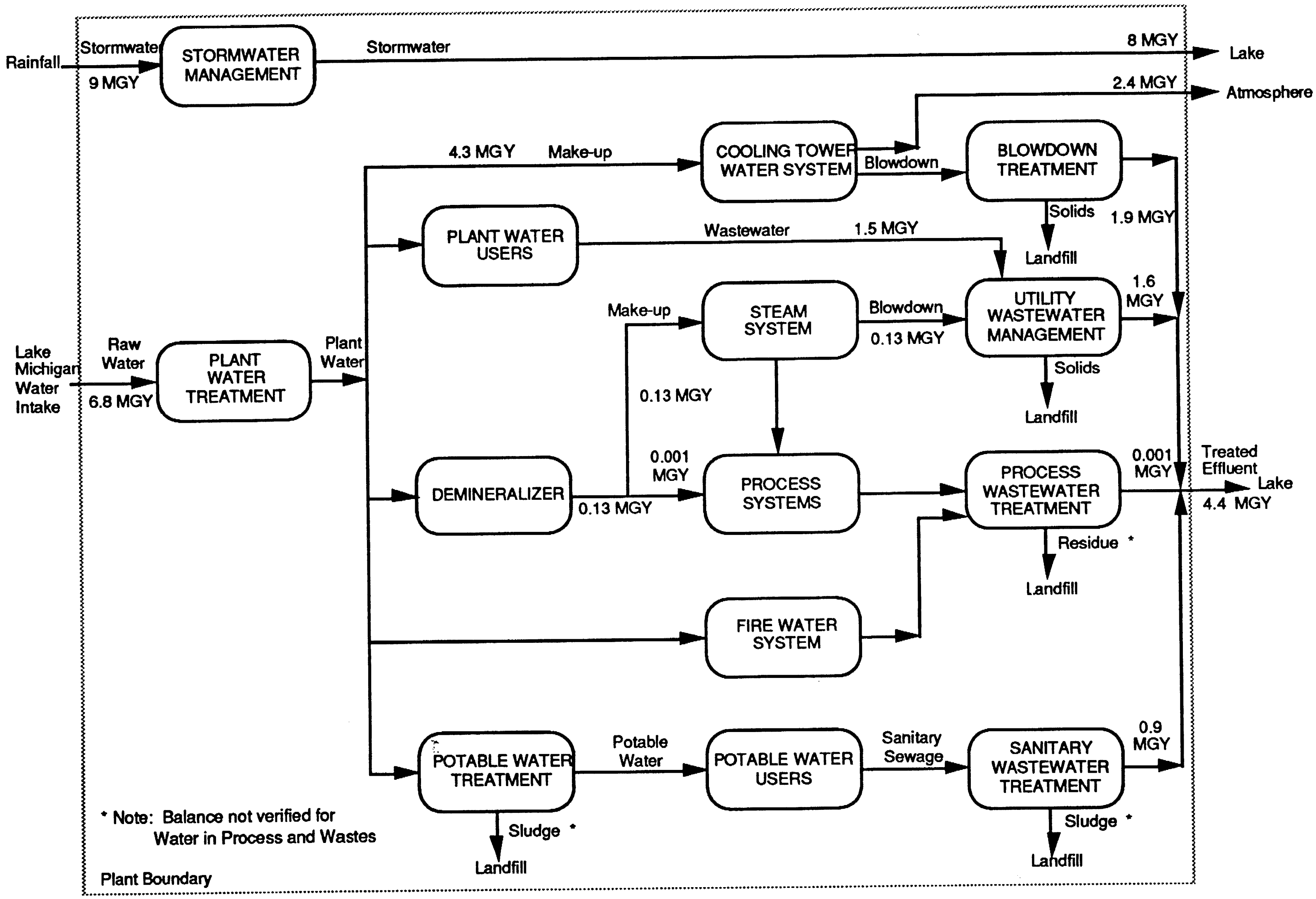


Figure 5-1 Preliminary Water Balance UF6 Transfer (Low Capacity Case)

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Cement	530
Potassium Hydroxide	930
Detergent	500
Liquid	
Sulfuric Acid (93% H_2SO_4)	470
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	970
Sodium Hydroxide (50% NaOH)	770
Sodium Hypochlorite	760
Copolymers	800
Phosphates	80
Phosphonates	80
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 4x2x7 ft boxes - see also Table 9-1)	286 drums 8 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	25,000 MWh	1.0 MW
Water	6.5×10^6 gal	600 gal
Solids		NA
Concrete	16,000 yd^3	
Steel (carbon or mild)	6,000 tons	
Electrical raceway	16,000 yd	
Electrical wire and cable	40,000 yd	
Piping	16,000 yd	
Steel decking	18,000 yd^2	
Steel siding	6,000 yd^2	
Built-up roof	7,800 yd^2	
Interior partitions	1,000 yd^2	
Lumber	4,000 yd^3	
HVAC ductwork	80 tons	
Asphalt paving	180 tons	
Liquids		
Fuel [2]	1.2×10^6 gals	
Gases		
Industrial Gases (propane)	3,500 gal	

[1] Peak demand is the maximum rate expected during any hour.
[2] Fuel is 50% gasoline and 50% diesel fuel.

The primary specialty material used for equipment fabrication is approximately 4 tons of Monel.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	6
Professionals	6
Technicians	5
Office and Clerical	20
Craft Workers (Maintenance)	10
Operators / Line Supervision	45/15
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	133

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4[1]
Process Building	13	10	10	10
Cylinder Storage Pads & Building	7	3	3	3
Utilities/Services/Admin Areas	29	15	15	15
TOTAL EMPLOYEES	49	28	28	28

1 The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	140	200	340	140
Construction Management and Support Staff	30	40	60	30
TOTAL EMPLOYEES	170	240	400	170

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		Boiler/Other[1]
Sulfur Dioxide	Boiler Stack / Grade	16/39
Nitrogen Dioxide	Boiler Stack / Grade	2,100/300
Hydrocarbons	Boiler Stack / Grade	44/240
Carbon Monoxide	Boiler Stack / Grade	1,040/2,000
Particulate Matter PM-10	Boiler Stack / Grade	78/60
OTHER POLLUTANTS		
HF	Process Building Exhaust Stack	1.8
UO_2F_2	Process Building Exhaust Stack	0.14
Copolymers	Cooling Tower	160
Phosphonates	Cooling Tower	16
Phosphates	Cooling Tower	16
Calcium	Cooling Tower	280
Magnesium	Cooling Tower	70
Sodium and Potassium	Cooling Tower	30
Chloride	Cooling Tower	50
Dissolved Solids	Cooling Tower	1,600

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg Exhaust Stack	2.0×10^{-5}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	2.5×10^{-4}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Quantity Packages
Low Level Waste					
Combustible solids	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	144,000	67	19 lb UO_2F_2	246 55-gal drums
Metal, surface contaminated	Failed equipment	8,100	5	11 lb UO_2F_2	19 55-gal drums
Noncombustible, compactible solids	HEPA filters	2,700	15	28 lb UO_2F_2	8 4x2x7 ft boxes (3/4" plywood)
Noncombustible, noncompactible solids	Grouted Waste See Sect. 4.3	2,600	0.7	60 lb $UO_2(OH)_2$	3 55-gal drums
Other	LabPack (chemicals plus absorbent)	800	0.5	1 lb UO_2F_2	2 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint, thinner	1,100	0.7 (150 gal)	See description	3 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	1,600	1	2 lb HF 2 lb NaOH	4 55-gal drums
Combustible debris	Wipes, etc. (plastic,paper, cloth)	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	410	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Inorganic process debris	Failed equipment (metal, glass)	400	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Combustible debris	Wipes, etc. (plastic, paper, cloth)	135	0.25	0.1 lb UO_2F_2 0.1 lb Acetone	1 55-gal drum

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	0.9×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	330	3.5×10^6
Recyclable Wastes	130	-

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	1.4
Nitrogen Dioxide	22
Hydrocarbons	6
Carbon Monoxide	150
Particulate Matter PM-10	40

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	40 yd^3
Hazardous Liquids	15,000 gals
Nonhazardous Solids	
Concrete	100 yd^3
Steel	30 tons
Other	800 yd^3
Nonhazardous Liquids	
Sanitary	2.3×10^6 gals
Other	1.0×10^6 gals

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Input Material #5
Transported Materials					
Type	UF_6	HCl	NaOH	H_2SO_4	KOH
Physical Form	Solid	Liquid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	H_2SO_4 / ambient	KOH / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	TBD	TBD
Container Weight (lb)	2,600	50	50	50	50
Material Weight (lb)	27,000	540	660	840	500
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	93% H_2SO_4	100% KOH
Shipments					
Average Volume (ft^3)/Year	44,500	15	7	7	15
Packages/Year	320	2	1	1	2
Packages/Life of Project	6,400	40	20	20	40
Packages/Shipment	1 (truck) or 4 (railcar), 3 cars/train	2	1	1	1
Shipments/Year	320 (truck) or 27 (rail)	1	1	1	1
Shipments/Life of Project	6,400 (truck) or 540 (rail)	20	20	20	20
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck
Destination - Facility Type	NA	NA	NA	NA	NA

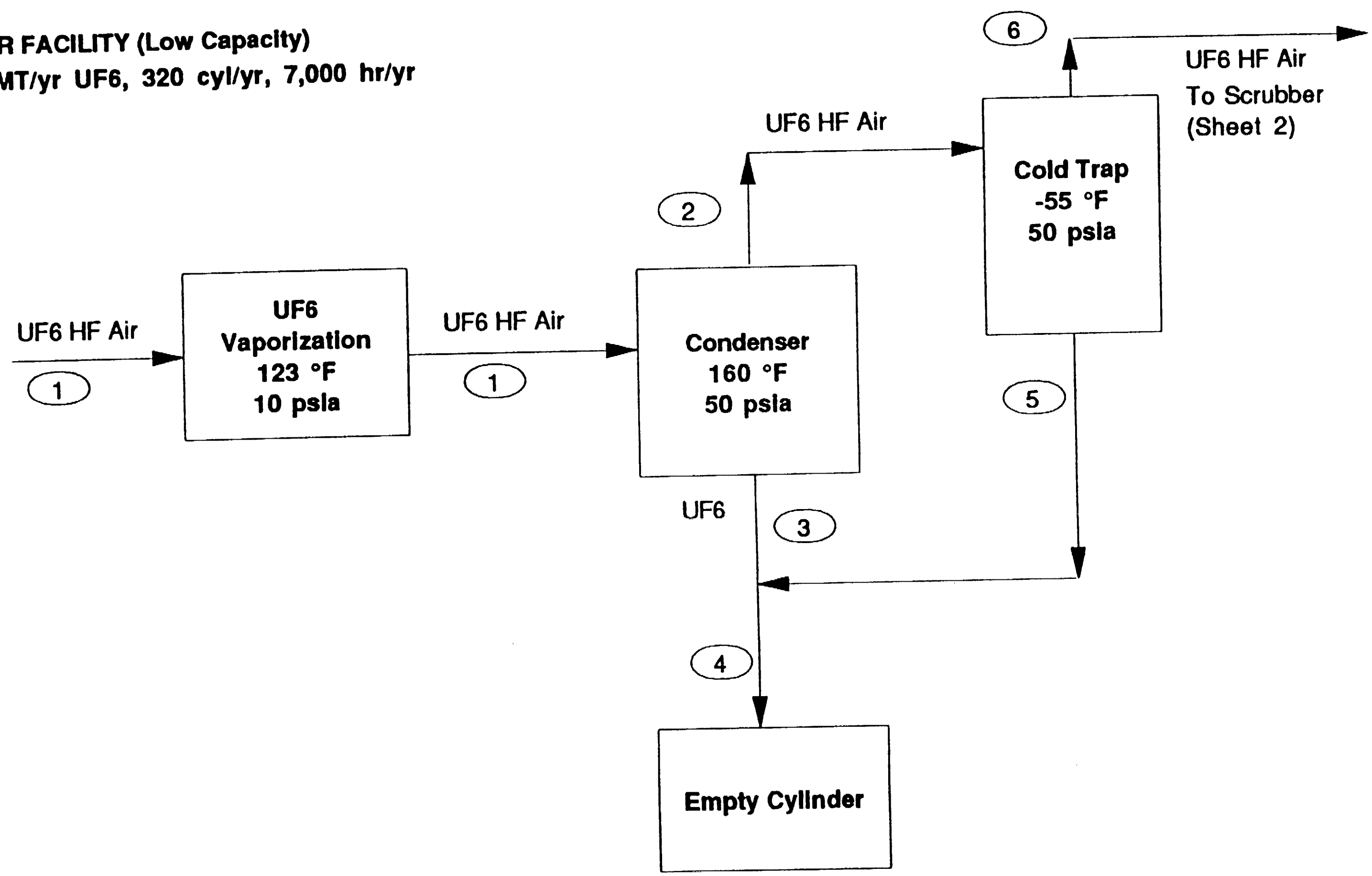
Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data
(continued)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	UF_6	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	Varies	Varies	Varies	48G
Container Weight (lb)	2,600	50/300	50	50	2,600
Material Weight (lb)	27,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% UF_6	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	44,600	2,500	100	20	44,500
Packages/Year	321	270/8	13	3	320
Packages/Life of Project	6,420	5,400/300	260	60	6,400
Packages/Shipment	1 (truck) or 4 (railcar) 3 cars/train	40/8	13	3	6 (truck) or 12 (railcar) 1 car/train
Shipments/Year	321 (truck) or 27 (rail)	7/1	1	1	54 (truck) or 27 (rail)
Shipments/Life of Project	6,420 (truck) or 540 (rail)	140/20	20	20	1,080 (truck) or 540 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	TBD	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

7A-Mass Bal MT/yr

UF6 TRANSFER FACILITY (Low Capacity)
Basis: 3,911 MT/yr UF6, 320 cyl/yr, 7,000 hr/yr
UF6 Transfer



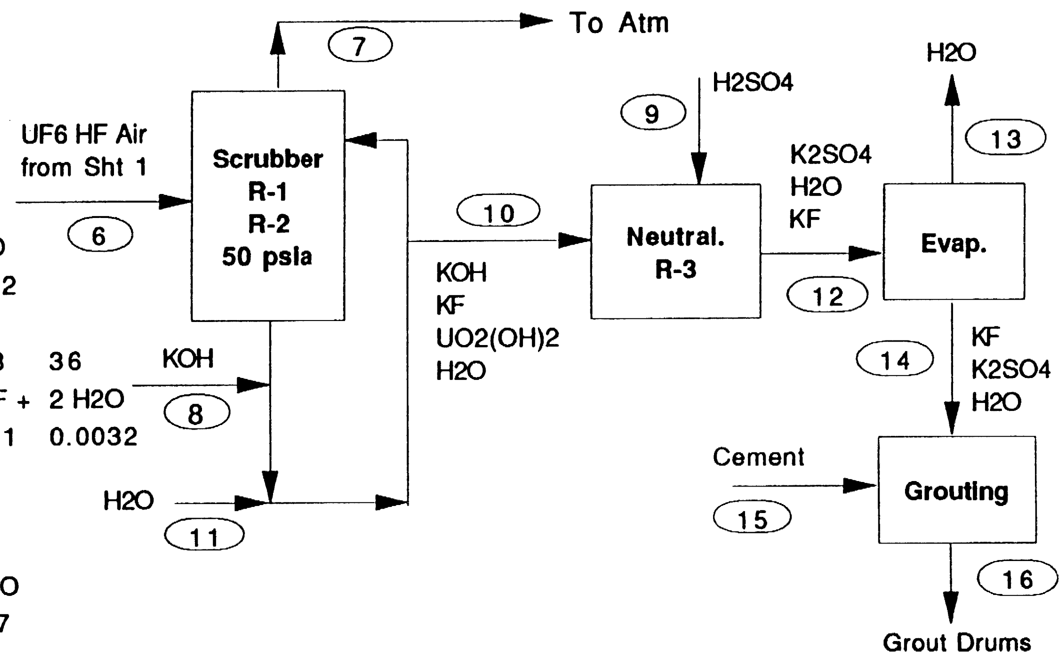
	Mol Wt	1	2	3	4	5	6
UF6	352	3,911	32.07	3,879	3,911	32.04	0.032
HF	20	0.058	0.058				0.058
Air	29	0.17	0.17				0.17
Total MT/yr		3,911	32.29	3,879	3,911	32.04	0.26
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

11/5/96

Sheet 1

UF6 TRANSFER FACILITY (Low Capacity)
Basis: 3,911 MT/yr UF6, 320 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

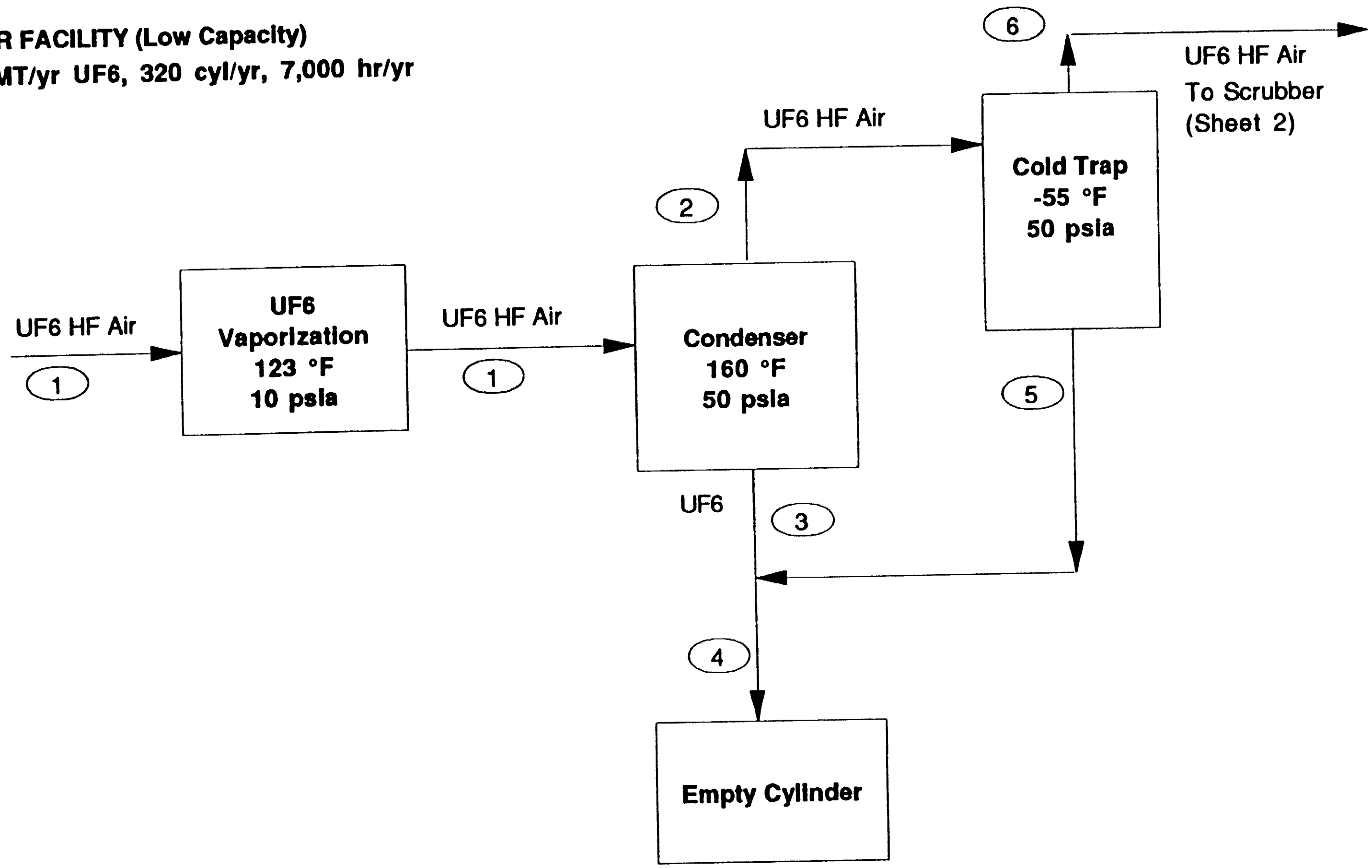
	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.057	0.16	0.17	0.052	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.032	0.030	0.027	0.031	0.0032
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	0.23	0.20	0.35	0.07	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.00032									
HF	20	0.00058									
Air	29	0.17									
KOH	56		0.42		0.23						
H2O	18		0.62	0.015	4.06	3.38	4.14	3.81	0.33		0.33
UO2(OH)2	304				0.027		0.027		0.027		0.027
KF	58				0.20		0.20		0.20		0.20
K2SO4	174						0.35		0.35		0.35
H2SO4	98			0.20							
Cement										0.24	0.24
Total MT/yr		0.17	1.04	0.21	4.51	3.38	4.72	3.81	0.91	0.24	1.15
kg/kg U		0.00006	0.0004	0.00008	0.0017	0.0013	0.0018	0.0014	0.0003	0.00009	0.0004

7A-Mass Bal lb/hr

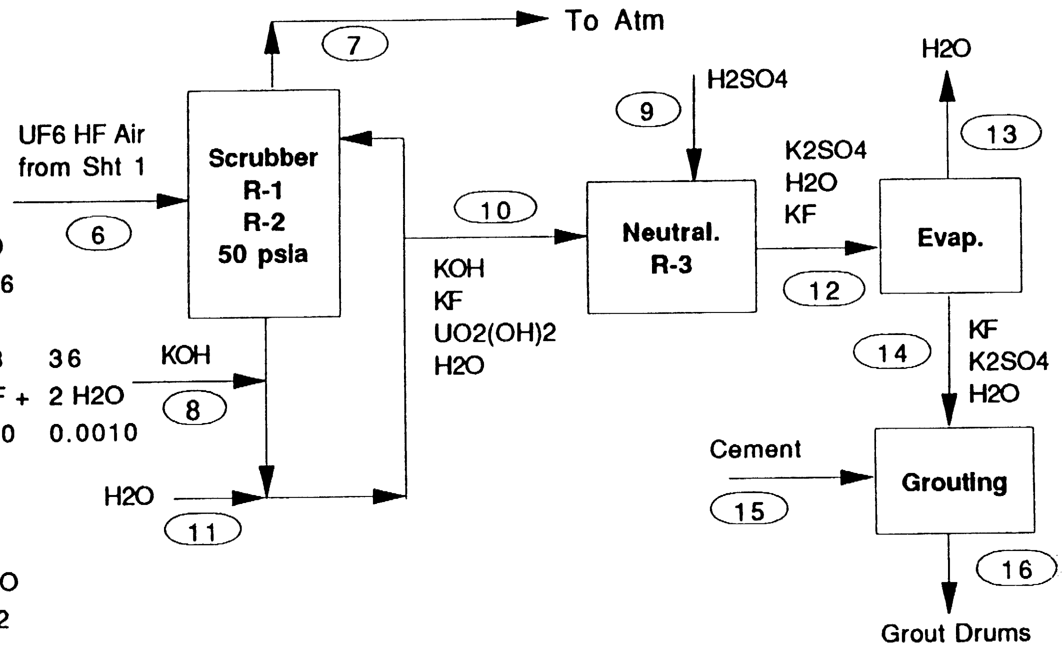
UF6 TRANSFER FACILITY (Low Capacity)
Basis: 3,911 MT/yr UF6, 320 cyl/yr, 7,000 hr/yr
UF6 Transfer



	Mol Wt	1	2	3	4	5	6
UF6	352	1,232	10.10	1,222	1,232	10.09	0.010
HF	20	0.018	0.018				0.018
Air	29	0.053	0.053				0.053
Total lb/hr		1,232	10.17	1,222	1,232	10.09	0.08
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

UF6 TRANSFER FACILITY (Low Capacity)
Basis: 3,911 MT/yr UF6, 320 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.018	0.051	0.053	0.016	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.010	0.010	0.009	0.010	0.0010
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	0.07	0.06	0.11	0.02	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.00010									
HF	20	0.00018									
Air	29	0.053									
KOH	56		0.13		0.07						
H2O	18		0.20	0.005	1.28	1.07	1.31	1.20	0.11		0.11
UO2(OH)2	304				0.0086		0.0086		0.0086		0.0086
KF	58				0.063		0.063		0.063		0.063
K2SO4	174						0.11		0.11		0.11
H2SO4	98			0.062							
Cement										0.076	0.076
Total lb/hr		0.054	0.33	0.067	1.42	1.07	1.49	1.20	0.29	0.076	0.36
kg/kg U		0.00006	0.0004	0.00008	0.0017	0.0013	0.0018	0.0014	0.0003	0.00009	0.0004

MAJOR EQUIPMENT LIST
UF6 Transfer Facility (Low Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (4)	7'Dx23'Lx 5/8" wall, carbon steel. A fixed head w/ movable shell section. 12-1/2 hp fans attached to shell inside	Proc. Bldg
Forced Air Blower (4)	3000 scfm, 15 hp	Proc. Bldg
Air Heater (4)	Electric type, 20 kw	Proc. Bldg
UF6 Compressor (2)	1400 lb/hr UF6 (45 cfm) at 10 psia inlet, 50 psia discharge, 5 hp	Proc. Bldg
Backing Compressor (2)	5 cfm, 1 psia inlet, 10 psia discharge, 0.5 hp	Proc. Bldg
Condenser	10" dia x 6' L, Monel shell with U tubes.	Proc. Bldg
Cold Trap (2)	12" dia x 8' H Monel shell with finned tubes.	Proc. Bldg
UF6 Accumulator	2' dia x 3' L, Monel, 70 gal	Proc. Bldg
UF6 Filling Station	Two (2) - 20 ton scales	Proc. Bldg
Off-Gas Scrubber	1'dia x10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	6" dia pipe x 5' L, steam jacketed	Proc. Bldg
Off-Gas HEPA Filter (2)	8"x8"x12"	Proc. Bldg
KOH Storage Tank	3' dia x 3' H, carbon steel	Proc. Bldg
KOH Pump	1 gpm	Proc. Bldg
Scrubber Pump	5 gpm, Monel	Proc. Bldg
Neutralization Tank	3' dia x 3' H, Monel, with cooling coils	Proc. Bldg
Neutralization Pump	5 gpm, Monel	Proc. Bldg
Evaporator	3' dia x 3' H, carbon steel with heating coils	Proc. Bldg
Slurry Pump	5 gpm, carbon steel	Proc. Bldg
Drum Filling Station	0.01 drum per day (avg.)	Proc. Bldg
Dry Tumbling Station	0.01 drum/day, carbon steel	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (Low Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Condenser Cooling Water System	43,000 BTU/hr, 140 °F, w/ heat exchanger tank and pump.	Proc. Bldg
Cold Trap Cooling System	900 Btu/hr, -75 °F, w/ tank, chiller & pump	Proc. Bldg
Cold Trap Heating System	600 Btu/hr, 185 °F, w/ tank, heater & pump	Proc. Bldg
Material Handling Systems	Two (2) flatbed trucks One (1) 20-ton crane Two (2) 20-ton yard cranes Two (2) forklift trucks Two (2) 20-ton cylinder straddle carriers 100 storage saddle/pallets Three (3) storage racks each for 26 cylinders	Yard Proc. Bldg Yard Proc. Bldg/Yard Proc. Bldg/ Storage Areas Proc. Bldg/ Storage Bldg
DUF_6 Cylinder Vacuum System	Two (2) vacuum systems with cold traps, NaF traps and vacuum pumps	Proc. Bldg
Decontamination & Maintenance Systems	Four (4) decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations w/ tanks.	Proc. Bldg
Process Control / Monitoring System	Distributed Control System(DCS) with centralized monitoring stations. Closed circuit TV monitoring system	Proc. Bldg
Sampling / Analytical Systems	Two (2) local sampling glove boxes with laboratory liquid / powder sample hardware. Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (Low Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Low Level Radioactive & Hazardous Waste Management System (continued)	• bar code reader / computerized • accountability system • 1-radwaste drum assay device	
Material Accountability System	•Computerized material control and accountability system (hardware & software).	Proc. Bldg
	•2 accountability scales for incoming and outgoing DUF_6 cylinders & waste drums	Proc. Bldg
	•2 bar code readers for DUF_6 cylinder and waste drums.	Proc. Bldg/Yard
	•Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF and UF_6) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (Low Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Utility / Services Systems	Boiler - 6,800 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing Air Compressors-2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, -40°F dew point	Util. Bldg
	Demineralized water system - 400 gpd	Util. Bldg
	Sanitary water treatment system - 2,500 gpd	Sanitary Waste Treatment Bldg
	Industrial wastewater treatment system - 13,000 gpd	Indus Waste Treatment Bldg
	Electrical substation - 900 kW	Substation
	Emergency generators - 2 @ 200 kW	Proc. Bldg
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 4.5 MM Btu/hr, 450 gpm	Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-2000 cfm, 5 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-30,000 cfm, 120 HP exhaust fans, 2-30,000 cfm 40 HP supply air units	DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 25 HP supply air units, 2-15,000 cfm, 10 HP exhaust fans, 2-15,000 cfm, 15 HP supply air units	Waste Process'g Control Room Support Areas
HVAC Chillers	3-170 ton chillers	Proc. Bldg
Circulating Pumps	3-275 gpm, 10 Hp	Proc. Bldg

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

TRANSFER FACILITY - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Unload arriving full incoming UF6 cylinder	3	0.50	320	1	3	Steel	1/4"	480.0
Inspect arriving full incoming UF6 cylinders	1	0.50	320	1	3	Steel	1/4"	160.0
Transfer full incoming UF6 cylinder to storage pad	2	0.50	320	1	6	Steel	1/4"	320.0
Unload full incoming UF6 cylinder at storage pad	2	0.50	320	1,7	3,3	Steel	1/4"	320.0
Load full incoming UF6 cylinder onto cart	2	0.50	320	1,7	3,3	Steel	1/4"	320.0
Transfer full incoming UF6 cylinder from storage to process building	2	0.50	320	1	6	Steel	1/4"	320.0
Inspect full incoming UF6 cylinders	2	0.50	320	1	3	Steel	1/4"	320.0
Load full incoming cylinder into autoclave from cart	3	0.50	320	1,5	3,3	Steel	1/4"	480.0
Autoclave pressure test	2	1.00	320	1	15	Steel	1/4"+1/4"	640.0
Unload autoclave	1	0.30	320	2	3	Steel	1/4"	96.0
Transfer empty outgoing UF6 cylinder to pallet	2	0.25	320	2	20	Steel	1/4"	160.0
Transfer empty outgoing UF6 cylinder to Storage Building	1	0.25	320	2	3	Steel	1/4"+1.25"	80.0
Store empty outgoing UF6 cylinder in Storage Building	1	0.25	320	2	3	Steel	1/4"	80.0
Move empty incoming UF6 cylinder to filling area	2	0.50	322	4,6	10	Steel	1/4"	322.0
Move full outgoing UF6 cylinder to storage area	3	0.50	322	4	6	Steel	1/4"	483.0
Transfer full outgoing UF6 cylinder to storage yard	2	0.50	322	4	6	Steel	1/4"	322.0
Prepare empty outgoing UF6 cylinder for shipment	2	0.50	320	3	3	Steel	1/4"	320.0
Load empty outgoing UF6 cylinder for shipment	3	0.50	320	3	6	Steel	1/4"	480.0
Load full outgoing UF6 cylinder for shipment	3	0.50	322	4	6	Steel	1/4"	483.0
Full incoming UF6 cylinder storage surveillance	1	0.50	2190	1,7	3	Steel	1/4"	1095.0
Autoclave, compressor, condenser surveillance	1	0.25	1752	1,4,5,6	3	Steel	1/4"	438.0
Full outgoing UF6 cylinder surveillance	1	0.50	2190	4,9	3	Steel	1/4"	1095.0
Cylinder Repair	2	4.00	34	1	2	Steel	1/4"	272.0
Off-gas Scrubbing / Process Liquid Treat. surveillance	1	0.50	1752	1,2	25	Steel	1/4"	876.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Waste grouting	2	2.00	15	10	3	Steel	0.06"	60.0
Transfer grouted drums to storage area	2	0.50	15	10	3	Steel	0.06"	15.0
Load grouted drums for shipment offsite	2	1.00	1	10	3	Steel	0.06"	2.0
Supervision	2	8.00	1100	1,2,3	15	Steel	1/4"	17600.0
Process control room operations	2	8.00	1100	4,6	25	Steel	1/4"	17600.0
Laboratory operations	1	8.00	1100	4,6	25	Steel	1/4"	8800.0
HP	2	8.00	1100	4,6	25	Steel	1/4"	17600.0
Management / Professionals	8	8.00	250	4,6	25	Steel	1/4"	16000.0
Accountability	2	2.00	1100	1,2	3	Steel	1/4"	4400.0
Industrial and sanitary waste treatment	2	8.00	1100	4,6	140	Steel	1/4"	17600.0
Utilities operations	2	8.00	1100	1,2	140	Steel	1/4"	17600.0
Warehouse	2	8.00	250	4,6	140	Steel	1/4"	4000.0
Administration	15	8.00	250	4,6	190	Steel	1/4"	30000.0
Guardhouses / Process Bldg.	6	8.00	1100	4;6	250;25	Steel	1/4"	52800.0
Maintenance								9348.0
								223387.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in the Cylinder Filling & Storage Area.
7) There are up to 30 full incoming UF6 cylinders in the storage area.
8) There are up to 90 empty outgoing UF6 cylinders in the storage building.
9) There are up to 30 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) 320 incoming UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    15 grouted waste drums/yr
    15 grouted waste drums/yr /15 drums per shipment = 1 transfers per year
12) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

TRANSFER FACILITY - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (12)	2	26	4	1,5,2	3	Steel	1/4"+1/4"	208
Forced Air Blower (12)	2	52	4	1,5;4	8	Steel	1/4"+1/4";1/4	416
Air Heater (12)	2	26	4	1,5;4	8	Steel	1/4"+1/4";1/4	208
UF6 compressors (6)	2	52	2	1,5;4	8	Steel	1/4"+1/4";1/4	208
Backing Compressor (6)	2	52	2	1,5;4	8	Steel	1/4"+1/4";1/4	208
Condenser (3)	2	26	1	14	6	Monel	1/4"	52
Cold Trap (6)	2	26	2	14	3	Monel	1/4"	104
Off-gas scrubber (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas heater (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas HEPA filters (2)	2	4	2	1,2	25	Steel	1/4"+1/4"	16
KOH pump (1)	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Scrubber Pump	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Neutralization pump (2)	2	52	2	1,2	25	Steel	1/4"+1/4"	208
Evaporator (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Slurry pump (1)	2	52	1	1,2	30	Steel	1/4"+1/4"	104
Grout mixing / drum tumbling station (1)	2	26	1	1,2	35	Steel	1/4"+1/4"	52
DUF6 Cylinder Vacuum System	2	26	1	1,2;4	10	Steel	1/4"+1/4";1/4	52
20 Ton Crane	2	52	1	1,2,5	35	Steel	1/4"+1/4"	104
Air Compressor, Water Systems in Process Bldg.	1	52	4	4,6	40	Steel	1/4"	208
HVAC equipment	2	520	1	4,6	40	Steel	1/4"	1040

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Boiler, Water Systems, Compressed Air, other Utilities	2	52	4	1;2	140	Steel	1/4"+1/4";1/4	416
Waste water treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Admin building	1	1000	1	4,6	190	Steel	1/4"	1000
								9348

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in a Cylinder Filling & Storage Area. There are 3 Cylinder Filling & Storage Areas.
7) There are up to 30 full incoming UF6 cylinders in the storage area.
8) There are up to 90 empty outgoing UF6 cylinders in the storage building.
9) There are up to 30 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) Loaded filter/bag.
12) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HVAC components
    6 hours per day on waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
13) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
14) Inventory in Cold Trap

Appendix E

DUF_6 Transfer Facility (High Capacity Case)

Summary

As part of a parametric analysis, the impact of a higher design throughput on the Depleted Uranium Hexafluoride Transfer Facility was studied. The facility described in this appendix is based on a total capacity of 32,000 substandard, existing cylinders, which is 5/3 of the baseline case. The facility is designed to transfer the UF_6 over 20 years at a rate of 1,600 cylinders per year.

There are five parallel trains of UF_6 transfer equipment. Each train consists of four autoclaves, two compressors (one is a spare), two backing compressors (one is a spare), one condenser, two cold traps, one accumulator and one cylinder fill station. One off-gas scrubbing system treats the off-gas from the five trains.

Major changes due to the increased throughput are shown in this report. Assumptions, design bases, facility and process descriptions, and accident analyses have not changed and can be found in the report for the baseline case.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	49,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
Outgoing Empty Cylinder Storage Building	79,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	7,200	1	No	Yes	General	Metal Frame
Administration Building	8,000	1	No	No	General	Metal Frame
Maintenance Shop	6,000	1	No	Yes	General	Metal Frame
Warehouse	6,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	6,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	1,800	1	No	No	General	Metal Frame
Cooling Tower	4,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Process Building Exhaust	100	101	80	60
Boiler	100	21	500	60

The total land area required during operations is approximately 644,000 ft^2 or about 15 acres. Land area requirements during construction are approximately 21 acres.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	14.6 GWh	1.9 MW
Liquid Fuel	6000 gals	NA
Natural Gas[2]	48.5×10^6 scf	NA
Raw Water	11.7×10^6 gals	NA

[1] Peak demand is the maximum rate expected during any hour.
[2] Standard cubic feet measured at 14.7 psia and 60 °F.

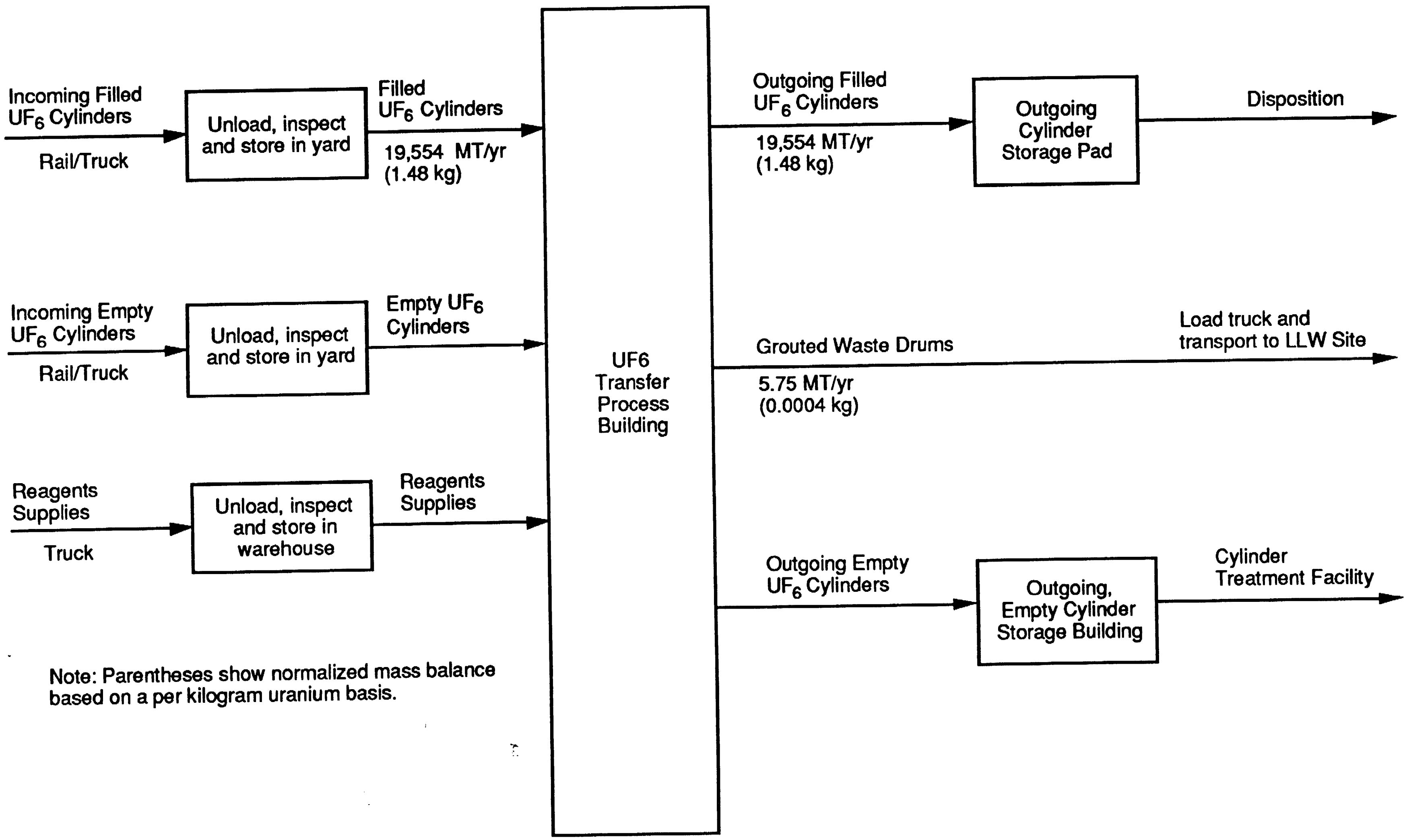


Figure 2-1 UF6 Transfer (High Capacity Case) Material Flow Diagram

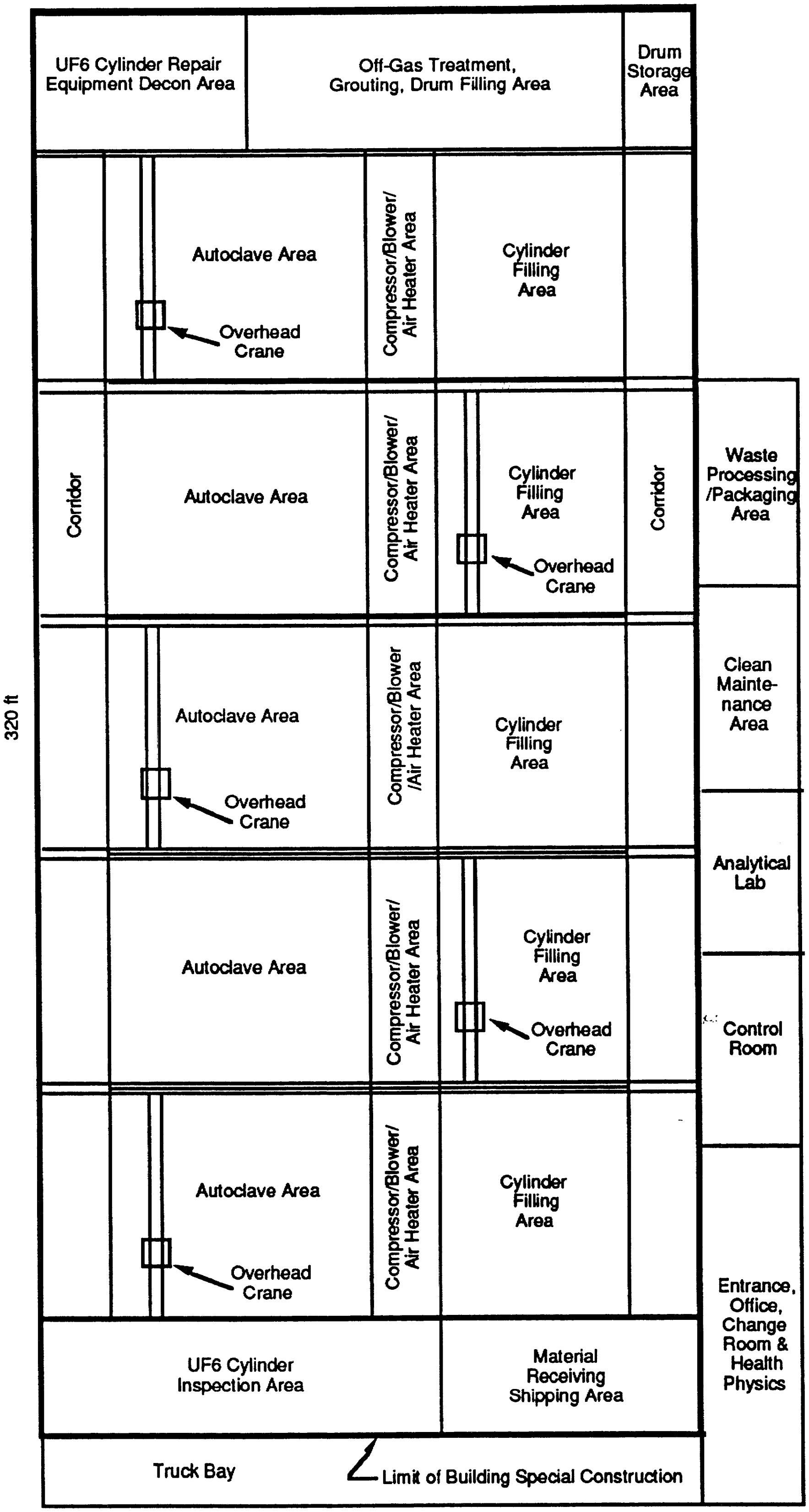


FIGURE 2-3
PROCESS BUILDING LAYOUT
UF6 TRANSFER FACILITY - HIGH CASE

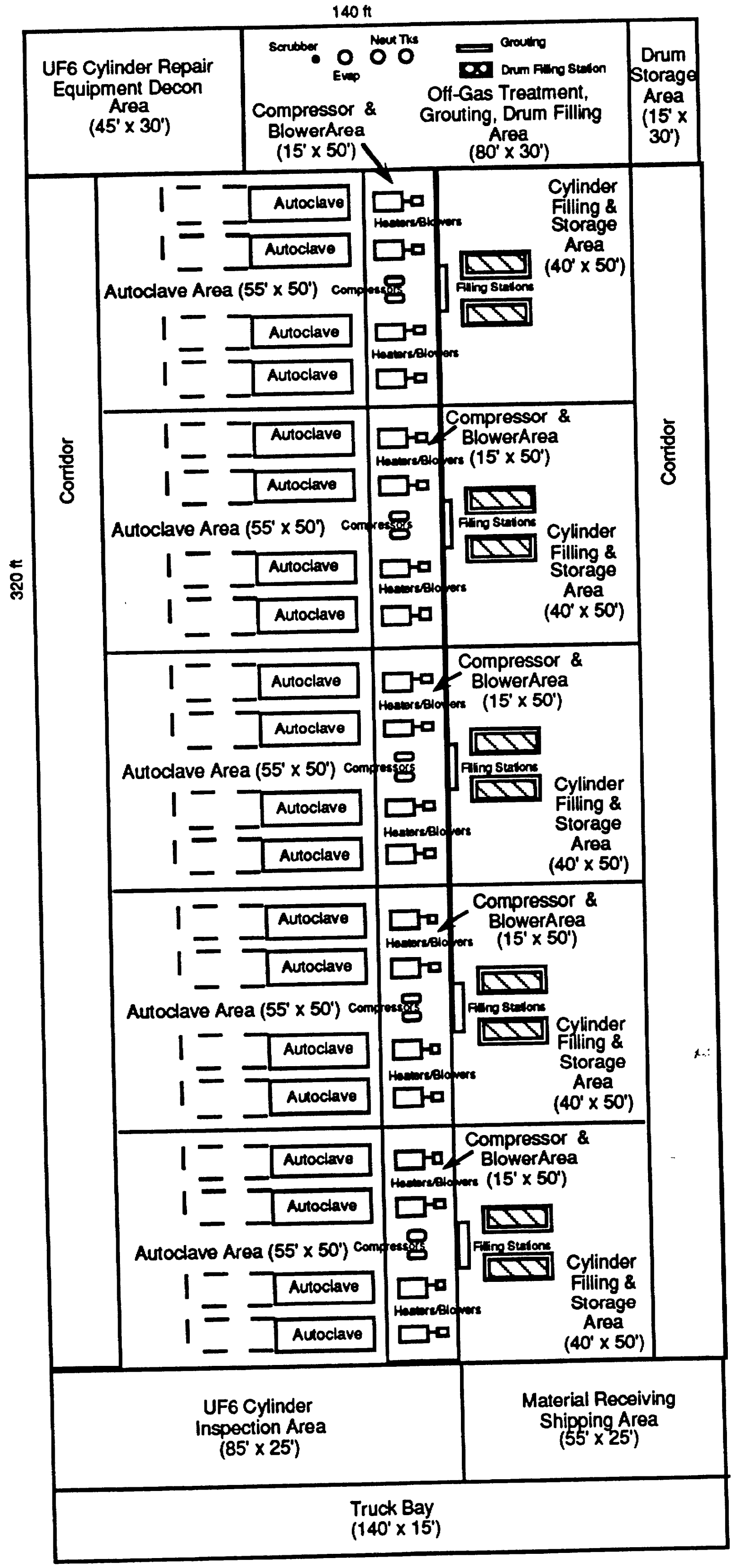


FIGURE 2-5
PROCESS EQUIPMENT ARRANGEMENT
UF6 TRANSFER FACILITY - HIGH CASE

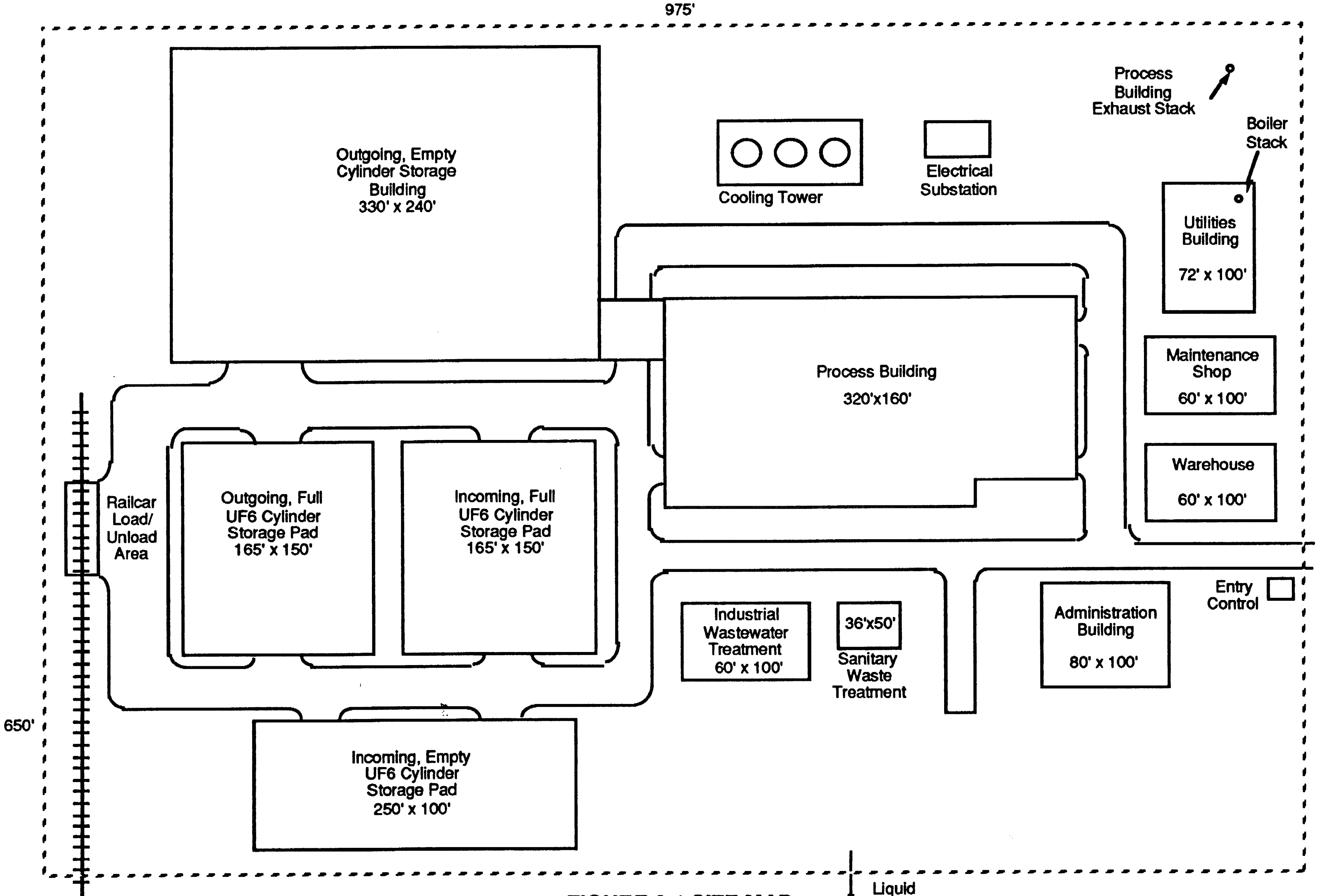


FIGURE 3-1 SITE MAP
DUF_6 TRANSFER FACILITY
HIGH CASE

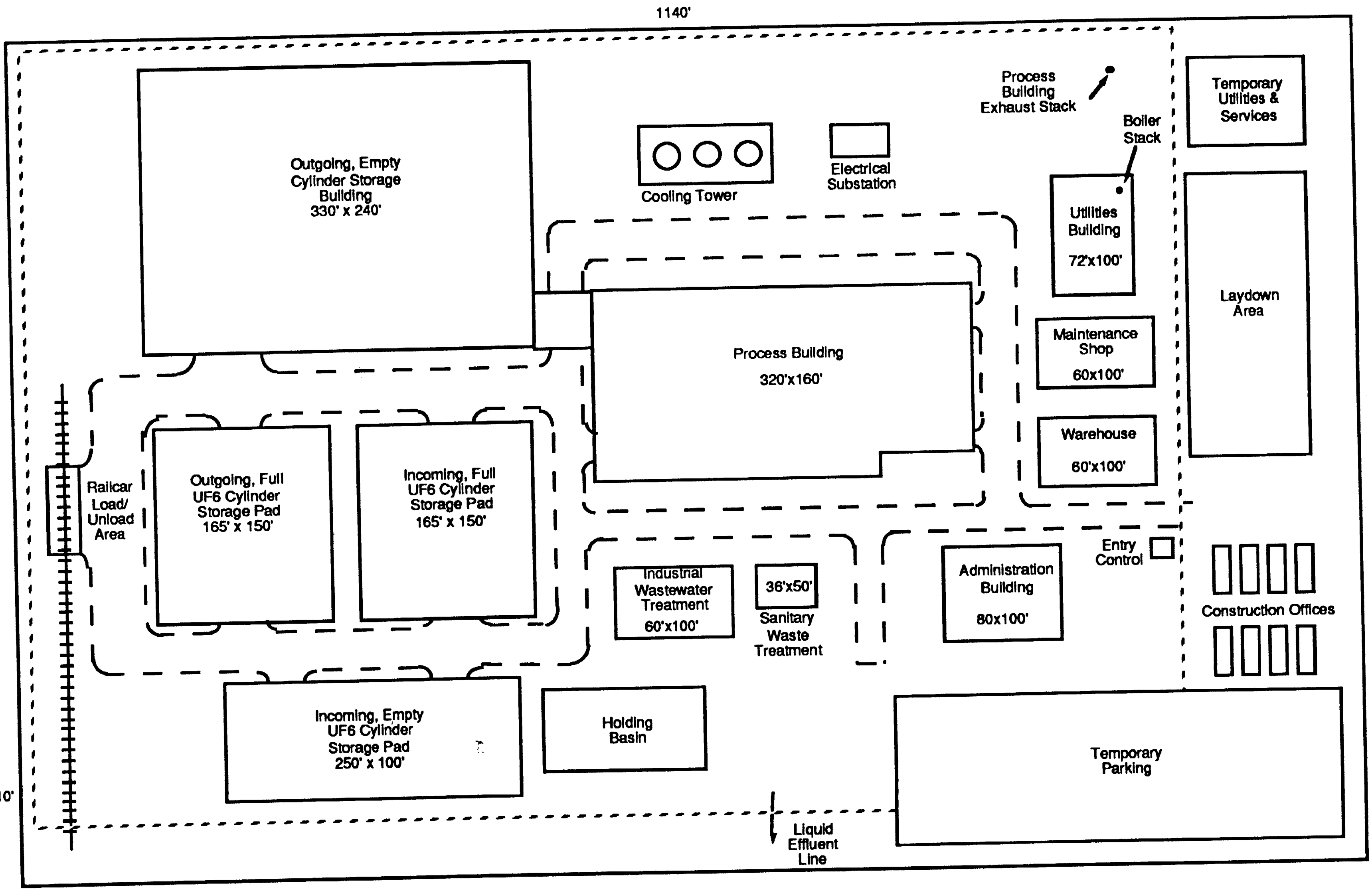


FIGURE 3-2, SITE MAP DURING CONSTRUCTION
DUF_6 TRANSFER FACILITY - HIGH CASE

Note: Parentheses show normalized mass balance based on a per kilogram uranium basis.

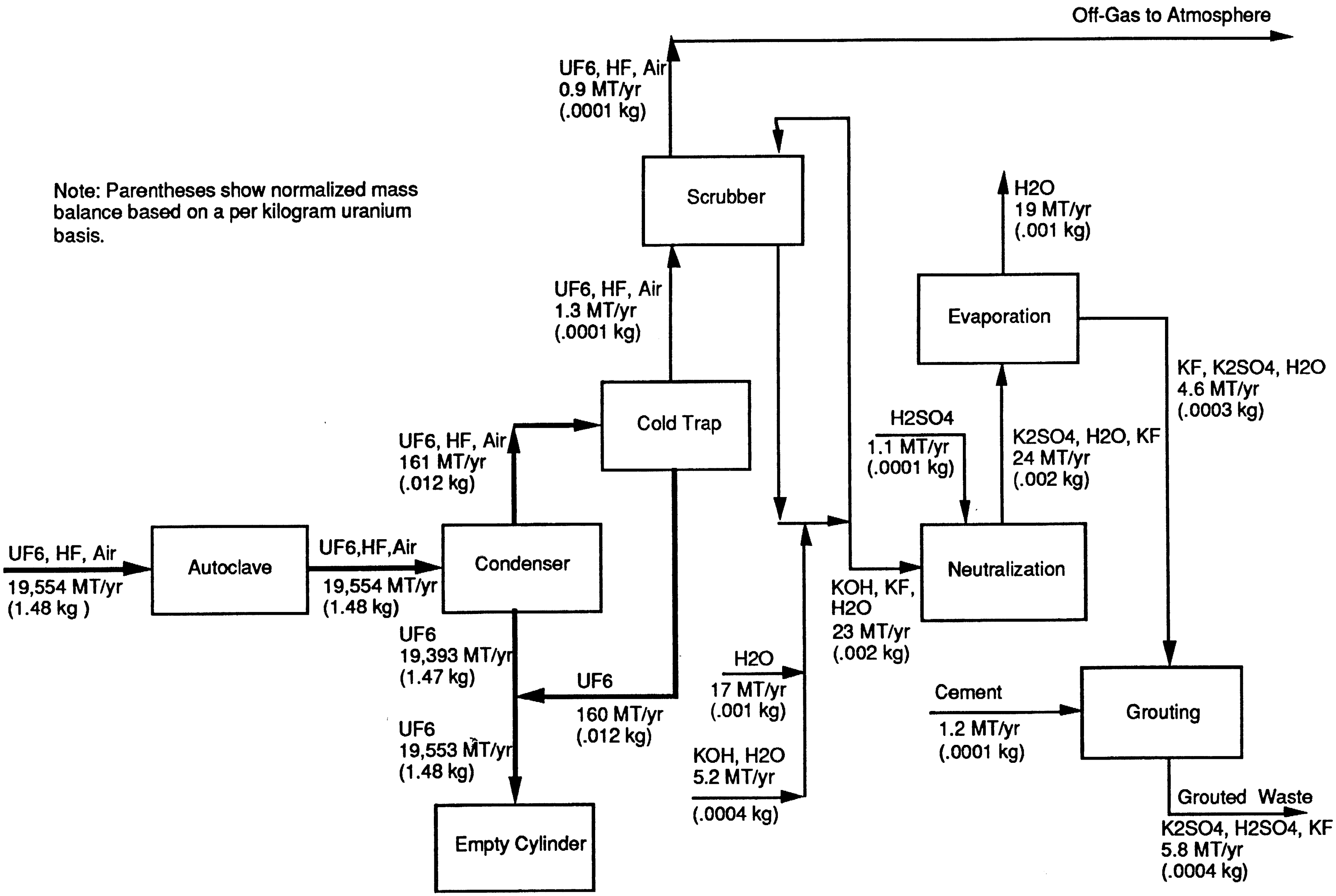


Figure 4-1 UF6 Transfer (High Capacity Case) Block Flow Diagram

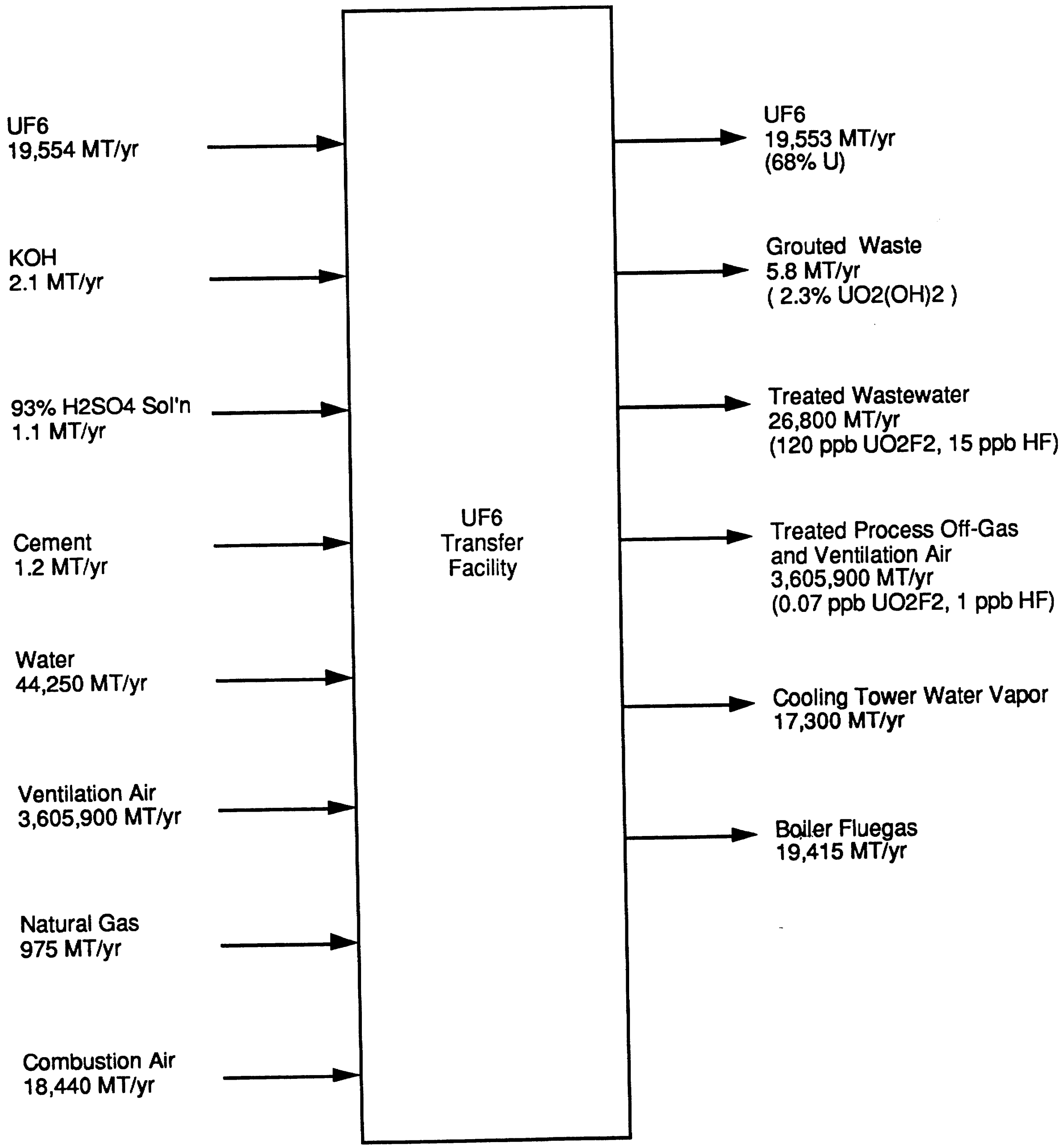


Figure 4-2 UF6 Transfer (High Capacity Case) Input / Output Diagram

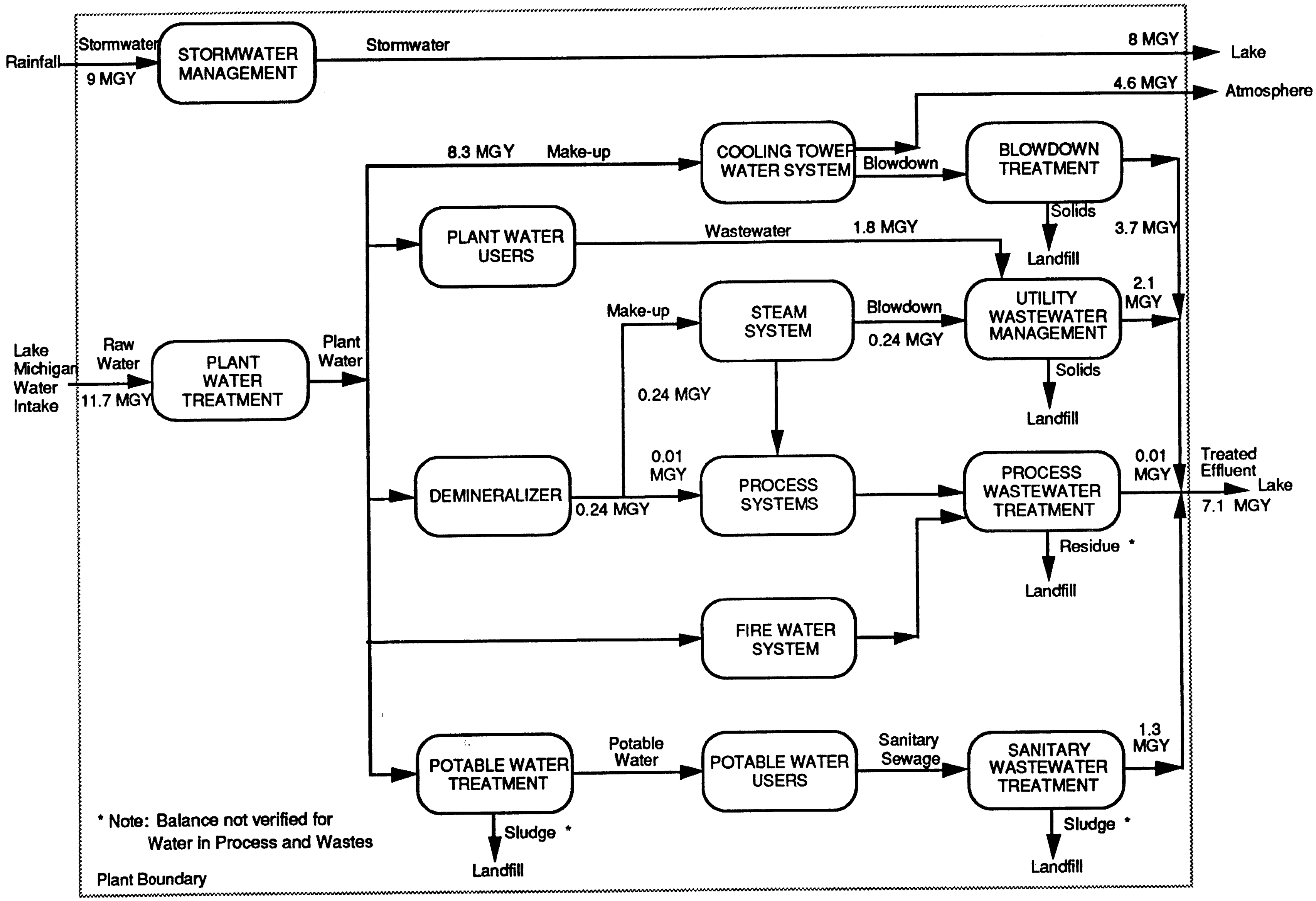


Figure 5-1 Preliminary Water Balance UF6 Transfer (High Capacity Case)

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Cement	2,700
Potassium Hydroxide	4,600
Detergent	500
Liquid	
Sulfuric Acid (93% H_2SO_4)	2,400
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	1,900
Sodium Hydroxide (50% NaOH)	1,500
Sodium Hypochlorite	1,500
Copolymers	1,500
Phosphates	150
Phosphonates	150
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 4x2x7 ft boxes - see also Table 9-1)	465 drums 14 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	40,000 MWh	2.0 MW
Water	10×10^6 gal	800 gal
Solids		NA
Concrete	23,000 yd^3	
Steel (carbon or mild)	9,000 tons	
Electrical raceway	30,000 yd	
Electrical wire and cable	65,000 yd	
Piping	25,000 yd	
Steel decking	30,000 yd^2	
Steel siding	13,000 yd^2	
Built-up roof	15,000 yd^2	
Interior partitions	1,700 yd^2	
Lumber	6,000 yd^3	
HVAC ductwork	150 tons	
Asphalt paving	300 tons	
Liquids		
Fuel [2]	1.8×10^6 gals	
Gases		
Industrial Gases (propane)	5,000 gal	

[1] Peak demand is the maximum rate expected during any hour.
[2] Fuel is 50% gasoline and 50% diesel fuel.

The primary specialty material used for equipment fabrication is approximately 7 tons of Monel.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	6
Professionals	6
Technicians	25
Office and Clerical	20
Craft Workers (Maintenance)	17
Operators / Line Supervision	77/27
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	204

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4[1]
Process Building	24	19	19	19
Cylinder Storage Pads & Building	8	6	6	6
Utilities/Services/Admin Areas	40	19	19	19
TOTAL EMPLOYEES	72	44	44	44

1 The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	190	300	510	250
Construction Management and Support Staff	30	60	90	50
TOTAL EMPLOYEES	220	360	600	300

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	29/44
Nitrogen Dioxide	Boiler Stack / Grade	4,000/380
Hydrocarbons	Boiler Stack / Grade	82/310
Carbon Monoxide	Boiler Stack / Grade	2,000/2,500
Particulate Matter PM-10	Boiler Stack / Grade	150/80
OTHER POLLUTANTS		
HF	Process Building Exhaust Stack	8.2
UO_2F_2	Process Building Exhaust Stack	0.57
Copolymers	Cooling Tower	310
Phosphonates	Cooling Tower	31
Phosphates	Cooling Tower	31
Calcium	Cooling Tower	540
Magnesium	Cooling Tower	140
Sodium and Potassium	Cooling Tower	56
Chloride	Cooling Tower	100
Dissolved Solids	Cooling Tower	3,000

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg Exhaust Stack	8.0×10^{-5}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	1.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Quantity Packages
Low Level Waste					
Combustible solids	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	221,000	87	29 lb UO_2F_2	377 55-gal drums
Metal, surface contaminated	Failed equipment	25,000	15	32 lb UO_2F_2	56 55-gal drums
Noncombustible, compactible solids	HEPA filters	5,100	29	113 lb UO_2F_2	14 4x2x7 ft boxes (3/4" plywood)
Noncombustible, noncompactible solids	Grouted Waste See Sect. 4.3	12,700	3.8	309 lb $UO_2(OH)_2$	14 55-gal drums
Other	LabPack (chemicals plus absorbent)	800	0.5	1 lb UO_2F_2	2 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint, thinner	1,100	0.7 (150 gal)	See description	3 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	1,600	1	2 lb HF 2 lb NaOH	4 55-gal drums
Combustible debris	Wipes, etc. (plastic,paper, cloth)	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	410	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Inorganic process debris	Failed equipment (metal, glass)	400	0.25	0.5 lb UO_2F_2 0.5 lb Acetone	1 55-gal drum
Combustible debris	Wipes, etc. (plastic, paper, cloth)	135	0.25	0.1 lb UO_2F_2 0.1 lb Acetone	1 55-gal drum

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.3×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	510	5.8×10^6
Recyclable Wastes	210	-

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2
Nitrogen Dioxide	33
Hydrocarbons	9
Carbon Monoxide	230
Particulate Matter PM-10	40

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	70 yd^3
Hazardous Liquids	25,000 gals
Nonhazardous Solids	
Concrete	130 yd^3
Steel	40 tons
Other	1,000 yd^3
Nonhazardous Liquids	
Sanitary	3.5×10^6 gals
Other	1.5×10^6 gals

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

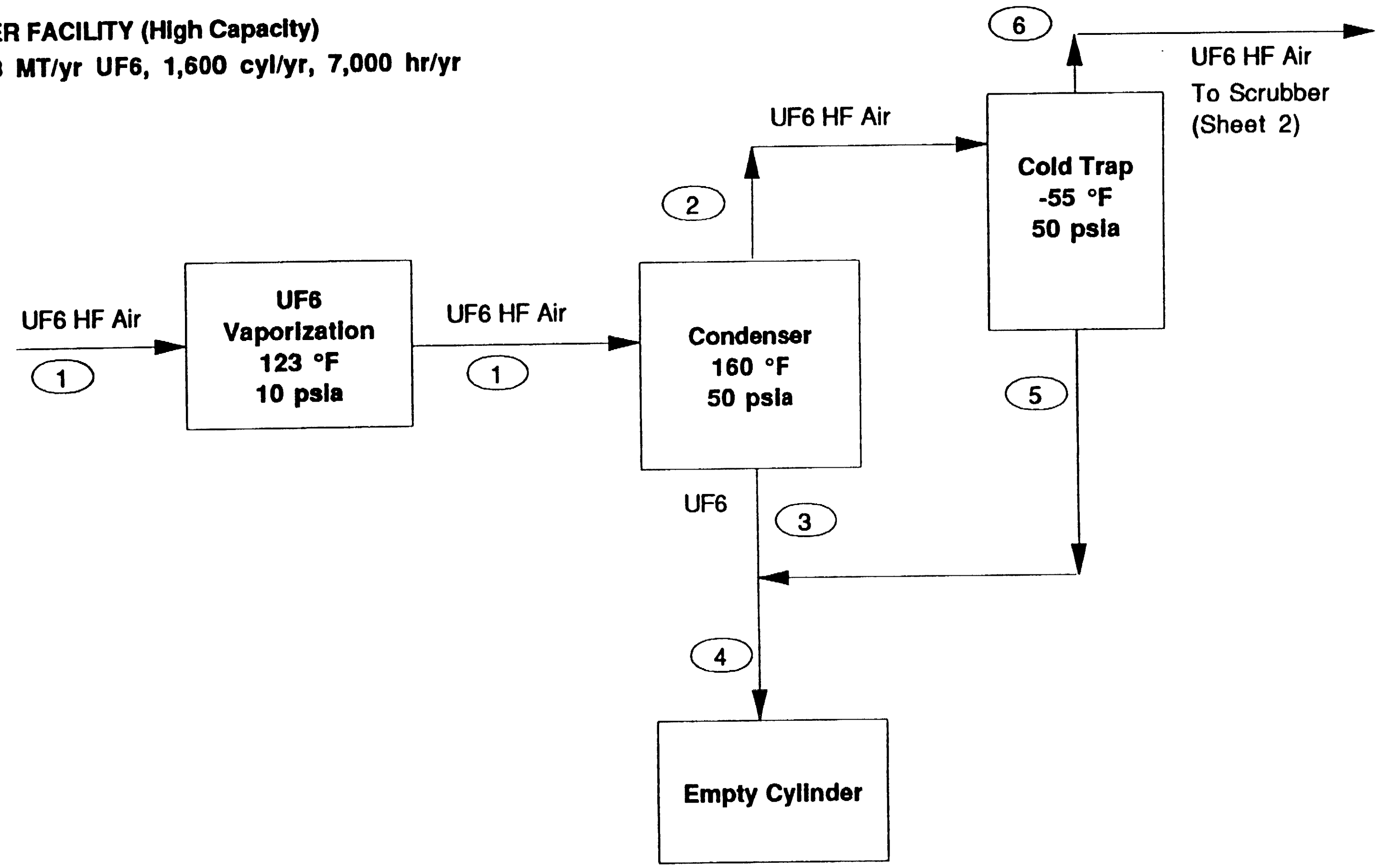
Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Input Material #5
Transported Materials					
Type	UF_6	HCl	NaOH	H_2SO_4	KOH
Physical Form	Solid	Liquid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	H_2SO_4 / ambient	KOH / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	TBD	TBD
Container Weight (lb)	2,600	50	50	50	50
Material Weight (lb)	27,000	540	660	840	500
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	93% H_2SO_4	100% KOH
Shipments					
Average Volume (ft^3)/Year	222,400	30	15	22	74
Packages/Year	1,600	4	2	3	10
Packages/Life of Project	32,000	80	40	60	120
Packages/Shipment	1 (truck) or 4 (rail car), 12cars/train	4	2	3	10
Shipments/Year	1,600 (truck) or 34 (rail)	1	1	1	1
Shipments/Life of Project	32,000 (truck) or 680 (rail)	20	20	20	20
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck
Destination - Facility Type	NA	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	UF_6	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	Varies	Varies	Varies	48G
Container Weight (lb)	2,600	50/300	50	50	2,600
Material Weight (lb)	27,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% UF_6	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	223,300	4,100	100	20	222,400
Packages/Year	1,606	449/14	13	3	1,600
Packages/Life of Project	32,120	8,980/280	260	60	32,000
Packages/Shipment	1 (truck) or 4 (railcar) 12cars/train	40/7	13	3	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	1,606 (truck) or 34 (rail)	12/2	1	1	267 (truck) or 34 (rail)
Shipments/Life of Project	32,120 (truck) or 680 (rail)	240/40	20	20	5,340 (truck) or 680 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	TBD	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

UF6 TRANSFER FACILITY (High Capacity)
Basis: 19,553 MT/yr UF6, 1,600 cyl/yr, 7,000 hr/yr
UF6 Transfer

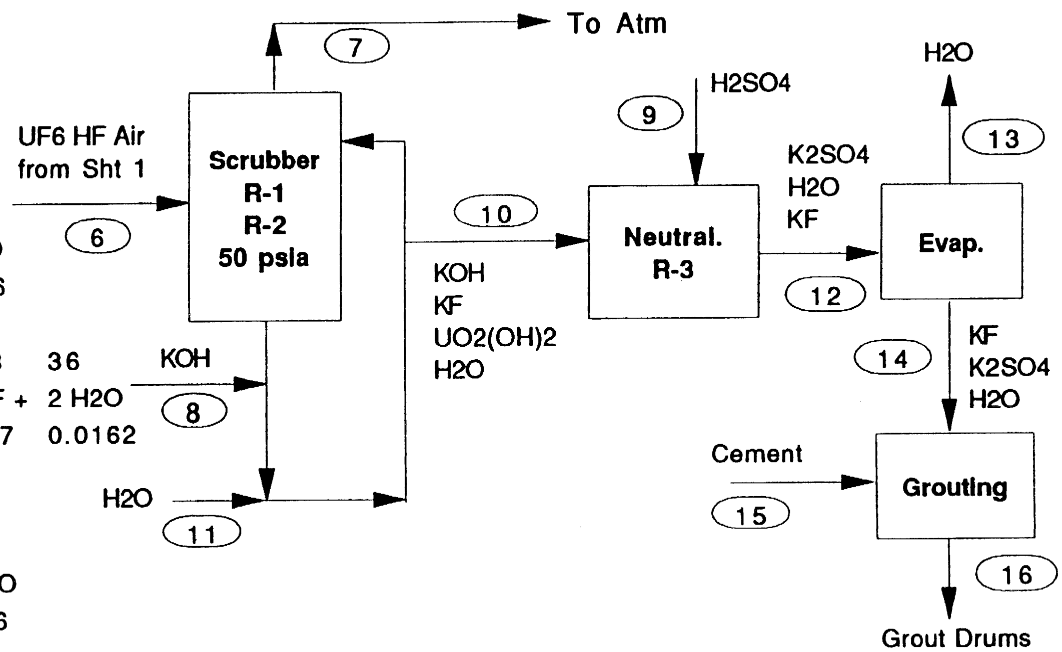


	Mol Wt	1	2	3	4	5	6
UF6	352	19,553	160.3	19,393	19,553	160.2	0.16
HF	20	0.29	0.29				0.29
Air	29	0.83	0.83				0.83
Total MT/yr		19,554	161.46	19,393	19,553	160	1.28
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

7B-Mass Bal MT/yr

UF6 TRANSFER FACILITY (High Capacity)
Basis: 19,553 MT/yr UF6, 1,600 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

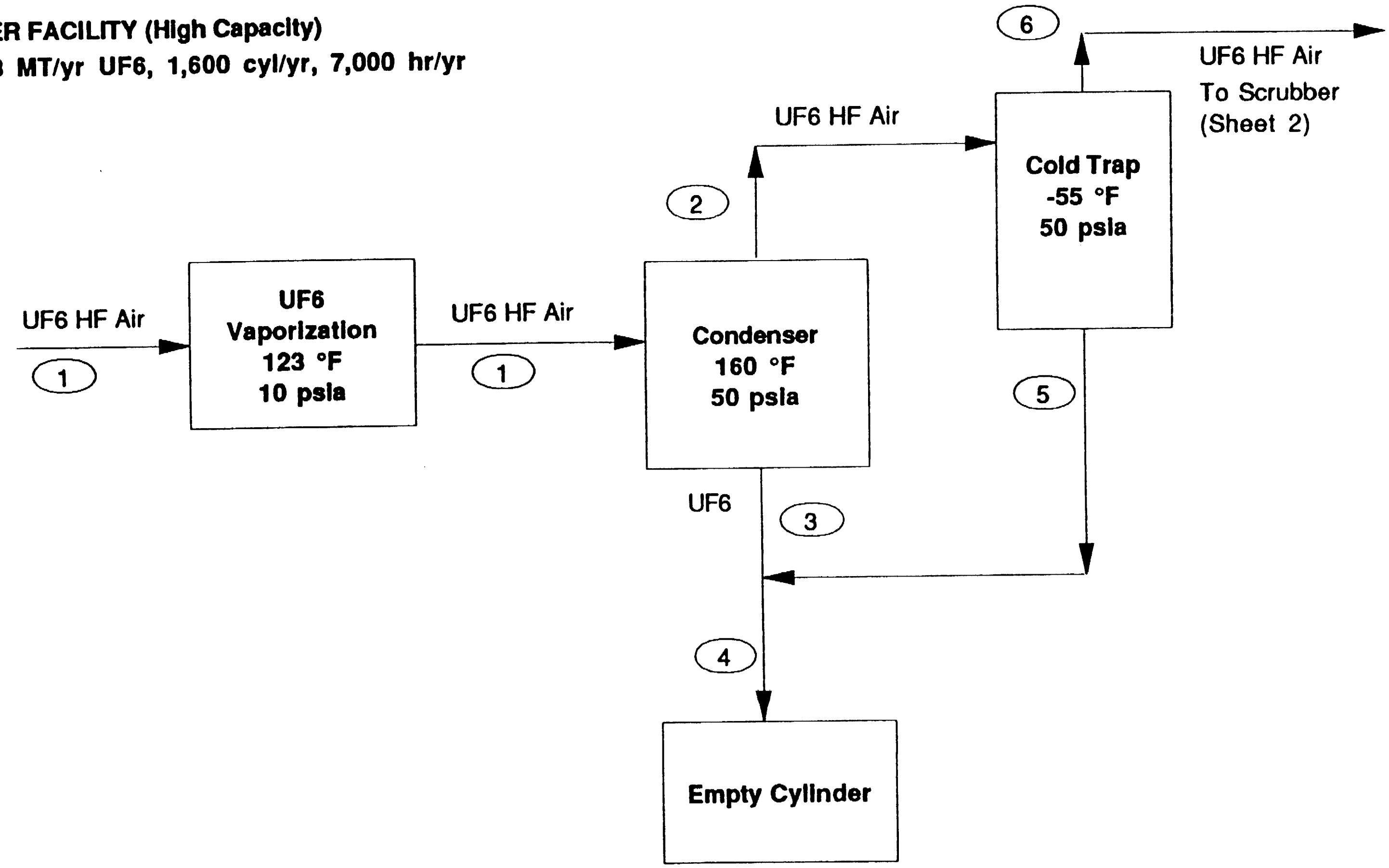
	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.29	0.80	0.83	0.26	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.159	0.152	0.137	0.157	0.0162
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	1.13	0.99	1.75	0.36	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.0016									
HF	20	0.0029									
Air	29	0.83									
KOH	56		2.08		1.13						
H2O	18		3.12	0.074	20.28	16.88	20.72	19.05	1.67		1.67
UO2(OH)2	304				0.14		0.14		0.14		0.14
KF	58				0.99		0.99		0.99		0.99
K2SO4	174						1.75		1.75		1.75
H2SO4	98			0.99							
Cement										1.21	1.21
Total MT/yr		0.84	5.21	1.06	22.53	16.88	23.59	19.05	4.55	1.21	5.75
kg/kg U		0.00006	0.0004	0.00008	0.0017	0.0013	0.0018	0.0014	0.0003	0.00009	0.0004

7B-Mass Bal lb/hr

UF6 TRANSFER FACILITY (High Capacity)
Basis: 19,553 MT/yr UF6, 1,600 cyl/yr, 7,000 hr/yr
UF6 Transfer

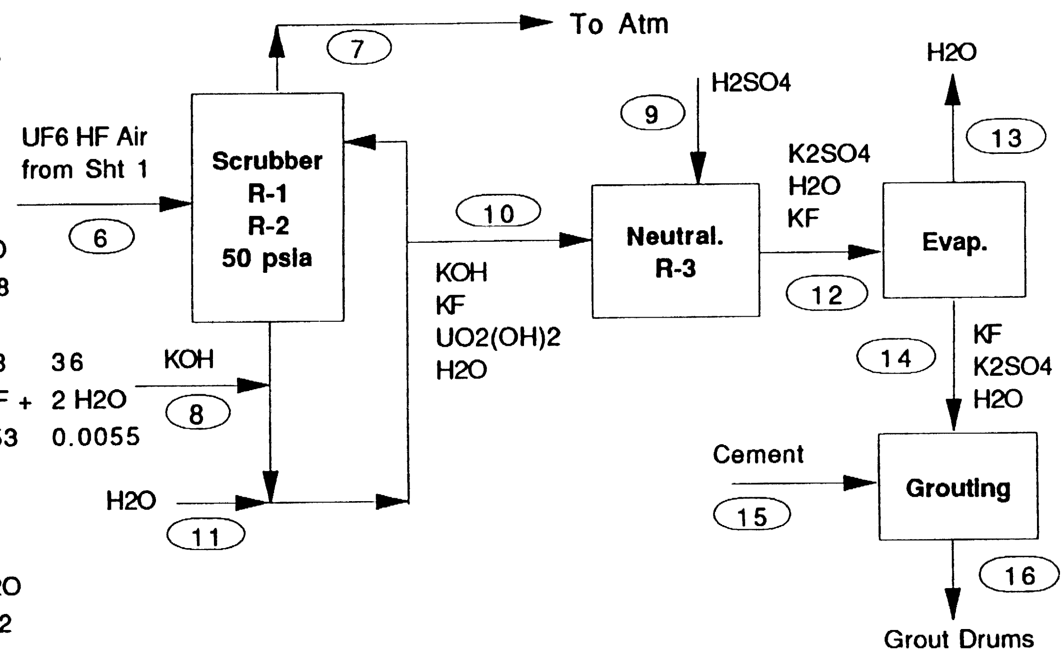


	Mol Wt	1	2	3	4	5	6
UF6	352	6,608	54.2	6,554	6,608	54.1	0.054
HF	20	0.092	0.092				0.092
Air	29	0.27	0.27				0.27
Total lb/hr		6,609	54.55	6,554	6,608	54	0.41
kg/kg U		1.48	0.012	1.47	1.48	0.012	0.0001

7B-Mass Bal lb/hr

UF6 TRANSFER FACILITY (High Capacity)
Basis: 19,553 MT/yr UF6, 1,600 cyl/yr, 7,000 hr/yr
Off-Gas Scrubber

	20	56	58	18	
R-1:	HF +	KOH-->	KF +	H2O	
	0.091	0.25	0.26	0.08	
	352	336	304	348	36
R-2:	UF6 +	6 KOH->	UO2(OH)2	+ 6 KF +	2 H2O
	0.054	0.051	0.046	0.053	0.0055
	112	98	174	36	
R-3:	2 KOH +	H2SO4->	K2SO4 +	2 H2O	
	0.36	0.32	0.56	0.12	



	Mol Wt.	7	8	9	10	11	12	13	14	15	16
UF6	352	0.00054									
HF	20	0.00092									
Air	29	0.27									
KOH	56		0.67		0.36						
H2O	18		1.00	0.024	6.53	5.44	6.67	6.13	0.54		0.54
UO2(OH)2	304				0.046		0.046		0.046		0.046
KF	58				0.32		0.32		0.32		0.32
K2SO4	174						0.56		0.56		0.56
H2SO4	98			0.32							
Cement										0.39	0.39
Total lb/hr		0.27	1.67	0.34	7.25	5.44	7.59	6.13	1.46	0.39	1.85
kg/kg U		0.00006	0.0004	0.00008	0.0016	0.0012	0.0017	0.0014	0.0003	0.00009	0.0004

MAJOR EQUIPMENT LIST
UF6 Transfer Facility (High Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (20)	7'Dx23'Lx 5/8" wall, carbon steel. A fixed head w/ movable shell section. 12-1/2 hp fans attached to shell inside	Proc. Bldg
Forced Air Blower (20)	3000 scfm, 15 hp	Proc. Bldg
Air Heater (20)	Electric type, 20 kw	Proc. Bldg
UF6 Compressor (10)	1400 lb/hr UF6 (45 cfm) at 10 psia inlet, 50 psia discharge, 5 hp	Proc. Bldg
Backing Compressor (10)	5 cfm, 1 psia inlet, 10 psia discharge, 0.5 hp	Proc. Bldg
Condenser (5)	10" dia x 6' L, Monel shell with U tubes.	Proc. Bldg
Cold Trap (10)	12" dia x 8' H Monel shell with finned tubes.	Proc. Bldg
UF6 Accumulator (5)	2' dia x 3' L, Monel, 70 gal	Proc. Bldg
UF6 Filling Station (5)	Two (2) - 20 ton scales	Proc. Bldg
Off-Gas Scrubber	1'dia x10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	6" dia pipe x 5' L, steam jacketed	Proc. Bldg
Off-Gas HEPA Filter (2)	8"x8"x12"	Proc. Bldg
KOH Storage Tank	3' dia x 3' H, carbon steel	Proc. Bldg
KOH Pump	1 gpm	Proc. Bldg
Scrubber Pump	5 gpm, Monel	Proc. Bldg
Neutralization Tank	3' dia x 3' H, Monel, with cooling coils	Proc. Bldg
Neutralization Pump	5 gpm, Monel	Proc. Bldg
Evaporator	3' dia x 3' H, carbon steel with heating coils	Proc. Bldg
Slurry Pump	5 gpm, carbon steel	Proc. Bldg
Drum Filling Station	0.05 drum per day (avg.)	Proc. Bldg
Dry Tumbling Station	0.05 drum/day, carbon steel	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (High Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Condenser Cooling Water System	215,000 BTU/hr, 140 °F, w/ heat exchanger tank and pump.	Proc. Bldg
Cold Trap Cooling System	4,500 Btu/hr, -75 °F, w/ tank, chiller & pump	Proc. Bldg
Cold Trap Heating System	2,700 Btu/hr, 185 °F, w/ tank, heater & pump	Proc. Bldg
Material Handling Systems	Two (2) flatbed trucks	Yard
	Five (5) 20-ton cranes	Proc. Bldg
	Two (2) 20-ton yard cranes	Yard
	Two (2) forklift trucks	Proc. Bldg/Yard
	Two (2) 20-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	450 storage saddle/pallets Five (5) storage racks each for 80 cylinders	Proc. Bldg/ Storage Bldg
DUF_6 Cylinder Vacuum System	Two (2) vacuum systems with cold traps, NaF traps and vacuum pumps	Proc. Bldg
Decontamination & Maintenance Systems	Four (4) decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations w/ tanks.	Proc. Bldg
Process Control / Monitoring System	Distributed Control System (DCS) with centralized monitoring stations. Closed circuit TV monitoring system	Proc. Bldg
Sampling / Analytical Systems	Two (2) local sampling glove boxes with laboratory liquid / powder sample hardware. Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (High Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Low Level Radioactive & Hazardous Waste Management System (continued)	• bar code reader / computerized • accountability system • 1-radwaste drum assay device	
Material Accountability System	•Computerized material control and accountability system (hardware & software).	Proc. Bldg
	•2 accountability scales for incoming and outgoing DUF_6 cylinders & waste drums	Proc. Bldg
	•2 bar code readers for DUF_6 cylinder and waste drums.	Proc. Bldg/Yard
	•Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF and UF_6,) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2, - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard

MAJOR EQUIPMENT LIST (Continued)
UF6 Transfer Facility (High Capacity Case)

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Utility /Services Systems	Boiler - 13,000 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing Air Compressors-2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, -40°F dew point	Util. Bldg
	Demineralized water system - 700 gpd	Util. Bldg
	Sanitary water treatment system - 3,700 gpd	Sanitary Waste Treatment Bldg
	Industrial wastewater treatment system - 16,000 gpd	Indus. Waste Treatment Bldg
	Electrical substation - 1900 kW	Substation
	Emergency generators - 2 @ 300 kW	Proc. Bldg
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 8.5 MM Btu/hr, 850 gpm	Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-2000 cfm, 5 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-30,000 cfm, 120 HP exhaust fans, 2-30,000 cfm 40 HP supply air units	DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 25 HP supply air units, 2-15,000 cfm, 10 HP exhaust fans, 2-15,000 cfm, 15 HP supply air units	Waste Process'g Control Room Support Areas
HVAC Chillers	3-310 ton chillers	Proc. Bldg
Circulating Pumps	3-500 gpm, 15 Hp	Proc. Bldg

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

TRANSFER FACILITY - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Unload arriving full incoming UF6 cylinder	3	0.50	1600	1	3	Steel	1/4"	2400.0
Inspect arriving full incoming UF6 cylinders	1	0.50	1600	1	3	Steel	1/4"	800.0
Transfer full incoming UF6 cylinder to storage pad	2	0.50	1600	1	6	Steel	1/4"	1600.0
Unload full incoming UF6 cylinder at storage pad	2	0.50	1600	1,7	3,3	Steel	1/4"	1600.0
Load full incoming UF6 cylinder onto cart	2	0.50	1600	1,7	3,3	Steel	1/4"	1600.0
Transfer full incoming UF6 cylinder from storage to process building	2	0.50	1600	1	6	Steel	1/4"	1600.0
Inspect full incoming UF6 cylinders	2	0.50	1600	1	3	Steel	1/4"	1600.0
Load full incoming cylinder into autoclave from cart	3	0.50	1600	1,5	3,3	Steel	1/4"	2400.0
Autoclave pressure test	2	1.00	1600	1	15	Steel	1/4"+1/4"	3200.0
Unload autoclave	3	0.50	1600	1,2	3,3	Steel	1/4"	2400.0
Transfer empty outgoing UF6 cylinder to pallet	3	0.50	1600	2	3	Steel	1/4"	2400.0
Transfer empty outgoing UF6 cylinder to Storage Building	1	0.50	1600	2	6	Steel	1/4"	800.0
Store empty outgoing UF6 cylinder in Storage Building	1	0.50	1600	2,8	3	Steel	1/4"	800.0
Move empty incoming UF6 cylinder to filling area	2	0.50	1607	4,6	10	Steel	1/4"	1607.0
Move full outgoing UF6 cylinder to storage area	3	0.50	1607	4	6	Steel	1/4"	2410.5
Transfer full outgoing UF6 cylinder to storage yard	2	0.50	1607	4	6	Steel	1/4"	1607.0
Prepare empty outgoing UF6 cylinder for shipment	2	0.50	1600	3	3	Steel	1/4"	1600.0
Load empty outgoing UF6 cylinder for shipment	3	0.50	1600	3	6	Steel	1/4"	2400.0
Load full outgoing UF6 cylinder for shipment	3	0.50	1607	4	6	Steel	1/4"	2410.5
Full incoming UF6 cylinder storage surveillance	1	0.50	2190	1,7	3	Steel	1/4"	1095.0
Autoclave, compressor, condenser surveillance	1	0.25	1752	1,4,5,6	3	Steel	1/4"	438.0
Full outgoing UF6 cylinder surveillance	1	0.50	2190	4,9	3	Steel	1/4"	1095.0
Cylinder Repair	2	4.00	167	1	2	Steel	1/4"	1336.0
Off-gas Scrubbing / Process Liquid Treat. surveillance	1	0.50	1752	1,2	25	Steel	1/4"	876.0

Case 7B Ops

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS
Waste grouting	2	2.00	74	10	3	Steel	0.06"	296.0
Transfer grouted drums to storage area	2	0.50	74	10	3	Steel	0.06"	74.0
Load grouted drums for shipment offsite	2	1.00	3	10	3	Steel	0.06"	6.0
Supervision	5	8.00	1100	1,2,3	15	Steel	1/4"	44000.0
Process control room operations	5	8.00	1100	4,6	25	Steel	1/4"	44000.0
Laboratory operations	1	8.00	1100	4,6	25	Steel	1/4"	8800.0
HP	2	8.00	1100	4,6	25	Steel	1/4"	17600.0
Management / Professionals	20	8.00	250	4,6	25	Steel	1/4"	40000.0
Accountability	2	2.00	1100	1,2	3	Steel	1/4"	4400.0
Industrial and sanitary waste treatment	2	8.00	1100	4,6	140	Steel	1/4"	17600.0
Utilities operations	2	8.00	1100	1,2	140	Steel	1/4"	17600.0
Warehouse	2	8.00	250	4,6	140	Steel	1/4"	4000.0
Administration	20	8.00	250	4,6	190	Steel	1/4"	40000.0
Guardhouses / Process Bldg.	6	8.00	1100	4;6	250;25	Steel	1/4"	52800.0
Maintenance								15432.0
								346683.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 11)	SOURCE	DISTANCE (ft)	MATERIAL (Note 12)	THICKNESS	PERSON HOURS

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in a Cylinder Filling & Storage Area. There are 5 Cylinder Filling & Storage Areas.
7) There are up to 134 full incoming UF6 cylinders in the storage area.
8) There are up to 420 empty outgoing UF6 cylinders in the storage building.
9) There are up to 134 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) 1600 incoming UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    74 grouted waste drums/yr
    74 grouted waste drums/yr /25 drums per shipment = 3 transfers per year
12) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

TRANSFER FACILITY - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (20)	2	26	20	1,5,2	3	Steel	1/4"+1/4"	1040
Forced Air Blower (20)	2	52	20	1,5;4	8	Steel	1/4"+1/4";1/4	2080
Air Heater (20)	2	26	20	1,5;4	8	Steel	1/4"+1/4";1/4	1040
UF6 compressors (10)	2	52	10	1,5;4	8	Steel	1/4"+1/4";1/4	1040
Backing Compressor (10)	2	52	10	1,5;4	8	Steel	1/4"+1/4";1/4	1040
Condenser (5)	2	26	5	14	6	Monel	1/4"	260
Cold Trap (10)	2	26	10	14	3	Monel	1/4"	520
Off-gas scrubber (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas heater (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Off-gas HEPA filters (2)	2	4	2	1,2	25	Steel	1/4"+1/4"	16
KOH pump (1)	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Scrubber Pump	2	52	1	1,2	25	Steel	1/4"+1/4"	104
Neutralization pump (2)	2	52	2	1,2	25	Steel	1/4"+1/4"	208
Evaporator (1)	2	26	1	1,2	25	Steel	1/4"+1/4"	52
Slurry pump (1)	2	52	1	1,2	30	Steel	1/4"+1/4"	104
Grout mixing / drum tumbling station (1)	2	26	1	1,2	35	Steel	1/4"+1/4"	52
DUF6 Cylinder Vacuum System	2	26	2	1,2;4	10	Steel	1/4"+1/4";1/4	104
20 Ton Crane	2	52	5	1,2,5	35	Steel	1/4"+1/4"	520
Air Compressor, Water Systems in Process Bldg.	1	52	4	4,6	40	Steel	1/4"	208
HVAC equipment	2	520	1	4,6	40	Steel	1/4"	1040

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR
Boiler, Water Systems, Compressed Air, other Utilities	2	52	4	1;2	140	Steel	1/4"+1/4";1/4	416
Waste water treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	4,6	140	Steel	1/4"	2190
Admin building	1	1000	1	4,6	190	Steel	1/4"	1000
								15432

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 12)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 13)	THICKNESS	PERSON HOURS PER YEAR

1) A single full incoming UF6 cylinder
2) A single fresh empty outgoing UF6 cylinder
3) A single 3 mo. old empty outgoing UF6 cylinder
4) A single full outgoing UF6 cylinder
5) There are up to 4 incoming UF6 cylinders in an autoclave area.
6) There are up to 5 full outgoing UF6 cylinders in a Cylinder Filling & Storage Area. There are 5 Cylinder Filling & Storage Areas.
7) There are up to 134 full incoming UF6 cylinders in the storage area.
8) There are up to 420 empty outgoing UF6 cylinders in the storage building.
9) There are up to 134 full outgoing UF6 cylinders in the storage area.
10) A drum of grouted waste.
11) Loaded filter/bag.
12) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HVAC components
    6 hours per day on waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
13) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
14) Inventory In Cold Trap

Section 6.3

Depleted Uranium Cylinder Treatment Facility

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Preface

This report provides a preliminary description of a stand-alone facility for removal of residual DUF_6 ("heels") remaining in the emptied DUF_6 cylinders. The DUF_6 heels are removed by washing. The wash solution is converted to triuranium octaoxide (U_3O_8). The by-product aqueous hydrogen fluoride (Hfaq) is neutralized with lime (CaO) to generate calcium fluoride (CaF_2). The U_3O_8 and CaF_2 are separately packaged in drums for use, storage or disposal.

The subsequential disposition of the cleaned cylinders depends on a variety of factors including the actually achieved level of decontamination. Appendix 6.3-A briefly discusses the possibilities. This report assumes that the cylinders are crushed and transported to the DOE scrap metal pile to be managed as scrap.

The facility described here bounds the land, resource, and transportation requirements for accomplishing the cylinder treatment function. It is likely that the Used Cylinder Treatment Facility (UCTF) would not be a stand-alone facility, but rather this function would be integrated into a DUF_6 conversion facility. The qualitative impacts of integration are discussed in Appendix 6.3-B. Appendix 6.3-C, 6.3-D, and 6.3-E present the worker radiation dose estimate, detailed flowsheets and material balances, and equipment list respectively.

6.3-1.Summary

6.3-1.1. Statement of Problem

The Depleted Uranium Disposition Program is developing options for the disposition of the depleted uranium hexafluoride (DUF_6) that is in the control of the Department of Energy (DOE). This amounts to about 560,000 metric tons. The DUF_6 is stored in large cylinders holding up to 14 tons each. The cylinders are principally stored at three sites: Paducah Kentucky, Oak Ridge Tennessee, and Portsmouth Ohio. There are about 29,000 cylinders at Paducah, 13,000 at Portsmouth and 5,000 at Oak Ridge. Many of the options being explored for the disposition involve removing the DUF_6 from the cylinders and converting it to another form or repackaging it to prepare for storage, use or disposal. These actions would generate about 46,440 cylinders for disposition. Each of these cylinders would contain a heel of DUF_6 that would require removal. This paper addresses the removal and processing of the heel. This report assumes that the cylinders are crushed and sent to the DOE scrap metal pile for storage. Alternatives for cylinder disposition are described in Appendix 6.3-A.

6.3-1.2. Approach

Cylinder washing is required because the cylinders contain heels that would not meet waste acceptance criteria for disposal because of the reactivity of the DUF_6. The cylinders are washed with water. The aqueous wash solution containing uranyl fluoride (UO_2F_2) and hydrogen fluoride (HF) is evaporated and converted to solid triuranium octaoxide (U_3O_8) and aqueous hydrogen fluoride (HFaq) by pyrohydrolysis. This is the simplest approach and only uses stream and heat. The HFaq is neutralized with calcium oxide (CaO) to calcium fluoride (CaF_2). Because of the small HF production, it is not believed economical to upgrade the HF to anhydrous HF or market it as the acid. The washed and dried cylinders are crushed and shipped to the DOE metal scrap pile to be managed as scrap.

6.3-1.3. Relation to Other Conversion Reports

This report supports all Conversion Data Reports where a large number of empty cylinders are generated. It also supports a possible DUF_6 storage option in which the DUF_6 is transferred to new cylinders prior to storage.

6.3-2.Design Basis Assumptions

The Used Cylinder Treatment Facility (UCTF) project design criteria follow basic DOE design criteria for DOE facilities.

6.3-2.1 Design Basis

The general design basis document used in designing the UCTF is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industry standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop hazard classifications and related design features of the facilities containing radioactive or hazardous materials. The guide presents a two-step process to determine the hazard class of a facility. The first step is an overall analysis based on what the facility contains and is not based on any safety or mitigation features that may exist. The second step looks at accident analysis and accounts for the safety and mitigation features. The second step will usually reduce the hazard classification of the building. Only the first step was applied in this report to determine the hazard classification of the buildings. Various hazards are reviewed in Section 6.3-10.

Design codes and standards applicable to "special facilities" as defined in DOE Order 6430.1A and facilities with high to low hazard classifications per DOE-STD-1027-92 and 40 CFR 355 include the following:

- Cylinder Storage Yard
- Process Building
- Product Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the UCTF include the following:

- CaF_2 Storage Building

- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower

6.3-2.2. Facility Design Assumptions

The results of this study are based on a set of assumptions about the state of the cylinders, processing parameters and the location of the UCTF. The assumptions are listed below:

A) The UCTF will be a stand-alone facility. All products, wastes and side streams will be processed to a final form within the facility. This assumption was selected to decouple the operation of the UCTF from assuming any particular disposition option or UCTF location. The facility description and information will be given on a module basis. Each module will be a collection of operations that are closely related. This allows modules to be included or excluded depending upon other collocated facilities that might be available.

B) The UCTF will process 46,440 cylinders (from all storage sites) over a time span of 20 years (2,322 cylinders per year).

C) The UCTF will receive "empty" cylinders by truck or rail. Outdoor storage for one calendar month supply of cylinders is provided. In addition, storage space for one calendar month of production of crushed cleaned cylinders is provided.

D) The DUF_6 remaining in the emptied cylinders is assumed to have the same uranium isotopic composition as the DUF_6 in the originally filled cylinders. The average isotopic composition is 10^{-3}% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} ci/g DU.

E) The radioactivity of each of the U-238 short lived daughter products remaining in the empty cylinders at the time of processing is 0.16 curies per cylinder. These daughter products are assumed to be uniformly deposited in a narrow band along the long (height) dimension of the cylinder or the bottom of the cylinder in the autoclave (6:00 position). The deposit is assumed to subtend an arc of 0.25 radians and extends from the cylinder base to a height of 8 feet.

F) The "empty" cylinders delivered to the facility are assumed to have on the average a residual 10 kg heel of DUF_6.

G) The UCTF will operate on a batch basis for 290 days per year and 24 hours per day (about 80% on-line efficiency).

H) The DUF_6 heels will be removed by washing the cylinders with water. This results in solutions containing UO_2F_2 and HF from the reaction of water with DUF_6 (hydrolysis). Steam pyrohydrolysis then converts the UO_2F_2 to U_3O_8 and produces additional HF. The HFaq from both steps will be neutralized with lime to produce CaF_2.

I) The resulting U_3O_8 and CaF_2 are packaged separately for disposal and/or storage.

J) On-site storage of feeds, reagents and products will be provided. The storage space will be the one calendar month of feed and reagents. The storage of products will be the maximum of one month of production or one truckload. The generation rates of the U_3O_8 and CaF_2 product are so low that a one month of production is too small to ship.

6.3-2.3. Uncertainties

Uncertainties associated with the UCTF include the following:

A) The optimum material of construction for the equipment exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.

B) The ultimate reuse or disposal form of the used cylinder has not been finalized. This report assumes that the cylinders will be crushed and shipped to the DOE scrap metal pile.

requirement, worker rotation, or extended storage of the cylinders prior to processing would be considered at a later date.

D) Due to the pre-conceptual nature of the facility design, development of process and support systems equipment and component design details as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment/system/facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.

6.3-2.4. Compliance Documents

The major applicable compliance documents for design of the UCTF are the following:

6.3-2.4.1. Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502, *Environmental Impact Statement*; 10 CFR 1021, *National Environmental Policy Act Implementing Procedures (for DOE)*; DOE Order 5400.1, *General Environmental Protection Program*; and DOE Order 5440.1E, *National Environmental Policy Act Compliance Program.*

The General DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria.* Applicable codes, standards, guidelines, etc., as referenced in Section 0106, "Regulatory Requirements," of DOE Order 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Section 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guide references in DOE Order 6430.1A will be used where appropriate.

6.3-2.4.2. Environmental, Safety, and Health (ES&H)

ES&H requirements will generally follow DOE Order 5480.4. *Environmental, Safety and Health Protection Standards*; DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1E, *National Environmental Policy Act Compliance Program.* Requirements for the facility fire protection systems will be according to DOE Order 5480.7A, *Fire Protection.*

6.3-2.4.3. Buffer Zones

The need for buffer zones surrounding the facility will be determined during site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities."

6.3-2.4.4. Decontamination and Decommissioning/ Conversion

Design requirements for decontamination and decommissioning (D&D) of the facility will be according to DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7, "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

6.3-2.4.5. Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and non-radioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE Order 5400 series. Effluent control and monitoring will be according to DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)." Effluent releases will not exceed limits referenced in DOE Order 5400.1, *General Environmental Protection Program Requirements*; the directive on *Radiation Protection of the Public and the Environment* in the DOE Order 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

6.3-2.4.6. Waste Management

Waste management systems provided for the facility will be according to the requirements of DOE Order 6430.1A, Section 1300-8, "Waste management (for Special Facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)". Specific DOE designs and operating requirements for radioactive wastes, including low-level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management.* Non radioactive, hazardous waste requirements appear in DOE Order 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program, including waste minimization, source reduction and recycling of solids, liquids, and air emissions, will be implemented according to DOE Order 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

6.3-2.4.7. Materials Accountability and Plant Security

The basic compliance documents for material accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE Orders.

6.3-2.5. Interfacing with other facilities

This report assumes that this treatment function is carried out in a stand-alone facility. This facility probably will not be stand-alone because of its small size. It probably will be collocated with another facility such as the conversion facility. The type of collocated facility will impact the amount of synergism that can occur between the two facilities. The UCTF process description is divided into a number of modules. The use of modules allows different sub-processes to be included or excluded depending upon what the collocated facility is (see Appendix 6.3-B).

6.3-3.Schedule

A preliminary schedule to deploy, operate, and decommission a representative depleted UF_6 conversion facility is illustrated in 6.3-3-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated 3 years following preliminary assessments. Design activities include both Preliminary and Final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant startup occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

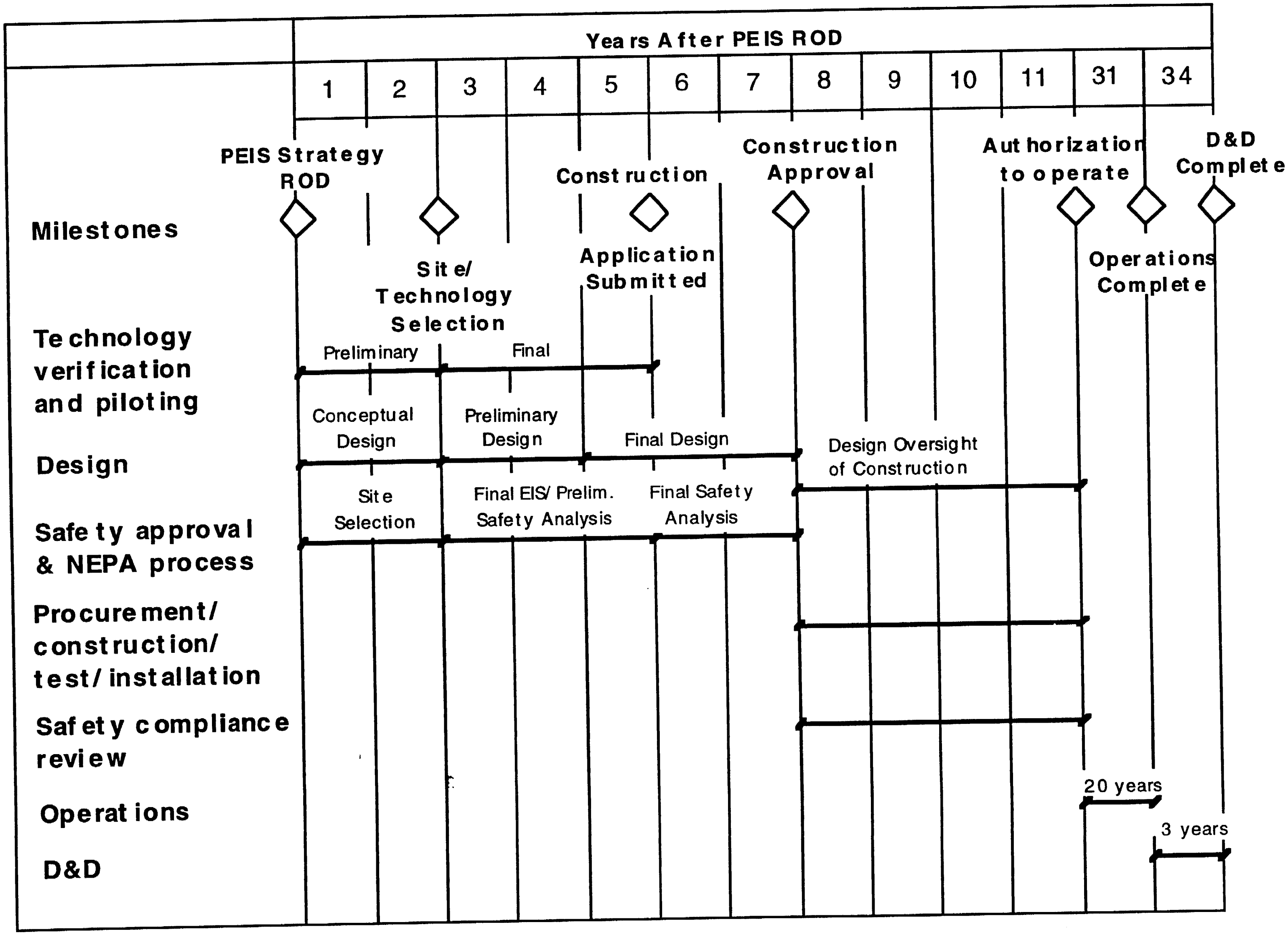

Figure 6.3-3-1 Preliminary Project Schedule

6.3-4.Facility Description

6.3-4.1. Functional Description

The process presented in this report consists of washing out the DUF_6 heels from the used cylinders. The wash solution is converted to solid U_3O_8 and CaF_2 and packaged for disposal. The cylinders are crushed and packaged for shipment to the DOE metal scrap pile. An intrasite material flow diagram is shown in Figure 6.3-4-1.

The "empty" cylinders are received and stored in the Cylinder Storage Yard. The heel of DUF_6 is removed and converted to U_3O_8 and CaF_2 in the process building. The product U_3O_8 and CaF_2 are packaged into 55 gallon drums and stored on-site until transported to the appropriate destination. The destination for the product U_3O_8 would be a storage, manufacturing or LLW disposal facility. The destination for the product CaF_2 would be a sanitary waste disposal site. The cylinders are crushed and stored in the Solid Product Storage Building until transported to the DOE scrap metal pile.

6.3-4.2. Plot Plan

A rendering of the facility is shown in Figure 6.3-4-2. The major structures on the site are the following:

- The Process Building;
- The Solid Product Storage Building;
- The CaF_2 Storage Building;
- The Cylinder Storage Yard;
- Miscellaneous support buildings including:
  The Administration Building,
  The Utilities Building,
  The Maintenance Shop,
  The Industrial Waste Treatment Building,
  The Sanitary Waste Treatment Building, and
  The Warehouse;
- Cooling tower;
- Ventilation exhaust and boiler stacks; and
- The perimeter fencing enclosing the entire site.

Note: The size, number and arrangement of facility buildings are pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumptions of a generic, greenfield site.

6.3-4.3. Building Descriptions

Building data is summarized in Table 6.3-4-1. The preliminary hazard classification is based on DOE-STD-1027-92 and 40 CFR 355.

Table 6.3-4-1: Facility Building Data

Building Name	Foot-print (Ft^2)	# of Levels (Height)	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazard Class [1] Rad/Chem	Construction Type
Processing Building	15,300	2	Yes	Yes	<HC-3/HH	Reinforced Concrete
Solid Product Storage Building	7,300	1	Yes	Yes	HC-3/G	Metal Frame
CaF_2 Storage Building	2,280	1	No	No	<HC-3/G	Shed
Admin. Building	4,500	1	No	No	General	Metal Frame
Utilities Building	2,500	1	No	Yes	General	Metal Frame
Maintenance Shop	2,000	1	No	Yes	General	Metal Frame
Industrial Waste Treatment Building	2,000	1	No	Yes	General	Metal Frame
Sanitary Waste Treatment Building	1,000	1	No	No	General	Metal Frame
Warehouse	2,000	1	No	Yes	General	Metal Frame
Cooling Tower	1,500	---	No	---	---	---

1: <HC-3 Less than radiological hazard category 3
HC-3 Radiological hazard category 3
HH High chemical hazard
G General use

6.3-4.3.1. Equipment List and Specification

Appendix 6.3-E contains a list of the major equipment used at the UCTF.

6.3-4.3.2. DUF_6 Cylinder Storage Yard

The DUF_6 cylinder storage yard will store one calendar month supply of cylinders to feed the facility. The largest cylinders sent to the facility are expected to be 12.5 feet long and 4 feet in diameter. The cylinders will be stored on an open concrete pad, supported off the ground. Each cylinder has a tare weight of typically 2,600 lb. and contains a 10 kg (22 lb.) heel of DUF_6.

The cylinders will be shipped to the UCTF by truck or rail. The cylinders will be moved from the truck or rail to the cylinder storage yard by crane. The layout of the cylinder yard allows room for the crane to maneuver between alternate rows of cylinders for the placement and removal of cylinders. The yard space also includes at least 3 feet between cylinder rows to allow inspection of both ends of the cylinders.

6.3-4.3.3. Process Building

The UCTF Process Building layout is shown in 6.3-4-3 and 6.3-4-4. The building is a two-story reinforced concrete structure classified radiologically as a very low hazard facility (<HC-3) and chemically as a high hazard (HH) facility where significant inventories of HF are present. These hazard classifications are defined by DOE-STD-1027-92 and 40 CFR 355. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems such as the heating, ventilation, and air conditioning (HVAC) systems and emergency power systems. HVAC system design is described in Section 6.3-7.3.

The process equipment layout for each module is shown in figures 6.3-4-5 to 6.3-4-10. The processing that occurs in each module is described in Section 6.3-6.

6.3-4.3.4. Product Storage Building

The Product Storage Building is a one-story metal frame structure classified as a radiologically low hazard (HC-3) and chemically general use (G) facility as defined in DOE-STD-1027-92 and 40 CFR 355. The building is primarily a warehouse that provides space for storage of crushed cylinders and drums containing U_3O_8 product. The building stores one calendar month of production of the crushed cylinders and a truckload of U_3O_8 solid product drums. A Zone 2 HVAC system with filtered exhaust air is provided in the event a U_3O_8 package is broken.

6.3-4.3.5. CaF_2 Storage Building

The CaF_2 product is stored separate from the crushed cylinders and U_3O_8 drums because it is considered a non-radioactive product. The CaF_2 is stored in 55 gallon drums in a shed next to the Solid Product Storage Building. This building has enough space to store a truckload of CaF_2 drums.

6.3-4.4. Other Buildings*

6.3-4.4.1. Utility Building

The Utility Building houses the general support equipment required for the UCTF. The support equipment includes:

- Boiler for steam generation
- Electrical substation and power switching equipment
- Backup generators for electrical power
- Main water inlet to facility

This building is a general use building and contains common industrial hazards.

6.3-4.4.2. Administrative Building

The Administration Building will provide office space for management, clerical and professional personnel. The building will include conference rooms and security operations.

6.3-4.4.3. Maintenance Shop

The maintenance shop will contain a machine shop and storage for maintenance equipment and parts needed to keep the facility operating. It will also contain offices for the maintenance personnel.

6.3-4.4.4. Warehouse

This building will store the cold chemicals, containers and other supplies.

* Ventilation and boiler stack specifications are given in Table 6.3-7-1

6.3-4.4.5. Industrial Waste Treatment Building

This building will receive waste generated in the facility and prepare it for off-site disposal or recycle. The types of materials are:

Liquids	Solids
Cooling water and Boiler Blowdown	Scrap Metal
Waste Solvents	Recycle Paper
Waste Chemicals	Rags
Laboratory Wastes	Waste Chemicals
	Laboratory Wastes

6.3-4.4.6. Sanitary Waste Treatment Building

This building will receive sanitary waste from drain and the sewer system. The UCTF is a small facility. Therefore, installing a full sanitary treatment facility will probably not be cost effective. It is assumed that the sanitary waste will be fully treated by a local sanitary treatment plant. The treatment plant could be on a DOE site, NRC site or a municipal system. The Sanitary Waste Treatment Building has equipment to check the sanitary waste stream for excessive radiation and other chemicals. If the waste stream exceeds limits, it is diverted and treated before release to the off-site treatment facility.

6.3-4.4.7. Cooling Tower

The Cooling Tower provides cooling water for a closed loop cooling system. The system is used to provide cooling to equipment in the Process Building.

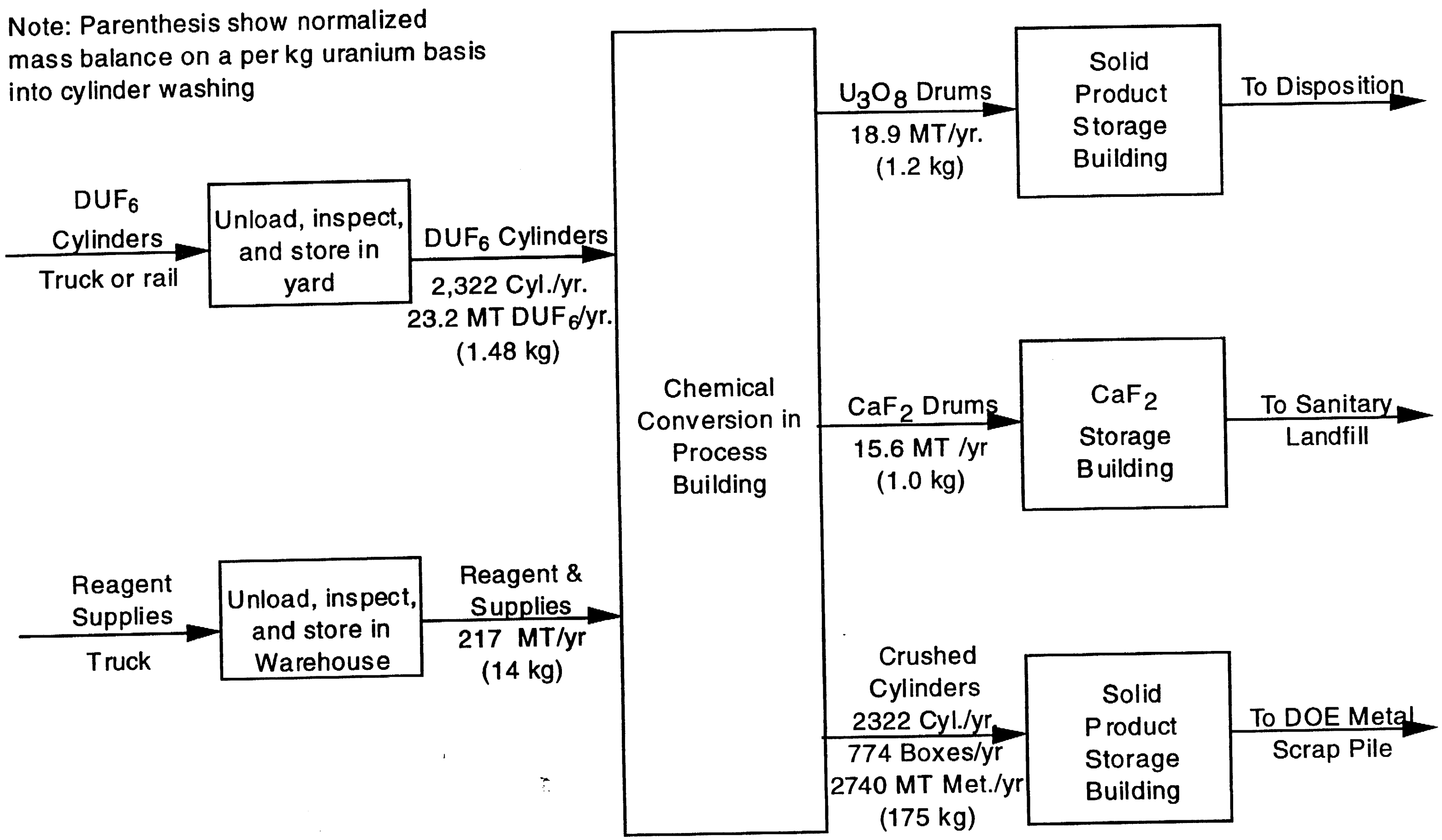

Figure 6.3-4-1: Intra-Facility Material Flow Diagram

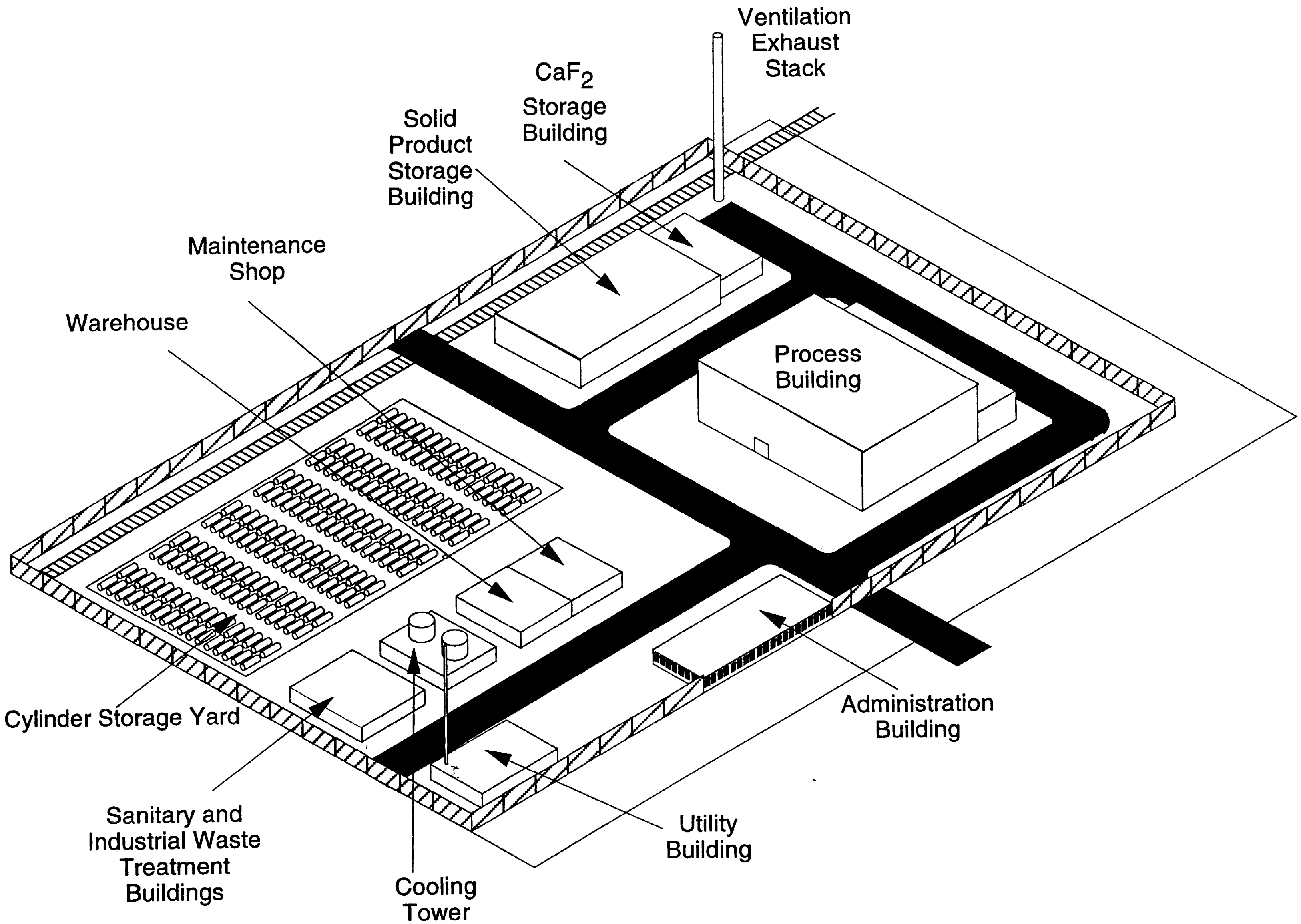

Figure 6.3-4-2: Plot Plan

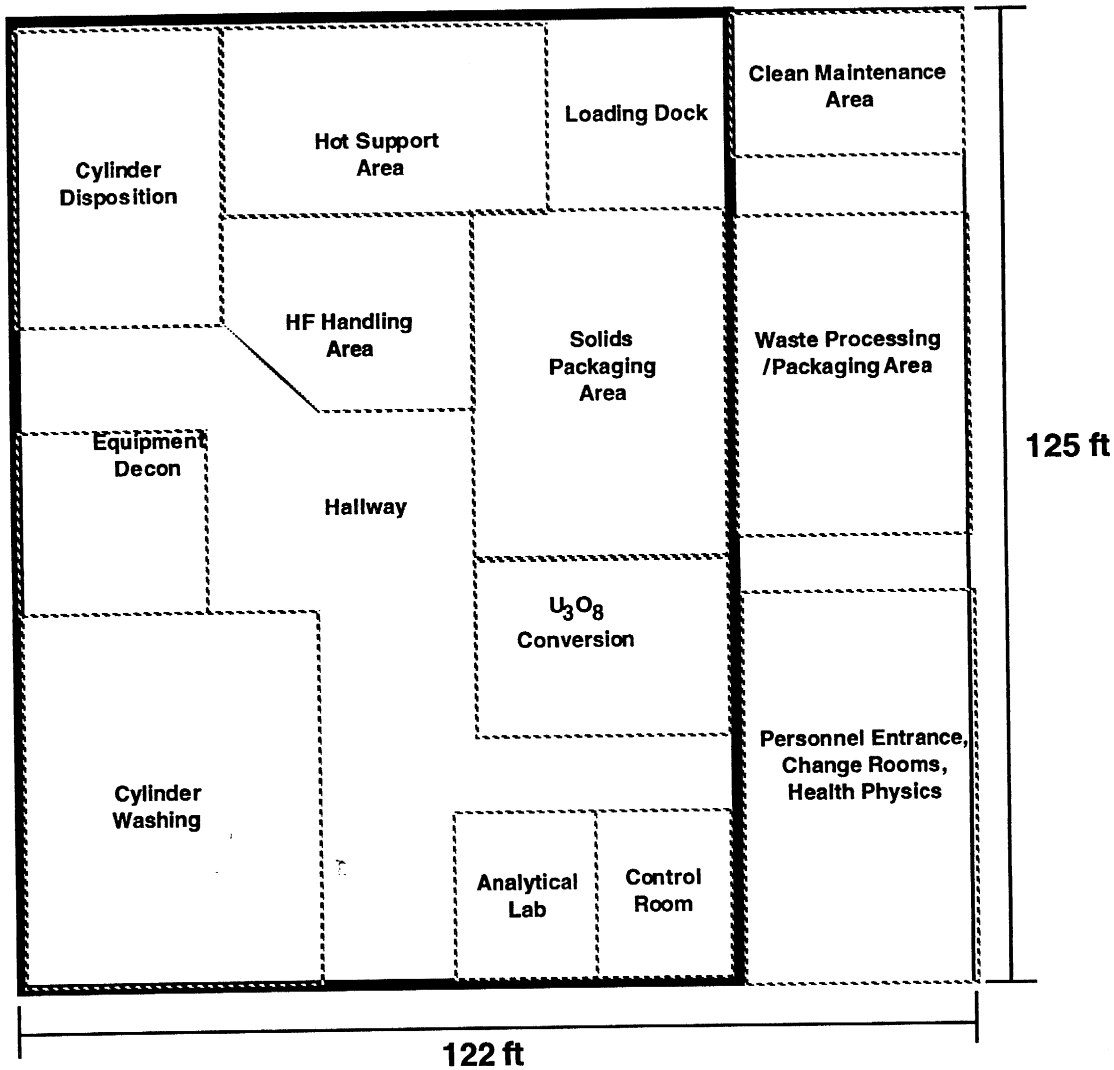

Figure 6.3-4-3: Process Building Layout

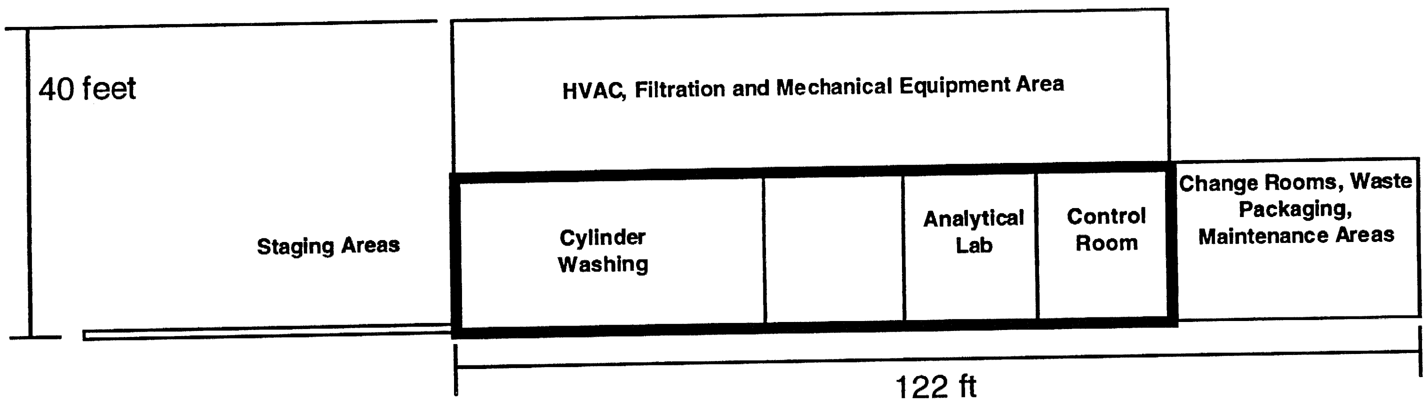

Figure 6.3-4-4: Process Building Section

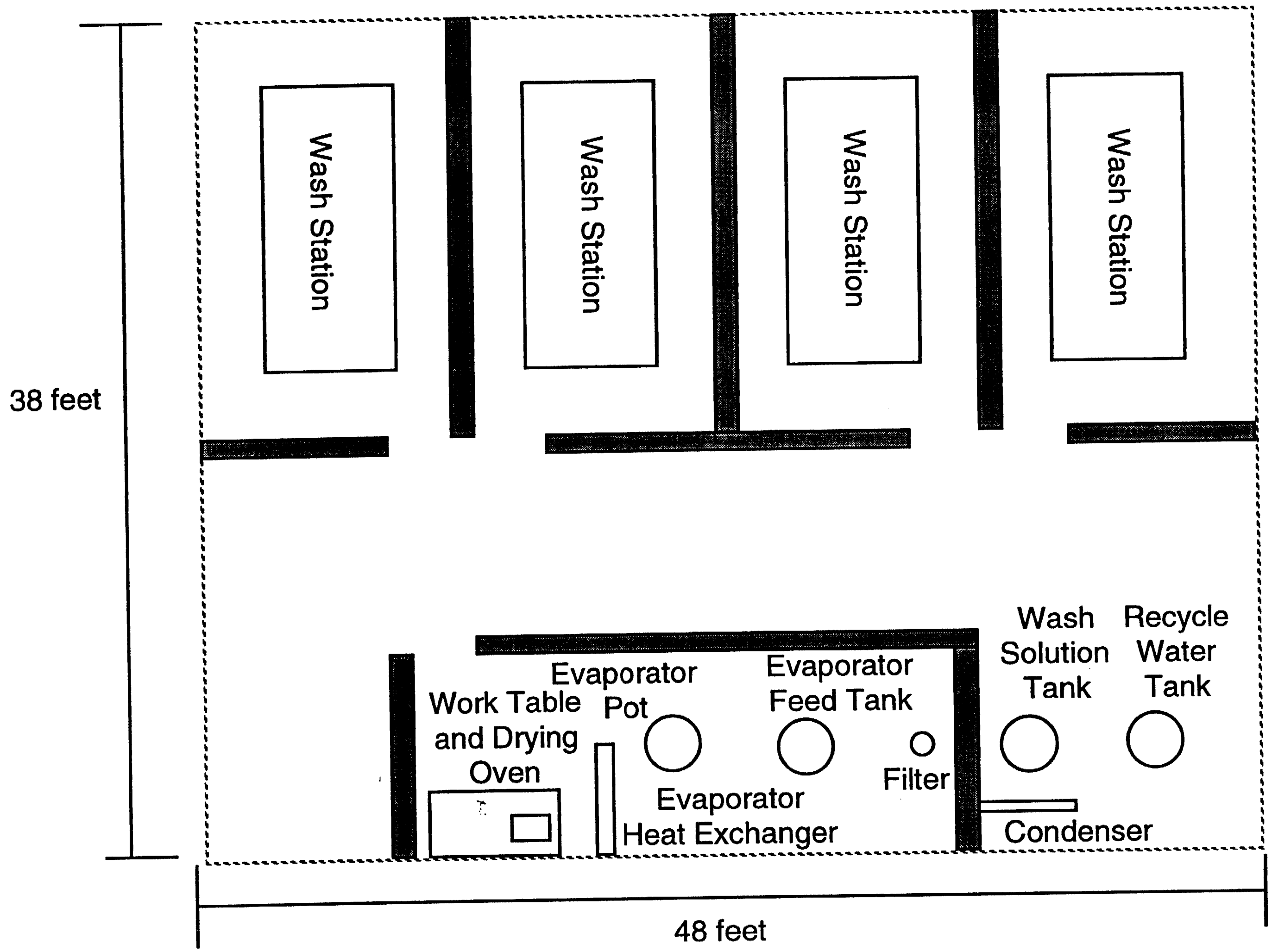

Figure 6.3-4-5: Process Equipment Layout - Cylinder Washing Module

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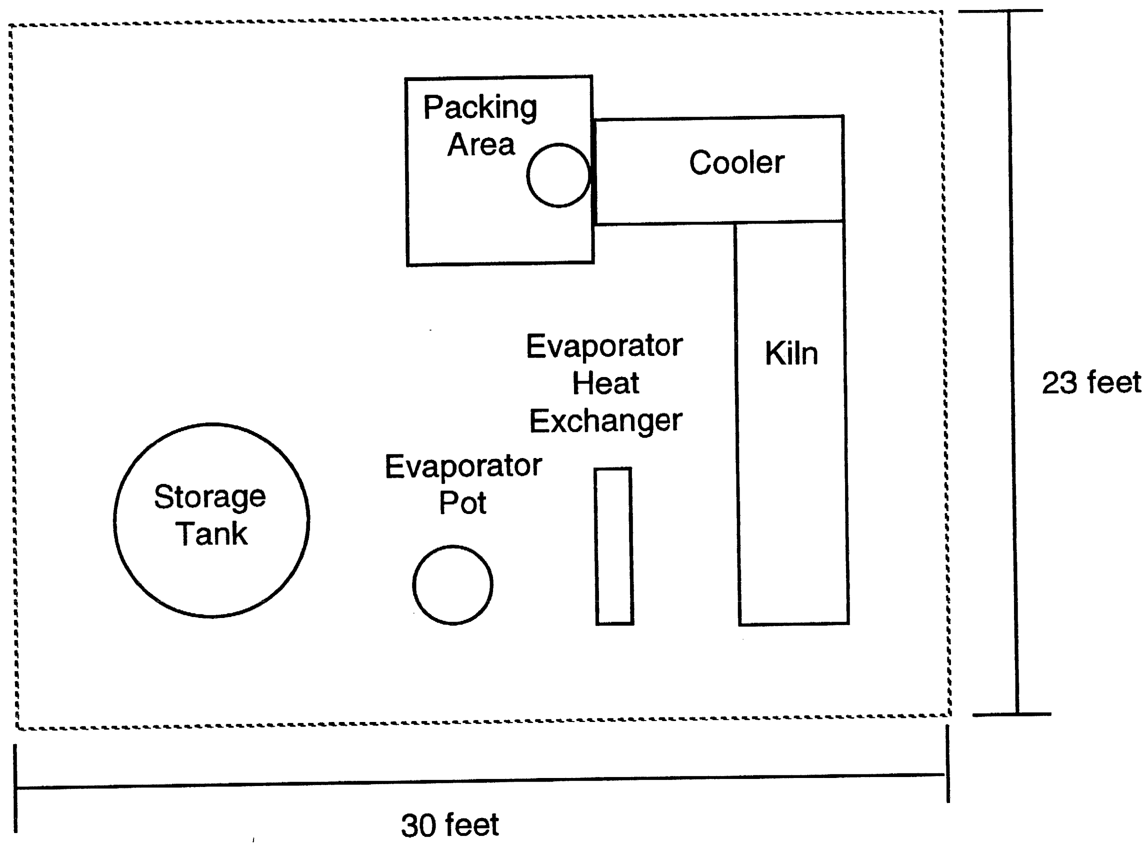

Figure 6.3-4-6: Process Equipment Layout - U_3O_8 Conversion

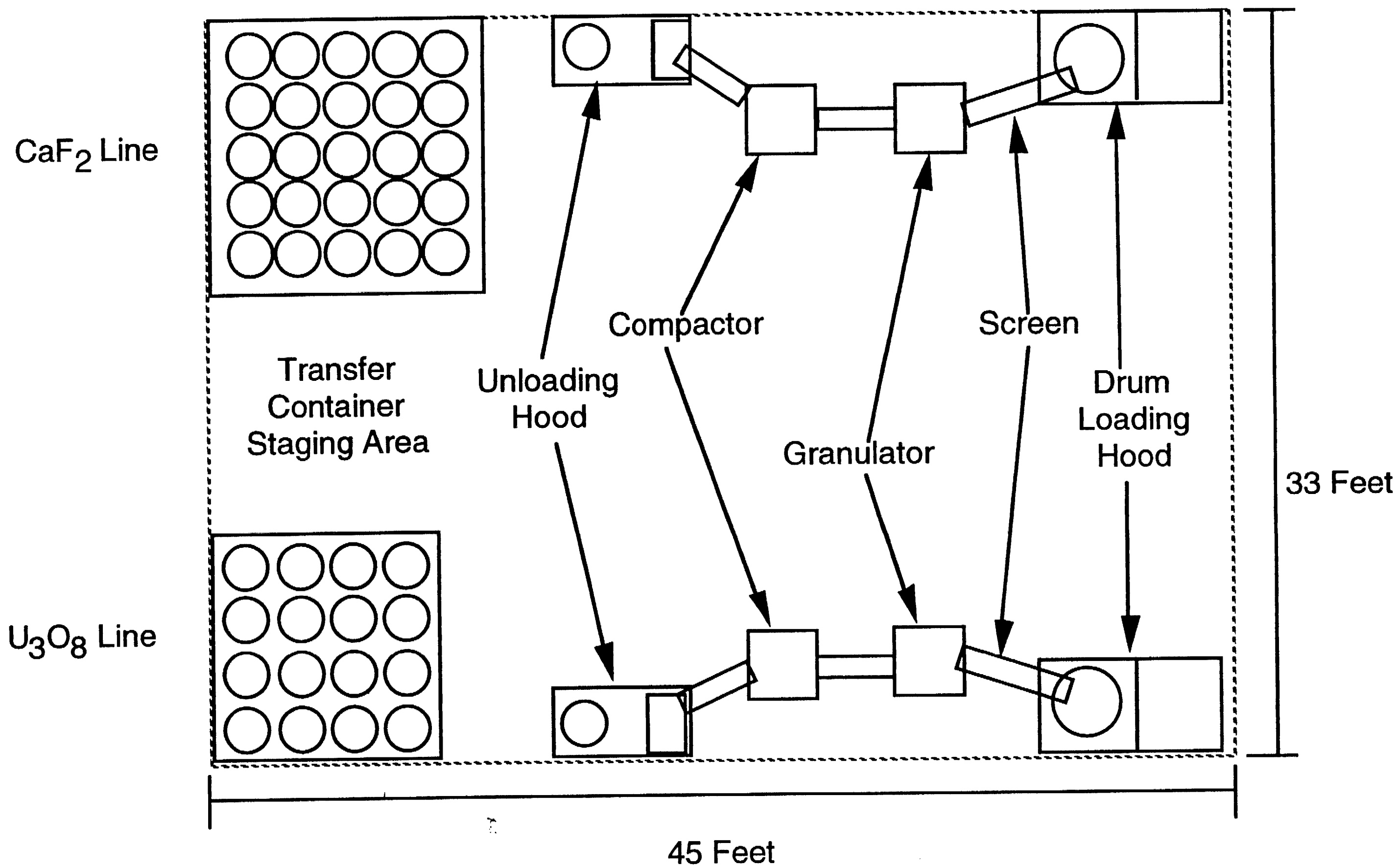

Figure 6.3-4-7: Process Equipment Layout - Solids Packaging

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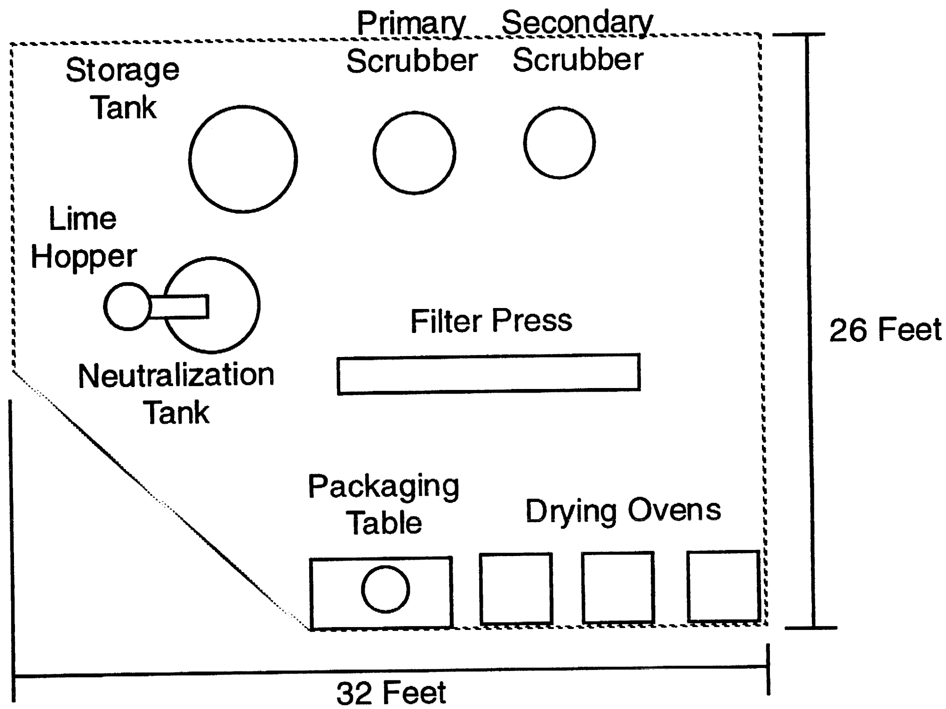

Figure 6.3-4-8: Process Equipment Layout - HF Handling Module

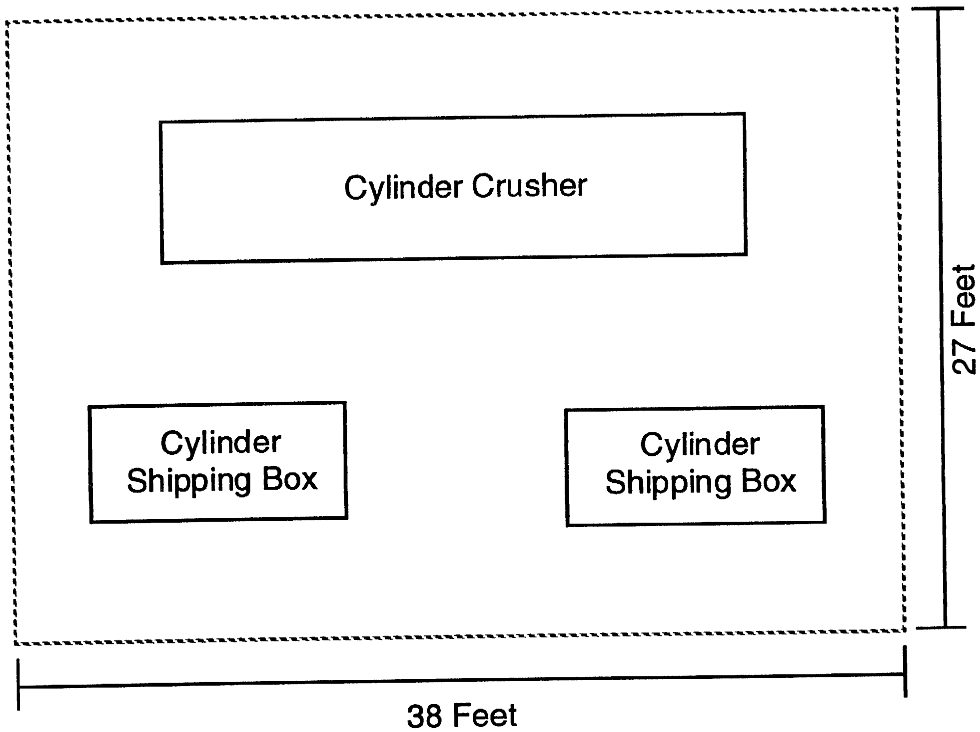

Figure 6.3-4-9: Process Equipment Layout - Cylinder Disposition Module

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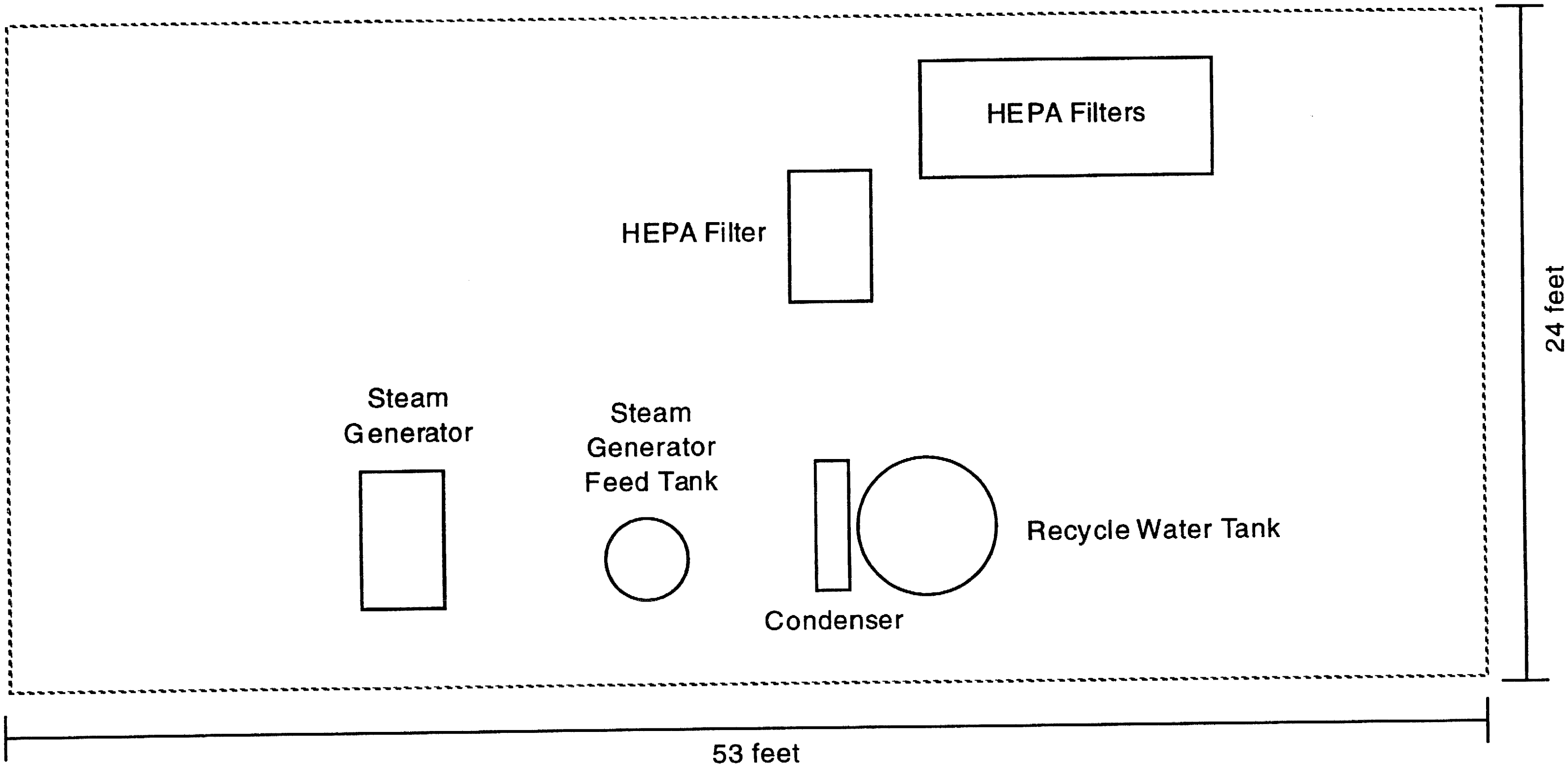

Figure 6.3-4-10: Process Equipment Layout - Support Systems Module

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6.3-5.Site Map and Land Requirements

6.3-5.1. Site Map

The facility site map is shown in Figure 6.3-5-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipments of cylinders into the facility and products out of the facility. A Process Building ventilation exhaust stack is provided for the Process Building. A stack is provided for the boiler in the Utility Building. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of this site discharge point will require adjustment during later site-specific studies.

6.3-5.2. Land Requirements During Operation

As shown in Figure 6.3-5-1, the total land area required during operations is approximately 198,000 square ft, or about 4.5 acres.

6.3-5.3. Land Requirements During Construction

Figure 6.3-5-2 shows the site map during construction. Land area requirements during construction are approximately 377,000 square feet or about 8.7 acres. Construction areas required in addition to the site structures and facilities are:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing on-site engineering support, construction supervision, and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note: The estimated construction area and layout will be adjusted during later site-specific studies.

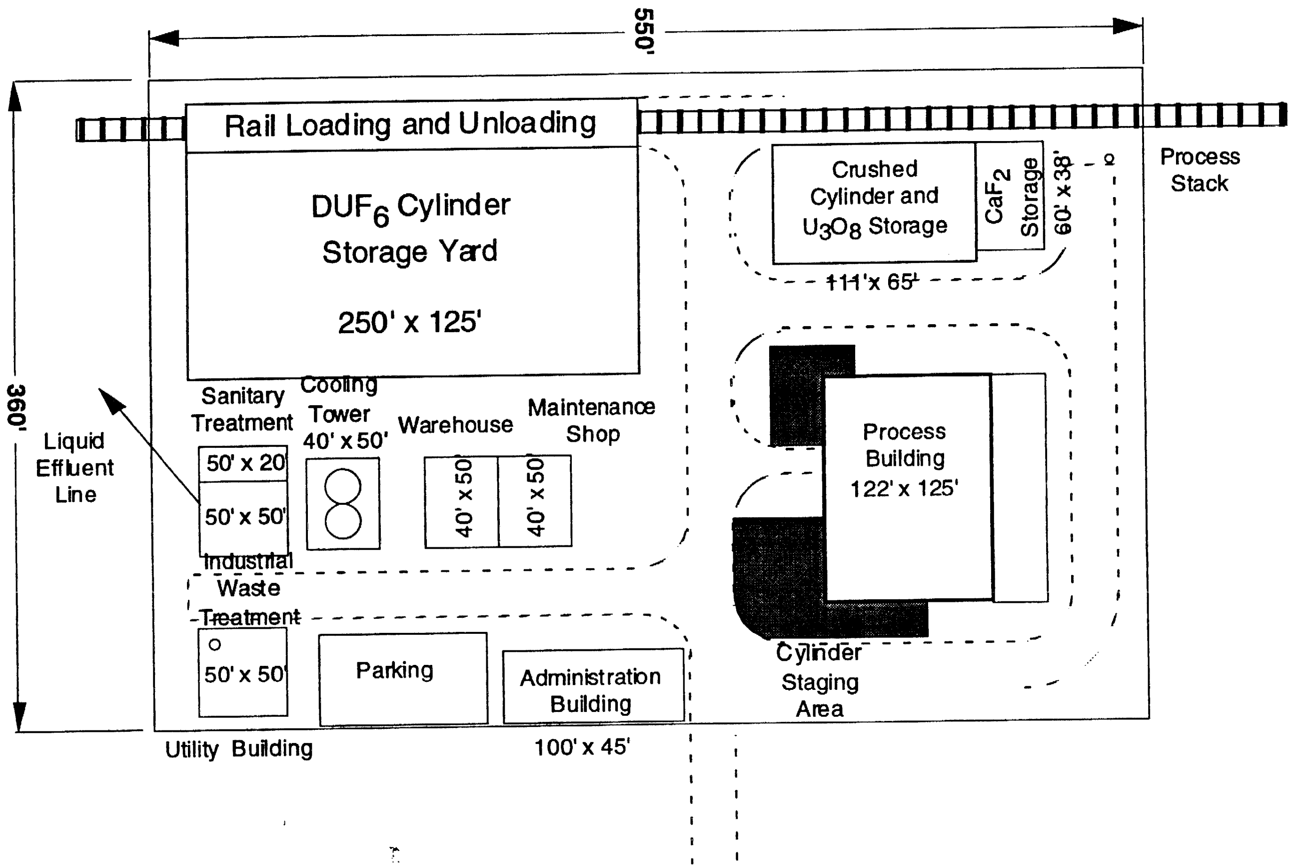

Figure 6.3-5-1: Facility Site Map

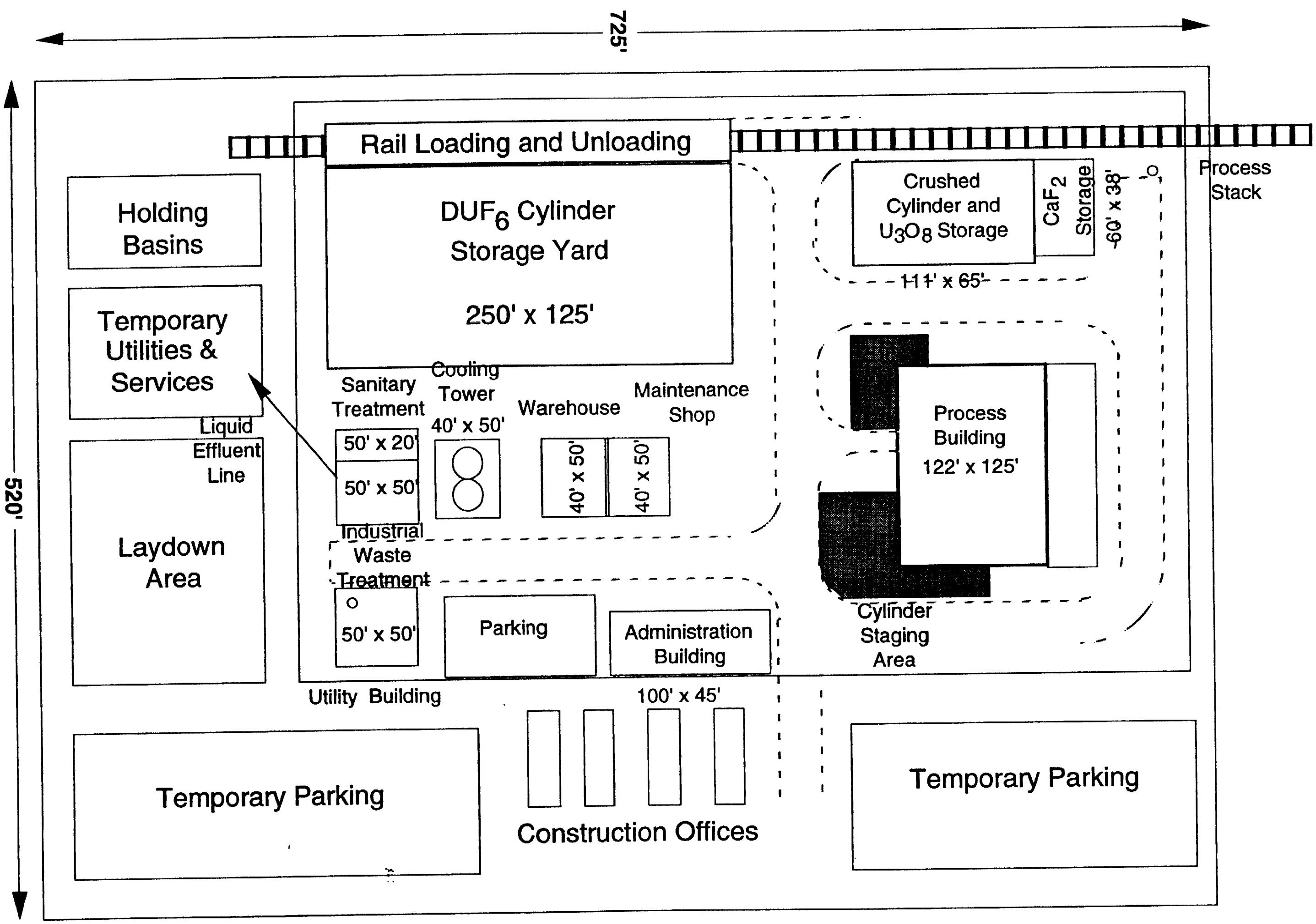

Figure 6.3-5-2:Facility Site Map During Construction

11/13/95

6.3-6. Process Descriptions

6.3-6.1. Overall Process

6.3-6.1.1. Summary

The DUF_6 heel is removed by washing the cylinder with water. The water reacts with the UF_6 to produce an aqueous solution of UO_2F_2 and HF. This reaction is exothermic and no heat has to be supplied

$$UF_{6(s)} + 2\ H_2O \rightarrow UO_2F_{2(aq)} + 4\ HF_{(aq)}$$

The UO_2F_2/HF solution is dried to a powder before pyrohydrolysis. The UO_2F_2 is converted (pyrohydrolysis) with steam to U_3O_8, additional HF, and oxygen (O_2) in a rotary kiln.

$$3\ UO_2F_{2(s)} + 3\ H_2O_{(g)} \rightarrow U_3O_{8(s)} + 6\ HF_{(g)} + 1/2\ O_{2(g)}$$

This reaction is highly endothermic. For complete conversion, a significant excess of steam and an elevated temperature (about 500 °C) are required. The U_3O_8 is packaged in 55 gallon drums.

The collected HF acid is neutralized with CaO to produce CaF_2 which is insoluble in water.

$$2\ HF_{(aq)} + CaO_{(s)} \rightarrow CaF_{2(s)} + H_2O$$

The calcium fluoride is then compacted and packaged in 55 gallon drums.

6.3-6.1.2. Flowsheet

The top level flowsheet (Figure 6.3-6-1) has 6 modules. The off-gas treatment and steam generation operations make up the support module. These modules were selected because products from them could interface with a collocated facility. Table 6.3-6-1 gives each module and its corresponding product. The flowsheet was developed based on information presented in the references: Charles, et al. and Mestepey, 1994.

Each module will be designed such that personnel will not be required to wear personal protection equipment (PPE) during normal operations. PPE will be available for special maintenance, special operational activities and emergency services.

Figure 6.3-6-2 gives an overall input/output flow of the facility. Appendix 6.3-D gives the detailed material balances and flowsheets for the overall process and the individual modules.

Table 6.3-6-1: Module Products

Module	Product
Cylinder Washing	UO_2F_2/HF solution
U_3O_8 Conversion	U_3O_8 powder and aqueous HF
Solids Packaging	Packaged U_3O_8 and CaF_2
HF Handling	CaF_2
Cylinder Disposition	Crushed Cylinders
Support (Steam Generation and Off-gas Treatment)	---

A brief description of each of the modules is included here. More detailed information about the modules are given in following sections.

6.3-6.1.2.1 Cylinder Washing Module

The cylinder washing module receives cylinders with heels, washes them with water to remove the heels and then dries the cylinders. The wash water goes to the U_3O_8 Conversion Module. The cleaned cylinders go to the Cylinder Disposition Module

6.3-6.1.2.2 U_3O_8 Conversion Module

The U_3O_8 Conversion module receives the solution from the Cylinder Washing Module. The solution is dried to a powder and then pyrohydrolized to U_3O_8 using steam. The solids go to the Solids Packaging Module. The offgas containing water, HF and oxygen is processed in the HF Handling Module.

6.3-6.1.2.3 Solids Packaging Module

The solids (U_3O_8, CaF_2 and wash solids) are densified and packaged into 55 gallon drums. The U_3O_8 and wash solids will be packaged together.

6.3-6.1.2.4 HF Handling Module

The HF Handling Module neutralizes the HF with CaO to generate CaF_2. The small amount of HF generated is assumed to be insufficient for sale offsite. The CaF_2 is sent to the Solids Packaging Module for packaging.

6.3-6.1.2.5 Cylinder Disposition Module

The Cylinder Disposition Module prepares the cylinders for disposition. For this report the disposition of the cylinders is to the DOE metal scrap pile. To decrease the storage volume, the cylinders are crushed.

6.3-6.1.2.6 Support Systems Module

The Support Systems Module supplies offgas treatment and a "hot" steam generator for the process.

6.3-6.2. Module Descriptions

6.3-6.2.1. Cylinder Washing Module

6.3-6.2.1.1. Description

The cylinder wash module removes the heel from the cylinder. In the process it generates a UO_2F_2/HF solution that is feed to the U_3O_8 Conversion Module. The flowsheet is shown in Figure 6.3-6-3.

The cylinder is assumed to have a 10 kg heel of DUF_6. This is removed by a four-step cleaning cycle. The cycle uses washing, flushing, rinsing and drying steps. The wash step washes the cylinder with 22 gallons of wash solution. The wash solution is the product of flushing previous cylinders. The solution comes from a wash solution tank. The cylinder is on a stand that allows it to be rotated and tilted to allow the wash solution to contact all internal surfaces. The final wash solution will contain about 10 wt% UO_2F_2 and 2.5 wt% HF. This wash solution is filtered and then evaporated to provide the UO_2F_2/HF solution to the U_3O_8 Conversion Module.

The second step is the flush step. The cylinder is flushed with wash solution. This step is not volume limited since the flush solution is returned to the wash solution tank.

The third step is the rinse step. In this step, 22 gallons of water is used to rinse the cylinders. The used rinse water is sent to the wash solution tank. The remaining holdup in the cylinder is expected to be about 1 pint.

The cylinder is dried with compressed air. Dry air at about 15 cfm is passed through the cylinder until the dew point of the exiting air is low enough. The air is vented to the facility ventilation system.

The cylinders are sent to the Cylinder Disposition Module.

6.3-6.2.1.2. Flowsheet

The flowsheet is shown in Figure 6.3-6-3. The washing, flushing, rinsing and drying steps are shown as four separate boxes. They are separate operations, but they all occur with the cylinder remaining on the stand. Because one stand is occupied by a cylinder for a substantial time, multiple stands are needed to maintain the required processing rate. It is estimated that the steps will take the following time periods:

Cylinder Cleaning Time

Step	**Time**
Load Stand	0.5 hr
Wash	1.0 hr
Flush	0.5 hr
Rinse	0.5 hr
Dry	6.2 hr[1]
Unload Stand	0.5 hr
Total Time	9.2 hr

1 - The drying time is based on equations in Brusaert 1982, page 31 and Chow, page 11-3.

At the assumed processing rate of:

46,440 cylinders
20 years of operation
290 days/yr. operation
24 hours/day

The washing module requires 3.1 stands. Four stands are provided.

6.3-6.2.2. U_3O_8 Conversion Module

6.3-6.2.2.1. Description

In U_3O_8 Conversion Facilities (other reports developed for this program), the UO_2F_2 from the steam hydrolysis of UF_6 is continuously fed into a rotary kiln as a powder. The UCTF will process much less uranium than other conversion facilities. Therefore, instead of using a continuously fed rotary kiln, the UCTF kiln will be batch fed. In addition, the kiln will be smaller than those used in the other reports.

The flowsheet for this module is shown in Figure 6.3-6-4. The UO_2F_2/HF solution will be stored in tanks until there is sufficient volume to be processed. The solution will be evaporated close to precipitation. Then the concentrated solution will be fed to the kiln.

The kiln will be run at 200 °C to dry the UO_2F_2 to a powder. After the UO_2F_2 is dried, the temperature of the kiln will be raised to 500 °C and steam will be introduced. After the reaction, the powder is removed and packaged in the Solids Packaging Module. The offgas from this module contains water, HF and oxygen. This stream is processed in the HF Handling Module.

6.3-6.2.2.2. Flowsheet

The flowsheet for this module is shown in Figure 6.3-6-4. The evaporator is a separate unit from the rotary kiln. In the rotary kiln the uranium is dried, reacted and calcined.

6.3-6.2.3. Solids Packaging Module

6.3-6.2.3.1. Description

In the Solids Packaging Module, the solids are compacted to increase their bulk density. The U_3O_8 density can be increased from 1.4 g/cc to about 3.0 g/cc. This is done to decrease the solid's volume. It also increases the particle size to reduce the hazard of respirable dust in the final waste form.

The flowsheet for this module is shown in Figure 6.3-6-5. The U_3O_8 density is increased by using a compactor. Specifically, this compactor is a mill with two closely spaced rollers that compact fine materials by pressure, producing a solid ribbon that is broken up (for packaging) in a granulator.

The solids from the granulator will be sent to a vibrating screen which will allow fines to pass through to be recycled and sent back to the compactor for further agglomeration. Material with acceptable particle size would be sent to the packaging station where it will be packaged in drums meeting DOT requirements and sent to the Solids Product Building.

There are two separate lines, one for radioactive material (U_3O_8 and wash solids) and one for the CaF_2 which should have a very low radioactive content.

The U_3O_8 equipment is enclosed to avoid spreading U_3O_8 dust. The U_3O_8 solids will be loaded into specially designed 55 gallon drums. These drums are constructed similar to standard 55 gallon drums but use thicker steel to accommodate the increased weight. These drums are described in more detail in Section 6.3-11.2.2.

The other solid handled in this module is CaF_2. The CaF_2 is the result of neutralizing the HF solution with CaO. This is considered a waste product from this facility.

6.3-6.2.3.2. Flowsheet

The Solids Packaging Module flowsheet is shown in Figure 6.3-6-5. The products are packaged into 55 gallon drums.

6.3-6.2.4. HF Handling Module

6.3-6.2.4.1. Description

The offgas from the UO_2F_2/HF evaporator and pyrohydrolysis kiln contain water, HF, and oxygen. The water and HF are removed in a two-stage scrubber condenser. The scrubber condenser uses a water spray to cool the offgas and scrub the HF out of it. The resulting offgas goes to the facility ventilation system.

The scrubber solution is collected in a storage tank for neutralization. When sufficient scrubber solution is collected, the solution is neutralized with CaO. The CaO reacts with the HF to generate CaF_2 and water. The CaF_2 is filtered out of the water. The water is reused within the facility.

The filtered CaF_2 is dried and sent to the Solids Packaging Module for packaging for disposal.

6.3-6.2.4.2. Flowsheet

The flowsheet for the HF Handling Module is shown in Figure 6.3-6-6.

6.3-6.2.5. Cylinder Disposition Module

6.3-6.2.5.1 Description

After washing the cylinders, they still may contain small amounts of radioactive nuclides. The cylinders need to be prepared for their disposition. There are several options for the disposition of the clean cylinders. These are discussed in Appendix 6.3-A. For this report the cylinder disposition is assumed to send the cylinders to the DOE scrap metal pile. To reduce the storage and transportation volume, the cylinders will be crushed and stored in cylinder shipment boxes (See Section 6.3-11.2). They are stored 3 to a box. The use of the boxes allows them to be handled easily.

6.3-6.2.5.2. Flowsheet

The flowsheet and for the Cylinder Disposition Module is shown in Figure 6.3-6-7.

6.3-6.2.6. Support System Module

6.3-6.2.6.1 Description

The functions supplied by the Support System Module are: offgas treatment, steam generation and internal water recycle. There are many other support functions that are supplied by the Utilities, Administration, Warehouse, and Maintenance Shop buildings.

Water is removed from the offgas stream and used for internal water recycle. The recycle water is feed to other modules as water or steam.

6.3-6.2.6.2. Flowsheet

The flowsheet for the Support Module is shown in Figure 6.3-6-8.

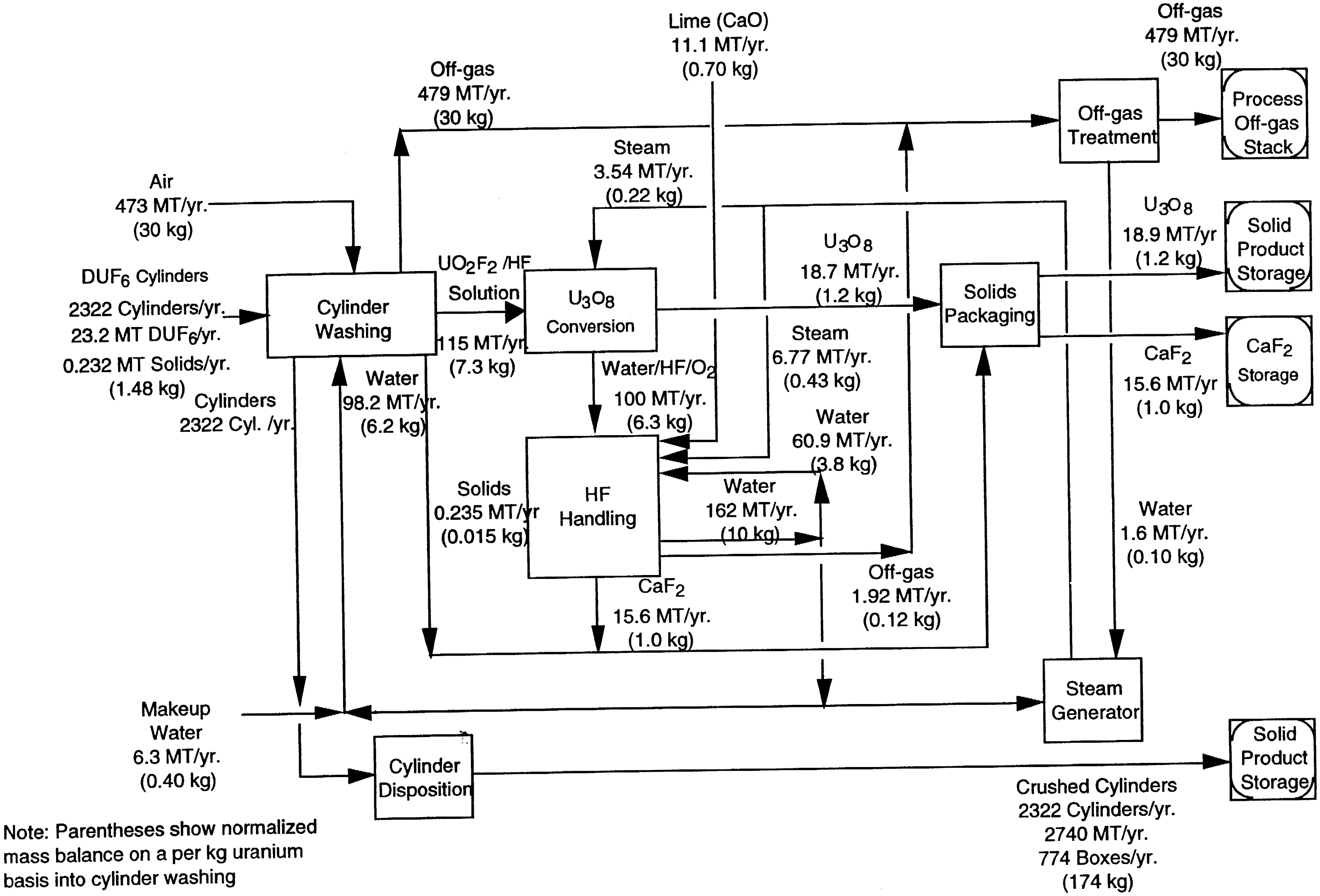

Figure 6.3-6-1: Overall Process Flowsheet

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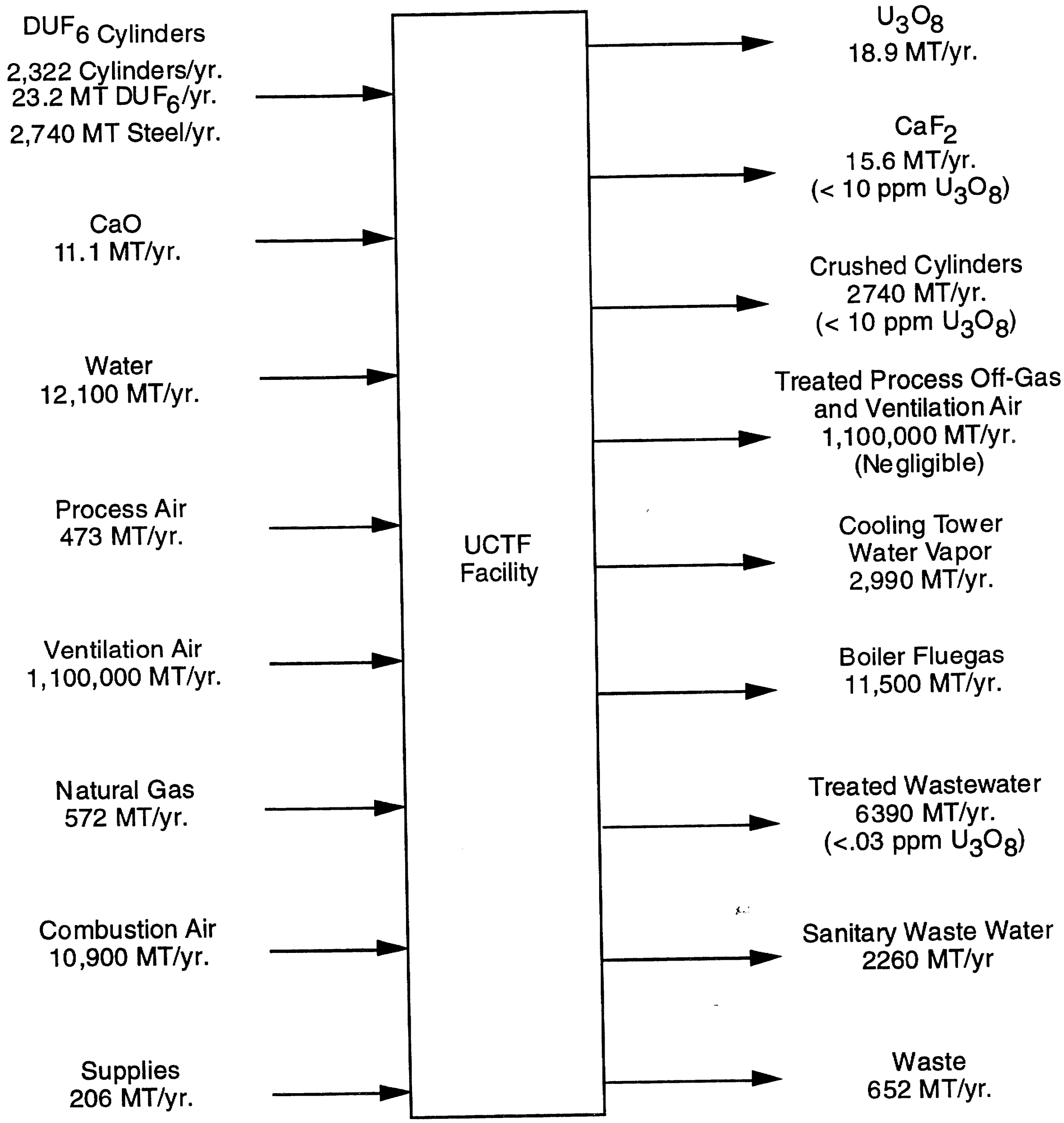

Figure 6.3-6-2 UCTF Input/Output Diagram

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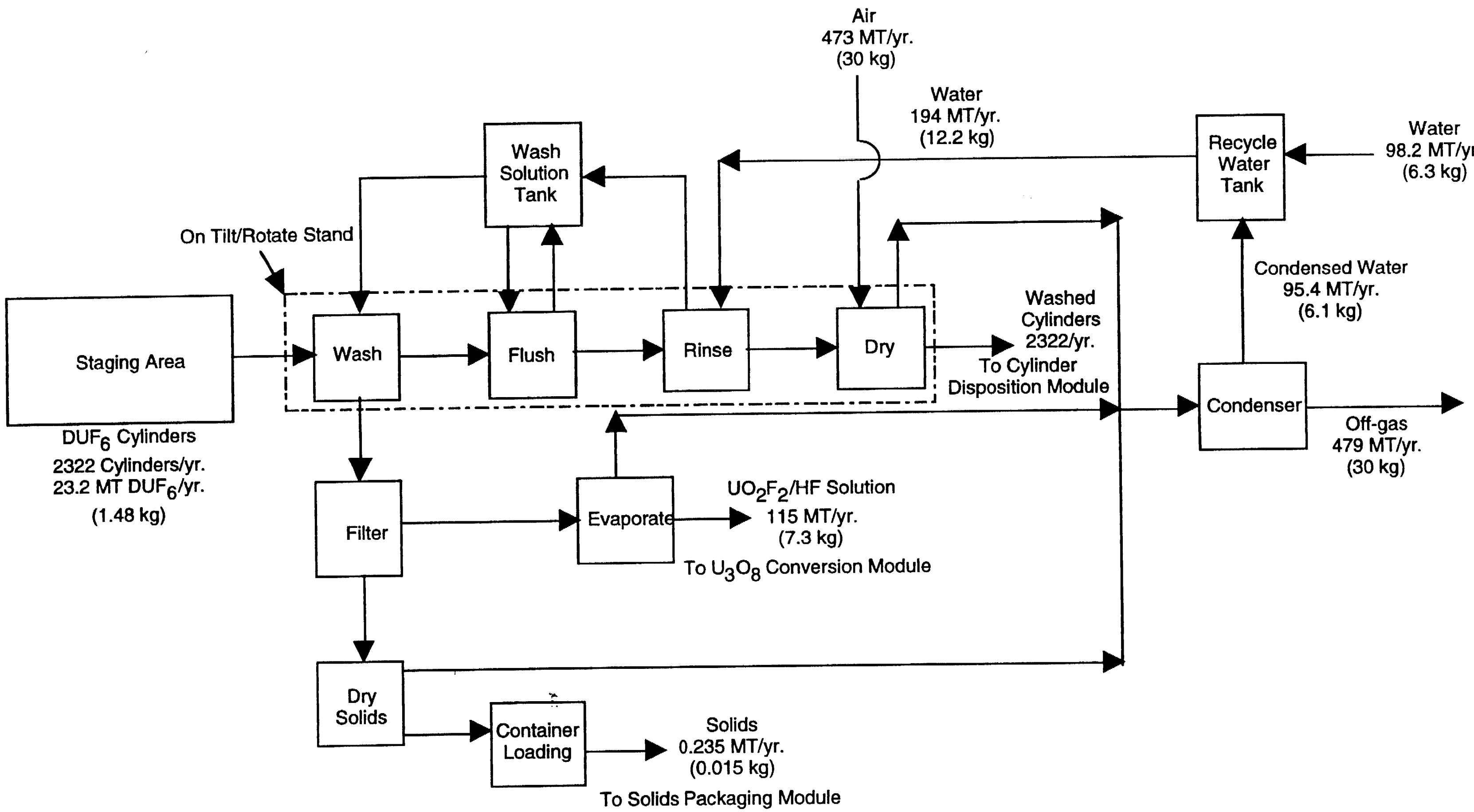
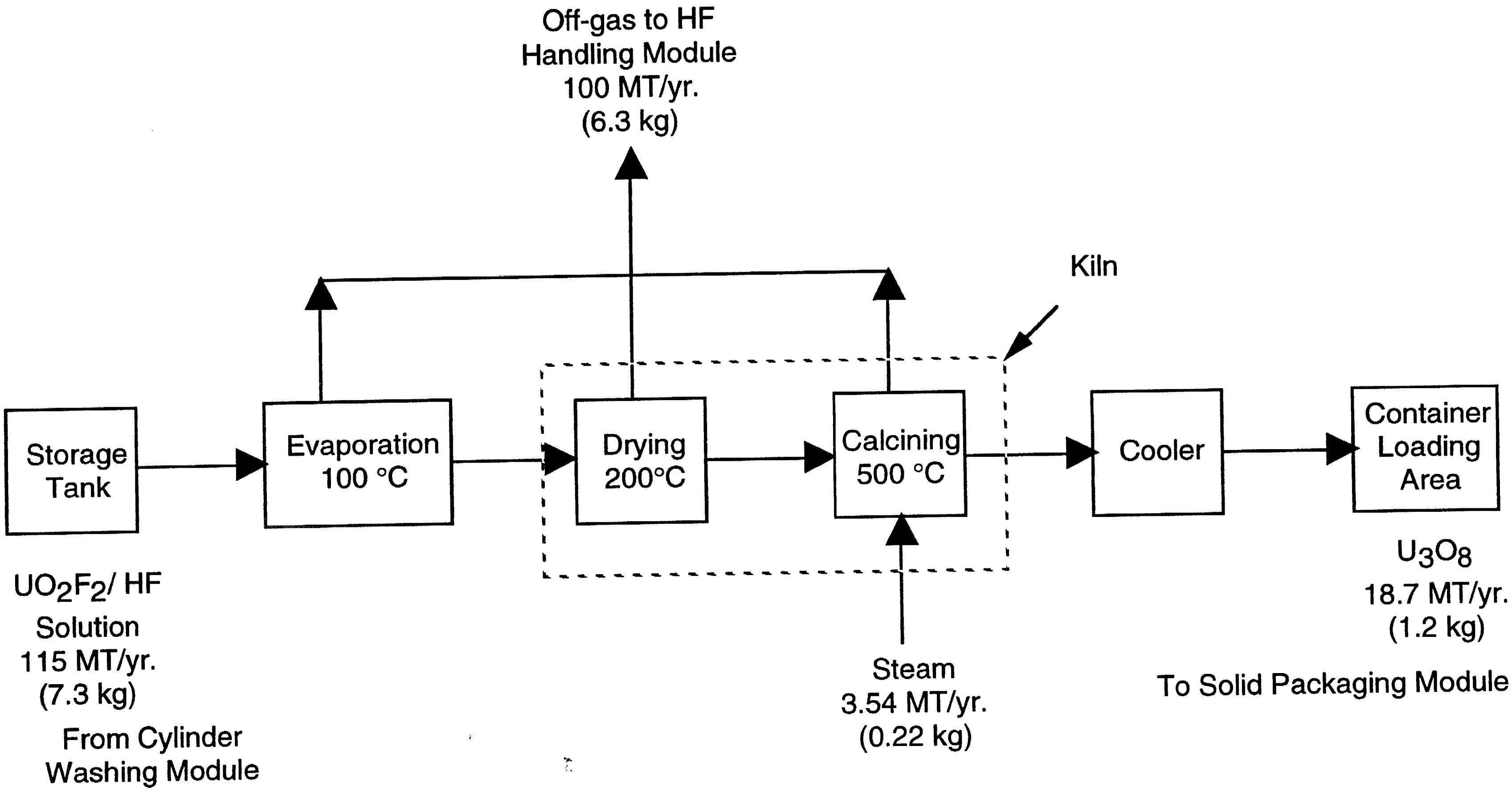


Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

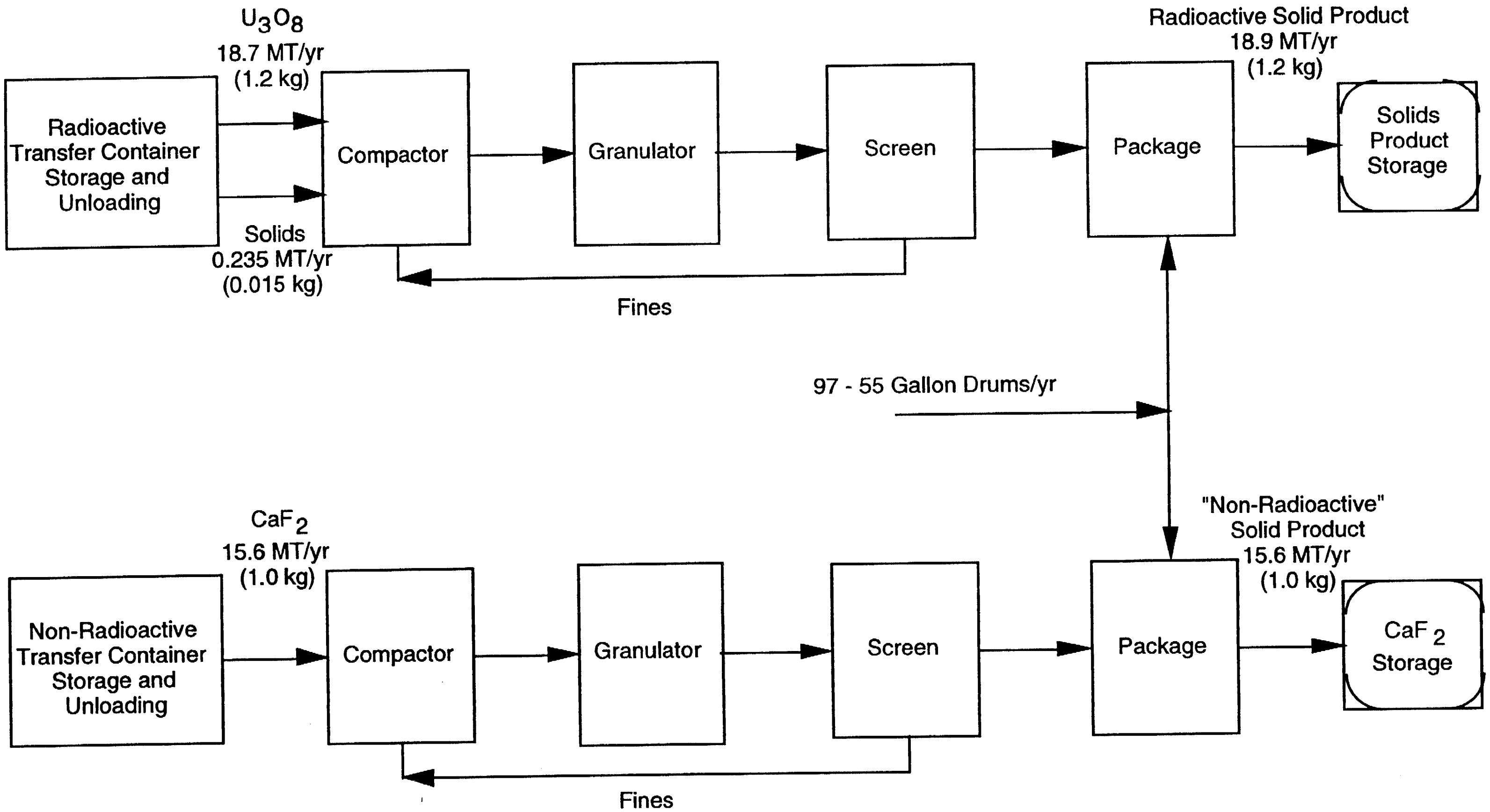
Figure 6.3-6-3: Cylinder Washing Process Flowsheet

3/11/96



Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

Figure 6.3-6-4: U_3O_8 Conversion Process Flowsheet 4/10/97



Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

Figure 6.3-6-5: Solids Packaging Module Process Flowsheet

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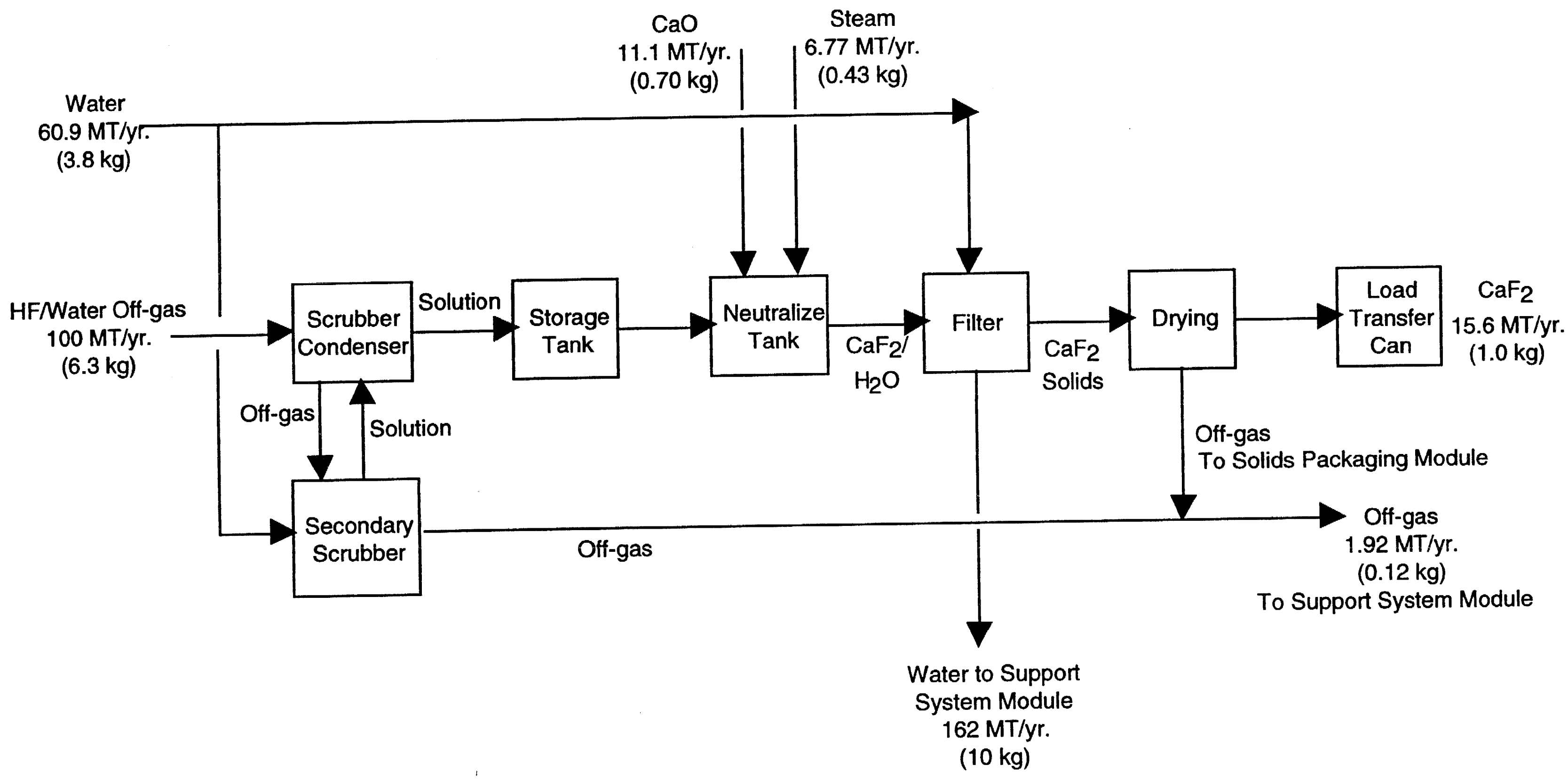
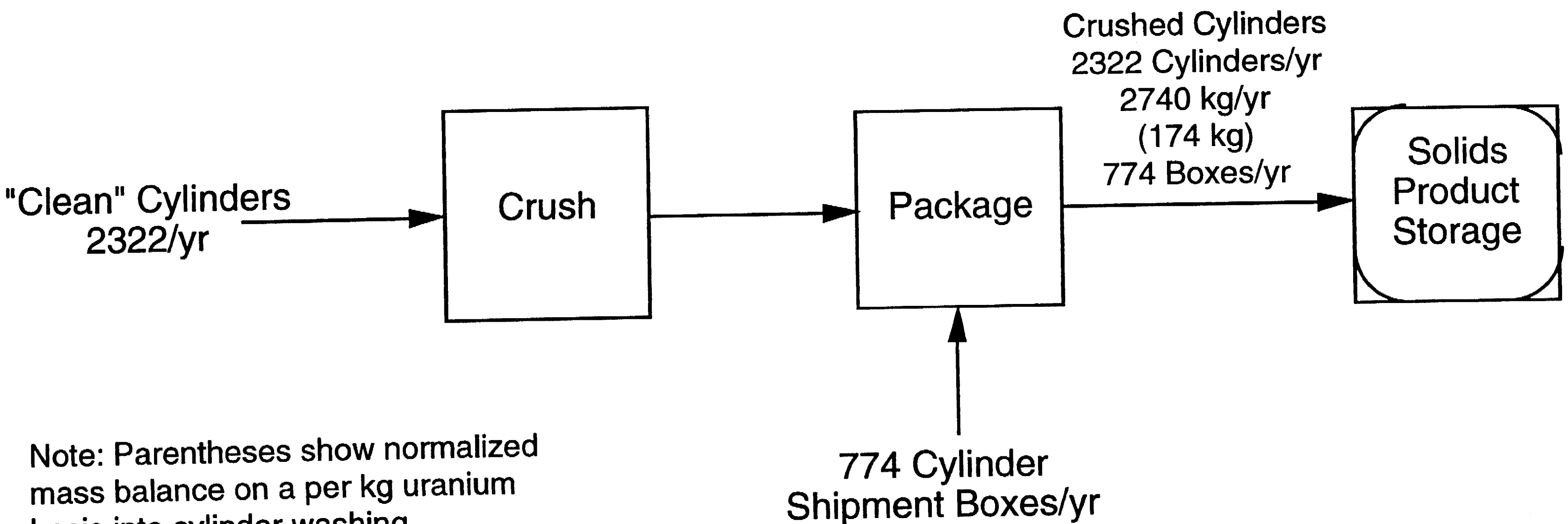


Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

Figure 6.3-6-6: HF Handling Process Flowsheet

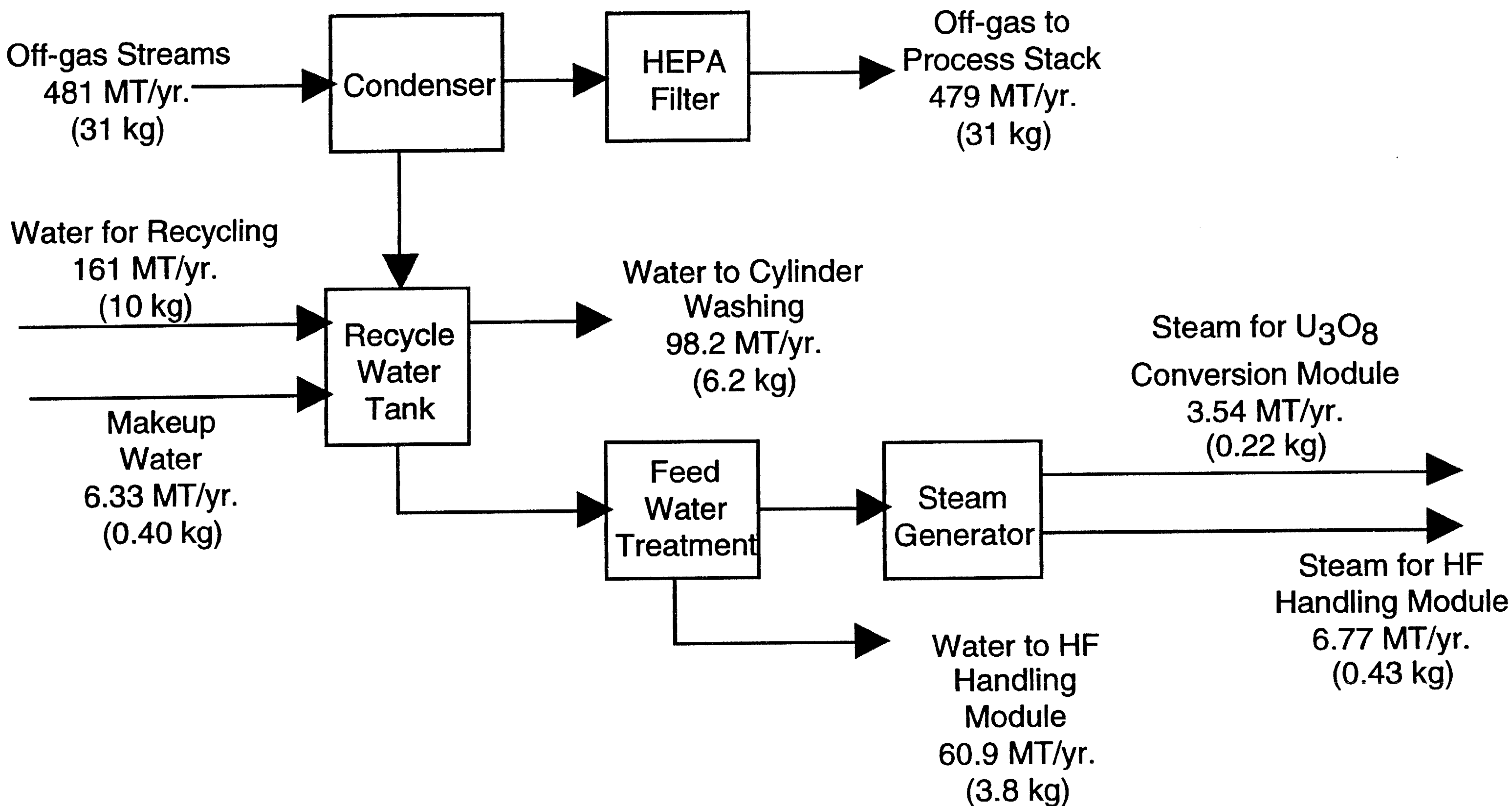
3/11/96



Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

Figure 6.3-6-7: Cylinder Disposition Module Process Flowsheet

3/11/96



Note: Parentheses show normalized mass balance on a per kg uranium basis into cylinder washing

Figure 6.3-6-8: Support System Process Flowsheet

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6.3-7.Facility Support Systems

6.3-7.1. Miscellaneous Support Facilities and Systems

In addition to the facilities previously described, the UCTF includes other facilities shown on the Site Map (Figure 6.3-5-1).

6.3-7.1.1. Facilities

A 31,300 ft^2 concrete pad stores a one month supply of "empty" DUF_6 cylinders.

A 7,300 ft^2 metal frame Product Storage Building stores one calendar month of production of crushed cylinders and one truckload of U_3O_8 drums.

A 2,280 ft^2 metal frame CaF_2 Storage Building stores one truckload of CaF_2 drums.

An 4,500 ft^2 metal frame or masonry Administration Building houses the facility support personnel.

A 2,500 ft^2 metal frame general use Utilities Building houses the raw water treatment system, water storage tanks, fire-water pumps, and steam heating boiler systems.

A 2,000 ft^2 metal frame general use Maintenance Shop contains clean maintenance operations and repair shops.

A 2,000 ft^2 Industrial Waste Treatment Facility receives, treats and prepares for disposal chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility waste water discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents are treated and discharged in this facility to assure that waste water discharges meet applicable environmental standards.

A 1,000 ft^2 Sanitary Treatment Facility with a capacity of approximately 1,600 gpd.

A 2,000 ft^2 Warehouse will store the reagents and supplies.

A 900 KBTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 90 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

6.3-7.1.2. Systems

The compressed air system includs plant air, instrument air and breathing air. A single set of two redundant 200 cfm reciprocating air compressors provide compressed air to the plant and instrument air systems. The plant air is dried in desiccant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver at 100 psig. The plant air also supplies air to the cylinder drying operation. A separate breathing air compressor and receiver provides air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

Building HVAC systems uses a chilled water system for building cooling. Three 50% capacity, 90 ton centrifugal water chillers, and three 160 gpm circulating pumps are provided. A steel stack serving the Process Building HVAC exhaust system is provided. The properties of the stack and exhaust gas are provided in Table 6.3-7-1.

A central steam plant is provided in the Utilities Building to produce steam for process uses and for building heating by the HVAC system. The plant produces 360 lb./hr of 50 psig steam that is distributed around the site by outside overhead piping. A steel stack serving the boiler exhaust system is provided. The properties of the stack and exhaust gas are provided in Table 6.3-7-1.

Table 6.3-7-1: Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Ventilation	100	60	80	60
Boiler	100	18	500	60

All cooling water systems are connected to the cooling tower system described above.

A demineralized water system to produce deionized water for steam boiler feed water and process water system makeup.

The site receives electric power at 13.8 kV from the utility grid system and distributes it on-site at the required voltages. The electrical substation has the capacity of 1000 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two redundant, 150 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. A 80 kva uninterruptible power supply (UPS) system is provided for the control system to ensure continued operation of safety equipment and system during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas that require special lighting for nighttime operation include the cylinder storage yard, the rail spur, the utility and the entry control areas.

Site security fencing as shown on the Site Map, Figure 6.3-5-1, consists of galvanized steel fabric with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

6.3-7.2. Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the storage containers, process vessels, piping, enclosures, and the facility ventilation systems. Ventilated enclosures are provided where uranium powders or hazardous chemicals pose a potential for release (e.g., solids processing area).

The secondary confinement system consists of the structure that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases according to DOE-STD-1020-94 and DOE-STD-1027-92.

6.3-7.3. Ventilation Systems

The HVAC systems will utilize a combination of dividing the building into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The building will be divided into three ventilation zones according to potential for uranium contamination: Zone 1 for areas of high contamination hazards, Zone 2 for areas of moderate to low potential for contamination, and Zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate, or low potential for hazardous chemical contamination. Zone 1 area of the Process Building will utilize gloveboxes and fume hoods for containment of uranium powders, once-through ventilation systems to prevent recirculation of contaminants, double filtration for building exhaust air through High Efficiency Particulate Air (HEPA) filters to prevent the release of radioactive particulate, and pressure control to assure air flows from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing ventilated enclosures, and other uranium processing areas. The ventilation system for these rooms utilizes once-through air flow to prevent recirculation of contaminates, double filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard. The Solids Product Storage Building will be treated as a Zone 2 area.

The remainder of the Process Building will be Zone 3, including waste processing areas, personnel change rooms and offices, chemical feed storage and preparation rooms, and support system areas. The ventilation systems for these rooms will utilize conventional recirculating air conditioning systems sized based on cooling and heating loads. These rooms will be maintained at a positive pressure with respect to the rest of the building, but slightly negative with respect to the outside.

6.3-7.4. Fire Protection

The requirements for fire protection for the facility are contained in DOE Order 6430.1A, *General Design Criteria*; DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*; and DOE Order 5480.7A, *Fire Protection.*

The facility fire protection systems design incorporates an "improved risk" level of fire protection as defined in DOE Order 5480.7A. This criterion requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7A to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

6.3-7.5. Material Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.5) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

6.3-8.Resource Requirements

6.3-8.1. Resource Requirements during Construction

This section provides preliminary estimates of the labor and resource needs of the facility during construction and operation. The values presented are for all on-site facilities.

6.3-8.1.1. Labor

Table 6.3-8-1 provides an estimate of the employment buildup by year during construction.

Table 6.3-8-1: Number of Construction Employees Needed by Year

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	80	110	190	110
Construction Management and Support Staff	15	20	40	20
Total Employment	**95**	**130**	**230**	**130**

6.3-8.1.2. Resources

Table 6.3-8-2 provides a preliminary estimate of the quantities of materials and resources consumed during construction.

6.3-8.2. Resource Requirements during Operation

6.3-8.2.1. Labor

Table 6.3-8-3, provides labor category descriptions and the estimated numbers of employees required to operate the facility.

6.3-8.2.2. Resources

Annual utility consumption for facility operation is presented in Table 6.3-8-4, including electricity, fuel, and water usage. This is followed by Table 6.3-8-5 showing consumable chemical and process material annual usage.

Table 6.3-8-2: Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	14,000 MWh	0.7 MW
Water	3.6×10^6 gals	2,300 gals/day
Solids		
Concrete[2]	6,400 yd^3	N/A
Steel	2,100 tons	
Electrical raceway	8,300 yd	
Electrical wire and cable	21,000 yd	
Piping	12,000 yd	
Steel decking	8,700 yd^2	
Steel siding	3,700 yd^2	
Built-up Roof	1,700 yd^2	
Interior partitions	700 yd^2	
Lumber	2,300 yd^3	
HVAC ductwork (steel)	41 tons	
Special coatings (epoxy)	1,700 yd^2	
Asphalt paving	100 tons	
Liquids		
Fuel	7.2×10^5 gals	
Gases		
Industrial gases (propane)	1,900 gals	

1 Peak demand is the maximum rate expected during any hour.

2 Concrete quantities assume one foot wall and roof thickness for the Process Building. A one foot slab thickness was assumed for the Process Building and cylinder pads.

Table 6.3-8-3: On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	4
Professionals	4
Technicians	18
Office and Clerical	14
Craft Workers (Maintenance)	12
Operators	52
Line Supervision	9
Security	19
Total Employees (for all on-site facilities)	**132**

6.3-8.2.2.1 Utilities Consumed

Table 6.3-8-4: Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	6 GWh	850 kW
Liquid Fuel	2,900 gal	N/A
Natural Gas[2]	2.8×10^7 scf	N/A
Raw Water	3.4×10^6 gals	N/A

1 Peak demand is the maximum rate expected during any hour

2 Standard Cubic Feet measured at 14.7 psia and 60°F.

6.3-8.2.2.2 Water Balance

Figure 6.3-8-1 is a preliminary conceptual UCTF water balance. This balance is based on a generic greenfield site that has a net rainfall of 4.4 MGY. The only effect on the water balance for a greenfield site in a different location will be the storm water runoff.

6.3-8.2.2.3 Chemicals and Materials Consumed

Table 6.3-8-5 shows that annual chemicals and materials consumed during normal operations. In addition to chemicals required for the process and support systems, estimated quantities of waste containers are included.

Table 6.3-8-5: Annual Chemicals and Materials Consumed During Normal Operations

Chemical	Quantity, kg (lb.)
Solid	
Lime	11,100 (24,400)
Detergent	99 (220)
Liquid	
Hydrochloric Acid (Water Treatment)	220 (470)
Sodium Hydroxide (Water Treatment)	230 (510)
Sodium Hypochlorite (Water Treatment)	140 (310)
Cooling Tower Chemicals	
Nonionic Polymers	5 (10)
Phosphates	23 (50)
Phosphonates	5 (10)
Gaseous	
None	
Containers[1]	**Quantity (no. of containers)**
U_3O_8 Containers (55 gal drums)	31
CaF_2 Containers (55 gal drums)	67
Cylinder Shipping Boxes (5 x 5 x 11.5' box)	7743
LLW Containers (55 gal drums & 4' x 2' x 7' [56 ft^3] boxes)	162 drums 10 boxes
Mixed LLW Containers (55 gal drums)	1
Hazardous Waste Containers (55 gal drums)	10

1 Containers listed include only those that are expected to be sent to ultimate disposal or storage and not reused.

6.3-8.2.2.4 Radiological Materials Required

The only radiological material input to the site is DUF_6.

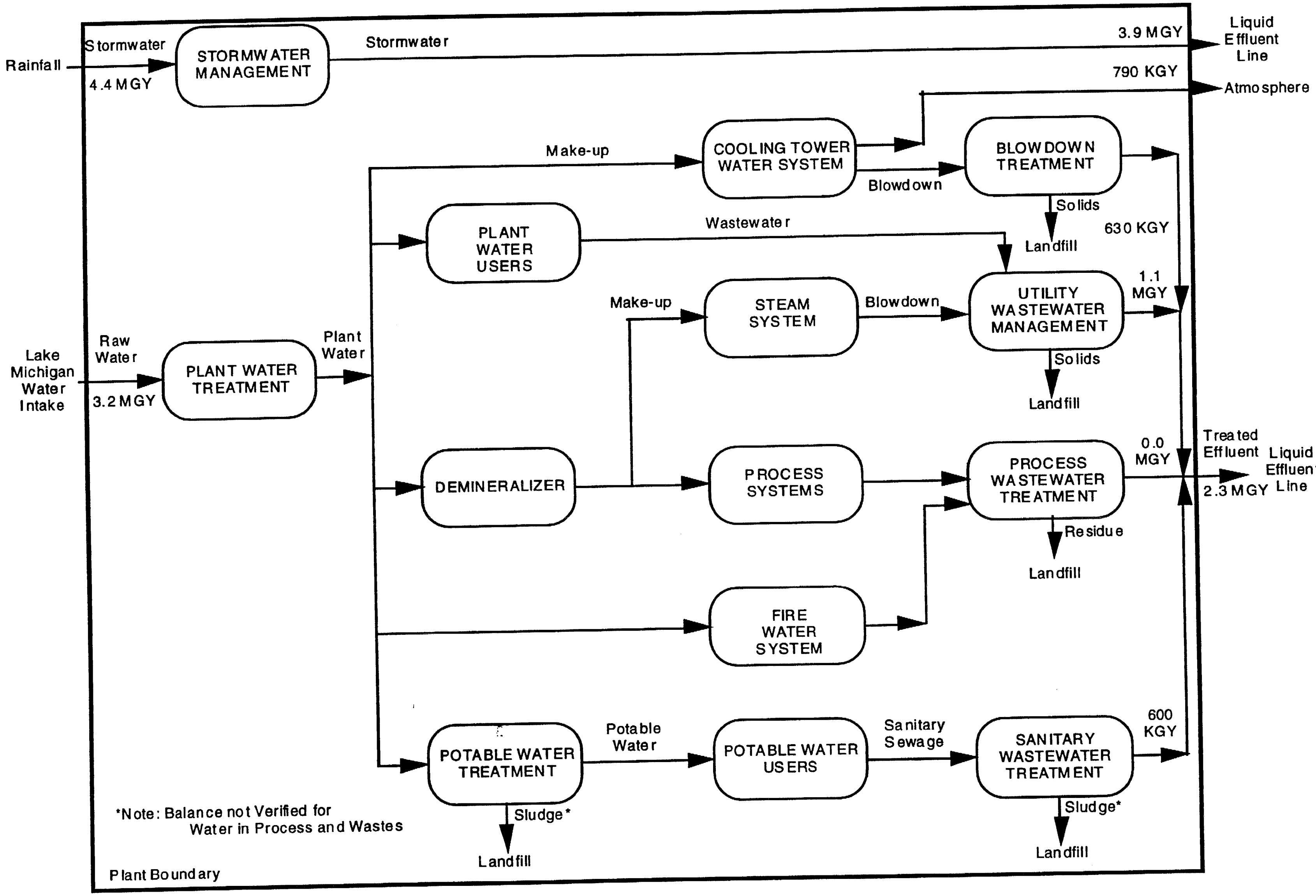

Figure 6.3-8-1: Water Balance

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6.3-9. Emissions and Wastes During Construction and Operation

This section provides the wastes and emissions generation estimates from the facility during the construction and operation phases. In general, the numbers are based on engineering judgment due to pre-conceptual nature of the design.

6.3-9.1. Wastes and Emissions During Construction

The wastes and emissions generated as the result of construction are given in Tables 6.3-9-1 and 6.3-9-2.

Table 6.3-9-1: Total Waste During Construction

Category	Solid	Liquid (gals)
Low-Level Waste (LLW)	N/A	N/A
Mixed Low-Level Waste	N/A	N/A
Hazardous Waste	23 yd^3	9100
Non-hazardous		
Concrete	43 yd^3	
Steel	13 tons	
Other Solids	340 yd^3	
Sanitary		6.89×10^6
Other Liquids		4.5×10^5

Table 6.3-9-2: Air Emissions During the Peak Construction year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	0.9
Nitrogen Dioxide	13
Hydrocarbons	3.6
Carbon Monoxide	86
Particulate Matter PM-10	18

6.3-9.1.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the UCTF since the site should not be contaminated. If the site is contaminated, then radioactive waste would be generated. This issue needs to be addressed when a specific site is selected.

6.3-9.1.2. Hazardous Wastes

Hazardous wastes generated from construction operations, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to a commercial waste facility off-site for treatment and disposal according to Environmental Protection Agency (EPA) Resource Conservation and Recovery Act (RCRA) guidelines.

6.3-9.1.3. Non-hazardous Wastes and Emissions

Solid non-hazardous wastes generated from construction activities, i.e., construction debris and rock cuttings, are disposed of in a sanitary landfill. Liquid non-hazardous wastes are either treated with a portable sanitary treatment system or hauled to off-site facilities for treatment and disposal.

6.3-9.2. During Operation

The amounts of waste and emission generated annually during operation are given in Tables 6.3-9-3, 6.3-9-4 and 6.3-9-5.

6.3-9.2.1. Low-Level Wastes

Low-level wastes generated from operation of the facility are treated by sorting, separation, concentration, and size reduction processes. Final LLW products are surveyed and shipped to a shallow land burial site for disposal. The volume of LLW listed in Table 6.3-9-3 does not include the U_3O_8 drums or crushed cylinders, which may go to a LLW disposal site.

6.3-9.2.2. Mixed (radioactive and hazardous) Low-Level Wastes

The amount of mixed waste generated from the facility will be minimized. The mixed waste will be packaged and shipped to a facility that can dispose of mixed wastes.

6.3-9.2.3. Hazardous Wastes

Hazardous wastes will be generated from the chemical makeup and reagents for support activities and lubricants and oils from process and support equipment. Hazardous wastes will be managed and hauled to a

Table 6.3-9-3: Annual Waste During Operation

Type	Description	Weight (lb.)	Volume (cu yd)	Contents (per year)	Form	Packages
Low Level Waste						
Combustible Solids	Gloves, wipes, clothing, etc. (plastic, paper, cloth)	85,000	40	5 lb. U_3O_8	Solid	147 55-gal drums
Metal, Surface Contaminated	Failed equipment (metal)	5,700	3.5	3.4 lb. U_3O_8	Solid	13 55-gal drums
Non-Combustible Compactable Solids	HEPA filters	1,900	11	5 lb. U_3O_8	Solid	10 4x2x7 ft wood boxes
Other	Lab Pack (chemicals and absorbent)	800	0.5	0.1 lb. U_3O_8	Solid	2 55-gal drums
Mixed Low Level Waste						
Labpacks	Lab Pack (chemicals plus absorbent)	Incl.	Incl.	Incl.	Solid	55-gal drums
Inorganic Process Debris	Failed equipment (metal, glass)	Incl.	Incl.	Incl.	Solid	55-gal drums
Combustible Debris	Wipes, etc. (plastic, paper, cloth)	Incl.	Incl.	Incl.	Solid	55-gal drums
Total		90	0.2	0.1 lb. U_3O_8, Organics, Corrosives (<1 wt%)	Solid	1 55-gal drums
Hazardous Waste						
Organic Liquids	Solvents, oil, paint, thinner	1,500	1 (200 gal)	See description	Liquid	4 55-gal drums
Combustible Debris	Wipes	180	0.3	See description	Solid	2 55-gal drums
Batteries.	Batteries	18	0.03	See description	Solid	0.2 55-gal drums
Inorganic Process Debris	Aerosol cans, paint cans, fluorescent bulbs, failed equip. (metal, glass)	2,200	1	HF, NaOH, contaminates (< 1 wt% of failed equip.)	Solid	4 55-gal drums
Non-Hazardous Waste						
Solid	Office Waste, Paper, Rags, Food	218,000	130		Solid	Truck to municipal landfill
Liquids	Treated waste water	14×10^6	8,400 (1.7×10^6 gal)		Liquid	Released at liquid effluent release point
Sanitary Waste						
	Sanitary Waste	5,000,000	3,000 (599000 gal)		Liquid	Released to local sanitary system
Recycling Wastes						
	Aluminum, steel, paper, and cardboard	73,000	43		Solid	Picked up by various recycling companies

Table 6.3-9-4: Annual Air Emissions During Operation

Category	Annual Emissions (lb.) Boiler/Other[1]
CRITERIA POLLUTANTS	
Sulfur Dioxide	10/29
Nitrogen Dioxide	1280/240
Hydrocarbons	26/190
Carbon Monoxide	640/1100
Particulate Matter PM-10	51/39
Other Pollutants From Process Stack	**Total (lb.)**
HF	1.0
U_3O_8	0.01
Cooling Tower Chemicals	
Nonionic Polymers	4.3
Phosphonates	4.3
Phosphates	21
Calcium	4.5
Magnesium	1
Sodium and Potassium	0.45
Chloride	0.75
Dissolved Solids	25

[1]Boiler stack velocity is assumed to be approximately 100 ft/sec and 500°F. Process stack velocity is assumed to be approximately 100 ft/sec and 80°F. Other emissions are from engines at grade

Table 6.3-9-5: Annual radiological Emissions During Operation

Radiological Isotope	Release Rate (Ci/yr.)[1]
Depleted Uranium in Gaseous Effluent	1.8×10^{-6}
Depleted Uranium in Liquid Effluent	1.6×10^{-6}

[1]Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium; see Section 6.3-2.2 for isotopic composition.

commercial waste facility off-site for treatment and disposal according to EPA RCRA guidelines.

6.3-9.2.4. Non-hazardous Wastes and Emissions

The non-hazardous waste and emissions include gaseous, liquid and solid waste streams. The non-hazardous gaseous emissions are released through the Process and Boiler stacks. The non-hazardous water emission is released from the discharge point to an off-site water system. The non-hazardous solid wastes, such as domestic trash and office waste, are hauled to an off-site municipal sanitary landfill for disposal. Other non-hazardous liquid wastes generated from facility support operations (e.g., cooling towers and evaporator condensate) are collected in a catch tank and sampled before being reclaimed, recycled or released to the environment. The volume of non-hazardous waste listed in Table 6.3-9-3 does not include the CaF_2 product drums.

6.3-9.2.5. Recyclable Wastes

Recyclable wastes include paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

6.3-10. Hazards

6.3-10.1. Bounding Accidents

The UCTF buildings include areas with hazard categories of chemically High Hazard (HH) for buildings containing DUF_6 and HF and radiologically low (HC-3) and very low hazard (<HC-3) for buildings containing U_3O_8. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 6.3-10-1 and are described in the following sections. Cylinder yard related accidents are described in Section 7.0 of the Draft Engineering Analysis Report. The description of each accident includes the following elements:

- A description of accident scenario,
- An estimate of the frequency of the scenario based on engineering judgment because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques,
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes,
- An estimate of the fraction of the effective material at risk that becomes airborne in respirable form,
- An estimate of the fraction of material airborne in respirable form released to the atmosphere taking into account the integrity of the containment system, and
- An estimate of release time.

Based on the postulated accidents and on DOE and NRC guidance, the following SSCs are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing large inventories of HF because their rupture could release HF with unacceptable consequences.
- The Process Building structure because it houses a large HF inventory. Building collapse could result in significant releases.

Table 6.3-10-1: Bounding Postulates Accident Summary

Accident	Frequency	Effective Material at Risk[a]	Respirable Airborne Fraction[b]	Fraction of respirable airborne material released to environment[c]	Duration
Earthquake	Extremely Unlikely	9,660 lb. U_3O_8	.0002[d]	1	30 min.
Tornado	Extremely Unlikely	1380 lb. U_3O_8	0.05[e]	1	30 sec.
Flood	Incredible	No Release	N/A	N/A	N/A
HF Aqueous Tank Failure	Extremely Unlikely	176 lb. HF	0.02[f]	1	60 min.
U_3O_8 Drum Spill	Anticipated	690 lb. U_3O_8	.0002[d]	1	30 min.
Loss of Electrical Power	Anticipated	No Release	N/A	N/A	N/A
Loss of Scrubber Water	Unlikely	26 lb. HF	1	1	30 min.

Frequency descriptions:

Anticipated:	$>10^{-2}$ events/yr.
Unlikely:	10^{-2} to 10^{-4} events/yr.
Extremely Unlikely:	10^{-4} to 10^{-6} events/yr.
Incredible:	$<10^{-6}$ events/yr.

Notes:

(a) Inventory at risk X Damage Factor

(b) Fraction airborne X Fraction in respirable range

(c) Building leak factor

(d) NUREG-1320, p. 4.71

(e) Airborne fraction is unity, fraction in respirable range is estimated to be 0.05.

(f) Calculated, see text.

The UCTF is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventative systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released materials.

Personnel will not be required to wear PPE during normal operations. PPE will be available for special maintenance or operational activities and emergency services.

Table 6.3-10-2 summarizes the significant mitigating design safety features provided for plant facilities.

6.3-10.1.1. Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234 and Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the DUF_6 cylinders and therefore these are concentrated in the empty cylinders.

Uranium and hydrofluoric acid (HFaq) are the primary hazardous materials handled in this facility. Uranium is toxic and hydrofluoric acid is both toxic and corrosive.

6.3-10.1.2. Natural Phenomena

6.3-10.1.2.1. Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 for the appropriate hazard safety classification. Systems, structures and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely

Table 6.3-10-2: Mitigating Safety Design Features

Building Name	Hazard Area	Exhaust Filtration	Structural Design	Other
Process Building	High	Zone 1 HVAC, Double HEPA Filters	PC-4 Design for DBE, DBT	
	Moderate	Zone 2 HVAC, Double HEPA Filters	PC-3	
	Low		PC-2 or 1	
Product Storage Building	Moderate	Zone 2 HVAC, Double HEPA Filters	PC-3	
Overall Site	N/A	N/A	N/A	Site Environmental Monitoring/ Alarm System

DBE Design Basis Earthquake
DBT Design Basis Tornado
HVAC Heating, Ventilation, and Air Conditioning
HEPA High Efficiency Particulate Air
PC Performance Category

unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94. Selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures.

Therefore, it would be incredible if this structure failed in the event of the DBE.

The Solids Product Building is vulnerable to earthquake damage. During an earthquake the building could be damaged and containers containing U_3O_8 could be breached. The building contains upwards of one truckload of U_3O_8 drums (38,640 lb.). Due to the severity of the earthquake, it is assumed that 50% of the drums are damaged and 50% of the material from these drums is released. Based on a respirable airborne fraction of 0.02% and loss of secondary containment, approximately 1.9 lb. of U3O8 is released to the environment. The release point is at grade (ground level). The accident duration is assumed to be 30 minutes. This accident is considered extremely unlikely

The DUF_6 storage pad holds DUF_6 cylinders that are 4 foot diameter vessels with a minimum of 1/4 in thick steel walls. It is assumed that the storage racks for these cylinders are designed to the appropriate DBE for performance category SSCs and therefore, the cylinders will not fall from their storage racks and that there would be no release from the cylinders during the DBE. In the extremely unlikely event of an earthquake exceeding the DBE or failure of a PC SSCs, the leakage from the cylinders is not anticipated to be a major incident since the DUF_6 is in solid form.

6.3-10.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 for each SSC at the appropriate hazard classification. Systems, structures and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are designed for the performance category PC-4 for chemically high hazard structures. These building areas are designed to resist the DBT for High Hazard Facilities. The DBT defined for these structures would not result in a significant release from this structure. Therefore, it would be incredible if this structure failed in the event of the DBT.

The Solids Product Building is vulnerable to tornado damage. During a tornado, a wind-blown missile could impact a U_3O_8 drum and release the 1380 lb. inventory of the drum. It is assumed that all the powder becomes airborne. Therefore, approximately 1380 lb. of U_3O_8 is released. However, the powder will be highly dispersed due to tornado wind conditions. Only about 5% (69 lbs) of the U_3O_8 powder will be in the respirable range. It is assumed that the tornado would remove the U_3O_8 powder in about 30 seconds. This accident is considered to be extremely unlikely.

A tornado wind-blown missile could impact the DUF_6 storage pad and damage some of the cylinders. This release is assumed to be bounded by the DUF_6 cylinder rupture accident described in Section 7.0.

6.3-10.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

6.3-10.1.3 Other Postulated Events

6.3-10.1.3.1. Aqueous HF Tank Failure

Aqueous solutions of HF are stored in tanks throughout the process building at various concentrations, temperatures, and volumes. The failure of a tank would release the aqueous HF solution to the building floor. The limited concentration and temperature of the tanks would prevent major releases of HF. The tank examined for this accident scenario has the highest temperature and highest concentration of HF. This tank is the U_3O_8 Conversion Module evaporator. It contains 154 gallons of 13.3% HF (176 lb. HF) at its boiling point.

It is postulated that the tank fails and the entire contents are spilled into a diked area. Two vaporization mechanisms are considered. The initial release is due to flash evaporation, while the second is normal evaporation from the pool of aqueous HF. The vaporized fraction from flash evaporation was estimated (AIChE, 1989, equation 2.1.9) as 0.01. This release fraction results in 1.8 lb. of HF flashed vaporized. Evaporation of the HF pool gave a HF release of 1.6 lb. over an assumed 60 minute period. The estimate was based on the surface evaporation rate (EPA 1987, pg. G-3) and the heat transfer rate (AIChE, 1989, equation 2.1.10) to the concrete floor.

The combined mechanisms results in a 3.4 lb. (2 wt% airborne release factor) release to the atmosphere through the process (ventilation stack). This accident is judged to be extremely unlikely.

6.3-10.1.3.2 U_3O_8 Drum Spill

Solid U_3O_8 is produced and packaged in drums in the Process Building. The drums are transported and stored in the Solid Product Storage Building. It is postulated that a drum is damaged by a forklift and spills its contents onto the ground outside the storage building. A drum contains 1380 lb. of U_3O_8. It is assumed that 50% of the U_3O_8 is released from the drum and 0.02% becomes airborne in the respirable range. Thus 0.138 lb. of U_3O_8 is released to the atmosphere and becomes respirable. The release is assumed to last 30 minutes. This accident has been judged to be anticipated.

6.3-10.1.3.3 Loss of Off-site Electrical Power

An uninterruptible power supply and backup diesel generators provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

6.3-10.1.3.4 Loss of Scrubber Water

The HF containing offgas goes through a scrubber to remove HF. If the scrubber water is lost from both scrubbers, then the HF gas would be released. Assuming a loss of water for 30 minutes at the peak HF flow time, there would be a release of 26 lb. of HF to the atmosphere through the Process Building stack. This accident has been judged to be unlikely.

6.3-11. Transportation

6.3-11.1. Intrasite Transportation

Intrasite transport of radioactive materials will be limited to transport of:

- Incoming DUF_6 feed containers from the truck or rail car to the Cylinder Storage Yard,
- 14-ton cylinders from the Cylinder Storage Yard to the Process Building,
- Solid product in 55 gallon drums from the Process Building to the Solids Product Storage Building,
- CaF_2 product in 55 gallon drums from the Process Building to the CaF_2 Storage Building,
- Crushed cylinders in shipping boxes from the Process Building to the Solids Product Storage Building,
- Waste in DOE approved containers from the Process Building to the Industrial Waste Treatment Building,
- Solid Product from the Solids Storage Building to a truck or rail car for transportation off-site,
- CaF_2 Product from the CaF_2 Storage Building to a truck or rail car for transportation off-site,
- Crushed cylinders from Solids Storage Building to a truck or rail car for transportation off-site, and
- Waste from the Industrial Waste Building to a truck or rail car for transportation off-site.

Intrasite transportation of hazardous materials will consist primarily of hazardous waste from the support buildings (Maintenance Shop and Utilities Building). These hazardous waste materials will consist of materials such as cleaning solutions, spent lubricants, contaminated clothing, rags, and wipes, laboratory wastes, etc. requiring special treatment before disposal. They will be packaged on-site for shipment to off-site hazardous waste treatment, storage and disposal facilities.

6.3-11.2. Intersite Transportation

Intersite transportation data for off-site shipment of principally radioactive and hazardous feed, product and waste materials is shown in Tables 6.3-11-1 and 6.3-11-2.

6.3-11.2.1. Input Material Streams

Uranium hexafluoride feed to the plant is assumed to arrive in DOT approved model 48F, G, H, Y, and HX steel cylinders containing a heel of approximately 10 kg of DUF_6. These cylinders are assumed to be shipped by either rail or truck. A truck shipment consists of 6 cylinders and a rail shipment consists of 12 cylinders per car. At the plant design throughput of 23.2 MT of DUF_6 per year, 2,322 cylinders are received each year or 46,440 over the 20 year operation of the facility. The number of truck shipments required to meet this demand is 387 shipment per year or 7,740 over the life of the facility. The number of rail shipments required to meet this demand is 194 shipment per year or 3,870 over the life of the facility.

Other materials included in Table 6.3-11-1 are calcium oxide, hydrochloric acid, and sodium hydroxide. The calcium oxide is for neutralization of the HFaq generated in the process. The hydrochloric acid and sodium hydroxide are for water treatment.

6.3-11.2.2. Output Material Streams

There are five output streams. These are the U_3O_8 solids, CaF_2 solids, crushed cylinders, LLW, mixed LLW and hazardous waste.

The U_3O_8 solids will be shipped from the facility in specially designed 55 gallon drums. These drums will contain 1,380 lb. of U_3O_8. Due to the weight, the drums will be made out of thicker steel than normal 55 gallon drums. The 55 gallon drum has a height of 34.7 inches and an outside diameter of 22.5 inches. The wall thickness is 0.053 (16 gauge). The drum weight is 75 pounds and the content weight is 1380 pounds.

At the design rate of production, approximately 31 drums per year will be produced, for a total of over 620 drums shipped over the 20 year life of the facility. The drums are assumed to be shipped with 28 drums per truck. This results in a little over 1 shipment per year or 22 shipments over the life of the facility.

The CaF_2 solids will be shipped from the facility in 55 gallon drums. At the design rate of production, approximately 68 drums per year will be produced, for a total of over 1360 drums shipped over the 20 year life of the facility. The drums are assumed to be shipped by truck with 68 drums per truck. This results in about 1 shipment per year or 20 shipments over the life of the facility.

The crushed cylinders will be shipped in a specially designed cylinder shipping box. The shipping box will hold three crushed cylinders. The design of the box is shown in 6.3-11-1. The boxes will be shipped by truck or rail. At the production rate, approximately 774 cylinder shipping boxes will be shipped per year, or 15,480 boxes over the life of the facility. It is assumed that a truck can carry 2 cylinder shipping boxes (6 cylinders) and a rail car can carry 6 cylinder shipping boxes (18 cylinders). This results in 387 truck shipments per year or 129 rail shipments per year. The number of shipments over the life of the facility would be 7740 by truck or 2,5820 rail.

LLW containing about 0.01 wt% uranium produced by the facility is assumed to be shipped in 55 gallon drums or disposal boxes. The facility generates about 162 drums and 10 disposal boxes per year or a total of about 3,240 drums and 200 boxes shipped over the life of the facility. Assuming 68 - 55 gallon drums per truck shipment, approximately 2.4 drum shipments per year or a total of 48 drum shipments over the life of the project. Assuming 5 boxes per truck shipment, there is approximately 2 box shipment per year or a total of 40 box shipments over the life of the project. Each disposal box is a typical 4 x 2 x 7 waste disposal box.

Mixed LLW (not shown in Table 6.3-11-2), containing about 0.1% uranium, is assumed to be shipped in 55 gallon drums. One drum would be generated annually and it would be shipped by truck.

Hazardous solid and liquid waste are assumed to be shipped in 55 gallon drums. The total estimated number of drums shipped per year is 10 resulting in one shipment per year and a total of 20 shipments over the life of the facility.

Table 6.3-11-1: Intersite Radioactive and Hazardous Material Transportation Data (Facility Input)

	Input* Material #1	Input Material #2	Input Material #3	Input Material #4
Transported Materials				
Type	Depleted Uranium Hexafluoride	Calcium Oxide**	Hydrochloric Acid	Sodium Hydroxide
Physical Form	Solid	Solid	Liquid	Liquid
Chemical Composition Temp °F Press. psi	UF_6 Ambient Ambient	CaO Ambient Ambient	HCl Ambient Ambient	NaOH Ambient Ambient
Packaging				
Type	14 Ton Cylinder	50 lb. Bag	55 Gal Drum	55 Gal Drum
Certified by	DOT	DOT	DOT	DOT
Identifier	48G	5H1, 5H2, 5H3, or 5H4	1H1 or 1H2	1H1 or 1H2
Container Weight (lb.)	2,600	1	50	50
Material Weight (lb.)	22	50	540	660
Chemical Content (%)	100% UF_6	100% CaO	37% HCl	50% NaOH
Average Shipping Volume				
Quantity/year	2,322	494	>1	>1
Average Number of Packages Shipped/year	2,322	494	>1	>1
Estimated Packages Shipped - Life of Project	46,440	9,880	16	14
Ave. Num. of Packages per Shipment	6 per truck 12 per rail car	80	1	1
No. of Shipments Per year	387 by tuck or 194 by rail	6	>1	>1
No. of Shipments Life of Project	7,740 by truck or 3,870 by rail	124	16	14
Form of Transportation/Routing				
Form of Transportation	Truck/Rail	Truck	Truck	Truck
Destination	UCTF Facility	UCTF Facility	UCTF Facility	UCTF Facility

* Assume cylinders are not contained in overpacks. If, for example, two thirds of cylinders require overpacks, the packages per shipment are 3 per truck and 4 per rail car.

** Nonhazardous

Table 6.3-11-2: Intersite Radioactive and Hazardous Material Transportation Data (Facility Output)

	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	U_3O_8 Solids	CaF_2 Solids*	Crushed Cylinders	LLW	Hazardous Waste
Physical Form	Solid	Solid	Solid	Solid	Solid/ Liquid
Chemical Composition Temp °F Press. psi	U_3O_8 Ambient Ambient	CaF_2 Ambient Ambient	Steel Ambient Ambient	See Table 6.3-9-3 Ambient Ambient	See Table 6.3-9-3 Ambient Ambient
Packaging					
Type	Special 55 Gal Drum	55 Gal Drum	Cylinder Shipping Box	55 Gal Drum Disposal Boxes	55 Gal Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	New Container	1A1 or 1A2	New Container	Drums 17C Boxes 7A	Drums 17C
Container Weight (lb.)	75	50	3,400	50	50
Material Weight (lb.)	1380	514	7,800	364/Drum 5,540/Box	387
Chemical Content (%)	100% U_3O_8	100% CaF_2	100% Steel	Table 6.3-9-3	Table 6.3-9-3
Average Shipping Volume					
Quantity/year	31	68	774	162/10	10
Ave. # of Packages Shipped/year	31	68	774	162/10	10
Estimated Packages Shipped - Life of Project	620	1360	15,480	3240/200	200
Ave. # of Packages per Shipment	28	68	2 per truck 6 per rail	68/5	10
# of Shipments Per year	1.1	1	387/Truck or 129/Rail	>2.4/2	1
#. of Shipments Life of Project	22	20	7,740/Truck or 2,580/Rail	48/40	20
Form of Transportation/Routing					
Form of Transportation	Truck	Truck	Truck/Rail	Truck	Truck
Destination	Storage, or LLW Disposal	Sanitary Landfill	DOE Scrap Metal Pile	LLW Disposal Site	Haz. Waste Treatment

* Nonhazardous

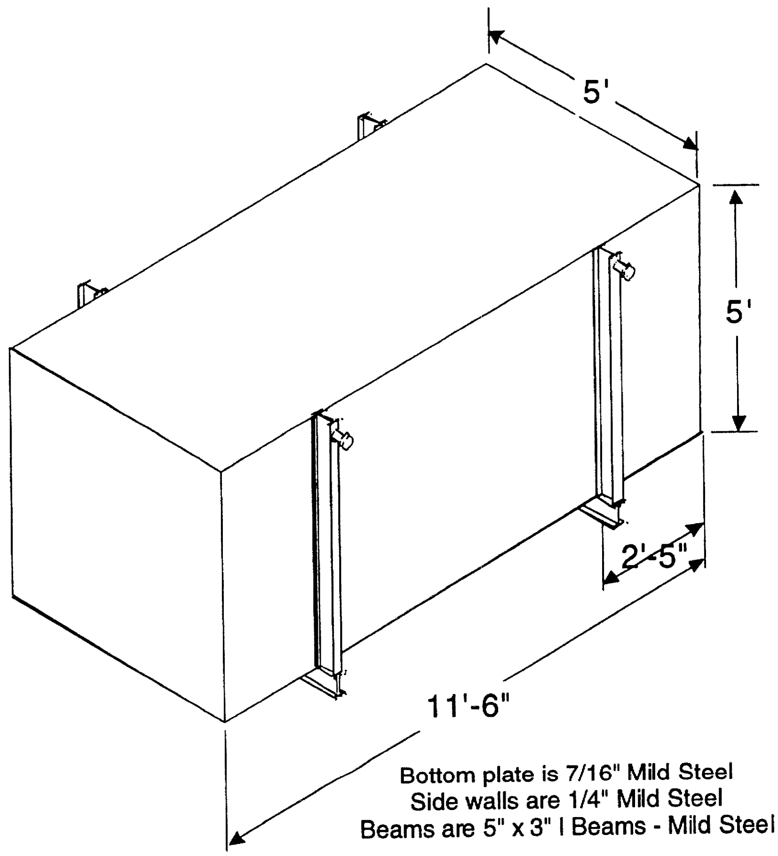

Figure 6.3-11-1 Cylinder Shipping Box

6.3-12. References

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6.3-13. Glossary

(aq)	Aqueous phase
°C	Degree Celsius
CaF_2	Calcium fluoride
CaO	Calcium oxide or lime
CAR	Cost Analysis Report
CBD	Commerce Business Daily
cc	Cubic centimeter
cfm	Cubic feet per minute
CFR	Code of Federal Register
ci	Curies
ci/g	Curies per gram
D&D	Decontamination and Decommissioning
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
DOE	Department of Energy
DU	Depleted uranium
DUF_6	Depleted uranium hexafluoride
EAP	Engineering Analysis Project
EAR	Engineering Analysis Report
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ES&H	Environmental, Safety and Health
°F	Degree Fahrenheit
ft	feet
ft/sec	Feet per second
G	General use
(g)	Gas phase
gal	Gallons
g/cc	grams per cubic centimeter
gpd	Gallons per day
gpm	Gallons per minute
GWh	Gigawatt hours
H_2O	Water
HC-1	Radiological Hazard Category 1, potential for significant off-site consequences from DOE-STD-1027-93
HC-2	Radiological Hazard Category 2, potential for significant on-site consequences from DOE-STD-1027-93

HC-3	Radiological Hazard Category 3, potential for only significant localized consequences from DOE-STD-1027-93
<HC-3	Less than Radiological Hazard Category 3, exempt from SAR Order 5480.23
HCl	Hydrochloric Acid
HEPA	High Efficiency Particulate Air
HF	Hydrogen fluoride
HFaq	Hydrogen fluoride aqueous
HH	Chemical High Hazard, exceeds reportable quantity in 40 CFR 355.
hr	hour
HVAC	Heating, ventilation, and air conditioning
KBTU	Kilo British Thermal Unit
kg	Kilograms
KGY	Kilo gallons per year
kV	Kilovolts
kva	Kilovolt-amps
kW	Kilowatts
lb.	pounds
LH	Chemical Low Hazard, Less than 0.1 times reportable quantity in 40 CFR 355.
LLNL	Lawrence Livermore National Laboratory
LLW	Low-level waste
MGY	Million gallons per year
MH	Chemical Moderate Hazard, Between 0.1 and 1 times the reportable quantity in 40 CFR 355
MT	Metric tons
MWh	Megawatt hours
MW	Megawatts
NaOH	Sodium hydroxide
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
O_2	Oxygen
P^3	Public Participation Plan
Pa	Protactinium
PC	Performance Category from DOE-STD-1020-94
pci	Picocuries
PEIS	Programmatic Environmental Impact Statement
PPE	Personnel Protection Equipment
ppm	Part Per Million

psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge (above atmospheric pressure)
RCRA	Resource Conservation and Recovery Act
RFP	Request for proposal
ROD	Record of Decision
(s)	Solid phase
SAR	Safety Analysis Report
scf	Standard cubic feet
SSC	Structures, systems and components
TAR	Technology Assessment Report
Th	Thorium
Title I Design	Preliminary design
Title II Design	Detailed design
U	Uranium
UCTF	Used Cylinder Treatment Facility
UF_6	Uranium hexafluoride
UO_2	Uranium dioxide
UO_2F_2	Uranyl fluoride
U_3O_8	Triuranium octaoxide
UPS	Uninterruptible Power Supply
WBS	Work Breakdown Structure
yd	Yard
yr.	Year

Appendix 6.3-A - Disposition of Cleaned Cylinders

6.3-A.1 Disposition Options

After the DUF_6 heels have been removed from the cylinders, there are several possible options for subsequent disposition of the cylinders. All of the options fall into the three categories: store, reuse, and dispose. Some of the cylinder disposition options are:

- Store
  1) Transfer to DOE scrap metal pile.
- Reuse
  2) Use to hold LLW or uranium oxide,
  3) Commercially sell as scrap metal (unrestricted use),
  4) Use in other U.S. Government programs (e.g., shielding), and
- Dispose
  5) Disposal as low level waste.

Option 1 was the option selected for this report.

6.3-A.1.1 Transfer to DOE scrap metal pile

The cylinders can be cleaned, crushed and stored for a future mission in the DOE scrap metal pile. This was the option chosen for this report because there is a significant amount of metal in the cylinders that might be useful for other programs.

6.3-A.1.2 Use to hold LLW or uranium oxide

One possibility that has been proposed in the past is using the cylinders as storage containers for depleted uranium oxide. In order to reuse the cylinders to hold material, their integrity needs to be determined.

6.3-A.1.3 Commercially sell as scrap metal

After the cylinders are emptied and washed, trace levels of uranium and daughter products will adhere to and or be entrained in the cylinder walls. The uranium level is expected to be well below 100 ppm (35 pci/gram). However in the absence of a de minimus value, it is unclear that the cylinders could be released for unrestricted use. Exemptions are uncertain based on the very large quantity of metal. In any event, a key issue would be the measurement of the remaining residual radioactivity.

Melt refining is a method for further decontamination. This approach melts the contaminated metal under an oxide flux. The flux converts the reactive uranium into an oxide that concentrates in the slag phase. Experimental work (Uda 1986, Uda 1987, Copeland 1981) on uranium contaminated steel resulted in uranium concentrations in the range of 0.01 to 1 ppm. This is comparable to the uranium level in normal steel. However, this or other processing approaches will likely involve significant additional costs and generate significant amounts of secondary wastes.

6.3-A.1.4 Use in other U.S. Government programs

There are needs for metal to be used in radioactive environments. This metal could be supplied from a non-radioactive source or radioactive metal could be used. Examples of uses for this metal would be shielding, waste drums or parts.

6.3-A.1.5 Disposal as low level waste

The drums would be disposed in a LLW disposal site.

Appendix 6.3-B - Integration with Conversion Facility

6.3-B.1 Introduction

The UCTF annually processes (23 tonnes) about three orders of magnitude less DUF_6 than the Conversion Facilities described in other Engineering Analysis Reports (28,000 tonnes). Therefore, it is likely that the UCTF functions would be collocated with the Conversion Facility(ies). The overall project benefits would be reduced costs and transportation requirements. This section addresses the impacts of integrating the UCTF functions into another DUF_6 Conversion Facility; and in particular, what UCTF elements would be eliminated or significantly reduced.

6.3-B.2 General Savings from Collocated Facilities

The collocation of the UCTF with another Conversion Facility would lead to a significant reduction in required infrastructure, as summarized here.

6.3-B.2.1 Cylinder Storage Yard

The outgoing Cylinder Storage Yard for the Conversion Facility as well as the incoming Cylinder Storage Yard for the UCTF would be effectively removed. The only additional cylinder storage requirement would be lag storage between the DUF_6 removal operations and the cylinder washing process.

6.3-B.2.2 Support buildings and systems

The support building space can be significantly reduced when the UCTF is collocated with another facility. The support buildings include the: Utility Building, Maintenance Shop, Warehouse, Industrial Waste, Sanitary Waste and Cooling Tower.

6.3-B.2.3 Roads and Grounds

The space for the roads, piping and ground of the UCTF can be significantly reduced because most of these needs will be met by the collocated facility.

6.3-B.3 Specific Savings from Collocated Facilities

There are a large number of options being explored for DUF_6 disposition. The effective starting point for most of these is the removal of the DUF_6 from the cylinders and then conversion to either an oxide (UO_2 or U_3O_8), or to metal (U).

The oxide conversion can be done by pyrohydrolysis or gelation. These processes react the DUF_6 with water or steam to generate UO_2F_2 (solution or solid) and HF(solution or gas). The UO_2F_2/HF solution from the UCTF can be used as is or dried and fed into one of these processes. The pyrohydrolysis process converts the uranyl fluoride to an oxide. The Gelation Report describes the aqueous process for conversion of the uranyl fluoride to dense UO_2 by gelation.

The metal conversion processes do not have a unit operation for the conversion of the uranyl fluoride solution to the metal. The UO_2F_2/HF solution can be converted to feed for the metal process by converting it to an oxide and then fluorinating it. This conversion of the solution to fluoride will require the same equipment as the UCTF as well as additional hydrofluorination equipment. However, this approach does not appear to be cost effective. Rather, the heel DUF_6 would be converted to the oxide for disposal.

6.3-B.3.1 Oxide Processes

The collocated process will be handling about 28,000 MT of DUF_6, while the UCTF will be handling about 23 MT/yr. of DUF_6. The introduction of the UO_2F_2 solution from the UCTF should have an insignificant impact on the collocated facility operation.

The integration of the UCTF into the an Oxide Facility would significantly reduce the size of the process building required for the UCTF function. The UCTF Process Building contains the following areas:

Cylinder Washing Module,
U_3O_8 Conversion Module,
Solids Packaging Module,
HF Handling Module,
Cylinder Disposition Module,
Hot Support Area,
Equipment Decontamination,
Analytical Lab,
Control Room,
Clean Maintenance,
Waste Processing/Packaging Area, and
Personal Entrance.

Of these areas, the only two that would be required from the UCTF function would be the Cylinder Washing Module and the Cylinder Disposition Module (compacting). The U_3O_8 Conversion Module, Solids Packaging Module, and HF Handling Module would not be needed because the UO_2F_2/HF solution would be processed by the collocated facility. The Hot Support Area, Equipment Decontamination, Analytical Lab, Control Room, Clean Maintenance, Waste Processing/Packaging Area, and Personnel Entrance would not be needed because the collocated facility would have these.

6.3-B.3.2 Metal Processes

Collocating the UCTF with a metal processing facility would not have as large a reduction as collocation with an oxide facility. There are two options in handling the UO_2F_2/HF solution generated by the UCTF. They are:

1) Convert the UO_2F_2 to an oxide and dispose of the oxide or
2) Convert the UO_2F_2 to an oxide, fluorinate the oxide, and then feed it to the metal conversion process.

Both of these options require the UO_2F_2 be converted to the oxide. The UCTF Process Building contains the following areas:

Cylinder Washing Module,
U_3O_8 Conversion Module,
Solids Packaging Module,
HF Handling Module,
Cylinder Disposition Module,
Hot Support Area,
Equipment Decontamination,
Analytical Lab,
Control Room,
Clean Maintenance,
Waste Processing/Packaging Area, and
Personal Entrance.

For either of these options the first 5 units would be required. The Hot Support Area, Equipment Decontamination, Analytical Lab, Control Room, Clean Maintenance, Waste Processing/Packaging Area, and Personnel Entrance would not be needed because the collocated facility would have these. Option 2 would require the addition of a hydrofluorination module and the associated equipment. However, this approach is not considered to be cost effective.

6.3-B.4 Estimated Quantitative Impacts

As indicated above, not all UCTF functions are required if cylinder treatment is integrated into a Conversion Facility. Integration of the cylinder treatment functions into a Conversion Facility will lead to small to moderate increases in the Conversion Facility size and resource requirements. Table 6.3-B-1 provides initial estimates of the principal increases.

Table 6.3-B-1: Impacts of Integration

Increased Requirement	Integration of UCTF functions into Oxide Conversion Facility	Integration of UCTF functions into Metal Conversion Facility
New Crushed Cylinder Storage Building	6,200 ft^2	6,200 ft^2
Incremental Process Building Area[1]	3,600 ft^2	7,300 ft^2
Incremental Site Area	0.5 Acres	0.7 Acres
Incremental Uranium and HF Emissions	Negligible	Negligible
Incremental Materials of Construction		
Concrete	590 yd^3	830 yd^3
Steel	200 tons	280 tons
Incremental Manpower	26 FTE	36 FTE

Notes:
1. Calculated by area of each module required and multiplied by 1.25 to account for halls.

Appendix 6.3-C - Radiation Exposure and Manpower Distribution Estimating Data

Table 6.3-C-1: Operational Activities

Activity	Number of Workers per Operation	Time per operation (hr)	Operations per Year	Source Number	Distance (ft.)	Material	Thickness	Person Hours
Unload arriving UF6 cylinder	2	0.5	2350.0	1	3	Steel	1/4"	2350
Inspect arriving UF6 cylinder	2	0.5	2350.0	1	3	Steel	1/4"	2350
Transfer UF6 Cylinder to Cylinder Storage Yard	2	0.5	2350.0	1,2	6	Steel	1/4"	2350
Unload UF6 Cylinder at Cylinder Storage Yard	2	0.5	2350.0	1,2	3	Steel	1/4"	2350
Store UF6 Cylinders at Cylinder Storage Yard								
Load UF6 Cylinder at Cylinder Storage Yard	2	0.5	2350.0	1,2	3	Steel	1/4"	2350
Transfer UF6 Cylinder to Process Building	2	0.5	2350.0	1	6	Steel	1/4"	2350
Unload UF6 Cylinder at Process Building	2	0.5	2350.0	1,3	6	Steel	1/4"	2350
Store Cylinder at Process Building								
Load Cylinder into Wash Stand	1	0.5	2350.0	1, 3, 4	3	Steel	1/4"	1175
Attach pipes and index cylinder	1	0.2	2350.0	1, 4	3	Steel	1/4"	470
Wash Cylinder								
Unload Wash Stand	1	0.5	2350.0	5, 4	3	Steel	1/4"	1175
Transfer Cylinder to Cylinder Disposition Module storage	1	0.5	2350.0	5, 6, 8	6	Steel	1/4"	1175
Transfer Cylinder From Storage to crusher	1	0.5	2350.0	5, 6, 8	6	Steel	1/4"	1175
Crush Cylinder								
Transfer Crushed Cylinder to Storage Box	1	0.8	2350.0	5, 6, 7, 8	6	Steel	1/4"	1880
Store Crushed cylinder in storage Box								
Transport Cylinder Storage Box to Solids Storage Building	1	0.5	783.3	8, 9	6	Steel	1/4"+1/4"	392
Store Cylinder Storage Boxes in Solids Storage Building								
Load Cylinder Storage Boxes on Transport	2	0.5	783.3	8,9	3	Steel	1/4"+1/4"	783

Table 6.3-C-1: Operational Activities

Activity	Number of Workers per Operation	Time per operation (hr)	Operations per Year	Source Number	Distance (ft.)	Material	Thickness	Person Hours
Transport Cylinder Storage Boxes to Disposition Site	1	8.0	391.7	8	6	Steel	1/4"+1/4"	3133
Cylinder Storage Yard Surveillance	1	0.5	2190.0	1,2	3	Steel	1/4"	1095
Operate Evaporator	1	3.5	870.0	4,10,11	6	Steel/Con	1/4" + 1'	3045
Load Solids into Drying Ovens from Filter	1	1.0	41.4	4, 10	3	Steel	1/8"	41
Load Solids Transfer Containers	1	1.0	41.4	4, 10	3	Steel	1/8"	41
Transfer Solids Transfer Containers	1	1.0	41.4	13	3	Steel	1/16"	41
Solids Product Building surveillance	1	0.5	2190.0	1,2	3	Steel	1/4"+1/4"	1095
Operate Conversion Evaporator	1	1.5	290.0	15,16,17	6	Steel	3/4"	435
Operate Conversion Kiln	1	1.6	290.0	15,16,17	6	Steel	3/4"	464
Operate Conversion Cooler	1	1.6	290.0	16,17,18	6	Steel	3/4"	464
Loading U3O8 Transfer Containers	1	0.5	885.0	17,15,16	1	Steel	1/8"	443
Transporting U3O8 Transfer Containers to Solids Packaging Module	1	0.3	885.0	17,16,18	3	Steel	1/8"	221
Load CaF2 into Solids Packaging Equipment	1	0.2	1532.9	18, 19	3	Steel	1/8"	307
Load CaF2 into Drums	1	0.5	67.5	18, 19	3	Steel	1/8"	34
Monitor equipment operation and cleanup	1	3.2	103.6	18, 19, 20	12	Steel	1/8"	331
Load U3O8/Solids into Solids Packaging Equipment	1	0.2	885.0	18, 19, 20	3	Steel	1/8"	177

Table 6.3-C-1: Operational Activities

Activity	Number of Workers per Operation	Time per operation (hr)	Operations per Year	Source Number	Distance (ft.)	Material	Thickness	Person Hours
Change U3O8 Storage Drum	1	0.5	31.2	19, 20, 18	3	Steel	1/4"	16
Transfer U3O8/Solids To Storage Area	1	0.5	7.8	20, 9	6	Steel	1/4"	4
U3O8/Solids Storage Surveillance (in Solids Storage Building)	1	0.5	2190.0	9,8,20,22	3	Steel	1/4"	1095
Load U3O8/Solids Drums on Transport	2	0.5	7.8	22,21	3	Steel	1/4"	8
Transport U3O8/Solids Drums to Disposal	1	8.0	1.0	20	6	Steel	1/4"	8
Transfer CaF2 to Storage Area	1	0.5	16.9	9	20	Steel	1/4"	8
CaF2 Storage Surveillance	1	0.5	2190.0	9	20	Steel	1/4"	1095
Load CaF2 Drums on Transport	2	0.5	16.9	9	20	Steel	1/4"	17
Transport CaF2 Drums to Disposal	1	1.0	1.0	9	40	Steel	1/4"	1
Load CaO Hopper	1	1.0	41.4	6	12	Steel	1/4"	41
Unload CaF2 Filter	1	0.5	414.3	6	20	Steel	1/4"	207
Load CaF2 Drying Trays	1	0.5	414.3	19	18	Steel	1/4"	207
Loading CaF2 Transfer Containers	1	0.5	414.3	19	18	Steel	1/4"	207
Transporting CaF2 Transfer Containers to Solids Packaging Module	1	0.3	1657.1	19	15	Steel	1/4"	414
Monitor Filter and Neutralization Operations	1	5.6	62.1	6,19	30	Steel	1/4"	348
Support Systems Module Surveillance	2	8.0	870.0	6	20	Steel	1/4"	13920
LLW Processing, packaging, and shipping	2	8.0	1092.0	19	35	Steel	1/4"	17472
Process control room operations	4	8.0	1092.0	15	25	Steel	1/4"	34944
Laboratory Operations	2	8.0	1092.0	15	15	Steel	1/2"	17472
HP	2	8.0	1092.0	1,8	30	Steel	1/4"	17472

Table 6.3-C-1: Operational Activities

Activity	Number of Workers per Operation	Time per operation (hr)	Operations per Year	Source Number	Distance (ft.)	Material	Thickness	Person Hours
Management/Professionals	6	8.0	290.0	1,8	30	Steel	1/4"	13920
Accountability	1	2.0	1092.0	1,8, 9	3	Steel	1/4"	2184
Industrial and Sanitary Waste Treatment	2	8.0	1092.0	2	40	Steel	1/4"	17472
Utilities Operations	2	8.0	1092.0	2	40	Steel	1/4"	17472
Administration	11	8.0	290.0	9, 22	70	Steel	1/4"	25520
Guardhouses/Process Bldg.	4	8.0	1092.0	9, 22	70	Steel	1/4"	34944
Maintenance								11258
Total								263770

Table 6.3-C-1: Operational Activities

Activity	Number of Workers per Operation	Time per operation (hr)	Operations per Year	Source Number	Distance (ft.)	Material	Thickness	Person Hours

Sources and Notes

Cylinders

Outside

1) A single empty UF6 cylinder
2) UF6 Cylinder Storage Yard
3) UF6 cylinder storage outside of Process Building

Washing Module

4) UF6 cylinders on wash stands
5) Washed UF6 cylinder

Cylinder Disposition Module

6) Washed UF6 cylinder stored by crusher
7) Washed UF6 cylinder in crusher
8) 1-3 Washed UF6 Cylinders in Storage Box

Solid Storage Building

9) Cylinder Storage boxes stored in Solids Storage Building

U3O8/Solids

Washing Module

10) Filter with Solids
11) Evaporator Feed Tank
12) Evaporator Pot
13) Drying Oven
14) Transfer Container with Solids

U3O8 Conversion Module

15) U3O8 Solution Storage Tank
16) Evaporator Pot
17) Kiln/Cooler
18) U3O8 Transfer Can

Solids Packaging Area

19) U3O8 Transfer Container Staging Area
20) Filling U3O8 Drum
21) 4 Filled U3O8 Drums
22) U3O8 Product Storage

Operations		
Cylinders to Process	47000.0	
Years to Process	20.0	
Operating Days/year	290.0	
Cylinders Processed/Year	2350.0	
Cylinders/Shipping Box	3.0	
Shipping Boxes/year	783.3	
Calender Days/year	365.0	
Shifts/day	3.0	
Shifts/year	870.0	
Inspection Times/Shift	2.0	
Inspections/yr	2190.0	
Days/Week	7.0	
Operating Weeks/Year	41.4	
Hrs/FTE	2000.0	
U3O8 buckets/year	885.0	
U3O8 Drums/yr	31.2	
MT U3O8/Yr	18.7	MT U3O8/yr.
Kg/MT	1000.0	kg/MT
lb/kg	2.2	lb/kg
Lbs/U3O8 Drum	1380.0	lb U3O8/Drum
CaF2 Buckets/yr	1532.9	
CaF2 Drums/yr	67.5	
U3O8 Pallets/yr	7.8	
CaF2 Pallets/yr	16.9	
Shifts/CY	1092.0	
Shipping Boxes/truck	2.0	
Shipping Box Trucks/yr	391.7	
U3O8 Conversion Cycles/yr	290.0	7 per week
Solids Packaging Module Cycle shifts	103.6	2.5 Shifts per operating week
HF_Neutralization_Shifts_per_Year	62.1	1.5 Shifts per Operating Week

Table 6.3-C-2: Maintenance Activities

Equipment	Number of Workers	Hours per Component Per Year [1]	Number of Components	Source Number	Distance (ft.)	Material [2]	Thickness	Person Hours per Year
Washing Module								
Wash Stands (4)	2	26	4	4	3	Steel	1/4"	208
Pumps (5)	2	52	5	10	6	Steel	1/8"	520
Condensor(1)	2	26	1	10	6	Steel	1/8"	52
Heat Exchanger (1)	2	26	1	11	6	Steel	1/2"	52
U3O8 Conversion Module								
Pumps(2)	2	52	2	15	6	Steel	1/2"	208
Heat Exchanger(1)	2	26	1	17	6	Steel	1/2"	52
Kiln(1)	2	108	1	17	3	Steel	1/2"	216
Cooler(1)	2	108	1	17	3	Steel	1/2"	216
Hood(1)	2	26	1	17	6	Steel	1/2"	52
Solids Packaging Module								
Conveyor(4)	2	108	4	19	20	Steel	1/8"	864
Compactor(2)	2	52	2	19	20	Steel	1/8"	208
Granulator(2)	2	52	2	19	30	Steel	1/8"	208
Vibrating Screen (2)	2	26	2	19	40	Steel	1/8"	104
Hood (2)	2	26	2	19	40	Steel	1/8"	104
HF Handling Module								
Pumps(5)	2	52	5	6,19	30	Steel	1/8"	520
Scrubbers (2)	2	26	2	6,19	30	Steel	1/8"	104
Solid Feeder(1)	2	108	1	6,19	30	Steel	1/8"	216
Filter Press(1)	2	26	1	6,19	30	Steel	1/8"	52
Support System Module								
Pumps(3)	2	52	3	6	20	Steel	1/4"	312
Condenser(1)	1	26	1	6	20	Steel	1/4"	26
Steam Generator(1)	2	108	1	6	20	Steel	1/4"	216
HEPA Filters(2)	2	4	2	6	20	Steel	1/4"	16
HVAC equipment	2	520	1	6	20	Steel	1/4"	1040
Boiler, Water Systems, other Utilities	2	52	3	2	40	Steel	1/4"	312
Waste Water Treatment Equipment	1	2190	1	2	40	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	2	40	Steel	1/4"	2190
Admin. Building	1	1000	1	9,20	70	Steel	1/4"	1000
Total								11258

Table 6.3-C-2: Maintenance Activities

Equipment	Number of Workers	Hours per Component Per Year [1]	Number of Components	Source Number	Distance (ft.)	Material [2]	Thickness	Person Hours per Year

Sources and Notes

Cylinders

Outside

1) A single empty UF6 cylinder
2) UF6 Cylinder Storage Yard
3) UF6 cylinder storage outside of Process Building

Washing Module

4) UF6 cylinders on wash stands
5) Washed UF6 cylinder

Cylinder Disposition Module

6) Washed UF6 cylinder stored by crusher
7) Washed UF6 cylinder in crusher
8) 1-3 Washed UF6 Cylinders in Storage Box

Solid Storage Building

9) Cylinder Storage boxes stored in Solids Storage Building

U3O8/Solids

Washing Module

10) Filter with Solids
11) Evaporator Feed Tank
12) Evaporator Pot
13) Drying Oven
14) Transfer Container with Solids

U3O8 Conversion Module

15) U3O8 Solution Storage Tank
16) Evaporator Pot
17) Kiln/Cooler
18) U3O8 Transfer Can

Solids Packaging Area

19) U3O8 Transfer Container Staging Area
20) Filling U3O8 Drum
21) 4 Filled U3O8 Drums
22) U3O8 Product Storage

Notes:

1) Average of 2 hours per week on Conveyor systems
   Average of 1 hour per week on active components (pumps, compactor, granulator)
   - includes instrumentation
   Average of 1/2 hour per week on passive components (condensors, heat exchangers, scrubbers)
   - includes instrumentation
   10 hours per week on HVAC components
   6 hours per day on waste water treatment components
   6 hours per day on sanitary waste treatment components
   1000 hours per year on administration building

2) Materials do not include walls between operating areas

Appendix 6.3-D - Detailed Material Balance and Flowsheets

The appendix contains the detailed material balance and flowsheets for the process at the UCTF. The flowsheets are in the following order:

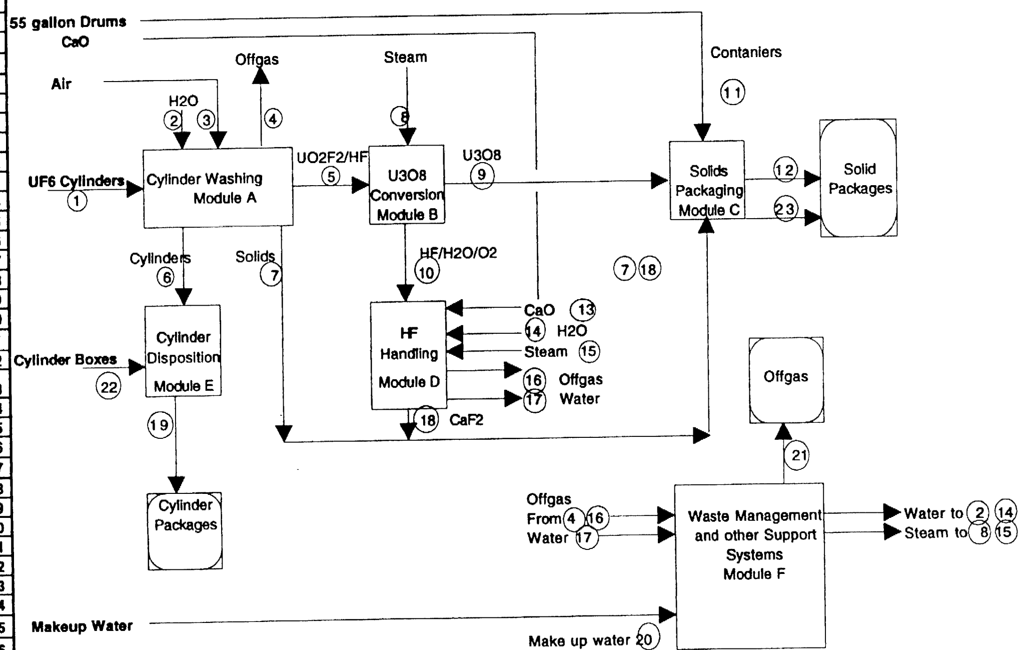
Table 6.3-D-1: Overall Flowsheet,
Table 6.3-D-2: Cylinder Washing Module Flowsheet,
Table 6.3-D-3: U_3O_8 Conversion Module Flowsheet,
Table 6.3-D-4: Solids Packaging Module Flowsheet,
Table 6.3-D-5: HF Handling Module Flowsheet,
Table 6.3-D-6: Cylinder Disposition Module Flowsheet, and
Table 6.3-D-7: The Support System Module Flowsheet.

Detailed Material Balance and Flowsheet

Table 6.3-D-1: Overall Material Balance and Flowsheet

Processing 2,322 **Cylinders/yr**

Heel Size 22 **lb**



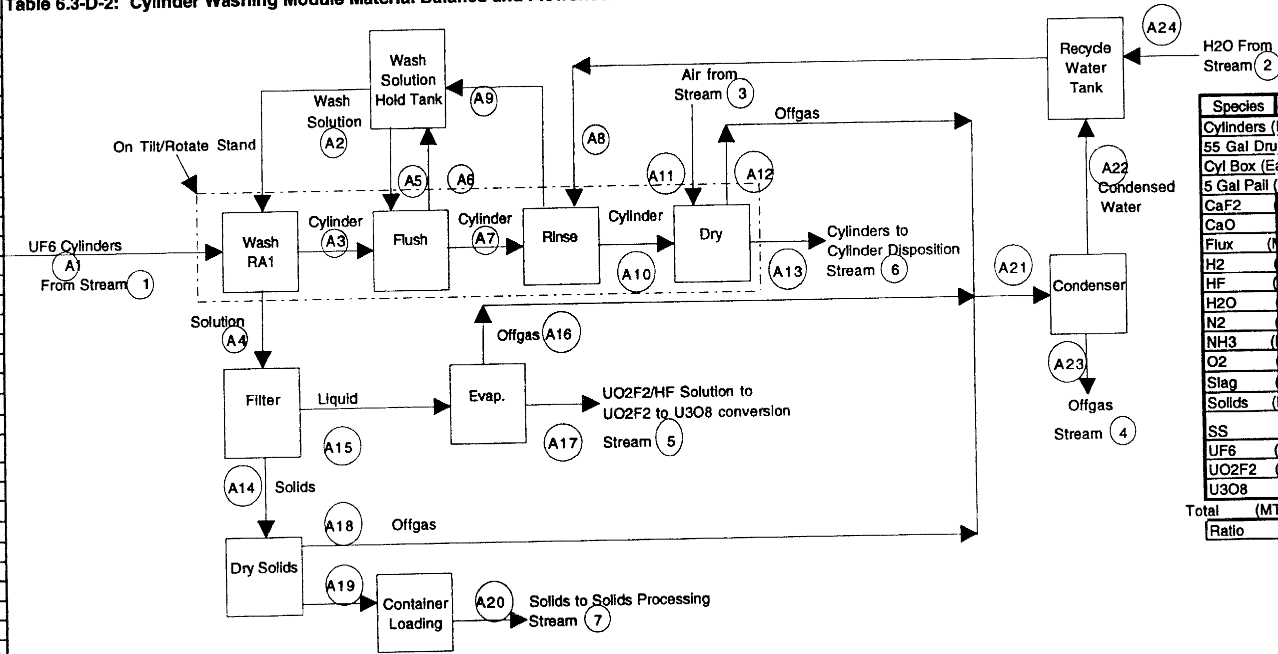
Species	19	20	21	22	23
Cylinders (	0	0	0	0	0
55 Gal Dru	0	0	0	0	66.6685
Cyl Box (E	774	0	0	774	0
5 Gal Pail (	0	0	0	0	0
CaF2	0	0	0	0	15.4503
CaO	0	0	0	0	0
Flux (N	0	0	0	0	0
H2	0	0	0	0	0
HF (	0	8.9E-16	0	0	0
H2O	0	6.33137	5.98661	0	0.15727
N2	0	0	378.139	0	0
NH3 (	0	0	0	0	0
O2	0	0	94.8864	0	0
Slag	0	0	0	0	0
Solids (	0	0.00169	0	0	0.00169
SS	2744.18	0	0	0	0
UF6 (	0	0	0	0	0
UO2F2 (	0	0	0	0	0
U3O8	0	0	0	0	0
Total (	2744.18	6.33306	479.012	0	15.6092
Ratio	173.177	0.39966	30.229	0	0.98505

Material Balance:

Species	MW	1	2	3	4	5	6	7	8	9
Cylinders (Each)		2322	0	0	0	0	2322	0	0	0
55 Gal Drum (Each)			0	0	0	0	0	0	0	0
Cyl Box (Each)			0	0	0	0	0	0	0	0
5 Gal Pail (Each)			0	0	0	0	0	0	0	0
CaF2 (MT/yr)	78		0	0	0	0	0	0	0	0
CaO (MT/yr)	56		0	0	0	0	0	0	0	0
Flux (MT/yr)			0	0	0	0	0	0	0	0
H2 (MT/yr)	2		0	0	0	0	0	0	0	0
HF (MT/yr)	20		0	0	0	5.27858	5.3E-06	0	0	0
H2O (MT/yr)	18		98.2116	0	5.98594	89.8467	0	0.00235	3.54357	0.18515
N2 (MT/yr)	28		0	378.139	378.139	0	0	0	0	0
NH3 (MT/yr)	17		0	0	0	0	0	0	0	0
O2 (MT/yr)	32		0	94.5347	94.5347	0	0	0	0	0
Slag (MT/yr)			0	0	0	0	0	0	0	0
Solids (MT/yr)		0.2322	0	0	0	0	2.3E-07	0.2322	0	0
SS (MT/yr)			0	0	0	0	0	0	0	0
UF6 (MT/yr)	352	23.22	0	0	0	0	0	0	0	0
UO2F2 (MT/yr)	308		0	0	0	20.318	2E-05	0	0	0
U3O8 (MT/yr)	842		0	0	0	0	0	0	0	18.5153
Total (MT/yr)		23.4522	98.2116	472.673	478.659	115.443	2.6E-05	0.23455	3.54357	18.7004
Ratio		1.48	6.19785	29.829	30.2068	7.28529	1.6E-06	0.0148	0.22362	1.18013
Error	Balance	1+2+3-4-5-6-7				5+8-9-10				7+9+11+18-12-23
5.16577E-05		4.6E-14		-6E-14		-3E-14	6+22-19			-4E-15
			4+16+17+20-2-14-8-15-21				2.6E-05			

Species	10	11	12	13	14	15	16	17	18
Cylinders (Each)	0	0	0	0	0	0	0	0	0
55 Gal Drum (Each)	0	97.5879	30.9194	0	0	0	0	0	0
Cyl Box (Each)	0	0	0	0	0	0	0	0	0
5 Gal Pail (Each)	0	0	0	0	0	0	0	0	0
CaF2 (MT/yr)	0	0	0	0	0	0	0	0	15.4503
CaO (MT/yr)	0	0	0	11.0973	0	0	0	0	0
Flux (MT/yr)	0	0	0	0	0	0	0	0	0
H2 (MT/yr)	0	0	0	0	0	0	0	0	0
HF (MT/yr)	7.91787	0	0	0	0	0	0	-9E-16	0
H2O (MT/yr)	92.0168	0	0.1875	0	60.893	6.76795	1.57185	161.514	0.15727
N2 (MT/yr)	0	0	0	0	0	0	0	0	0
NH3 (MT/yr)	0	0	0	0	0	0	0	0	0
O2 (MT/yr)	0.35178	0	0	0	0	0	0.35178	0	0
Slag (MT/yr)	0	0	0	0	0	0	0	0	0
Solids (MT/yr)	0	0	0.2322	0	0.00169	0	0	0	0.00169
SS (MT/yr)	0	0	0	0	0	0	0	0	0
UF6 (MT/yr)	0	0	0	0	0	0	0	0	0
UO2F2 (MT/yr)	0	0	0	0	0	0	0	0	0
U3O8 (MT/yr)	0	0	18.5153	0	0	0	0	0	0
Total (MT/yr)	100.286	0	18.935	11.0973	60.8947	6.76795	1.92362	161.514	15.6092
Ratio	6.32879	0	1.19493	0.70032	3.84289	0.42711	0.12139	10.1927	0.98505
Error				-2E-14		1+3+11+13+20-12-19-21-23			
5.16577E-05			10+13+14+15-16-17-18			2.6E-05			

Table 6.3-D-2: Cylinder Washing Module Material Balance and Flowsheet



Species	A20	A21	A22	A23	A24
Cylinders (Each)		0	0	0	0
55 Gal Drum (Each)		0	0	0	0
Cyl Box (Each)		0	0	0	0
5 Gal Pail (Each)		0	0	0	0
CaF2	0	0	0	0	0
CaO	0	0	0	0	0
Flux	0	0	0	0	0
H2	0	0	0	0	0
HF	0	0	0	0	0
H2O	0.00235	101.359	95.3735	5.98594	98.2116
N2	0	378.139	0	378.139	0
NH3	0	0	0	0	0
O2	0	94.5347	0	94.5347	0
Slag	0	0	0	0	0
Solids	0.2322	0	0	0	0
SS	0	0	0	0	0
UF6	0	0	0	0	0
UO2F2	0	0	0	0	0
U3O8	0	0	0	0	0
Total (MT	0.23455	574.033	95.3735	478.659	98.2116
Ratio	0.0148	36.2255	6.01874	30.2068	6.19785

RxnA1: 1 UF6 + 2 H2O -> 1 UO2F2 + 4 HF

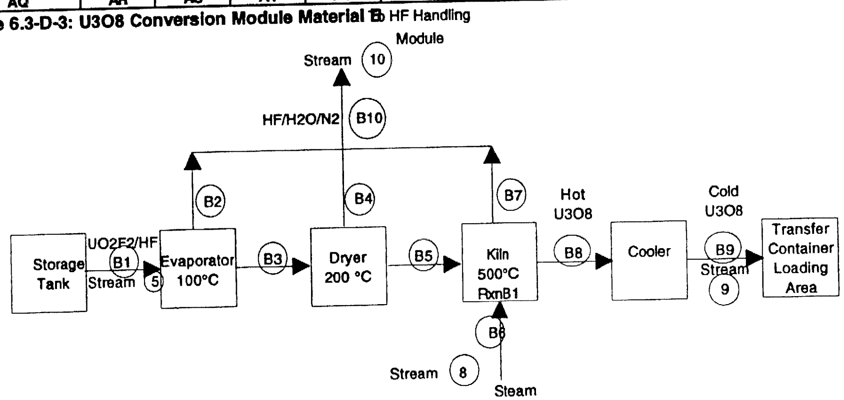
Species	MW	A1	A2	RA1	A3	A4	A5	A6	A7	A8
Cylinders (Each)	0	2322		2322	2322	0		0	2322	
55 Gal Drum (Each)	0	0		0						
Cyl Box (Each)	0	0		0						
5 Gal Pail (Each)	0	0		0						
CaF2 (MT/yr)	78	0		0						
CaO (MT/yr)	56	0		0						
Flux (MT/yr)		0		0						
H2 (MT/yr)	2	0		0						
HF (MT/yr)	20	0	0.05278	5.33137	0.05279	5.27858	0.05278	0.10504	0.00053	0
H2O (MT/yr)	18	0	193.585	191.209	1.09992	190.109	193.585	193.585	1.09992	193.585
N2 (MT/yr)	28	0		0						
NH3 (MT/yr)	17	0		0						
O2 (MT/yr)	32	0		0						
Slag (MT/yr)		0		0						
Solids (MT/yr)	0	0.2322	0.00232	0.23452	0.00232	0.2322	0.00232	0.00462	2.3E-05	0
SS (MT/yr)		0		0	0					
UF6 (MT/yr)	352	23.22		0		0		0		
UO2F2 (MT/yr)	308	0	0.20316	20.5212	0.20318	20.318	0.20316	0.40431	0.00203	0
U3O8 (MT/yr)	842	0		0						
Total (MT/yr)		23.4522	193.843	217.296	1.3582	215.937	193.843	194.099	1.1025	193.585
		1.48	12.2329	13.7129	0.08571	13.6272	12.2329	12.249	0.06958	12.2166

Species	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
Cylinders (Each)		2322			2322		0	0	0	0	
55 Gal Drum (Each)											
Cyl Box (Each)											
5 Gal Pail (Each)											
CaF2 (MT/yr)											
CaO (MT/yr)											
Flux (MT/yr)											
H2 (MT/yr)											
HF (MT/yr)	0.00052	5.3E-06			5.3E-06		5.27858	0	5.27858	0	
H2O (MT/yr)	193.585	1.09992	0	1.09992	0	4.4118	185.697	95.8501	89.8467	4.40945	0.00235
N2 (MT/yr)			378.139	378.139	0		0	0	0	0	
NH3 (MT/yr)											
O2 (MT/yr)			94.5347	94.5347	0		0	0	0	0	
Slag (MT/yr)											
Solids (MT/yr)	2.3E-05	2.3E-07			2.3E-07	0.2322	0	0	0	0	0.2322
SS (MT/yr)											
UF6 (MT/yr)	0				0		0	0	0	0	
UO2F2 (MT/yr)	0.00201	2E-05			2E-05		20.318	0	20.318	0	
U3O8 (MT/yr)											
Total (MT/yr)	193.588	1.09994	472.673	473.773	2.6E-05	4.644	211.293	95.8501	115.443	4.40945	0.23455
	12.2168	0.06941	29.829	29.8984	1.6E-06	0.29307	13.3341	6.04882	7.28529	0.27827	0.0148

Error	1.57268E-13	Balance	
Wash	A1+A2-A3-A4	0	
Flush		-1E-14	
Rinse	A7+A8-A9-A10	-2E-14	
Dry		1.7E-14	
Wash Solution Hold Tank	A9+A6-A2	5.7E-14	
Filter		0	
Dry Solids		1.7E-16	
Evap	A15-A16-A17	0	
Solids Package	A19-A20	0	
Condenser	A12+A16+A18-A22-A23	0	% Moisture 0.95
Recycle	A22+A24-A8	0	
Overall	A1+A11+A24-A13-A17-A20-A23	5.7E-14	% Moisture 0.01

AQ AR AS AT AU AV AW AX AY AZ BA BB BC BD BE BF

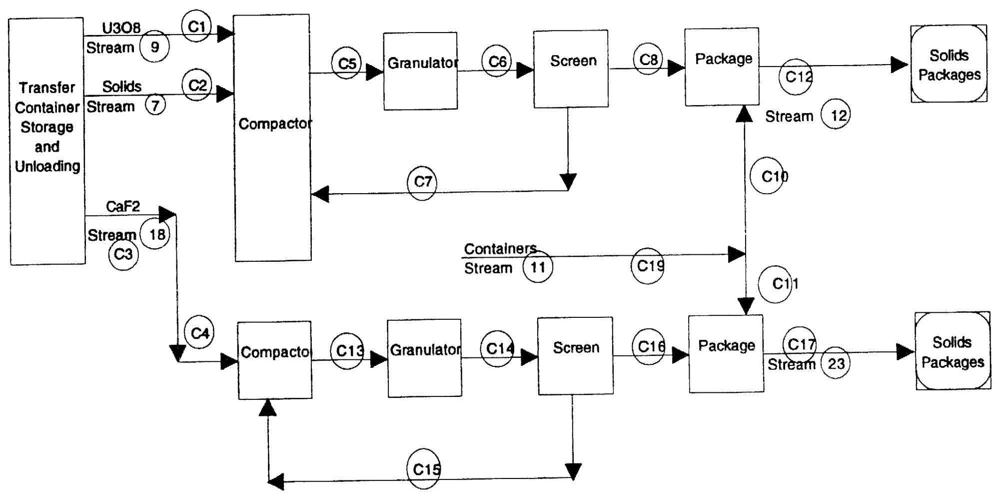
1 **Table 6.3-D-3: U3O8 Conversion Module Material B**



Row														
36	RxnB1		3 UO2F2 +		2 H2O +		1 H2 -->		1 U3O8 +		6 HF			
37	RXnB2		3 UO2F2 +		3 H2O +		0 H2 -->		1 U3O8 +		6 HF +		0.5 O2	
38	Species	MW	(B1)	(B2)	(B3)	(B4)	(B5)	(B6)	RxnB in	RxnB out	(B7)	(B8)	(B9)	(B12)
39	Cylinders (Each)	0	0	0		0			0	0				
40	55 Gal Drum (Eac	0	0	0		0			0					
41	Cyl Box (Each)	0	0	0		0			0					
42	5 Gal Pail (Each)	0	0	0		0			0					
43	CaF2 (MT/yr)	78	0	0		0			0	0		0	0	0
44	CaO (MT/yr)	56	0	0		0			0	0		0	0	0
45	Flux (MT/yr)		0	0		0			0	0		0	0	0
46	H2 (MT/yr)	2	0	0		0			0	0	0	0	0	0
47	HF (MT/yr)	20	5.27858	1.12212	4.15646	4.02848	0.12798		0.12798	2.76727	2.76727	0	0	7.91787
48	H2O (MT/yr)	18	89.8467	83.1395	6.70726	6.50073	0.20653	3.54357	3.75009	2.56178	2.37663	0.18515	0.18515	92.0168
49	N2 (MT/yr)	28	0	0		0			0	0	0	0	0	0
50	NH3 (MT/yr)	17	0	0		0			0	0	0	0	0	0
51	O2 (MT/yr)	32	0	0		0			0	0.35178	0.35178	0	0	0.35178
52	Slag (MT/yr)		0	0		0			0	0		0	0	0
53	Solids (MT/yr)	0	0	0		0			0	0		0	0	0
54	SS (MT/yr)		0	0		0			0	0		0	0	0
55	UF6 (MT/yr)	352	0	0		0			0	0		0	0	0
56	UO2F2 (MT/yr)	308	20.318	0	20.318	0	20.318		20.318	0		0	0	0
57	U3O8 (MT/yr)	842	0	0		0			0	18.5153		18.5153	18.5153	0
58	Total (MT/yr)		115.443	84.2616	31.1817	10.5292	20.6525	3.54357	24.1961	24.1961	5.49568	18.7004	18.7004	100.286
59	Ratio		7.28529	5.3175	1.96779	0.66447	1.30332	0.22362	1.52695	1.52695	0.34682	1.18013	1.18013	6.32879

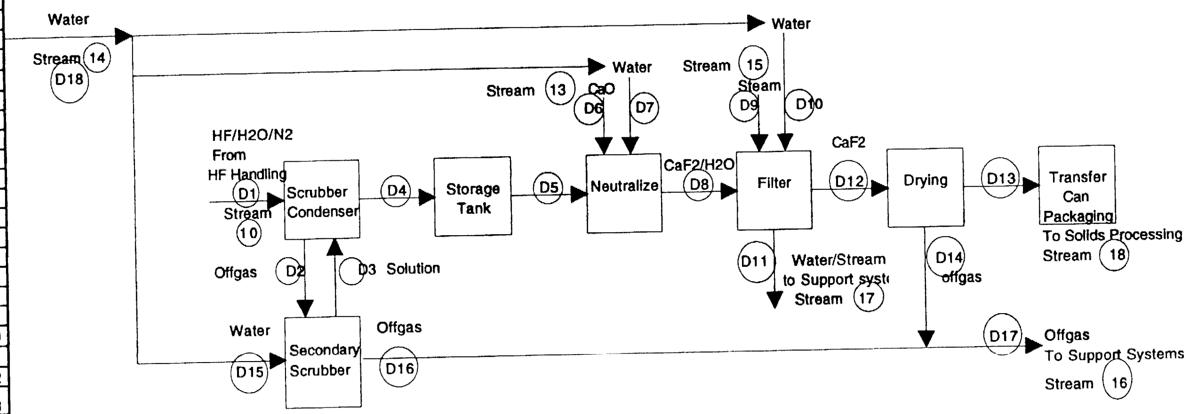
Row						
60	Error	Balance	B3-B4-B5 0	% H2O Re 1.00% Ok	B5+B6-B7-B8	B2+B4+B7-B10	B1+B6-B9-B10
61	6.03961E-14	B1-B2-B3	wt% UO2F 65.16%	wt% HF in 38.26% Ok	3.6E-15	-3E-14	-3E-14
62		0	wt% HF in 38.26% Ok		lb H2O/U3O8 0.13836 OK		
63					M H2O/UO2F2 3		

Table 6.3-D-4 Solids Packing Module Material Balance and Flowsheet



Species	MW	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17
Cylinders (Each)		0	0	0	0													
55 Gal Drum (Each)		0	0	0	0					97.5879	30.9194	66.6685	30.9194					66.6685
Cyl Box (Each)		0	0	0	0													0
5 Gal Pail (Each)		0	0	0	0													0
CaF2 (MT/yr)	78	0	0	15.4503	15.4503	0	0	0	0				0	19.3128	19.3128	3.86256	15.4503	15.4503
CaO (MT/yr)	56	0	0	0	0	0	0	0	0				0	0	0	0	0	0
Flux (MT/yr)		0	0	0	0	0	0	0	0				0	0	0	0	0	0
H2 (MT/yr)	2	0	0	0	0	0	0	0	0				0	0	0	0	0	0
HF (MT/yr)	20	0	0	0	0	0	0	0	0				0	0	0	0	0	0
H2O (MT/yr)	18	0.18515	0.00235	0.15727	0.15727	0.23437	0.23437	0.04687	0.1875				0.1875	0.19658	0.19658	0.03932	0.15727	0.15727
N2 (MT/yr)	28	0	0	0	0	0	0	0	0				0	0	0	0	0	0
NH3 (MT/yr)	17	0	0	0	0	0	0	0	0				0	0	0	0	0	0
O2 (MT/yr)	32	0	0	0	0	0	0	0	0				0	0	0	0	0	0
Slag (MT/yr)		0	0	0	0	0	0	0	0				0	0	0	0	0	0
Solids (MT/yr)		0	0.2322	0.00169	0.00169	0.29025	0.29025	0.05805	0.2322				0.2322	0.00211	0.00211	0.00042	0.00169	0.00169
SS (MT/yr)		0	0	0	0	0	0	0	0				0	0	0	0	0	0
UF6 (MT/yr)	352	0	0	0	0	0	0	0	0				0	0	0	0	0	0
UO2F2 (MT/yr)	308	0	0	0	0	0	0	0	0				0	0	0	0	0	0
U3O8 (MT/yr)	842	18.5153	0	0	0	23.1441	23.1441	4.62882	18.5153				18.5153	0	0	0	0	0
Total (MT/yr)		18.7004	0.23455	15.6092	15.6092	23.6687	23.6687	4.73374	18.935	0	0	0	18.935	19.5115	19.5115	3.9023	15.6092	15.6092
Ratio		1.18013	0.0148	0.98505	0.98505	1.49366	1.49366	0.29873	1.19493				1.19493	1.23132	1.23132	0.24626	0.98505	0.98505
Error	C4-C6	C1+C2+C7-C5			C1+C2-C8		C6-C7-C8		C8+C10-C12			C4+C15-C13		C4-C16		C16+C11-C17		
1.42109E-14	0	3.6E-15			0		-4E-15		0			3.6E-15		0		0		-4E-15
																		C1+C2+C3+C9-C12-C17

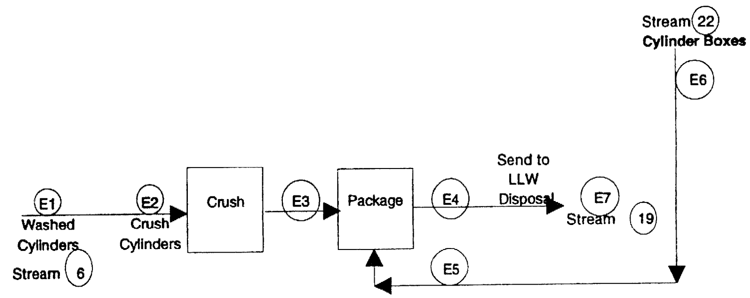
Table 6.3-D-5: HF Handling Module Material Balance and Flowsheet



RxnD1	1 CaO +	2 HF-->	1 CaF2 +	1 H2O
RxnD2	1 CaO +	1 H2O-->	1 Ca(OH)2	
RxnD3	1 Ca(OH)2 +	2 HF-->	1 CaF2 +	2 H2O

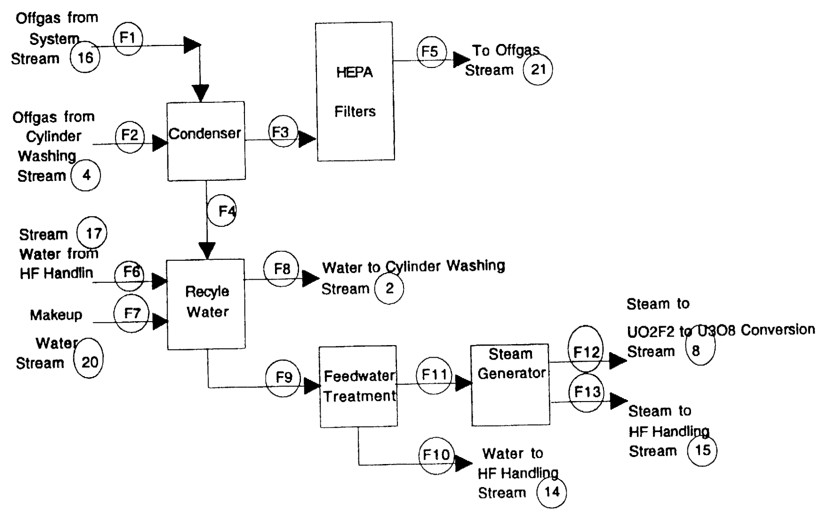
Species	MW	D1	D2	D3	D4	D5	D6	D7	RxnD1 In	RxnD1 Out	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18
Cylinders (Each)		0									0			0							
55 Gal Drum (Each)		0									0			0							
Cyl Box (Each)		0									0			0							
5 Gal Pail (Each)		0									0			0							
CaF2 (MT/yr)	78	0			0	0			0	15.4503	15.4503			0	15.4503	15.4503	0			0	0
CaO (MT/yr)	56	0			0	0	11.0973		11.0973	0	0			0			0			0	0
Flux (MT/yr)		0			0	0			0	0	0			0			0			0	0
H2 (MT/yr)	2	0			0	0			0	0	0			0			0			0	0
HF (MT/yr)	20	7.91787	0.67302	0.67302	7.91787	7.91787			7.91787	-9E-16	-9E-16			-9E-16			0		0	0	0
H2O (MT/yr)	18	92.0168	0.01242	58.4227	150.427	150.427		0	150.427	153.992	153.992	6.76795	2.4703	161.514	1.7167	0.15727	1.55943	58.4227	0.01242	1.57185	60.893
N2 (MT/yr)	28	0	0	0	0	0			0	0	0			0			0		0	0	0
NH3 (MT/yr)	17	0	0		0	0			0	0	0			0			0			0	0
O2 (MT/yr)	32	0.35178	0.35178		0	0			0	0	0			0			0		0.35178	0.35178	0
Slag (MT/yr)		0			0	0			0	0	0			0			0			0	0
Solids (MT/yr)		0			0	0			0	0	0		0.00169	0	0.00169	0.00169	0			0	0.00169
SS (MT/yr)		0			0	0			0	0	0			0			0			0	0
UF6 (MT/yr)	352	0			0	0			0	0	0			0			0			0	0
UO2F2 (MT/yr)	308	0			0	0			0	0	0			0			0			0	0
U3O8 (MT/yr)	842	0			0	0			0	0	0			0			0			0	0
Total (MT/yr)		100.286	1.03721	59.0958	158.345	158.345	11.0973	0	169.442	169.442	169.442	6.76795	2.47199	161.514	17.1686	15.6092	1.55943	58.4227	0.3642	1.92362	60.8947
Ratio		6.32879	0.06546	3.72936	9.99269	9.99269	0.70032	0	10.693	10.693	10.693	0.42711	0.156	10.1927	1.08346	0.98505	0.09841	3.68689	0.02298	0.12139	3.84289
Error		D1-D2+D3-D4		D15+D2-D3-D16		D4+D6+D7-D8			wt% CaF2	D8+D9+D10-D11-D12			D12-D13-D14		wt% H2O	wt% H2O	D14+D16-D17		D18-D7-D10-D15		
5.01266E-14		0	-2E-14	-2E-16		0			9.12%	-3E-14			6.7E-16		10.00%	1.01%	0		0		
		D1+D6+D9+D18-D11-D13-D17																			

Table 6.3-D-6: Cylinder Disposition Module Material Balance and Flowsheet



Species	MW	E1	E2	E3	E4	E5	E6	E7
Cylinders (Each)		2322	2322		0		0	0
55 Gal Drum (Each)		0	0		0		0	0
Cyl Box (Each)		0	0		774	774	774	774
5 Gal Pail (Each)		0	0		0		0	0
CaF2 (MT/yr)	78	0	0		0		0	0
CaO (MT/yr)	56	0	0		0		0	0
Flux (MT/yr)		0	0		0		0	0
H2 (MT/yr)	2	0	0		0		0	0
HF (MT/yr)	20	5.3E-06	5.3E-06		0		0	0
H2O (MT/yr)	18	0	0		0		0	0
N2 (MT/yr)	28	0	0		0		0	0
NH3 (MT/yr)	17	0	0		0		0	0
O2 (MT/yr)	32	0	0		0		0	0
Slag (MT/yr)		0	0		0		0	0
Solids (MT/yr)		2.3E-07	2.3E-07		0		0	0
SS (MT/yr)		0	0	2744.18	2744.18		0	2744.18
UF6 (MT/yr)	352	0	0		0		0	0
UO2F2 (MT/yr)	308	2E-05	2E-05		0		0	0
U3O8 (MT/yr)	842	0	0		0		0	0
Total (MT/yr)		2.6E-05	2.6E-05	2744.18	2744.18	0	0	2744.18
Ratio		1.6E-06	1.6E-06	173.177	173.177	0	0	173.177
Error		E1-E2	E2-E3	E3+E5-E4		E5-E6		E4-E7
0		0	0	0		0		0

Table 6.3-D-7: Support System Module Material Balance and Flowsheet



RxnF1 2 NH3--> 3 H2 + 1 N2

Species	MW	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13
Cylinders (Each)		0	0		0		0	0	0	0	0	0	0	0
55 Gal Drum (Each)		0	0		0		0	0	0	0	0	0	0	0
Cyl Box (Each)														
5 Gal Pail (Each)														
CaF2 (MT/yr)	78	0	0		0	0	0	0	0	0	0	0	0	0
CaO (MT/yr)	56	0	0		0	0	0	0	0	0	0	0	0	0
Flux (MT/yr)		0	0		0	0	0	0	0	0	0	0	0	0
H2 (MT/yr)	2	0	0	0	0	0	0	0	0	0	0	0	0	0
HF (MT/yr)	20	0	0		0	0	-9E-16	8.9E-16	0	0	0	0	0	0
H2O (MT/yr)	18	1.57185	5.98594	5.98661	1.57118	5.98661	161.514	6.33137	98.2116	71.2046	60.893	10.3115	3.54357	6.76795
N2 (MT/yr)	28	0	378.139	378.139	0	378.139	0	0	0	0	0	0	0	0
NH3 (MT/yr)	17	0	0		0	0	0	0	0	0	0	0	0	0
O2 (MT/yr)	32	0.35178	94.5347	94.8864	0	94.8864	0	0	0	0	0	0	0	0
Slag (MT/yr)		0	0		0	0	0	0	0	0	0	0	0	0
Solids (MT/yr)		0	0		0	0	0	0.00169	0	0.00169	0.00169	0	0	0
SS (MT/yr)		0	0		0	0	0	0	0	0	0	0	0	0
UF6 (MT/yr)	352	0	0		0	0	0	0	0	0	0	0	0	0
UO2F2 (MT/yr)	308	0	0		0	0	0	0	0	0	0	0	0	0
U3O8 (MT/yr)	842	0	0		0	0	0	0	0	0	0	0	0	0
Total (MT/yr)		1.92362	478.659	479.012	1.57118	479.012	161.514	6.33306	98.2116	71.2062	60.8947	10.3115	3.54357	6.76795
Ratio		0.12139	30.2068	30.229	0.09915	30.229	10.1927	0.39966	6.19785	4.49362	3.84289	0.65073	0.22362	0.42711

Error 1.81188E-13

F1+F2-F3-F4		F3-F5	F4+F6+F7-F8-F9	F9-F11-F12	F11-F12-F13
-6E-14	-1E-13	0	1.4E-14	-2E-15	8.9E-16

F1+F2+F6+F7-F5-F8-F10-F12-F13

Appendix 6.3-E - Equipment List and Specifications

Table 6.3-E-1 is the major equipment list for the UCTF. Note that the equipment list covers only the major process and support equipment. The list tabulates equipment by name, quantity, capacity, and material of construction. Equipment components such as small process pumps, agitators, blowers, auxiliary heat exchanges, etc. are not included. Support systems equipment such as process system material handling; maintenance equipment; sampling, analytical, and plant security and ambient air monitoring systems have not been defined in detail due to the preliminary status of the facility design. Utility and service system equipment and components are not included. General description for these systems can be found in Section 6.3-6.0 of this report.

Additional equipment specification information includes the following:

- Equipment and associated piping containing primary process materials are generally of all welded construction.
- Equipment, piping and instrumentation exposed to fluorides are constructed of special alloy or corrosion resistant plastic materials.
- Processing areas where there is a potential for release of uranium powders or noxious fluoride-containing materials (including UF_6, UO_2F_2 and HF) are generally contained in gloveboxes or located in hood ventilated areas. These areas include the Solids Processing area.
- Equipment contaminated with uranium or fluorides will generally be subjected to decontamination fluids prior to maintenance, reuse or disposal as waste.
- All equipment and components serving as primary confinement barriers for UF_6, HF and U_3O_8 will meet high-quality industrial design, fabrication and testing specifications.
- Process equipment is located within the Process Building as shown on the process equipment arrangement drawing Figures 6.3-4-5 to 6.3-4-10.

Table 6.3-E-1: Major Equipment List

Equipment Name	#	Equipment Description	Location
Mobile Crane	2	10 ton crane. This crane performs the following actions: 1) move "empty" DUF_6 cylinders from the trucks and rail cars to the cylinder yard. 2) move cylinders within the cylinder yard. 3) move cylinders from the cylinder yard to the staging area outside the cylinder washing module. 4) move full cylinder shipping boxes from the box staging area to the warehouse. 5) move the cylinder shipping boxes from the warehouse onto trucks or rail cars for transportation offsite.	Cylinder Yard
Overhead Cylinder Handling Crane	1	10 Ton Crane. This crane will perform the following actions: 1) Move the cylinders from an outside staging pad onto the tilt/rotate stands for washing. 2) After washing, move the washed cylinders to the cylinder crushing equipment 3) Move the crushed cylinders into a shipping box using an electromagnet 4) move the shipping box to staging area.	Proc. Building, Cyl. Washing and Cyl. Disposal
Tilt and Rotate Stand	4	The stands allow the large DUF_6 cylinders to be rotated and tilted during the washing operations	Proc. Building, Cyl. Washing
Recycle Water Tank	1	180 gal, 3' dia. by 5' Tank. Solution will contain traces of HF.	Proc. Building, Cyl. Washing
Wash Solution Tank	1	180 gal, 2.5' dia by 5' Tank. Solution will contain 0.10 wt% UO_2F_2 and 0.027 wt% HF	Proc. Building, Cyl. Washing

Table 6.3-E-1: Major Equipment List (Cont.)

Equipment Name	#	Equipment Description	Location
Filter	1	Plastic in-line cleanable cartridge filter. Batch feed at 2.2 gpm for 10 min. every 2.2 hours. Solution composition is 10 wt% UO_2F_2, 2.5 wt% HF, and 0.11 wt% solids.	Proc. Building, Cyl. Washing
Wash Evaporator Feed Tank	1	180 gal, 2.5' dia x 5' plastic or plastic lined tank. Solution composition is 10 wt% UO_2F_2 and 2.5 wt% HF	Proc. Building, Cyl. Washing
Wash Evaporator	1	Feed rate is 0.25 gpm Evaporate 61 lb./hr Operate 12 hr./day Final solution composition is 18 wt% UO_2F_2 and 4.6 wt% HF	Proc. Building, Cyl. Washing
Condenser	1	Cool 61 lb./hr steam to 70 °F, Heat duty of 90 kBTU/hr. Traces of HF in solution. Operate 12 hr/day	Proc. Building, Cyl. Washing
Drying Oven	1	Small Laboratory Scale Drying Oven	Proc. Building, Cyl. Washing
Storage Tank	1	1100 gals, Solution Composition: 4.6 wt% HF, 18 wt% UO_2F_2, 6.75' d x 5', Insulated	Proc. Building, U_3O_8 Conver.
Kiln Feed Evaporator	1	Feed Rate = 183 lb/hr Evap. Rate = 134 lb./hr Operate 49 hr/week 13 wt% HF, 65 wt% UO_2F_2	Proc. Building, U_3O_8 Conver.
Rotary Kiln	1	Indirect Fired with natural gas, 2 ft. dia., 8 ft long, Inconel	Proc. Building, U_3O_8 Conver.
U_3O_8 Cooler	1	Tumbling, Circulated cooling water. Tube is 1.5 ft dia. x 6 ft long	Proc. Building, U_3O_8 Conver.
U_3O_8 Packaging Hood	1	Hood is 3' x 4', to accommodate a 5 gallon bucket for loading	Proc. Building, U_3O_8 Conver.
U_3O_8 Unpacking Hood CaF_2 Unpacking Hood	2	Hood is 3' x 4', to accommodate a 5 gallon bucket for unloading	Proc. Building, Solids Pkg.

Table 6.3-E-1: Major Equipment List (Cont.)

Equipment Name	#	Equipment Description	Location
U_3O_8 Conver system CaF_2 Conver system	2	0.07 tons/hr. 1) From unloading station to compactor, 2) from compactor to granulator, and 3) from granulator to screen	Proc. Building, Solids Pkg.
U_3O_8 Compactor CaF_2 Compactor	2	Roll press, 0.07 tons/hr. Operate 7 hr. per week. 12" dia x 5.0" rollers, 41 ton pressure	Proc. Building, Solids Pkg.
U_3O_8 Granulator CaF_2 Granulator	2	Roll crusher, 0.07 tons/hr, operate 7 hr/week. 6.5" dia x 6" roller	Proc. Building, Solids Pkg.
U_3O_8 Vibrating Screen CaF_2 Vibrating Screen	2	6" x 24", 1/4" square opening mesh.	Proc. Building, Solids Pkg.
U_3O_8 Packaging Hood CaF_2 Packaging Hood	2	Hood is 3' x 6', to accommodate a 55 gallon drum for loading	Proc. Building, Solids Pkg.
Hoist	1	Lift filled 55 gallon Drums. Drum weight will be 1,380 pounds.	Proc. Building, Solids Pkg.
Scrubbing Condenser	1	3.5' dia X 8' tall, scrubber solution flowrate of 23 gpm, solution composition is 7.8 wt% HF	Proc. Building, HF Handling
Secondary Scrubber	1	3' dia X 6' tall, scrubber solution flowrate of 1 gpm, solution composition is 7.8 wt% HF	Proc. Building, HF Handling
HF Solution Tank	1	943 gal 4.5' dia x 8' tall, solution composition: 7.8 wt% HF	Proc. Building, HF Handling
CaO Hopper	1	2' dia x 3' tall, 9.5 ft^3	Proc. Building, HF Handling
Neutralization Tank	1	4' dia x 4' tall, 286 gal., solution will vary from 7.8 wt% HF to 13.7 wt% CaF_2	Proc. Building, HF Handling
Filter	1	50 frame filter press, runs 10 hours out of 7 days.	Proc. Building, HF Handling

Table 6.3-E-1: Major Equipment List (Cont.)

Equipment Name	#	Equipment Description	Location
Drying Oven	1	3 - 27 ft^3 drying ovens	Proc. Building, HF Handling
CaF_2 Packaging Hood	1	Hood is 3' x 4', to accommodate a 5 gallon bucket for loading	Proc. Building, HF Handling
Cylinder Crusher	1	604 ton press	Proc. Building, Cyl. Disposal
Electromagnet attachment for crane	1	Lift 5,000 lb.	Proc. Building, Cyl. Disposal
Gantry Crane	1	10 ton crane. This crane is used to move filled cylinder shipment boxes into, around, and out of the warehouse	Solid Product Building
Forklift	1	Used to move pallets with 55 gallon drums around solid product storage building	Solid Product Building
Forklift	1	To move supplies around the warehouse and between the warehouse and the other buildings	Warehouse
Flatbed Truck	1	To move materials between buildings	Warehouse

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Section 6.4

U3O8: Defluorination / Anhydrous HF Facility

Section 6.4
U_3O_8: Defluorination / Anhydrous HF Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into U_3O_8 and byproduct anhydrous HF (AHF). Due to its chemical stability, U_3O_8 is a principal option for either long term storage or disposal. UF_6 defluorination is achieved through a steam hydrolysis/pyrohydrolysis route, which is generically the same as the existing industrial (Cogema) process practiced in France. Upgrading of the aqueous HF to AHF is accomplished by conventional distillation. Specific process aspects for flowsheet modeling were based on the Allied Signal/General Atomic Sequoyah Fuels patent.

Process Summary

Depleted uranium hexafluoride (UF_6) is processed to produce triuranium octaoxide (U_3O_8) and byproduct anhydrous hydrogen fluoride (AHF). A dry process (steam hydrolysis/steam pyrolysis) is used for conversion to the uranium oxide.

The UF_6 is converted to U_3O_8 in two steps. The UF_6 is vaporized using steam heated autoclaves and fed to a reactor, where it is mixed with a HF-steam mixture. Solid uranyl fluoride (UO_2F_2) is produced and it flows to a second reactor, where it is mixed with nitrogen and superheated steam to produce U_3O_8. The oxide is discharged from the reactor, cooled, compacted and packaged for shipment.

Vapor containing HF and water vapor flows to the HF distillation column. Distillation of the stream produces AHF which can be sold commercially. The HF azeotrope (distillation column bottoms) is vaporized and recycled to the first reactor. Uncondensed off-gas from the distillation process flows to the scrubber system.

1.0 DUF_6 Conversion Facility - Missions, Assumptions, and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Defluorination/Anhydrous Hydrofluoric Acid (AHF) Conversion Facility converts depleted UF_6 into triuranium octoxide (U_3O_8) for stable, long-term storage or disposal.

1.2 ASSUMPTIONS AND DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail car. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure, and the assumed average isotopic composition is: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinder, the short lived daughter products of U-238, Th-234 and Pa-234 are in the same equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is assumed to be 7000 hours based on a plant availability factor of 0.8.
- A single train of process equipment is provided to produce the plant processing capacity, except in the UF_6 reactor systems, where two parallel trains are provided.
- The hydrofluoric acid (HF) produced in the process is stored in tanks and loaded into railcars or tank trucks for shipment off-site. Indoor on-site storage of one months production is provided.
- U_3O_8 and CaF_2 products are packaged in 55 gallon drums. Since the weight of U_3O_8 in a full drum exceeds the maximum weight

limitations for a standard drum, it is assumed that specially engineered drums are used for U_3O_8. Indoor on-site storage space for 1 months production is provided.

- On-site storage of one months supply of calcium hydroxide and cement feed material is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- Indoor storage of one months production of grouted waste is provided.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities", as defined in DOE Order 6430.1A, and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- HF Storage Building
- U_3O_8 Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility, including the following:

- CaF_2 Storage Building
- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20-year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

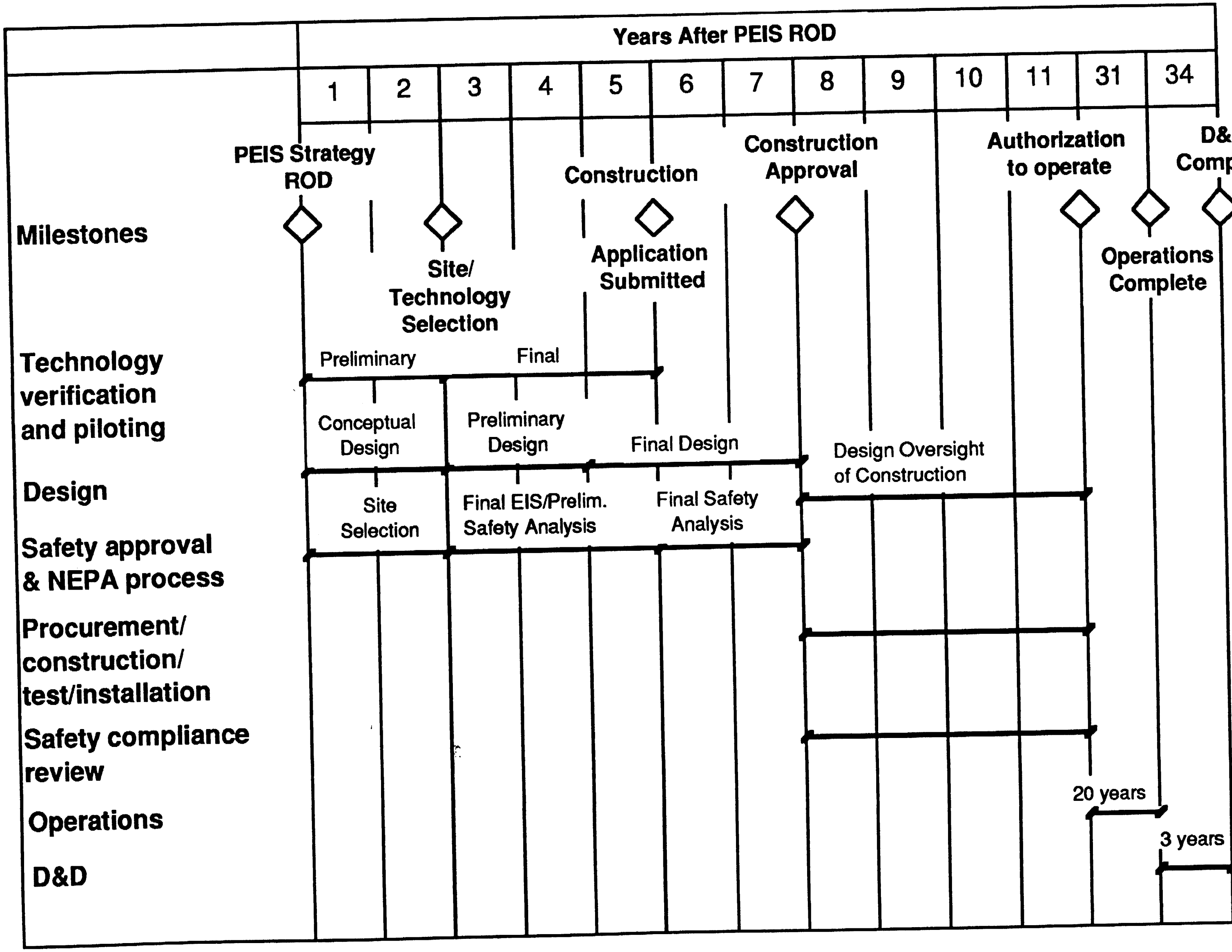


Figure 1-1 Preliminary Project Schedule

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502, *Environmental Impact Statement*, 10 CFR 1021, *National Environmental Policy Act Implementing Procedures (for DOE)*, and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program*.

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, and guidelines, as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*, DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act*. Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection*.

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements*; the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process include the following:

- The process has not been demonstrated on a throughput scale assumed for this study (28,000 MT/yr UF_6). Primary concern is direct scaleup of the conversion reactors.
- The optimum material of construction for reactor system process equipment and components exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.
- The ultimate storage or disposal form of the U_3O_8 product has not been finalized. Also, the viability of shipment of compacted U_3O_8 powder in 55 gallon drums has not been determined.
- The relative hazards and economics of on-site storage of large quantities of hydrofluoric acid (HF) in tanks versus on-site storage of HF in rail tank cars has not been fully assessed.
- Due to the pre-conceptual nature of the facility design, design details of process and support system equipment and components as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment, system, and facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF6 Conversion Facility Description

2.1 General Facility Description

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium oxide (U_3O_8), calcium fluoride (CaF_2) and anhydrous hydrofluoric acid (HF) by defluorination with steam. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a series of two reactors to solid U_3O_8 product which is packaged in 55 gallon drums. The product uranium oxide is stored on-site until it is transported to another site for subsequent disposition: long term storage, use, or disposal. The anhydrous HF is shipped off-site in rail cars and is assumed to be sold. The CaF_2 is packaged in 55 gallon drums and shipped off-site by truck.

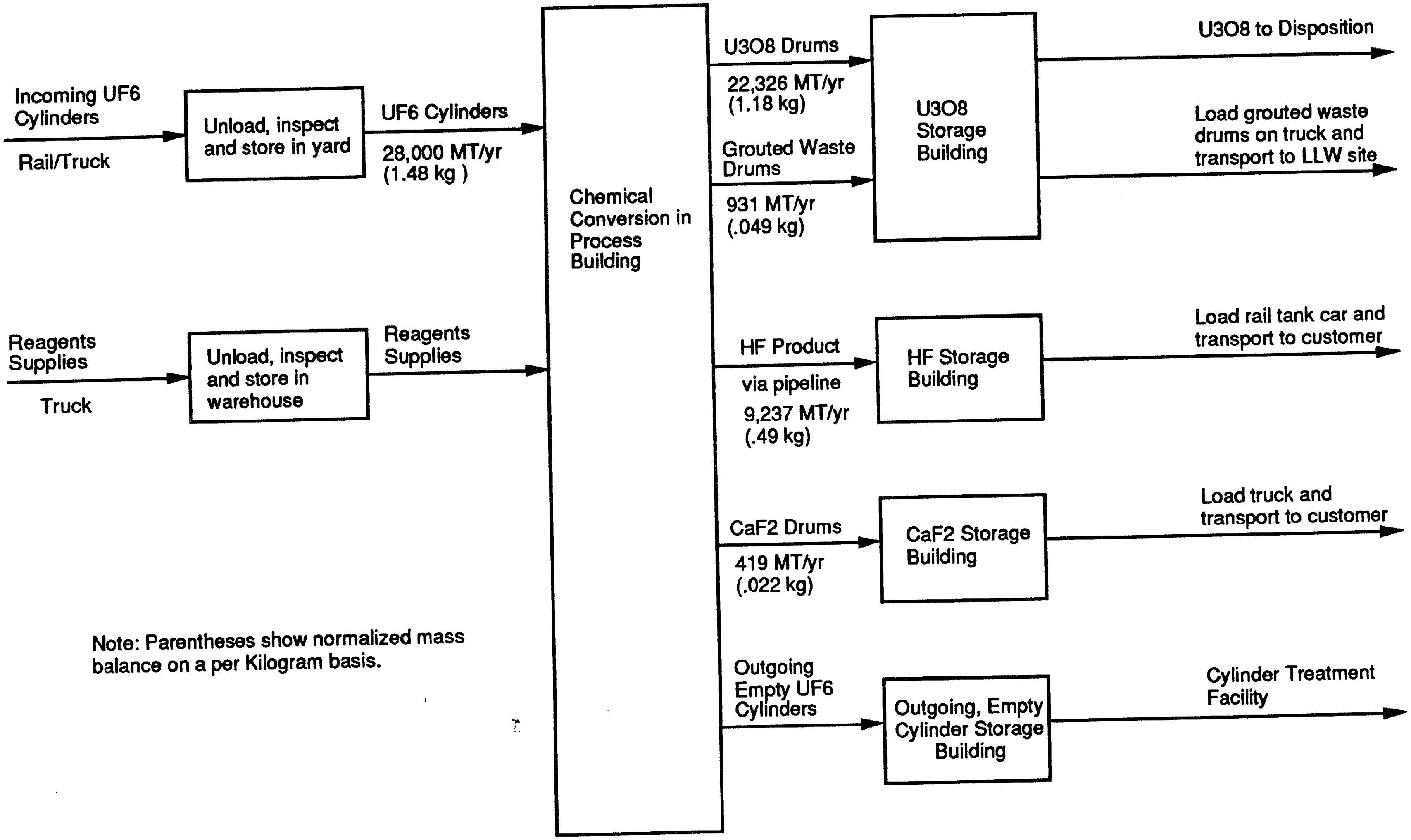
2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2–2 Plot Plan.

The major structures on the site are as follows:

- Process Building
- HF Storage Building
- U_3O_8 Storage Building
- CaF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse.
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site

Note: The size, number and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.



Note: Parentheses show normalized mass balance on a per Kilogram basis.

Figure 2-1 Inter-Facility Material Flow Diagram

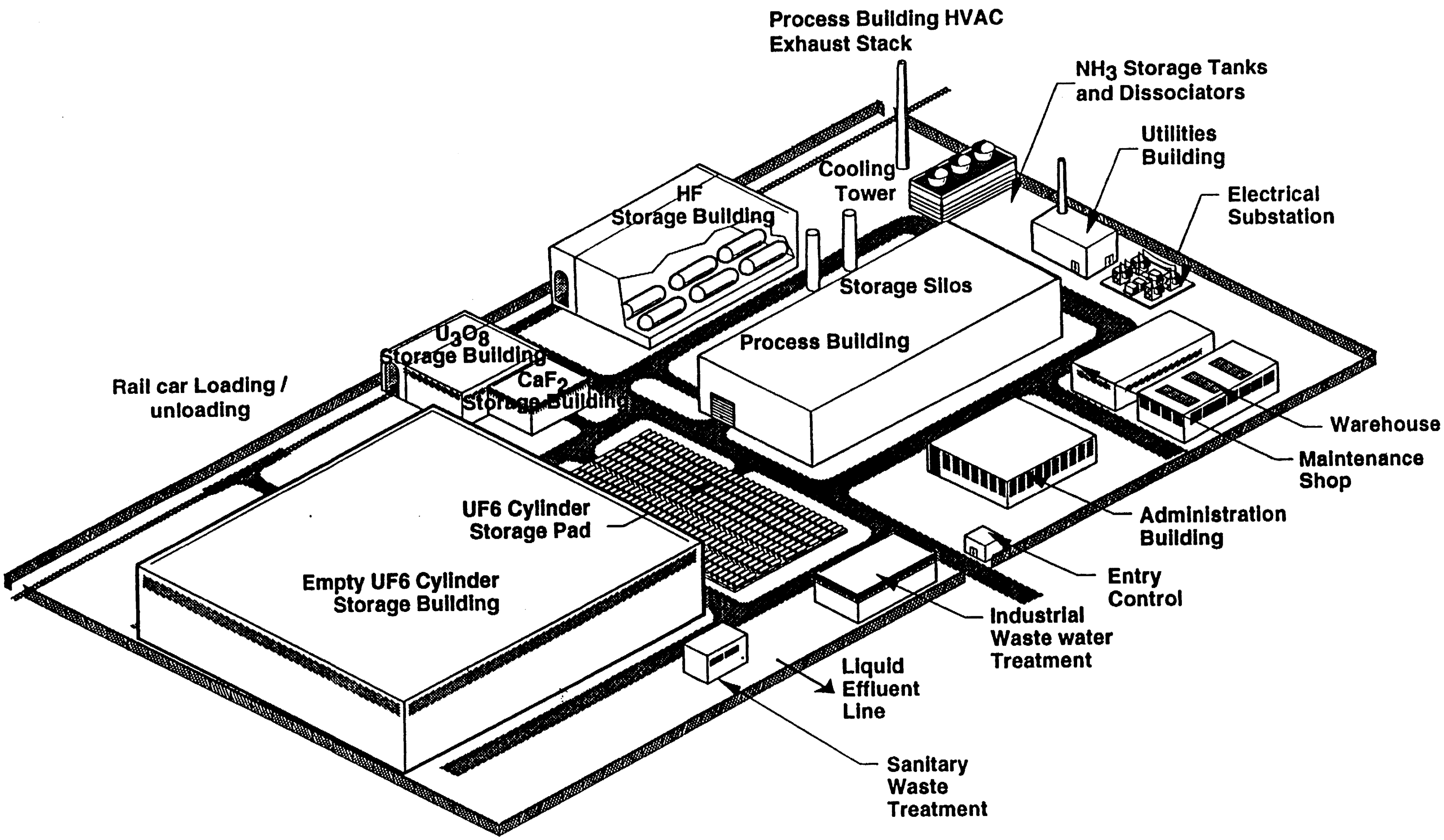


Figure 2-2 Plot Plan
Defluorination / Anhydrous HF Facility

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	35,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
HF Storage Building	10,500	1	No	Yes	NA / HH	Reinforced Concrete
U_3O_8 Storage Building	8,000	1	Yes	Yes	HC2 / MH	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
CaF_2 Storage Building	1,800	1	No	No	N/A	Metal Frame
Utilities Building	6,000	1	No	Yes	General	Metal Frame
Administration Building	8,000	1	No	No	General	Metal Frame
Maintenance Shop	5,000	1	No	Yes	General	Metal Frame
Warehouse	5,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	1,500	1	No	No	General	Metal Frame
Cooling Tower	5,000	---	No	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The Process Building and process equipment layouts and section are shown in Figures 2-3, 2-4 and 2-5. The building is a two-story reinforced concrete structure classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where large inventories of UF_6 and HF are present.

These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems such as the heating, ventilating and air conditioning systems and emergency electric power systems.

2.1.3.2 HF Storage Building

Due to the presence of a large inventory of HF, the HF Storage Building is classified as a nonradiological, chemically high hazard (HH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is a one-story reinforced concrete structure which provides space for tank storage of one months production of HF. The facility is provided with a rail car loading bay and space for the required storage tanks. An air refrigeration system is provided to maintain temperatures in the building in the range of 45 to 55°F to limit vaporization of HF in the event of a spill. Also, a water spray system and diked floor are provided to mitigate the effects of an HF spill.

2.1.3.3 U_3O_8 Storage Building

The U_3O_8 Storage Building is a one-story metal frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for one months production of U_3O_8 and grouted waste. A zone 2 HVAC system with filtered exhaust air is provided. (See also Sections 2.2 and 2.2.5)

2.1.3.4 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three

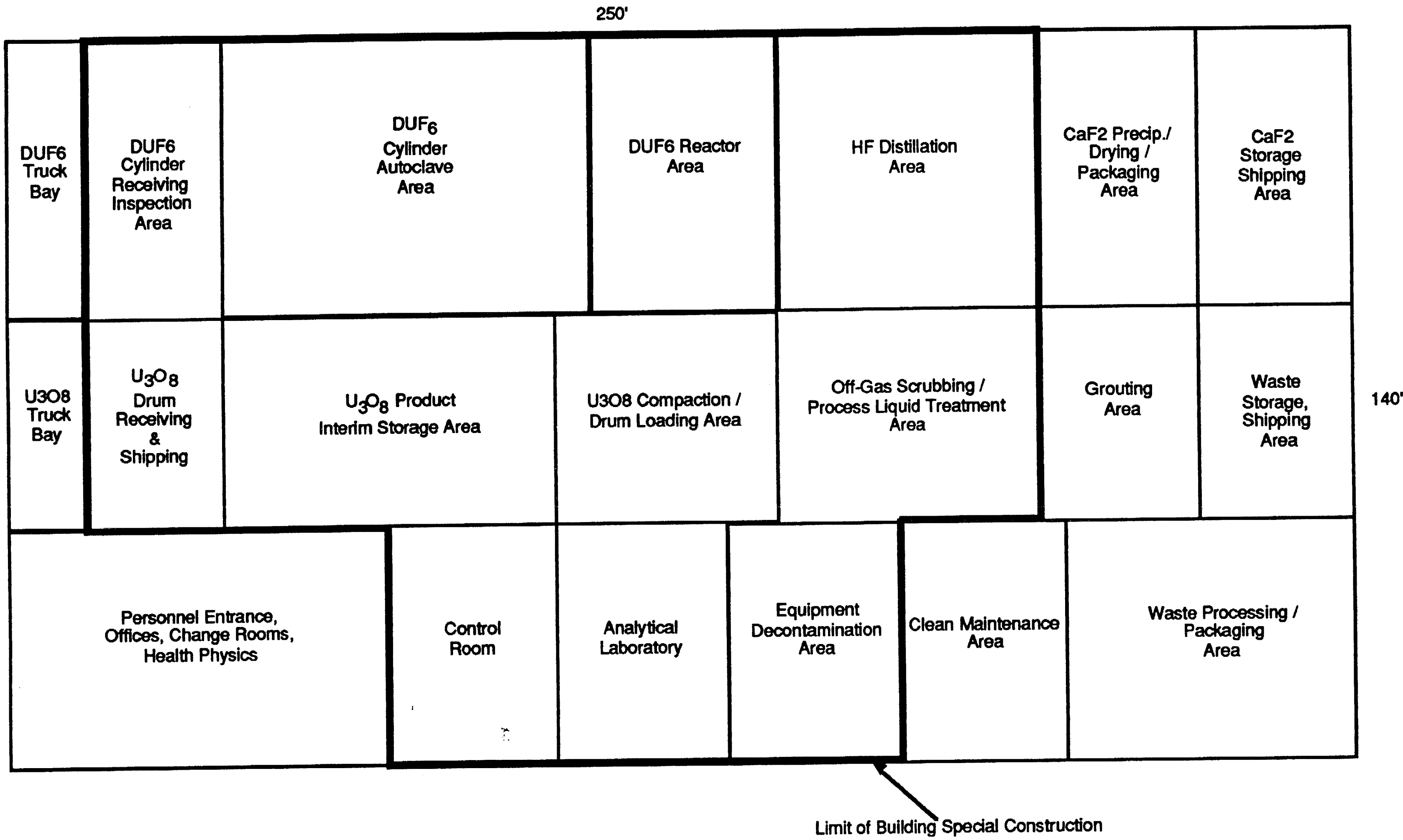


FIGURE 2-3 PROCESS BUILDING LAYOUT DEFLUORINATION / ANHYDROUS HF

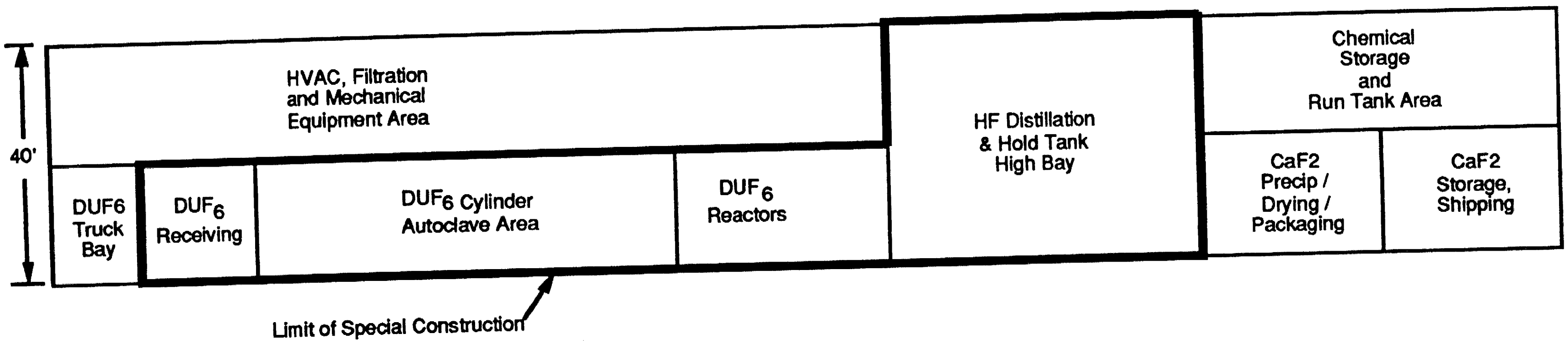


FIGURE 2-4 PROCESS BUILDING SECTION DEFLUORINATION / ANHYDROUS HF

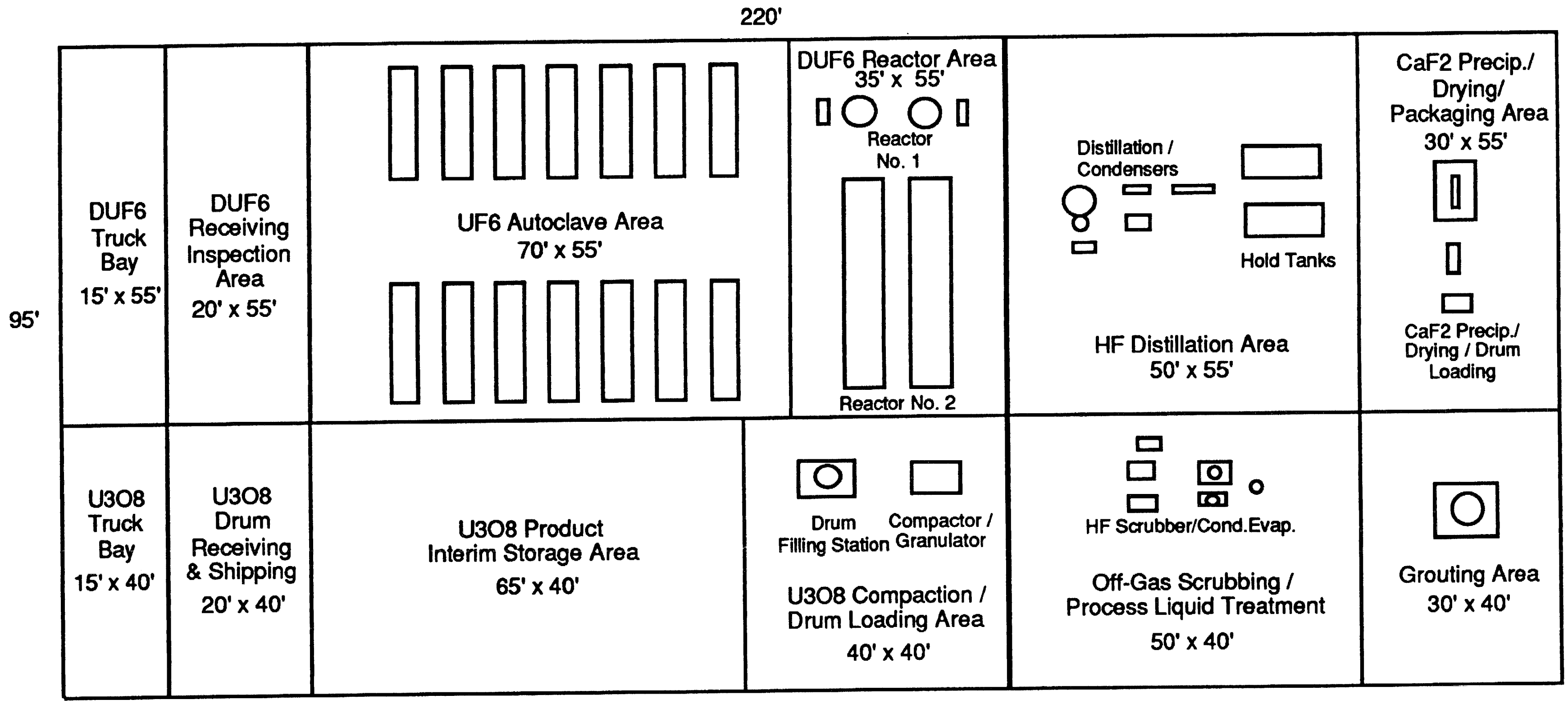


FIGURE 2-5 PROCESS EQUIPMENT ARRANGEMENT DEFLUORINATION / ANHYDROUS HF

months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.5 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the DUF_6 Defluorination / AHF Facility includes the following facilities and systems: (Facilities are shown on Site Map Fig. 3-1.)

A metal frame CaF_2 Storage Building for storage of one months production of CaF_2.

A metal frame general use Utilities Building housing raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal frame or masonry Administration Building to house the facility support personnel.

A metal framed general use Maintenance Shops Building for housing clean maintenance and repair shops.

An 19 MM BTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 1,900 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility for the receipt, treatment and disposal of noncontaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility with a capacity of approximately 3,300 gpd.

Compressed air systems including plant air, instrument air and breathing air. A single set of two redundant 300 cfm reciprocating air compressors provide compressed air to both systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in dessicant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

A 1,400 ft^3 lime silo and a 700 ft^3 cement storage silo located in the yard.

Building heating, ventilating and air conditioning (HVAC) systems use a central chilled water system for building cooling. Three 50% capacity, 250 ton centrifugal water chillers, and three 400 gpm circulating pumps are provided. A steel stack serves the Process Building HVAC exhaust systems. The steam plant boiler vents through a dedicated steel stack (see Table 2-3 for stack dimensions).

An 800 ton process refrigeration system for 30°F coolant for the main HF condenser and a 5 ton system for minus 30°F coolant for the final HF off-gas condenser are provided.

All cooling water systems are connected to the cooling tower system described above.

A central steam plant is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 16,000 lb/hr of 50 psig steam which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration and chlorination. The demineralized water is used in the process and for steam boiler feedwater (See also Fig. 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a capacity of 1,500 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 300-kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas which require special lighting for nightime operation include the UF_6 cylinder storage pad areas, the railcar spur area, the utility area and the site entry control area.

Site security fencing as shown on Site Map, Figure 3-1, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventive systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSC's) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety class systems, structures, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornadoes

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Distillation Areas
U_3O_8 Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
HF Storage Building	Zone 1 - High Chemical Hazard	Conventional	PC-4 for High Hazard Areas	Automatic water spray and shutdown of HVAC system upon HF leak
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1.3 Floods

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480.7. This criteria requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

2.2.3 Materials Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF storage containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., U_3O_8 drum loading operations, HF sampling stations, etc.).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL 15910.

2.2.5 Ventilation Systems

The HVAC systems will utilize a combination of dividing the buildings into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breached or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing autoclaves and other uranium processing areas. The ventilation system for these rooms utilize once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard. The U_3O_8 Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting areas, CaF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a higher pressure than the rest of the building. The HVAC for the Process Building is based on six air changes per hour and once through ventillation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The HF distillation area and off-gas scrubbing area of the Process Building have high chemical hazard potential and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a HF leak. The HF Storage Building will also be a high chemical hazard area.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on the Site Map, Figure 3-1. This figure also shows the effluent air release point ventilation and boiler stacks.

Table 2-3 summarizes the facility effluent air release points.

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	85	80	60
Boiler	100	25	500	60

3.0 Site Map and Land Use Requirements

3.1 SITE MAP

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and HF and U_3O_8 from the facility. Air emission points are the Process Building ventilation exhaust stack and the boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 LAND AREA REQUIREMENTS DURING OPERATION

As shown in Figure 3-1, the total land area required during operations is approximately 565,000 ft^2 or about 13 acres.

3.3 LAND AREA REQUIREMENTS DURING CONSTRUCTION

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 20 acres. Construction areas required in addition to the site structures and facilities include:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

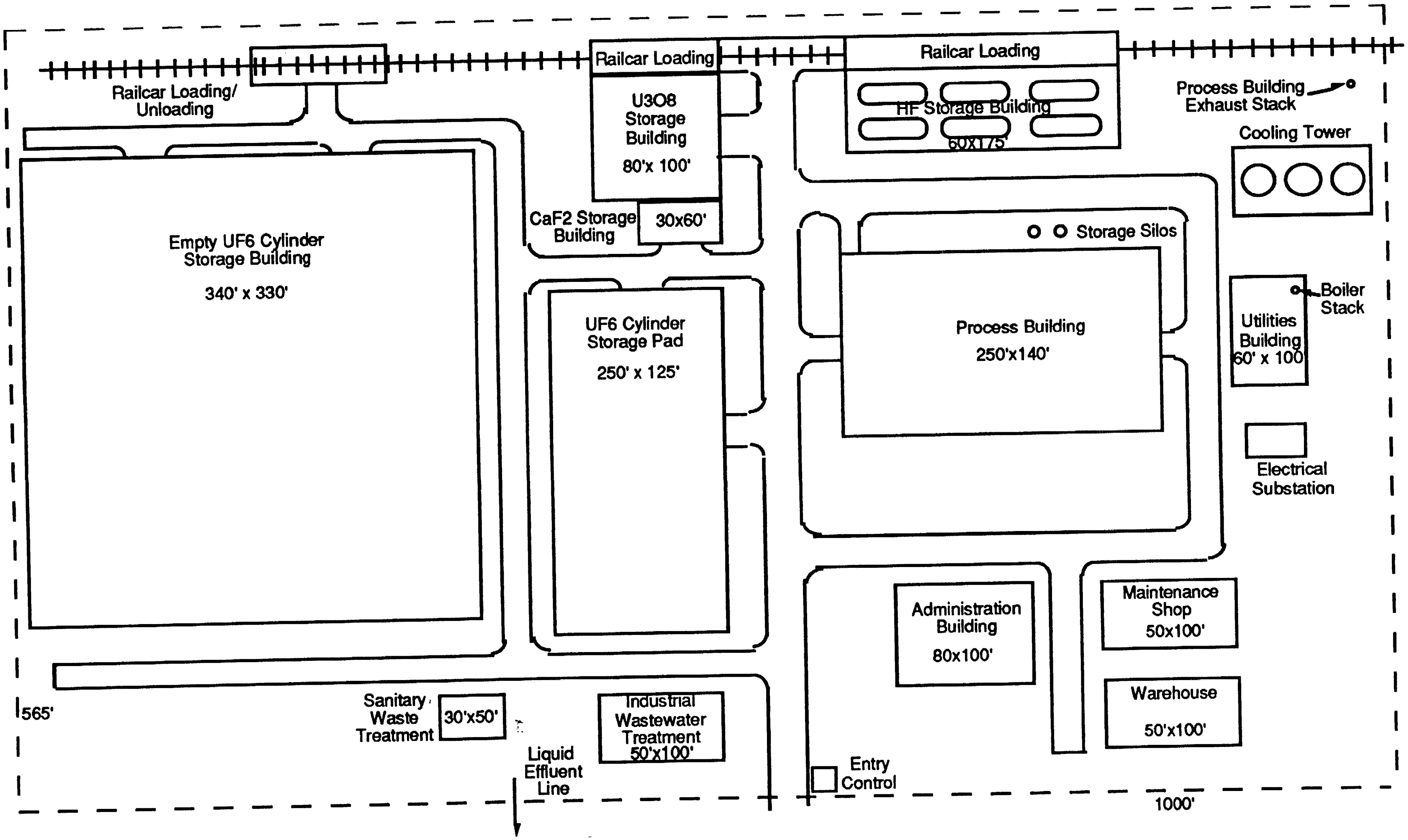


FIGURE 3-1 SITE MAP
DEFLUORINATION / ANHYDROUS HF FACILITY

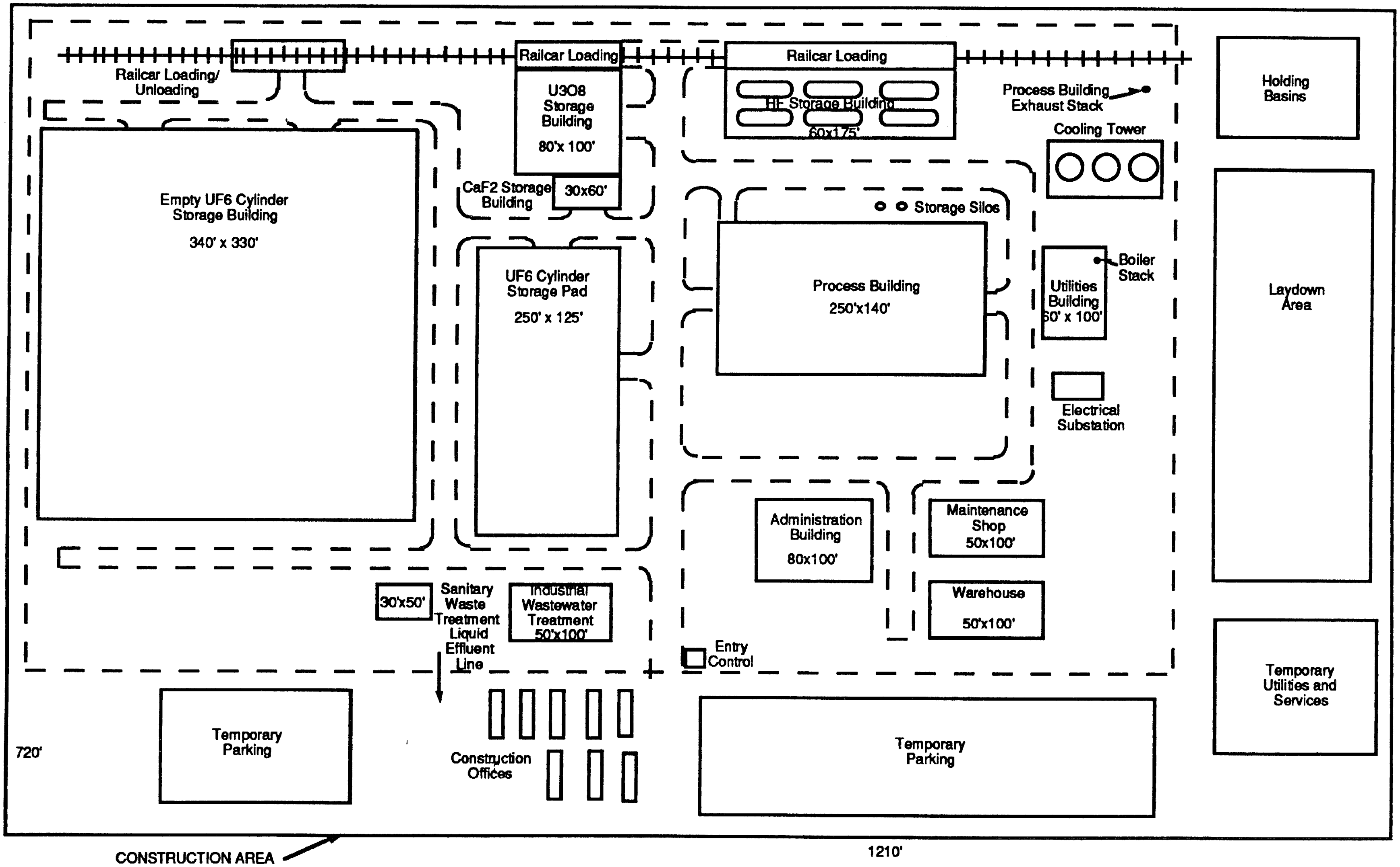


FIGURE 3-2 SITE MAP DURING CONSTRUCTION
DEFLUORINATION / ANHYDROUS HF FACILITY

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is processed to produce uranium oxide (U_3O_8), calcium fluoride (CaF_2) and anhydrous hydrofluoric acid (HF). The CaF_2 and HF are of sufficient purity to be sold commercially. Impurities (primarily uranium byproducts) from the process are grouted and disposed of as low level waste. The process is shown in Figures 4-1 and 4-2. Annual and hourly material balances are given in Appendix A.

The UF_6 is converted to U_3O_8 in a two-step process. The UF_6 is vaporized using steam heated autoclaves and fed to Reactor No. 1, where it is mixed with 45% HF-water vapor. Solid UO_2F_2 is produced and flows to Reactor No. 2. Vapor containing HF and water flows to the HF distillation column. In the second reactor, the UO_2F_2 is mixed with steam to produce solid U_3O_8. Vapor containing HF, water and oxygen flows to the HF distillation column. The U_3O_8 is discharged from the reactor, cooled, compacted and packaged in drums.

The HF distillation column receives feed from Reactors No. 1 and 2. The column purifies the HF to produce anhydrous HF. The HF product is pumped to storage tanks and loaded into railroad tank cars for delivery to customers. The distillation column bottoms stream is collected, vaporized and recycled to Reactor No. 1. Uncondensed off-gas from the distillation column flows to the scrubber system.

The HF in the off-gas is removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The solid CaF_2 is separated by filtering, washed with water, dried and packaged in drums. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution.

To prevent the buildup of uranium and other impurities in the HF distillation column bottoms stream that is recycled to Reactor No. 1, a small purge stream is continuously withdrawn. This purge stream is neutralized with hydrated lime, and mixed with cement and water to form a grout. The solid waste grout is packaged in drums and disposed as low level waste.

The facility has two reactor trains of defluorination process equipment. Critical equipment such as a blowers or filters have spares installed in parallel. Specific aspects of the conversion of UF_6 to U_3O_8 are based on a process patented by Sequoyah Fuels Corporation.

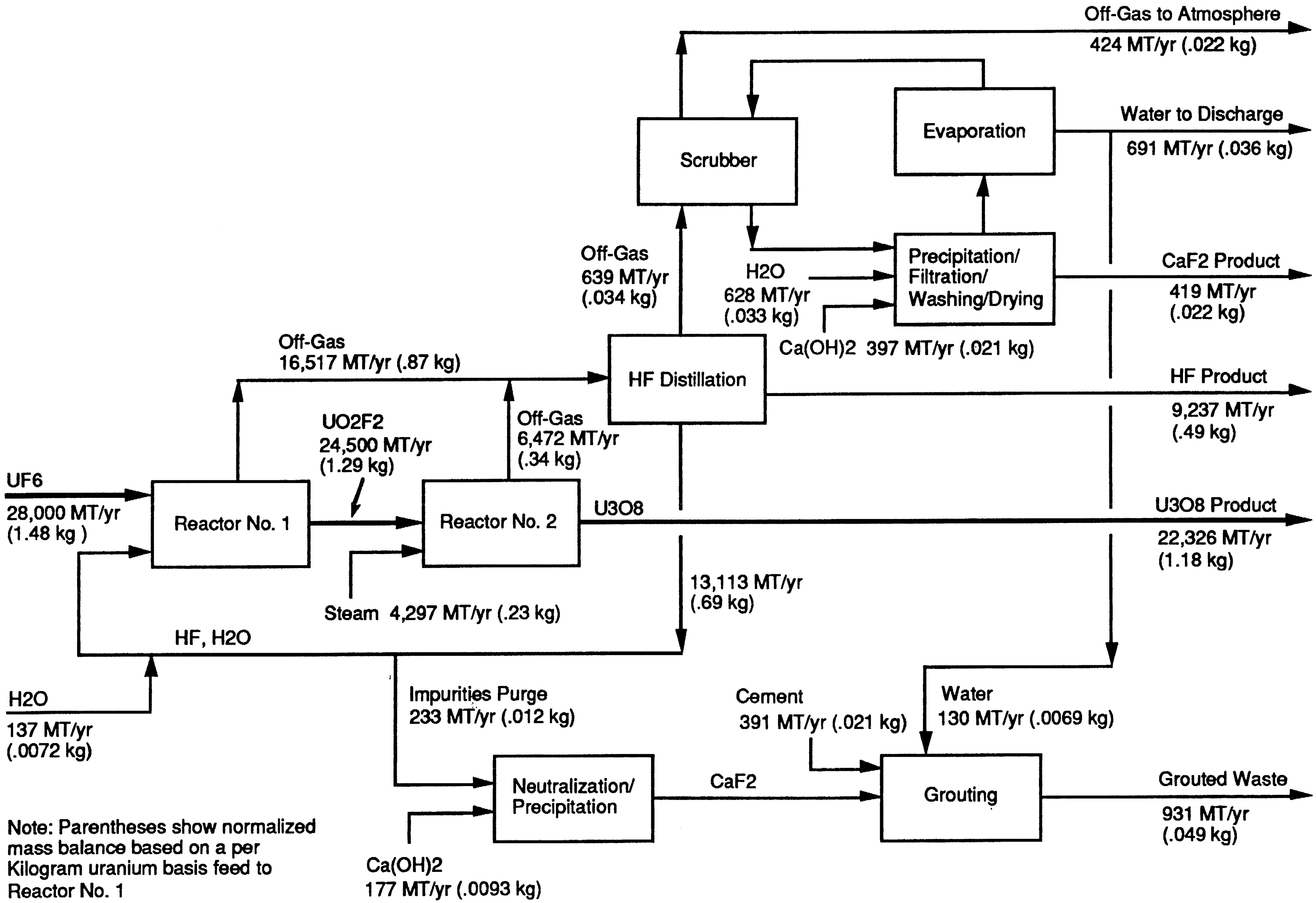


Figure 4-1 Defluorination / Anhydrous HF Block Flow Diagram

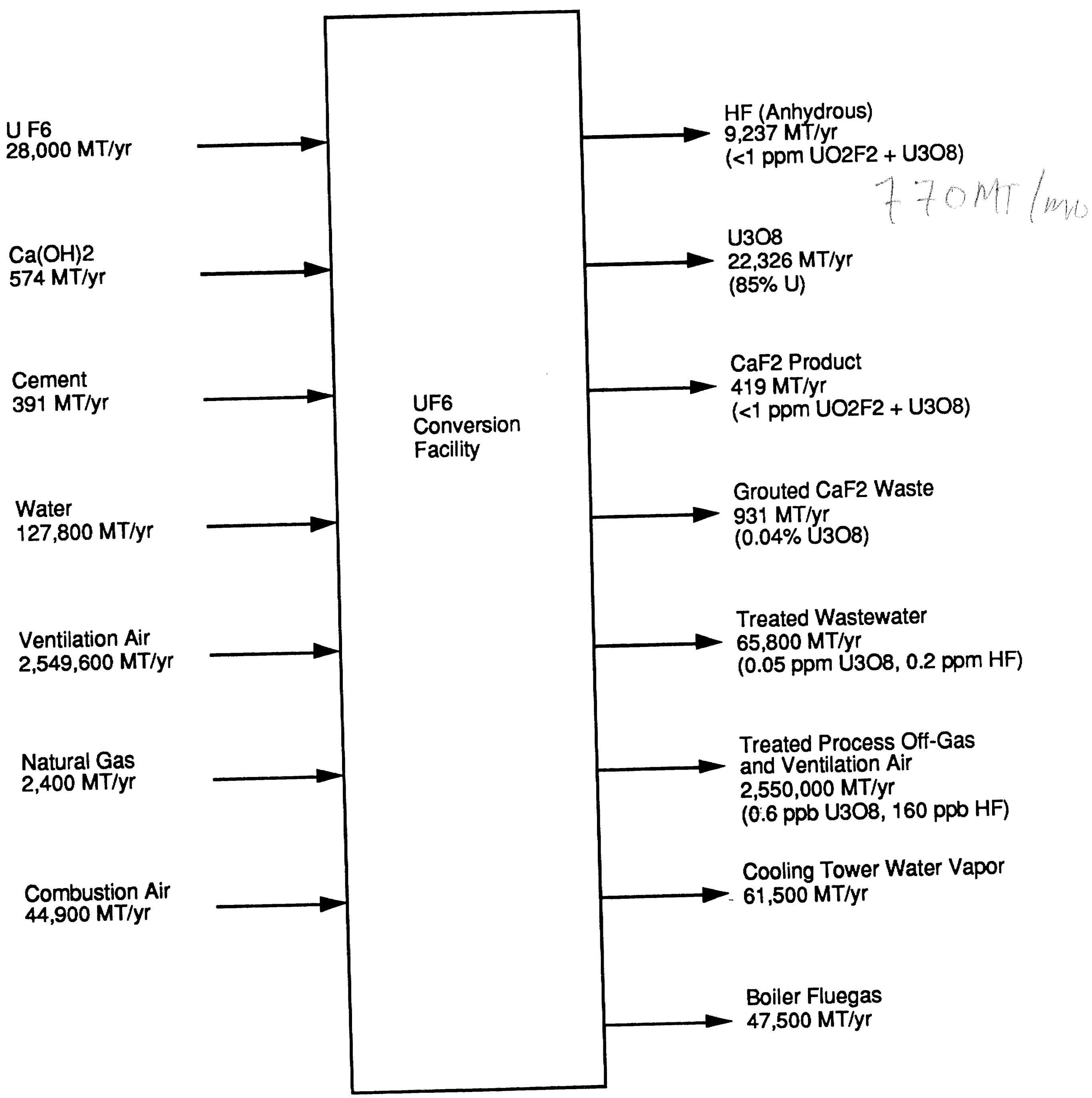


Figure 4-2 Defluorination / Anhydrous HF Input/Output Diagram

4.1 UF_6 CONVERSION REACTIONS

Reactor No. 1 converts UF_6 feed into UO_2F_2 and HF by hydrolysis in a fluidized bed. The chemical reaction is $UF_6 + 2\ H_2O \longrightarrow UO_2F_2 + 4\ HF$. This system is shown in Figure 4-3.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in a steam-heated autoclave and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is vaporized by heating, and gaseous UF_6 is fed by compressor into a fluidized bed reactor containing UO_2F_2 particles. Eleven cylinders simultaneously feed the required UF_6 feed rate of 8,800 lb/hr. The bottoms stream from HF distillation and makeup water are vaporized in a steam-heated exchanger. This 45% HF-water vapor enters the bottom of the reactor and acts as the fluidizing gas. Water vapor reacts with the UF_6 to form solid UO_2F_2 and gaseous HF. The reaction is exothermic, and cooling water is provided to maintain the reactor at about 550°F. A small heater is provided for reactor start-up.

The solid UO_2F_2 flows from this reactor to Reactor No. 2. The HF-water vapor flows through a cyclone and sintered metal filter to remove UO_2F_2 particulates, which are discharged back into the reactor. The HF-water vapor flows to the HF distillation column. A small purge stream is discharged from the vaporizer to prevent buildup of uranium and impurities. This stream is sent to the impurities neutralization system. After cooling, the empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

Reactor No. 2 converts UO_2F_2 into U_3O_8 and HF in a rotary kiln. The chemical reaction is $3UO_2F_2 + 3H_2O \longrightarrow U_3O_8 + 6HF + 0.5O_2$. This system is shown in Figure 4-4.

Solid UO_2F_2 from Reactor No. 1 flows into the rotary kiln, where it reacts with steam to form solid U_3O_8 and gaseous HF and O_2. The reaction is endothermic, and the kiln is indirectly heated with natural gas to maintain the temperature at about 900°F. The solid U_3O_8 is discharged from the reactor, cooled, compacted and granulated. It is assumed that the compaction results in a final U_3O_8 density of 3 g/cm^3. After filling, the drums are cleaned and transported to the warehouse for storage.

The HF, oxygen and water vapor flow through a cyclone and sintered metal filter to remove U_3O_8 particulates, which are discharged back into the reactor. The off-gas vapor flows to the HF distillation column.

Preliminary major equipment descriptions for the conversion process include 14 autoclaves and UF_6 compressors, two 3 ft-6 in diameter by 10 ft high Monel fluidized bed reactors, two 6 ft by 30 ft long Inconel rotary kilns, two 12 in by 8 ft long screw conveyor/coolers, a solids compactor / granulator and a drum loading station.

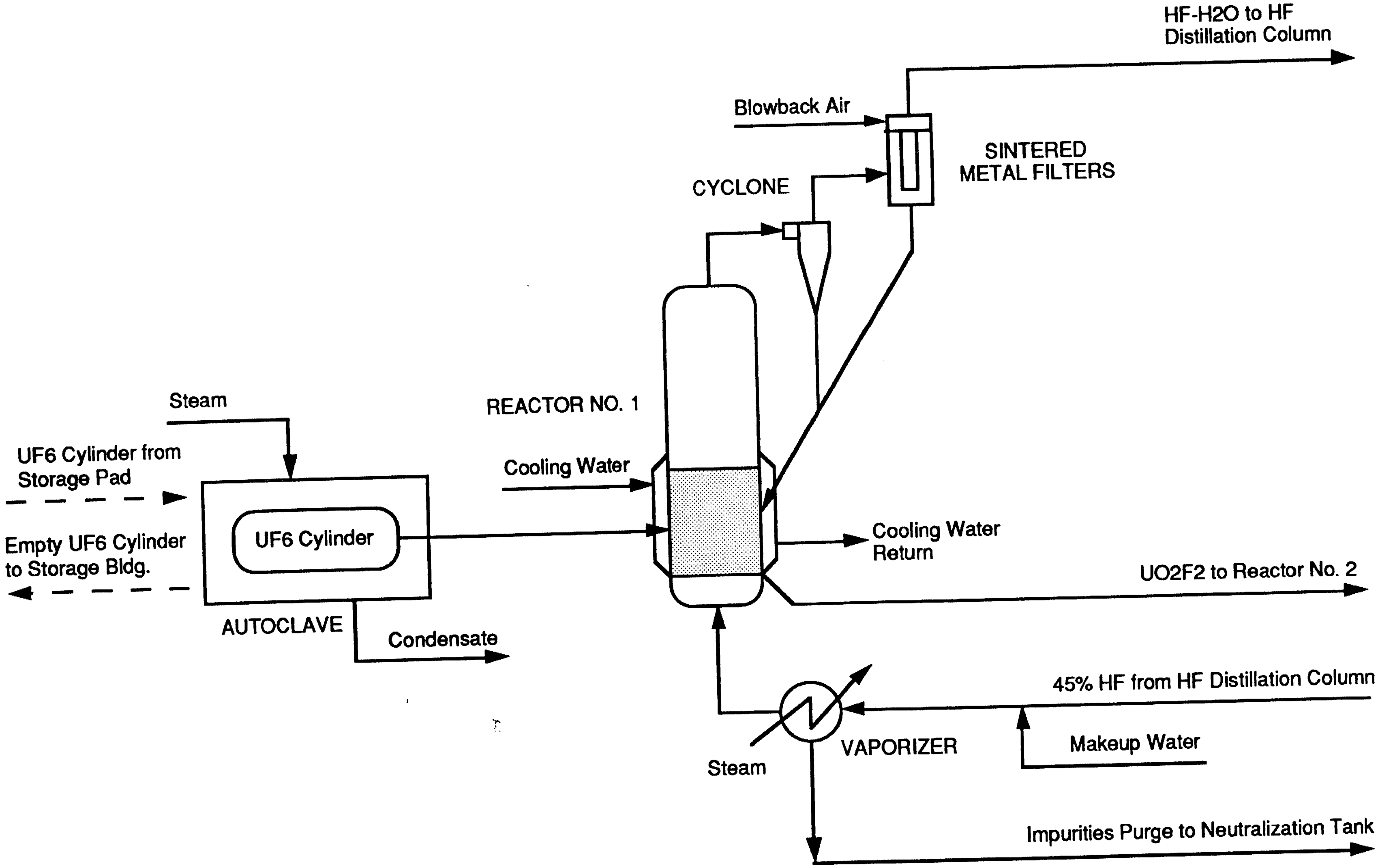


Figure 4-3 Reactor No. 1 Process Flow Diagram

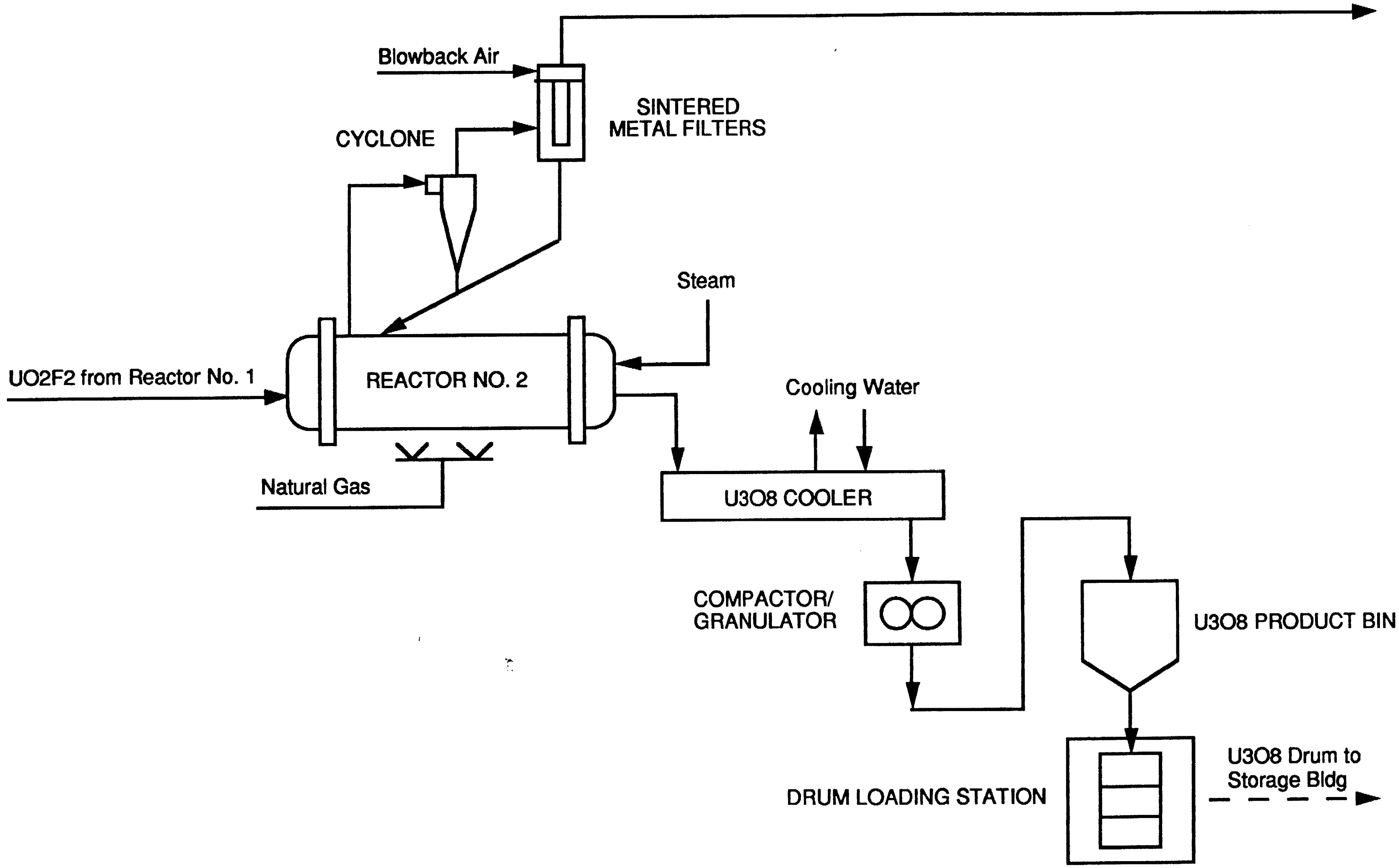


Figure 4-4 Reactor No. 2 Process Flow Diagram

4.2 HF DISTILLATION

The hot off-gas and vapor from the reactors flow to a distillation column for HF purification and recovery. The system is shown in Figure 4-5.

The vapor is first quenched with distillation column bottoms to cool the superheated vapor to its saturation temperature. The saturated vapor is fed to the column, which produces an anhydrous HF overhead product at 67°F containing about 200 ppm water, and a 45 wt% HF bottoms stream at 230°F that is recycled to Reactor No. 1.

The overhead product is condensed in a chilled water condenser at 40°F, collected and sampled. Upon satisfactory analysis, the HF is pumped through an underground pipeline to storage tanks in the HF storage building. The HF is then loaded into railroad tank cars or tank trucks for shipment to customers.

The noncondensible gases, primarily oxygen, pass through a -20°F refrigerated condenser to recover additional HF. The gases then flow to the HF scrubbing system.

Major process equipment for the HF distillation process includes a 4 ft-six in diameter by 23 ft high Monel distillation column, equipped with a 2 ft diameter by 6 ft high shell and tube reboiler, a 4 ft diameter by 12 ft long 3,500 ft^2 40°F condenser, a 2 ft diameter by 6 ft long 150 ft^2 -20°F condenser, and two 6 ft diameter by 14 ft long 3,000 gallon hold tanks equipped with cooling coils, and six 12 ft diameter by 45 ft long 38,000 gallon storage tanks.

4.3 HF SCRUBBING SYSTEM

Off-gas from HF Distillation is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The HF is recovered and converted to solid CaF_2 product for sale. The system is shown is Figure 4-6.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \rightarrow KF + H_2O$. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2KF + Ca(OH)_2 \rightarrow CaF_2 + 2KOH$. A minimum level of KF is maintained in the scrub solution by adding less then the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities and dried in a steam-heated rotary dryer. After cooling, the CaF_2 is packaged in drums and sent to the warehouse for storage. The KOH filtrate and spent wash water are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and

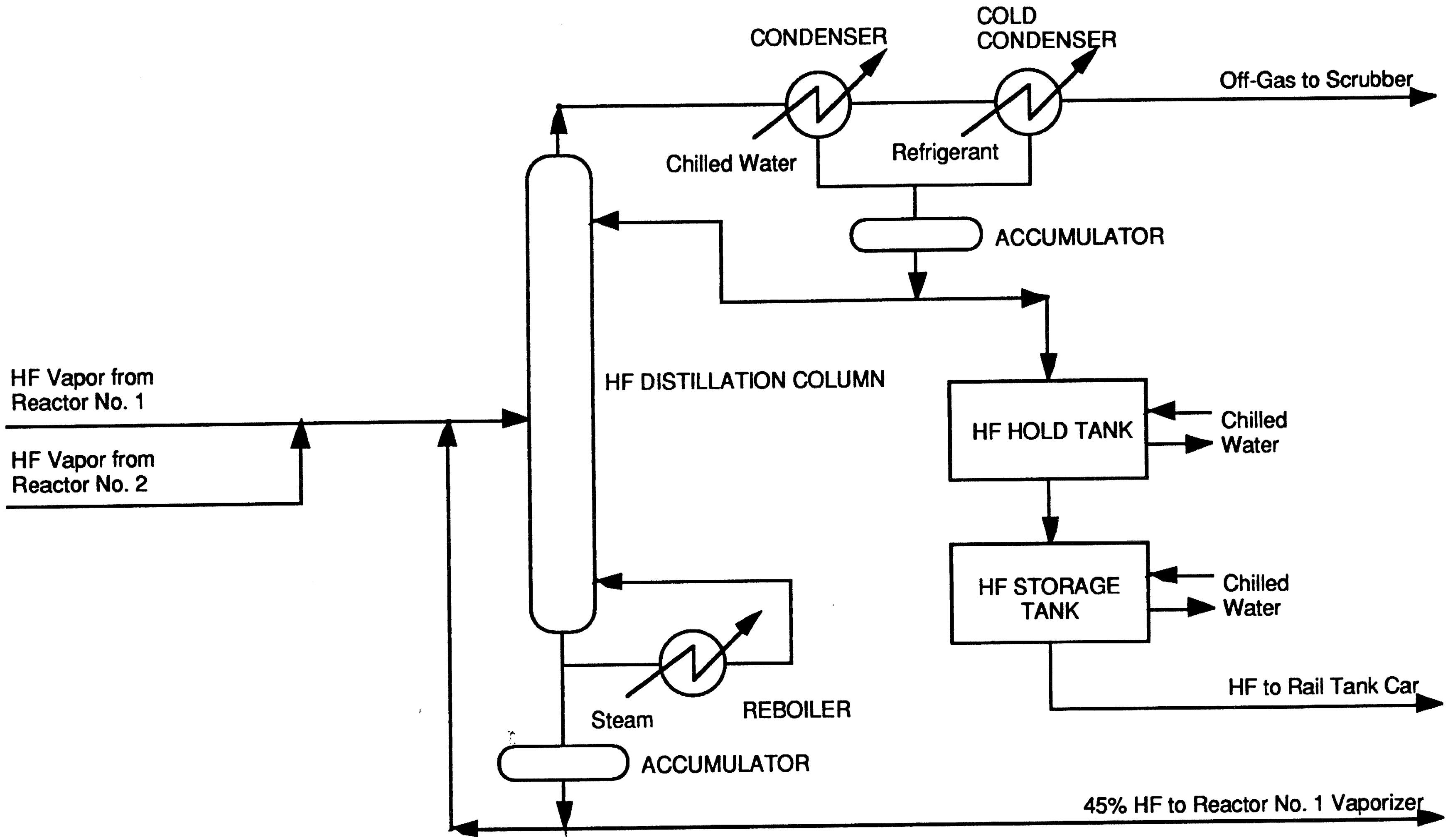


Figure 4-5 HF Distillation Process Flow Diagram

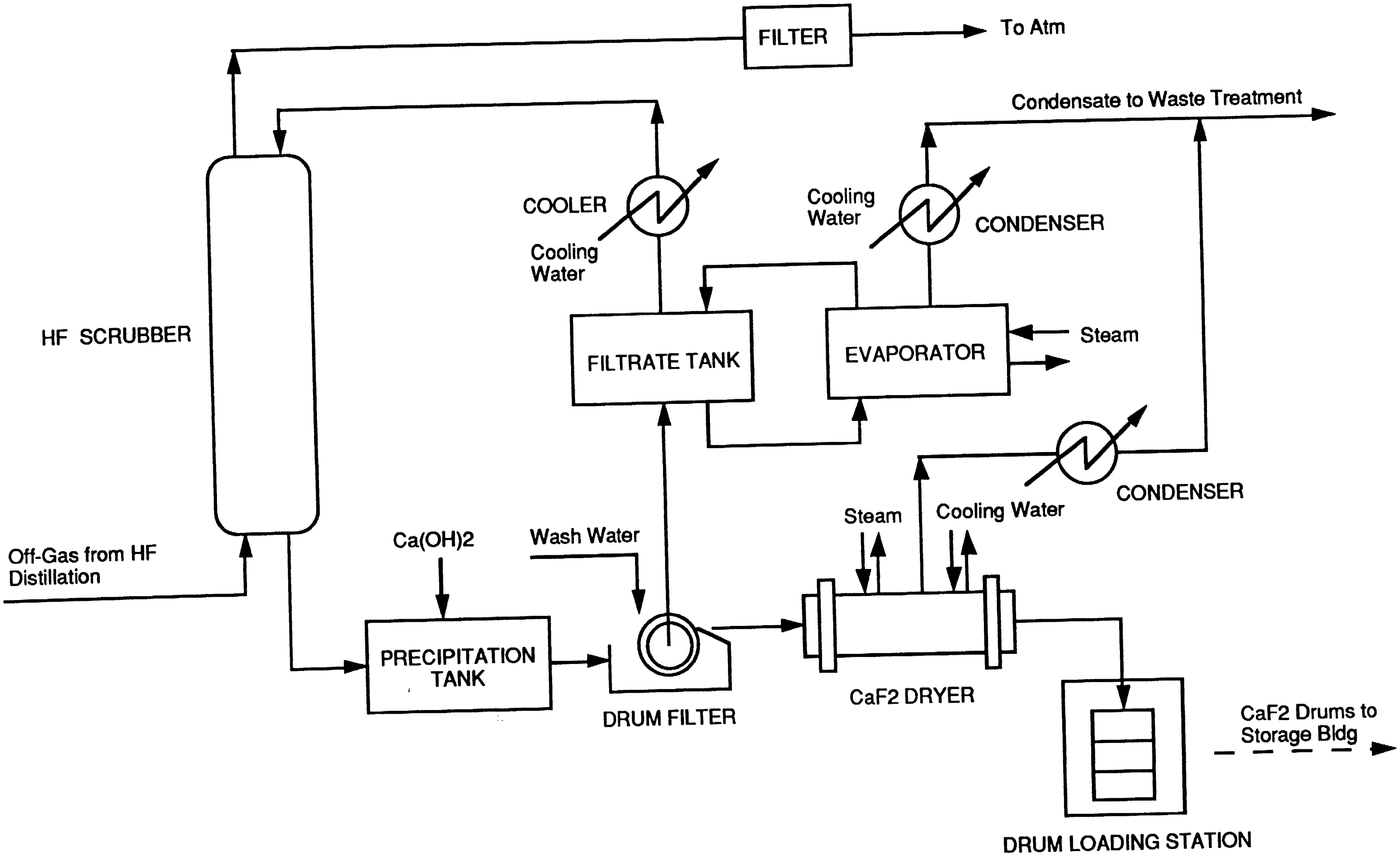


Figure 4-6 HF Scrubber Process Flow Diagram

the water added for CaF_2 washing. The scrub solution is then cooled and pumped back to the scrubber.

Major equipment includes a 1 ft diameter by 10 ft high Monel HF scrubber with plastic packing, 4 ft diameter by 5 ft high 450 gallon Monel precipitation and filtrate tanks, a 2 ft diameter by 6 ft long Monel drum filter, a 2 ft diameter by 4 ft high Monel evaporator/ condenser unit, a 1 ft-6 in diameter by 5 ft long rotary dryer and associated tanks and pumps.

4.4 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.5 WASTE MANAGEMENT

The primary wastes produced by the process are empty UF_6 cylinders and vaporizer blowdown liquid. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment. The treatment of blowdown wastes is shown in Figure 4-7.

The blowdown stream from the vaporizer to Reactor No. 1 is converted into a solid grout for disposal. The blowdown stream, containing HF, water, uranium and impurities, is neutralized with hydrated lime. The main reaction is $2HF + Ca(OH)_2 \longrightarrow CaF_2 + 2H_2O$. The slurry is then mixed with cement and water in a drum to form a grout. After solidification, the waste

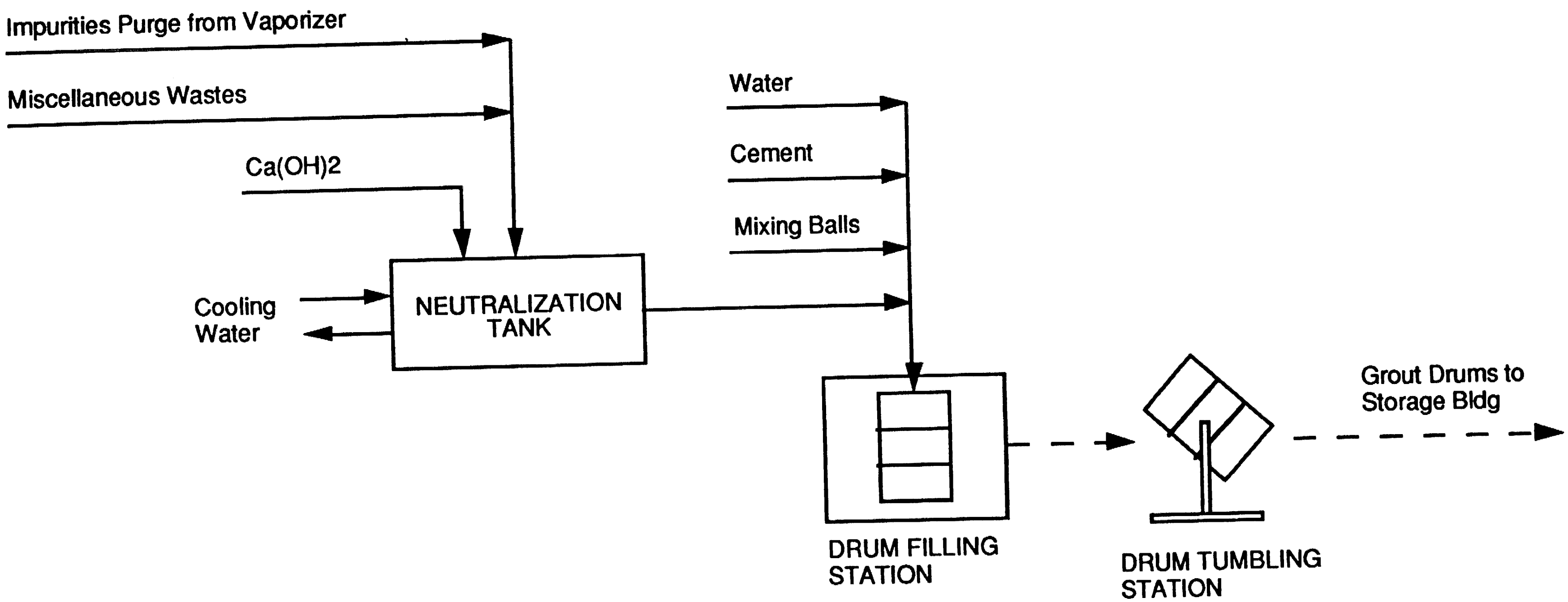


Figure 4-7 Waste Grouting Process Flow Diagram

drums are transported to the warehouse for storage, and then sent to a low level waste disposal site. The composition of the grout is 42% cement, 38% H_2O, 20% CaF_2, and 0.04% U_3O_8.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	11 GWh	1.5 MW
Liquid Fuel	6,000 gals	NA
Natural Gas[2]	118×10^6 scf	NA
Raw Water	34×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual DUF_6 Defluorination/AHF Conversion Facility Water Balance. This balance is based on the greenfield generic midwestern U.S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5–2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

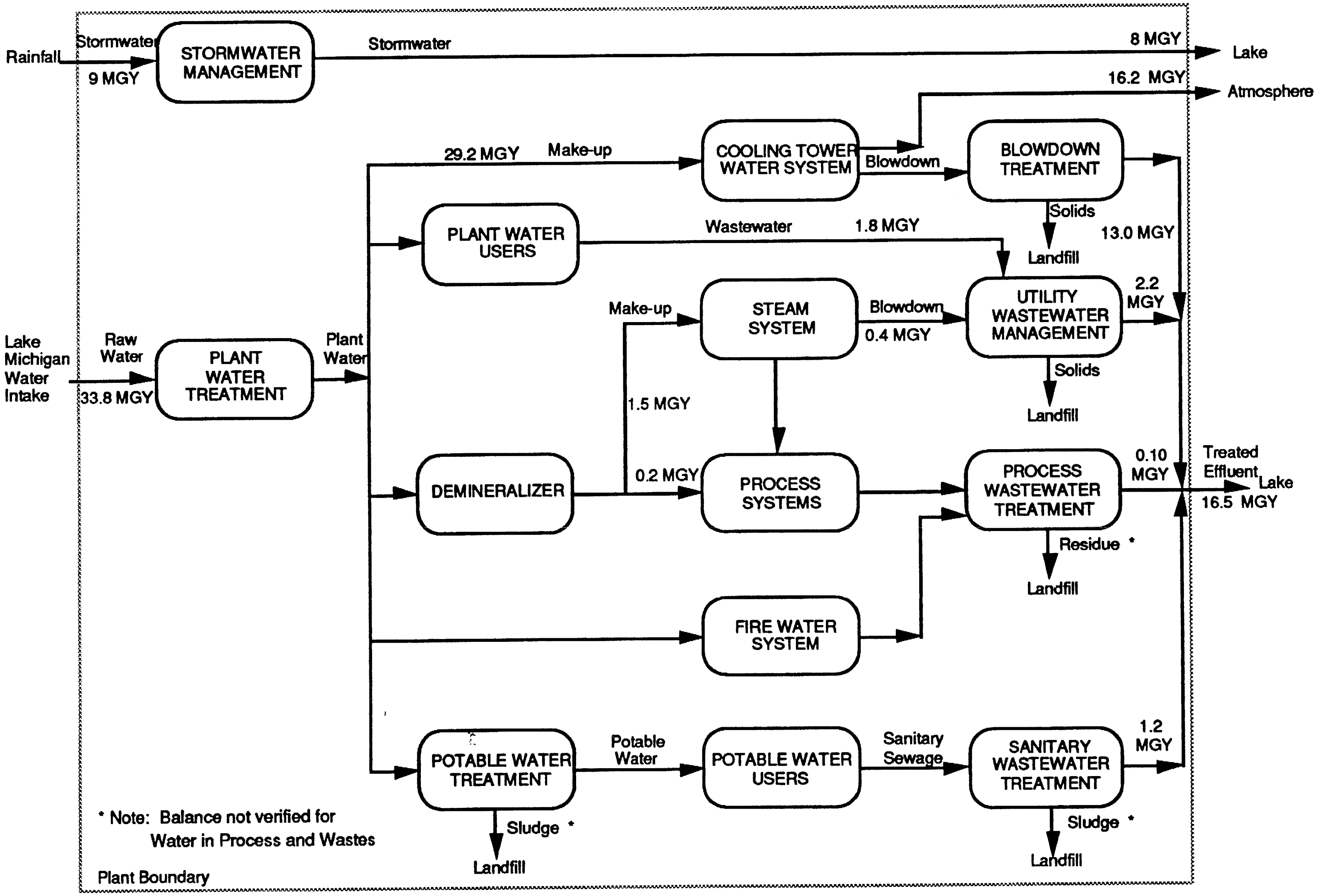


Figure 5-1 Preliminary Water Balance Defluorination / Anhydrous HF

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6).

The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14-ton DOT approved carbon steel containers.

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	**Quantity (lb/yr)**
Solid	
Calcium Hydroxide (Hydrated Lime)	1,270,000
Cement	862,000
Detergent	500
Liquid	
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	11,100
Sodium Hydroxide (50% NaOH)	8,800
Sodium Hypochlorite	3,200
Copolymers	5,400
Phosphates	550
Phosphonates	550
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (low-level radioactive and hazardous) Waste Containers (55 gallon drums & 56 ft^3 boxes - see also Table 9-1)	2,804 drums 20 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5–3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	30,000 MWh	1.5 MW
Water	8×10^6 gal	600 gal
Solids		NA
Concrete	18,000 yd^3	
Steel (carbon or mild)	6,000 tons	
Electrical raceway	20,000 yd	
Electrical wire and cable	50,000 yd	
Piping	30,000 yd	
Steel decking	20,000 yd^2	
Steel siding	10,000 yd^2	
Built-up roof	17,500 yd^2	
Interior partitions	1,500 yd^2	
Lumber	5,000 yd^3	
HVAC ductwork	100 tons	
Special coatings	4,000 yd^2	
Asphalt paving	250 tons	
Liquids		
Fuel[2]	1.5×10^6 gals	
Gases		
Industrial Gases (propane)	4,000 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used materials of construction (i.e. carbon steel, stainless steel, etc.) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for process equipment fabrication includes approximately 25 tons of Monel and 10 tons of Inconel 625.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 Employment Needs During Operation

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	6
Professionals	6
Technicians	29
Office and Clerical	20
Craft Workers (Maintenance)	10
Operators / Line Supervision	91/15
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	203

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 Employees at Risk of Radiological Exposure

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF (e.g., connecting the tank car loading hose), the operator will wear acid-resistant protective gear including a respirator.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4[1]
Process Building	33	24	24	24
HF Storage Building	2	1	1	1
U_3O_8 Storage Building	3	1	1	1
CaF_2 Storage Building	1	0	0	0
Cylinder Storage Pad & Building	7	3	3	3
Utilities/Services/Admin Areas	40	10	10	10
TOTAL EMPLOYEES	86	39	39	39

1 The 4th shift allows coverage for 7 days per week operations.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	250	420	170
Construction Management and Support Staff	30	50	80	30
TOTAL EMPLOYEES	200	300	500	200

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	70/50
Nitrogen Dioxide	Boiler Stack / Grade	9,600/380
Hydrocarbons	Boiler Stack / Grade	200/320
Carbon Monoxide	Boiler Stack / Grade	4,800/2,500
Particulate Matter PM-10	Boiler Stack / Grade	360/80
OTHER POLLUTANTS		
HF	Process Bldg. Stack	900
U_3O_8	Process Bldg. Stack	3.3
Copolymers	Cooling Tower	1,100
Phosphonates	Cooling Tower	110
Phosphates	Cooling Tower	110
Calcium	Cooling Tower	1,900
Magnesium	Cooling Tower	500
Sodium and Potassium	Cooling Tower	200
Chloride	Cooling Tower	350
Dissolved Solids	Cooling Tower	10,500

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	5.0×10^{-4}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	1.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (plastic, paper, cloth)	216,000	100	26 lb U3O8	370 55-gal drums
Metal,surface contaminated	Failed equipment	65,000	40	77 lb U3O8	148 55-gal drums
Noncombustible compactible solid	HEPA filters	7,600	41	637 lb U3O8	20 4x2x7 ft boxes (3/4" plywood)
Noncombustible noncompactible solid	Grouted waste See Sect. 4-5	2,053,000	609	821 lb U3O8	2,236 55-gal drums
Other	LabPack (chemicals plus absorbent)	3,500	2.2	4 lb U3O8	8 55-gal drums
Hazardous Waste					
Organics liquids	Solvents, oil, paint	4,500	3 (600 gal)	See description	11 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	8,100	5	8 lb HF 8 lb NaOH	19 55-gal drums
Combustible debris	Wipes, etc.	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb U3O8, 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb U3O8, 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb U3O8, 0.1 lb Acetone	2 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.3×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	500	15.3×10^6
Recyclable Wastes	200	-

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 WASTES AND EMISSIONS GENERATED DURING CONSTRUCTION

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7–5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	1.7
Nitrogen Dioxide	28
Hydrocarbons	8
Carbon Monoxide	190
Particulate Matter PM-10	40

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7–6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	50 yd^3
Hazardous Liquids	20,000 gals
Nonhazardous Solids	
Concrete	100 yd^3
Steel	30 tons
Other	800 yd^3
Nonhazardous Liquids	
Sanitary	3×10^6 gals
Other	1×10^6 gals

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The DUF_6 Conversion Facility buildings include areas with hazard categories of chemically high hazard (HH) for buildings containing DUF_6 and HF and radiologically moderate hazard (HC2) for buildings containing U_3O_8. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgement and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario,
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques,
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of the effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following systems, structures and components (SSC's) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing large inventories of HF because their rupture could release HF with unacceptable consequences.
- Vessels containing significant inventories of HF and UF_6 at elevated temperatures because their rupture could release HF or UF_6 with unacceptable consequences.
- The Process Building, HF Storage Building and U_3O_8 Building structures because they house large HF and uranium inventories or UF_6 at elevated temperatures, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	41 lb U_3O_8
Tornado	Extremely Unlikely	69 lb U_3O_8
Flood	Incredible	No Release
HF System Leak	Anticipated	216 lb HF
HF Pipeline Rupture	Unlikely	500 lb HF to soil
HF Storage Tank Overflow	Unlikely	45 lb HF
U_3O_8 Drum Spill	Anticipated	1.4×10^{-4} lb U_3O_8
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	22 lb HF

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	205,000 lb U_3O_8	2.0×10^{-4} (a)	1.0	30 min
Tornado	1,380 lb U_3O_8	0.05 (b)	1.0	30 sec
Flood	No Release	NA	NA	NA
HF System Leak	540 lb HF	1.0	0.4 (c)	15 min
HF Pipeline Rupture	500 lb HF	(d)	(d)	10 min
HF Storage Tank Overflow	830 lb HF	0.22 (e)	0.25 (f)	15 min
U_3O_8 Drum Spill	690 lb U_3O_8	2.0×10^{-4} (a)	1.0×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	22 lb HF	1.0	1.0	2 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).

2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).

3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on powder spill in NUREG-1320, *Nuclear Fuel Cycle Accident Analysis Handbook,* May 1988, p. 4.71. Also consistent with free-fall spill of powders in DOE-HDBK-0013-93, *Recommended Values and Technical Bases for Airborne Release Fractions, Airborne Release Rates and Respirable Fractions at DOE Non-Reactor Nuclear Facilities,* July 1993, p. 4-5.

b. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

c. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

d. Assume 100% of the HF drains into the ground at a point 3 ft below grade during a 10 minute period. The contaminated soil is removed after 48 hrs.

e. Airborne release fraction is .22 based on 0.06 lb/min-sq ft evaporation rate, 200 sq ft spill area and 15 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*, American Industrial Hygiene Association Journal, November 1974. Fraction in respirable range is 1.

f. Based on 3 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234 and Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about 2 months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium and hydrofluoric acid are the primary hazardous materials handled in this facility. Uranium is toxic and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

The HF Storage Building and selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where high inventory of HF or UF_6 at elevated temperatures is present. Therefore, it would be incredible if these structures failed in the event of the DBE.

The U_3O_8 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for these facilities would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,974 drums each containing 1,380 lb of U_3O_8. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum covers are lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Approximately 0.02% of this powder could be expected to become respirable airborne. Thus, approximately 41 lb of U_3O_8 is released to the environment. The release point is at grade.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building and the HF Storage Building are performance category PC-4 for structures for chemically high hazard facilities. These building areas are designed to resist the DBT for high hazard facilities. The DBTs defined for these structures would not result in a significant release from these structures. The U_3O_8 Storage Building is a category PC-3 structure for moderate hazard facilities. The DBT defined for this structure would withstand the DBT and not result in a significant release. However, in the extremely unlikely event of a DBT exceeding the PC-3 defined DBT or failure of PC-3 SSCs, a tornado wind-driven missile could impact a U_3O_8 storage drum and release the 1,380 lb inventory of the drum. It is assumed that all of the powder becomes airborne and 5% is in the respirable size range. Therefore, approximately 69 lb of respirable U_3O_8 is released during this extremely unlikely event. However, the powder will be highly dispersed due to tornado wind conditions.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF Distillation System Leak

Gaseous HF is produced from the conversion reactions. The HF is separated in a distillation column to form anhydrous (~100%) HF and 45 wt% HF in water. The boiling point of anhydrous HF is 67°F and that of 45 wt% HF is 230°F. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the distillation column overhead vapor line carrying anhydrous HF leaks 5% of its flowing contents for 10 minutes, thus releasing 540 lb of HF into the process building. After the leak is detected by air monitoring instruments, the distillation column operation and reactor feed are halted to stop the leak. It is assumed that 40% of the HF vapor (216 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 HF Pipeline Rupture

Anhydrous HF is pumped from the Process Building to the HF Storage Building through an underground pipeline. The pipe is double-walled to contain possible leakage and has a leak detection alarm. It is postulated that an earthquake ruptures the pipeline and its outer pipe. Assuming it takes 5 minutes to stop the HF pump, the pipeline is 200 ft of 1" pipe, and the pump runs at 10 gpm, it is estimated that approximately 60 gallons (500 lb) of anhydrous HF is released into the ground in a 10 minute period. The contaminated soil is removed after 48 hours. This accident has been judged to be unlikely.

8.1.3.4 HF Storage Tank Overflow

Anhydrous HF is stored in six 38,000-gallon tanks in the HF Storage Building. Each tank contains about 282,000 lb of HF. The tanks and building are cooled to about 50°F to minimize the HF that vaporizes if a spill should occur. The tanks are performance category PC-4, have high level alarms and interlocks that stop the transfer pump, and are diked to contain spillage. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

It is postulated that during filling, a storage tank overflows at 10 gpm for 10 minutes and releases 100 gallons (830 lb) of HF. The HF spills onto the floor and drains to a covered sump. The HF evaporates at a rate of 12 lb/min for 15 minutes, based on an evaporation rate of 0.06 lb/min-sq ft and a spill area of 200 sq ft. The building HVAC system discharges 25% of the HF vapor (45 lb) to atmosphere in a 15 minute period, based on 3 air changes/hr and a mixing factor of 0.33. The building HVAC system is then shut down to stop further releases to atmosphere and the building water spray system is activated to absorb HF vapor remaining in the building. The release point is the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.5 U_3O_8 Drum Spill

Solid U_3O_8 is produced and packaged in drums in the Process Building. The drums are transported and stored in the U_3O_8 Storage Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the storage building floor. A drum contains 1,380 lb U_3O_8 . It is assumed that 50% of the U_3O_8 is released from the drum and 0.02% becomes respirable airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne U_3O_8. Thus 0.00014 lb of U_3O_8 is discharged through the U_3O_8 Building HVAC exhaust to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.6 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a significant release to the environment.

8.1.3.7 Loss of Cooling Water

The distillation column and conversion reactors operate at pressures up to 15 psig. Pressure relief valves are provided to protect vessels and equipment. Loss of cooling water to the distillation column condenser would cause the pressure in the column to rise and the relief valve to open. The relief valve outlet is piped to a bed of limestone to neutralize the HF vapor (or a water quench tank to absorb the vapor) before discharging to atmosphere.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 1,100 lb of HF. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. Assuming that the limestone bed has a 98% removal efficiency for HF, about 22 lb of HF would be released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

9.0 Transportation

9.1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, U_3O_8 product in 55 gallon drums from the Process Building to the U_3O_8 Storage Building, and low level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car transport of byproduct anhydrous hydrofluoric acid from the HF Storage Building to the plant boundary. Hazardous waste materials such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, laboratory wastes, etc. requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary for shipment to off-site hazardous waste treatment, storage and disposal facilities.

9.2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product and waste materials is shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH) and hydrochloric acid (HCl). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium oxide (U_3O_8), hydrofluoric acid (HF), low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

The U_3O_8 product is packaged in 55 gallon steel drums that are 35 inches high by 22.5 inches outside diameter. The empty drum weighs 75 lbs and has a wall thickness of 0.053 inches (16 gage). Each drum contains 1,380 lbs of U_3O_8.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Output Material #1
Transported Materials				
Type	UF_6	HCl	NaOH	Uranium Oxide
Physical Form	Solid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	U_3O_8 / ambient
Packaging				
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	TBD
Container Weight (lb)	2,600	50	50	75
Material Weight (lb)	27,000	540	660	1,380
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% U_3O_8
Shipments				
Average Volume (ft^3)/Year	323,000	154	95	262,400
Packages/Year	2,322	21	13	35,700
Packages/Life of Project	46,440	420	260	714,000
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	11	7	28 (truck) or 80 (railcar), 4 cars/train
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	1,275 (truck) or 112 (rail)
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	25,500 (truck) or 2,240 (rail)
Form of Transport/Routing				
Form of Transportation	Truck/Rail	Truck	Truck	Truck/Rail
Destination - Facility Type	NA	NA	NA	TBD

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #2	Output Material #3	Output Material #4	Output Material #5	Output Material #6
Transported Materials					
Type	Hydrofluoric Acid	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Liquid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition/ Temperature, Pressure	HF / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	Rail Tankcar 11,000 gal	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	105A-300-W	Varies	Varies	Varies	48G
Container Weight (lb)	TBD	50/300	50	50	2,600
Material Weight (lb)	84,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% HF	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	358,000	21,400	265	44	323,000
Packages/Year	243	2,762/20	36	6	2,322
Packages/Life of Project	4,860	55,240/400	720	120	46,440
Packages/Shipment	12 railcars/ train	40/10	18	6	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	20	69/2	2	1	387 (truck) or 49 (rail)
Shipments/Life of Project	400	1,380/40	40	20	7,740 (truck) or 980 (rail)
Form of Transport/Routing					
Form of Transportation	Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	Customer	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
atm	atmosphere
CaF_2	calcium fluoride
CAR	Cost Analysis Report
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft^2	square feet
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt hour(s) (1×10^9 watt-hour)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement

psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

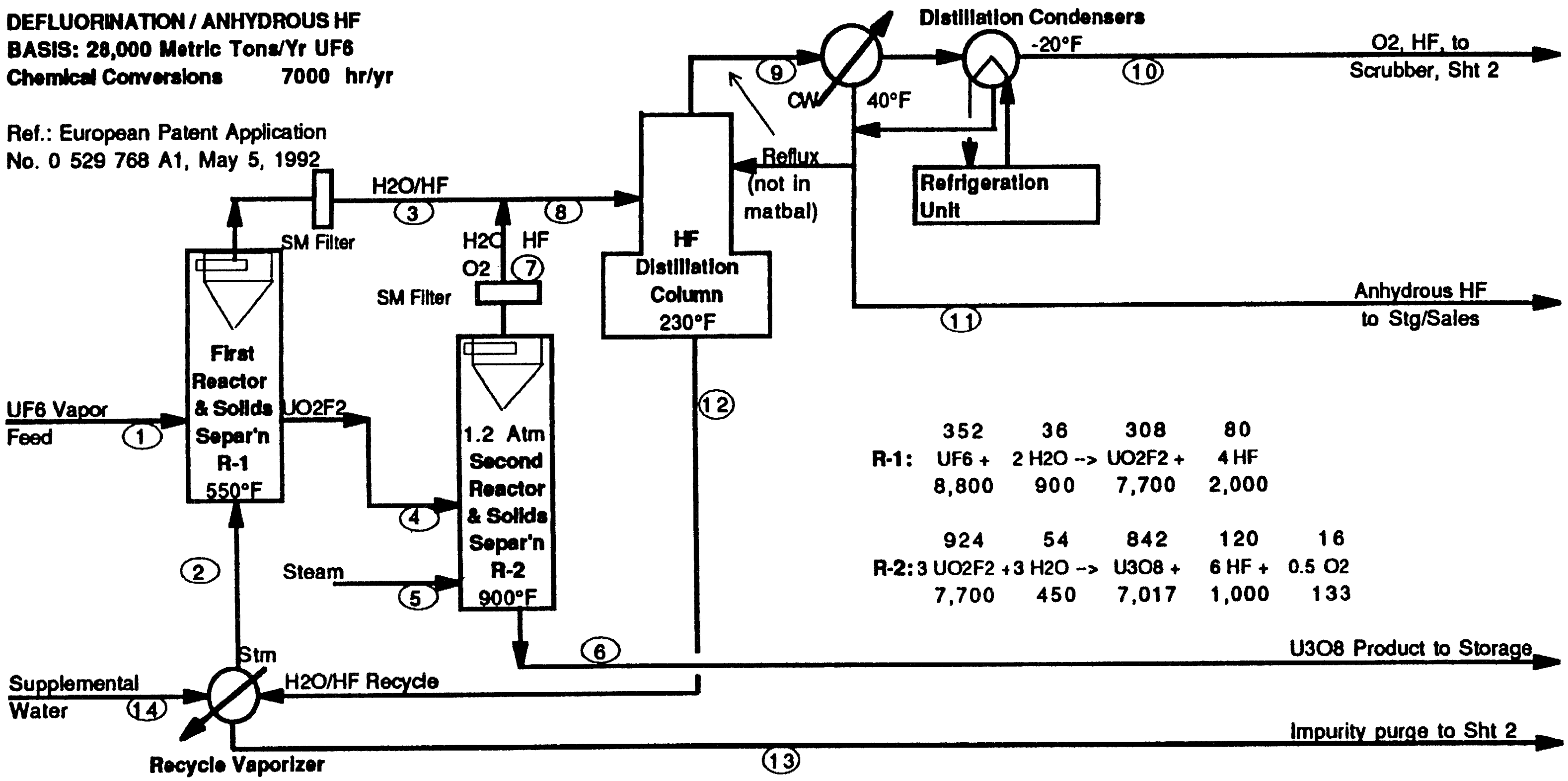
Appendix A

Material Balance

1-Mass Balance lb/hr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Chemical Conversions 7000 hr/yr

Ref.: European Patent Application No. 0 529 768 A1, May 5, 1992



	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
UF6	352	8,800															
UO2F2	308				7,700												
U3O8	842						7,017										
HF	20		1,841	3,841				1,000	4,841	2,970	68	2,902	1,871	30		0.1	
H2O	18		2,250	1,350		1,351		901	2,251	1	0	1	2,250	43	43	0	3,349
O2	32							133	133	133	133					133	
KOH	56																236
KF	58																20
Impurities													trace	trace			
Total lb/hr		8,800	4,091	5,191	7,700	1,351	7,017	2,034	7,225	3,104	201	2,903	4,121	73	43	133	3,605
kg/kg U		1.48	0.69	0.87	1.29	0.23	1.18	0.34	1.21	0.52	0.034	0.49	0.69	0.012	0.0073	0.022	0.61

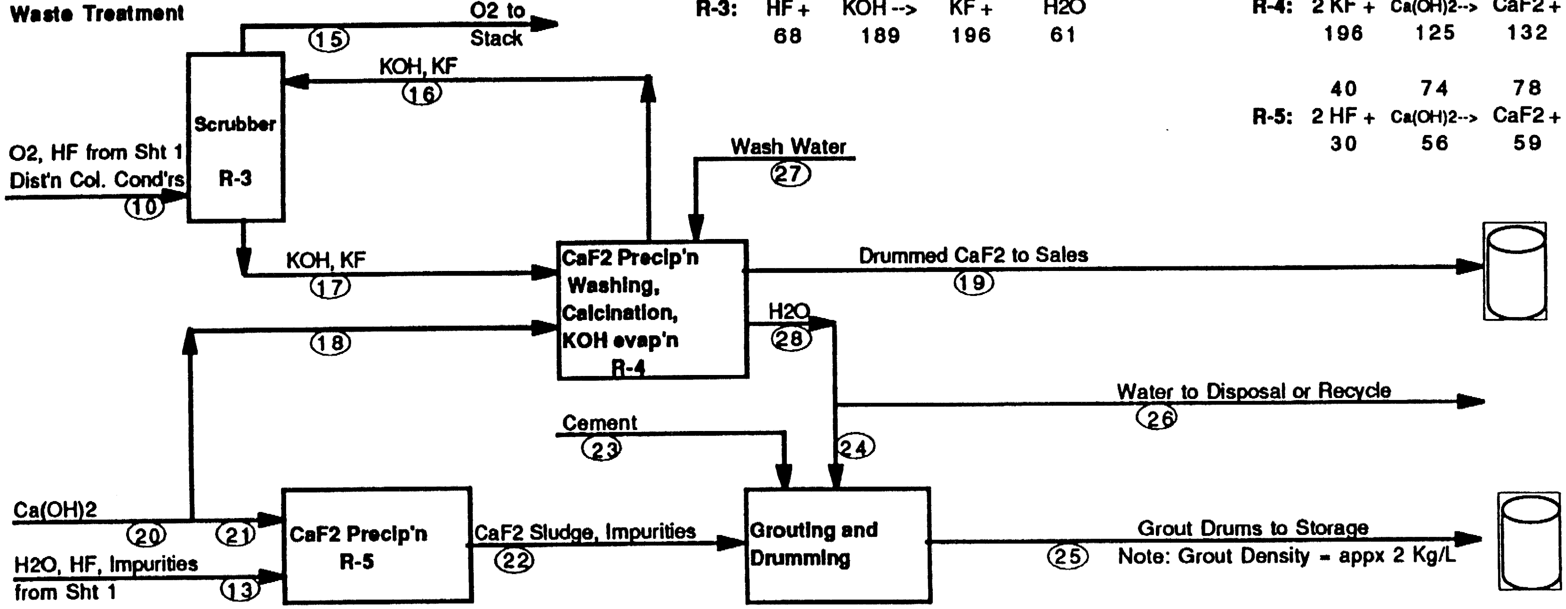
1-Mass Balance lb/hr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Waste Treatment

	20	56	58	18
R-3:	HF +	KOH -->	KF +	H2O
	68	189	196	61

	116	74	78	112
R-4:	2 KF +	Ca(OH)2-->	CaF2 +	2 KOH
	196	125	132	189

	40	74	78	36
R-5:	2 HF +	Ca(OH)2-->	CaF2 +	2 H2O
	30	56	59	27

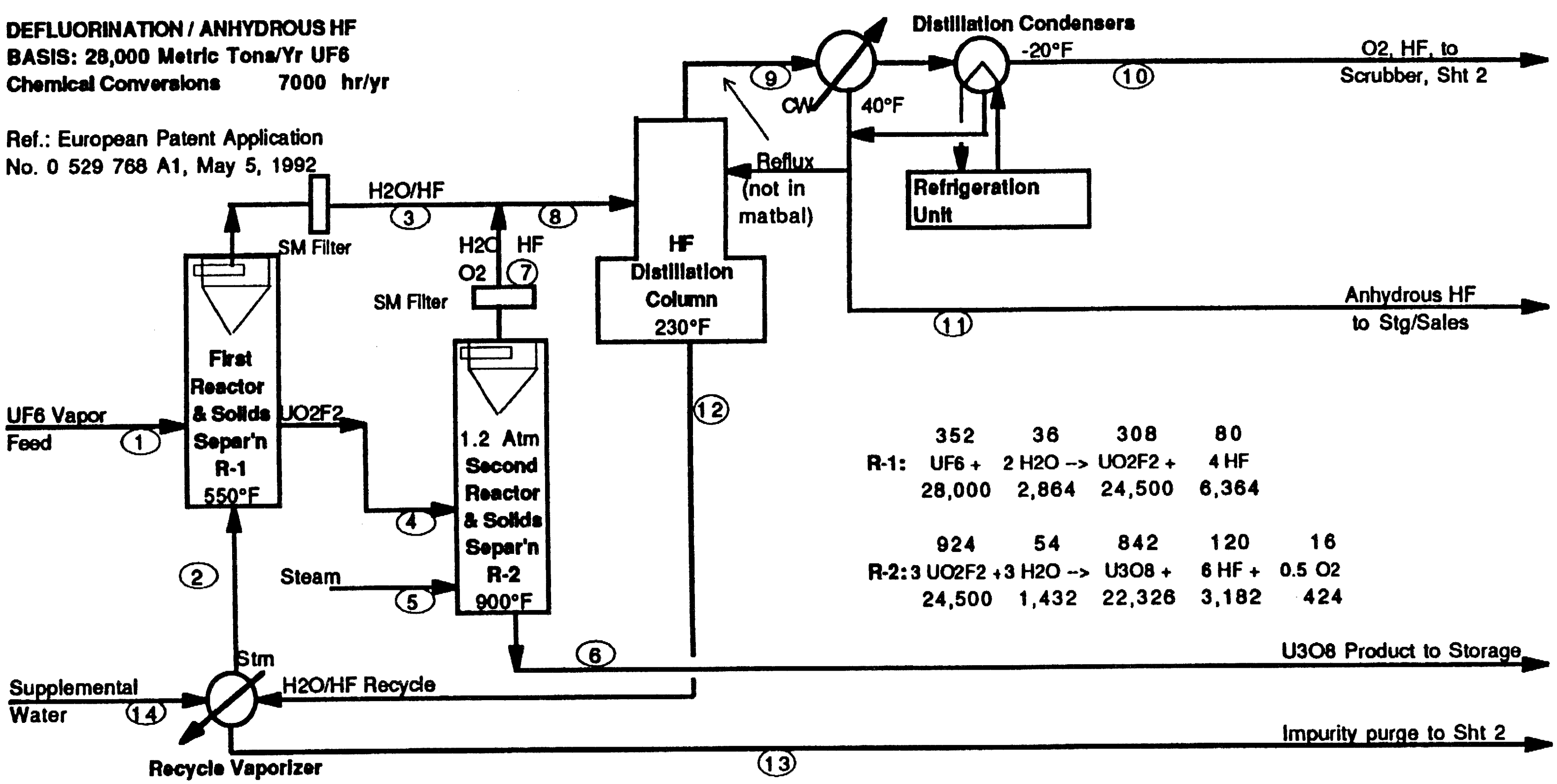


	Mol Wt	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Cement								123		123							
KOH	56	47															
KF	58	215															
Ca(OH)2	74		125		180	56											
CaF2	78			132			59			59							
HF	20									0							
H2O	18	3,409					70		41	111	217	197	258				
O2	32																
Impurities	na						trace			trace							
Total lb/hr		3,672	125	132	180	56	129	123	41	293	217	197	258				
kg/kg U		0.62	0.021	0.022	0.030	0.0093	0.022	0.021	0.0069	0.049	0.037	0.033	0.043				

1-Mass Balance MT/yr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Chemical Conversions 7000 hr/yr

Ref.: European Patent Application
No. 0 529 768 A1, May 5, 1992

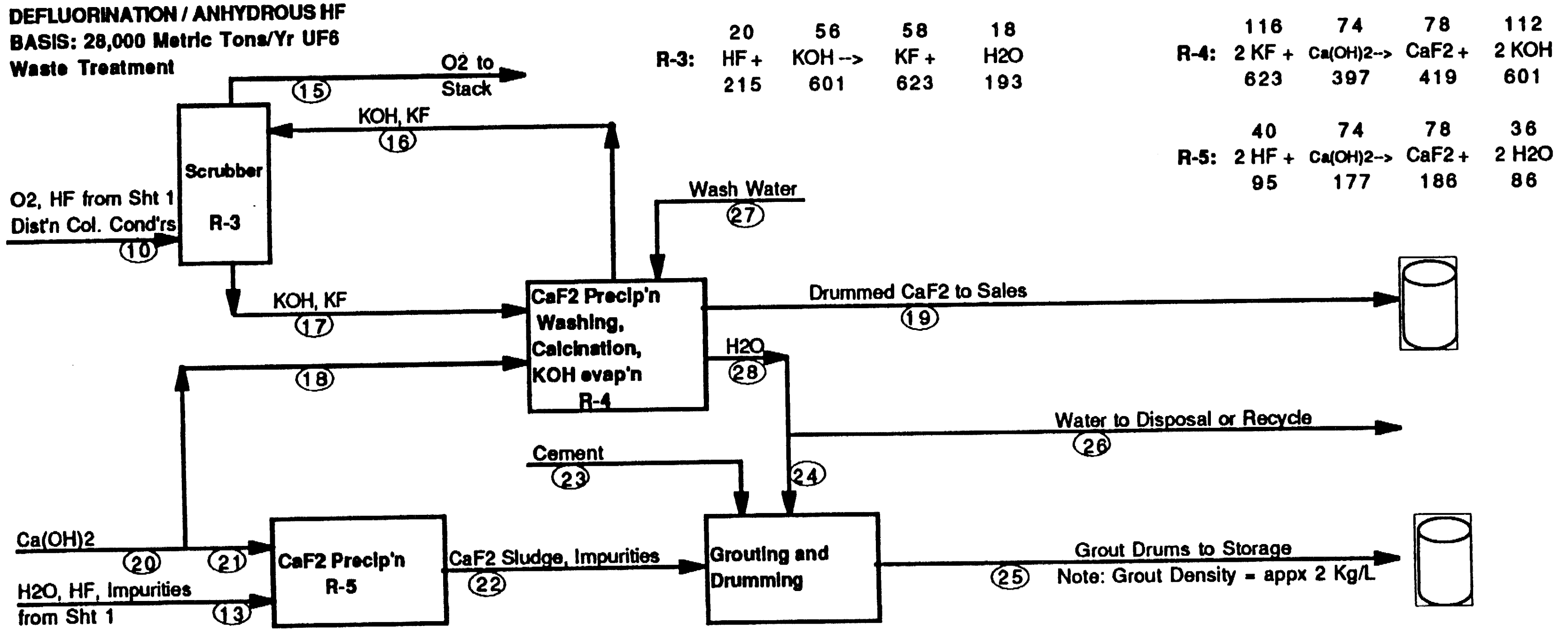


	352	36	308	80	
R-1:	UF_6 +	2 H_2O -->	UO_2F_2 +	4 HF	
	28,000	2,864	24,500	6,364	
	924	54	842	120	16
R-2:	3 UO_2F_2 +	3 H_2O -->	U_3O_8 +	6 HF +	0.5 O_2
	24,500	1,432	22,326	3,182	424

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
UF6	352	28,000															
UO2F2	308				24,500												
U3O8	842						22,326										
HF	20		5,857	12,221				3,182	15,403	9,450	215	9,235	5,953	95		0.2	
H2O	18		7,159	4,295		4,297		2,865	7,161	2	0	2	7,159	137	137	0	10,655
O2	32							424	424	424	424					424	
KOH	56																752
KF	58																62
Impurities													trace	trace			
Total MT/yr		28,000	13,017	16,517	24,500	4,297	22,326	6,472	22,988	9,876	639	9,237	13,112	233	137	424	11,469
kg/kg U		1.48	0.69	0.87	1.29	0.23	1.18	0.34	1.21	0.52	0.034	0.49	0.69	0.012	0.0073	0.022	0.61

1-Mass Balance MT/yr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Waste Treatment



	Mol Wt	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Cement								391		391							
KOH	56	150															
KF	58	685															
Ca(OH)2	74		397		574	177											
CaF2	78			419			186			186							
HF	20									0							
H2O	18	10,848					223		130	354	691	628	822				
O2	32																
Impurities	na						trace			trace							
Total MT/yr		11,684	397	419	574	177	409	391	130	931	691	628	822				
kg/kg U		0.62	0.021	0.022	0.030	0.0093	0.022	0.021	0.0069	0.049	0.037	0.033	0.043				

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Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Defluorination / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclaves (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressors (14)	800 lb/hr UF6, 15 psig discharge press.	Proc. Bldg
Reactor No. 1 (2)	3'6"Dx10'H fluidized bed, cooling jacket Monel	Proc. Bldg
Screw Conveyor (2)	Monel, 6"Dx10'L, 40 cfh	Proc. Bldg
Reactor No. 2 (2)	6'Dx30'L rotary kiln, indir. heat'g, Inconel	Proc. Bldg
Vaporizer (2)	2'Dx6'L, 150 sq ft, Monel tubes, stl shell	Proc. Bldg
U3O8 Product Cooler (2)	12"Dx8'L, screw conveyor with cooling water, steel, 40 cfh	Proc. Bldg
U3O8 Bucket Elevator No. 1 (2)	20'H, 40 cfh	Proc. Bldg
U3O8 Roller Compactor	80 cfh	Proc. Bldg
U3O8 Granulator	40 cfh	Proc. Bldg
U3O8 Bucket Elevator No. 2	20'H, 40 cfh	Proc. Bldg
U3O8 Product Bin	4'Dx8'H, 80 cf, steel	Proc. Bldg
U3O8 Drum Filling Station	5.1 drums/hr, glovebox	Proc. Bldg
U3O8 Dust Collector	baghouse	Proc. Bldg
HF Distillation Column	4'6"Dx24'H, Monel	Proc. Bldg
Reboiler	2'Dx6'H, 150 sq ft, Monel tubes, steel shell	Proc. Bldg
40°F Condenser	4'Dx12'L, 3500 sq ft, Monel tubes, steel shell	Proc. Bldg
-20°F Condenser	2'Dx6'L, 150 sq ft, Monel tubes, steel shell	Proc. Bldg
Reflux Drum	3'Dx4'L, Monel	Proc. Bldg
Reflux Pump	135 gpm, Monel	Proc. Bldg
30°F Chiller	9.3 MMBTU/hr, 750 hp	Proc. Bldg
-30°F Chiller	54,000 BTU/hr, 15 hp	Proc. Bldg
Bottoms Pump	10 gpm, Monel	Proc. Bldg
HF Hold Tanks (2)	6'Dx14'L, 3000 gal, cooling coils, steel	Proc. Bldg
HF Transfer Pump	10 gpm, bronze	Proc. Bldg
HF Bulk Storage Tanks (6)	12'Dx45'L, 38,000 gal, cooling coils, steel	HF Bldg
HF Loading Pump	25 gpm, bronze	HF Bldg
Off-Gas Scrubber	1'Dx10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
Off-Gas HEPA Filters (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhausters (2)	100 scfm	Proc. Bldg
Lime Feed Bin	3'Dx7'H, 40 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 132 lb/hr	Proc. Bldg
Precipitation Tank	4'Dx5'H, 450 gal, Monel	Proc. Bldg
Drum Filter	2'Dx6'L, 40 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 scfm	Proc. Bldg
Filtrate Tank	4'Dx5'H, 450 gal, Monel	Proc. Bldg
Scrub Solution Cooler	2'Dx4'L, 50 sq ft, Monel tubes, st'l shell	Proc. Bldg
Scrub Solution Pump	8 gpm, Monel	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
Evaporator	2'Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	2'Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
		Proc. Bldg
Evaporator Condensate Tanks (2)	5'Dx5'H, 750 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
CaF2 Screw Conveyor	6"Dx10'L, steel	Proc. Bldg
CaF2 Rotary Dryer	1'6"Dx5'L, steel	Proc. Bldg
CaF2 Drum Filling Station	0.2 drum /hr glovebox	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg
Impurities Neutralization Tank (2)	5'Dx5'H, 750 gal, cooling jacket, Monel	Proc. Bldg
Lime Feed Bin	3'6"Dx7'H, 50 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 2000 lb/hr	Proc. Bldg
Neutralized Waste Feed Pump	5 gpm, 316 SS	Proc. Bldg
Cement Feed Bin	4'Dx10'H, 90 cf, steel	Proc. Bldg
Cement Feeder	6"Dx6'L screw feeder, steel	Proc. Bldg
Grout Mixing/Drum Tumbling Station		Proc. Bldg
Cement Silo	7'Dx23'H, 700 cf, steel	Yard
Cement pneumatic conveyor	4 tons / hr	Yard
Lime Silo	8'Dx31'H, 1400 cf, steel	Yard
Lime pneumatic conveyor	2 tons / hr	Yard
SUPPORT SYSTEMS		
Process Material Handling Systems	<u>DUF_6 cylinder handling:</u>	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated carbon steel storage racks for 14-ton DUF_6 cylinders	Proc. Bldg
	Two (2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	<u>U_3O_8 drum handling:</u>	
	-3 flatbed trucks	Yard
	-3 55 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg/ U_3O_8 Bldg
	-3 forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ U_3O_8 Bldg
	<u>Grouted waste & CaF_2 handling:</u>	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ CaF_2 Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U_3O_8 drum handling, waste grouting / LLW packaging and CaF_2 drum handling areas	Proc. Bldg
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms & controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg / Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-6 local sampling glove boxes with lab liquid / powder sample hardware	Proc. Bldg
	-Complete analytical lab equipped with laboratory hoods, sinks, cabinets, analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste evaporator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U_3O_8 drums	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U_3O_8 tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 16,000 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2 @ 300 cfm 150 psig	Util. Bldg
	Breathing air compressors 2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, minus 40°F dew point	Util. Bldg
	Demineralized water system - 5000 gpd	Util. Bldg
	Sanitary water treatment system - 3300 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 50,000 gpd	Wastewater Treatment area
	Electrical substation - 1500 kW	Substation
	Emergency generators - 2 @ 300kW	Substation
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 19 MM Btu/hr, 1900 gpm	Yard

MAJOR EQUIPMENT LIST (Continued)
Defluorination / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-2000 cfm, 10 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-40,000 cfm, 75 HP exhaust fans, 2-40,000 cfm 75 HP supply air units	U_3O_8 Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	3-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, 2-10,000 cfm, 15 HP supply air units	Grout Areas CaF_2 Areas Waste Proc'g Control Room Support Areas
HF Area HVAC	2-20,000 cfm, 20 HP exhaust fans, 2-20,000 cfm, 20 HP supply air units, Emergency shutdown on HF leak	HF Areas
HVAC Chillers	3-250 ton chillers	Proc. Bldg
Circulating Pumps	3-400 gpm, 15 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

DEFLUORINATION / ANHYDROUS HF - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	30	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	21	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	21	6	Steel	1/4"	3483.0
UO2F2 reactor surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
U3O8 reactor surveillance	1	0.50	1752	7	3	Inconel	1.5"	876.0
U3O8 compactor surveillance	1	0.50	1752	8,9	3	Steel	1/4"	876.0
Transfer U3O8 drums to interim storage	2	0.50	7137	10,11	3	Steel	0.06"	7137.0
Transfer U3O8 drums to storage building	2	0.50	7137	10,11	3	Steel	0.06"	7137.0
Load U3O8 drums for shipment offsite	1	1.00	1200	10,13	3	Steel	0.06"	1200.0
U3O8 interim storage surveillance	1	0.50	2190	10,14	3	Steel	0.06"	1095.0
U3O8 storage building surveillance	1	0.50	2190	10,15	3	Steel	0.06"	1095.0
HF distillation surveillance	1	0.50	1752	6,7	30	Monel,Inconel	3/4",1.5"	876.0
HF loading for shipment offsite	2	10.00	243	15	150	Steel	0.06"	4860.0
HF building surveillance	1	0.50	2190	15	150	Steel	0.06"	1095.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS
Off-gas Scrubbing / Process Liquid Treat. surveillance	1	0.50	1752	8,9	20	Steel	1/4"	876.0
CaF2 processing surveillance	1	0.50	1752	12,16	3	Steel	1/4",0.06"	876.0
Waste grouting surveillance	1	0.50	1752	8,9	3	Steel	0.06"	876.0
Transfer grouted drums to storage area	2	0.50	320	12	3	Steel	0.06"	320.0
Load grouted drums for shipment offsite	1	1.00	56	8,9	3	Steel	0.06"	56.0
Transfer CaF2 drums to interim storage	2	0.50	165	6,7	75	Monel,Inconel	3/4",1.5"	165.0
Transfer CaF2 drums to storage area	2	0.50	165	6,7	70	Monel,Inconel	3/4",1.5"	165.0
Load CaF2 drums for shipment offsite	1	1.00	29	6,7	108	Monel,Inconel	3/4",1.5"	29.0
CaF2 interim storage surveillance	1	0.50	2190	6,7	75	Monel,Inconel	3/4",1.5"	1095.0
CaF2 storage building surveillance	1	0.20	2190	15	30	Steel	0.06"	438.0
LLW processing, packaging, and shipping	2	8.00	1100	20	3	Steel	0.06"	17600.0
Process control room operations	8	8.00	1100	10,14	30	Steel	0.06"	70400.0
Laboratory operations	4	8.00	1100	8,9	30	Steel	1/4"	35200.0
HP	2	8.00	1100	10,14	30	Steel	0.06"	17600.0
Management / Professionals	12	8.00	250	6,7	30	Monel,Inconel	3/4",1.5"	24000.0
Accountability	2	2.00	1100	3,4,15	3	Steel	1/4",0.06"	4400.0
Industrial and sanitary waste treatment	4	8.00	1100	2,5	50	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	6,7	120	Monel,Inconel	3/4",1.5"	35200.0
Administration	20	8.00	250	2,5	100	Steel	1/4"	40000.0
Guardhouses / Process Bldg.	5	8.00	1100	2,5	100	Steel	1/4"	44000.0
Maintenance								14556.0
								400268.6

Case 1 Ops; Page 2

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) U3O8 Compactor feed bin; there are 2 bins.
9) U3O8 drum fill bin.
10) Drum of U3O8.
11) Each transfer consists of 5 U3O8 drums.
12) Drum of grouted waste.
13) There are 30 U3O8 drums per shipment.
14) There are 120 U3O8 drums in interim storage
15) There are 3,000 U3O8 drums in the storage building.
16) Each transfer consists of 7 CaF2 (or grouted waste) drums
17) There are 40 CaF2 (or grouted waste) drums per shipment
18) 2322 UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    35683 U3O8 drums/yr / 5 drums per transfer = 7137 transfers per year
    35683 U3O8 drums/yr / 30 drums per transfer = 1200 shipments per year
    243 railcars/yr of HF
    1152 CaF2 drums/yr / 7 drums per transfer = 165 transfers per year
    1152 CaF2 drums/yr / 40 drums per shipment = 29 transfers per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    2236 grouted waste drums/yr /7 drums per transfer = 320 transfers per year
    2236 grouted waste drums/yr /40 drums per shipment = 56 transfers per year
19) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
20) Batch of LLW
21) A single 3 mo. old empty UF6 cylinder

DEFLUORINATION / ANHYDROUS HF - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UO2F2 Reactor (Reactor No. 2) (2)	2	52	2	6	3	Monel	3/4"	208
UO2F2 screw conveyor (2)	2	108	2	6	3	Monel	3/4"	432
UO2F2 sintered metal filter (2)	2	4	2	15	1			16
Vaporizer (2)	2	52	2	6	3	Monel	3/4"	208
U3O8 reactor (Reactor No. 2) (2)	2	108	2	7	3	Inconel	1.5"	432
U3O8 product cooler (2)	2	108	2	7	3	Inconel	1.5"	432
U3O8 sintered metal filter (2)	2	4	2	15	1			16
U3O8 bucket elevator No. 1 (2)	2	108	2	7	3	Inconel	1.5"	432
U3O8 compactor (1)	2	52	1	8,9	3	Steel	1/4"	104
U3O8 granulator (1)	2	52	1	8,9	3	Steel	1/4"	104
U3O8 bucket elevator No. 2 (1)	2	104	1	8,9	3	Steel	1/4"	208
U3O8 dust collector (1)	2	4	1	15	1			8
HF distillation column (1)	2	26	1	6,7	16	Monel,Inconel	3/4",1.5"	52
HF distillation reboiler (1)	2	26	1	6,7	16	Monel,Inconel	3/4",1.5"	52
40 deg F condenser (1)	2	26	1	6,7	16	Monel,Inconel	3/4",1.5"	52
-20 deg F condenser (1)	2	26	1	6,7	16	Monel,Inconel	3/4",1.5"	52
HF distillation reflux pump (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
30 deg F chiller (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
-30 deg F chiller (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
HF distillation bottoms pump (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
HF transfer pump (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
HF loading pump (1)	2	52	1	6,7	16	Monel,Inconel	3/4",1.5"	104
Off-gas scrubber (1)	2	26	2	8,9	30	Steel	1/4"	104
Off-gas heater (1)	2	26	2	8,9	30	Steel	1/4"	104
Off-gas HEPA filters (2)	2	4	2	8,9	30	Steel	1/4"	16

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR
Off-gas exhausters (2)	2	52	2	8,9	30	Steel	1/4"	208
Lime feeder (1)	2	104	1	6,7	60	Monel,Inconel	3/4",1.5"	208
Drum filter (1)	2	26	1	6,7	60	Monel,Inconel	3/4",1.5"	52
Vacuum pump (1)	2	52	1	6,7	60	Monel,Inconel	3/4",1.5"	104
Scrub solution cooler (1)	2	26	1	6,7	60	Monel,Inconel	3/4",1.5"	52
Scrub solution pump (1)	2	52	1	6,7	60	Monel,Inconel	3/4",1.5"	104
Evaporator (1)	2	26	1	6,7	60	Monel,Inconel	3/4",1.5"	52
Condenser (1)	2	26	1	6,7	60	Monel,Inconel	3/4",1.5"	52
Condensate pump (1)	2	52	1	6,7	60	Monel,Inconel	3/4",1.5"	104
CaF2 screw conveyor (1)	2	104	1	6,7	60	Monel,Inconel	3/4",1.5"	208
CaF2 rotary dryer (1)	2	104	1	6,7	60	Monel,Inconel	3/4",1.5"	208
CaF2 dust collector (1)	2	4	1	6,7	60	Monel,Inconel	3/4",1.5"	8
Lime feeder (1)	2	104	1	6,7	60	Monel,Inconel	3/4",1.5"	208
Neutralized waste feed pump (1)	2	52	1	8,9	70	Steel	1/4"	104
Cement feeder (1)	2	104	1	8,9	70	Steel	1/4"	208
Grout mixing / drum tumbling station (1)	2	52	1	8,9	70	Steel	1/4"	104
HVAC equipment	2	520	1	6,7	30	Monel,Inconel	3/4",1.5"	1040
Boiler, Water Systems, other Utilities	2	52	3	6,7	175	Monel,Inconel	3/4",1.5"	312
Waste water treatment equipment	1	2190	1	2,5	50	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	6,7	120	Steel	3/4", 1.5"	2190
Admin building	1	1000	1	2,5	50	Steel	1/4"	1000

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EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) U3O8 Compactor feed bin; there are 2 bins.
9) U3O8 Drum fill bin.
10) Drum of U3O8.
11) Each transfer consists of 5 U3O8 drums.
12)
13) Average of 2 hours per week on conveyor systems
Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - Includes instrumentation
Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - Includes instrumentation
10 hours per week on HVAC components
6 hours per day on waste water treatment components
6 hours per day on sanitary waste treatment components
1000 hours per year on the administration building
14) Materials do not include walls between operating areas.
15) Loaded filter/bag.

Section 6.5

U_3O_8: Defluorination / HF Neutralization Facility

Section 6.5
U_3O_8: Defluorination / HF Neutralization Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into U_3O_8 and byproduct calcium fluoride (CaF_2). Due to its chemical stability, U_3O_8 is a principal option for either long term storage or disposal. UF_6 defluorination is achieved through a steam hydrolysis/pyrohydrolysis route, which is generically the same as the existing industrial (Cogema) process practiced in France. The aqueous hydrofluoric acid (HF) produced is then neutralized with lime.

Process Summary

Depleted uranium hexafluoride (UF_6) is processed to produce uranium octaoxide (U_3O_8) and byproduct calcium fluoride (CaF_2). A dry process (steam hydrolysis/ steam pyrohydrolysis) is used for conversion to the uranium oxide.

The UF_6 is converted to U_3O_8 in two steps. The UF_6 is vaporized using steam heated autoclaves and fed to a reactor, where it is mixed with steam and nitrogen. Solid uranyl fluoride (UO_2F_2) is produced and it flows to a second reactor, where it is mixed with superheated steam, nitrogen and hydrogen to produce U_3O_8. The oxide is discharged from the reactor, cooled, compacted and packaged for shipment.

Vapor containing HF and water vapor from both reactors flows to HF absorption columns. The resulting HF solution is neutralized with slaked lime (CaO). The resulting CaF_2 precipitate is separated, dried, and packaged in drums for sale.

1.0 DUF6 Conversion Facility – Missions, Assumptions and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Defluorination/Hydrofluoric Acid (HF) Neutralization Conversion Facility process converts depleted UF_6 into triuranium octoxide (U_3O_8) for stable, long-term storage or disposal.

1.2 ASSUMPTIONS & DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail car. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure, and the assumed average isotopic composition is: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinder, the short lived daughter products of U-238, Th-234 and Pa-234 are in the same equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is assumed to be 7,000 hours based on a plant availability factor of 0.8.
- A single train of process equipment is provided to produce the plant processing capacity, except in the UF_6 reactor systems, where two parallel trains are provided.
- The hydrofluoric acid (HF) produced in the process is converted to CaF_2 which is sold.
- U_3O_8 and CaF_2 products are packaged in 55 gallon drums. Since the weight of U_3O_8 in a full drum exceeds the maximum weight limitations for a standard drum, it is assumed that specially engineered

drums are used for U_3O_8. Indoor on-site storage space for one months production is provided.

- On-site storage of one weeks supply of lime (calcium oxide) and one months supply of ammonia is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities" as defined in DOE Order 6430.1A and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- U_3O_8 Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility including the following:

- CaF_2 Storage Building
- Administration Building
- Utilities Building

- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20 year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502 - *Environmental Impact Statement*, 10 CFR 1021, *National*

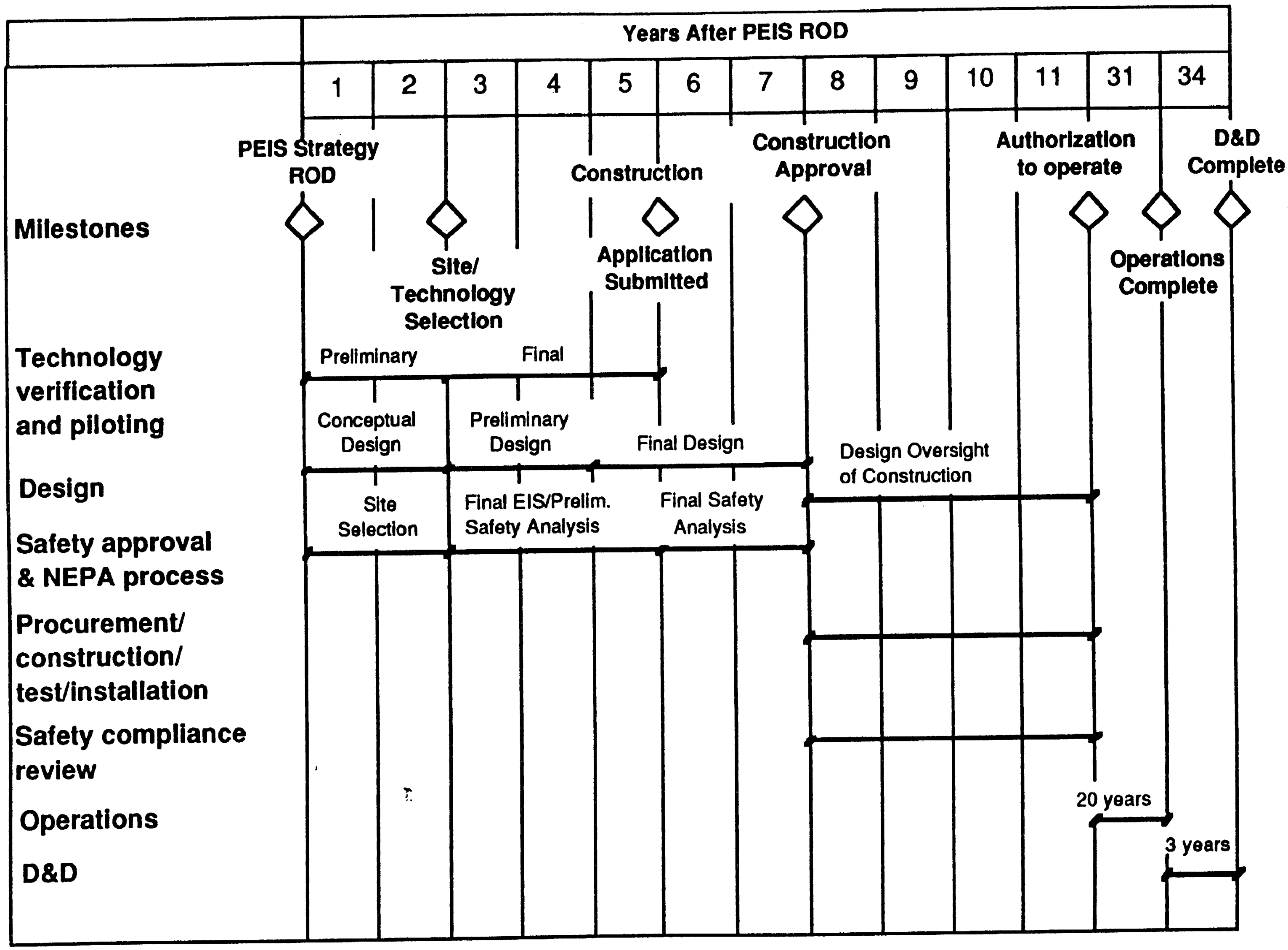

Figure 1-1 Preliminary Project Schedule

Environmental Policy Act Implementing Procedures (for DOE) and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program.*

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, guidelines, etc. as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable NRC regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*; DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, National Environmental Policy Act. Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection.*

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined during the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements*; the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning/Conversion

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program—including waste minimization, source reduction, and recycling of solid, liquid, and air emissions—will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program;* and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria,* Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process include the following:

- This process has not been demonstrated on a throughput scale assumed for this study (28,000 MT/yr UF_6). Primary concern is direct scaleup of the conversion reactors.
- The optimum material of construction for reactor system process equipment and components exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.

- The ultimate storage or disposal form of the U_3O_8 product has not been finalized. Also, the viability of shipment of compacted U_3O_8 powder in 55 gallon drums has not been determined.
- Due to the pre-conceptual nature of the facility design, development of process and support system equipment and component design details as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment / system / facility descriptions are based primarily on engineering judgement and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium oxide (U_3O_8) and calcium fluoride (CaF_2) by defluorination with steam and hydrogen. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a series of two reactors to solid U_3O_8 product which is packaged in 55 gallon drums. The product uranium oxide is stored on-site until it is transported to another site for subsequent disposition; long term storage, use, or disposal. Hydrofluoric acid (HF) produced in the reaction is neutralized with lime (CaO) to produce the byproduct calcium fluoride, which is sold.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2–2 Plot Plan.

The major structures on the site are as follows:

- Process Building
- U_3O_8 Storage Building
- CaF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse.
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site

Note: The size, number and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

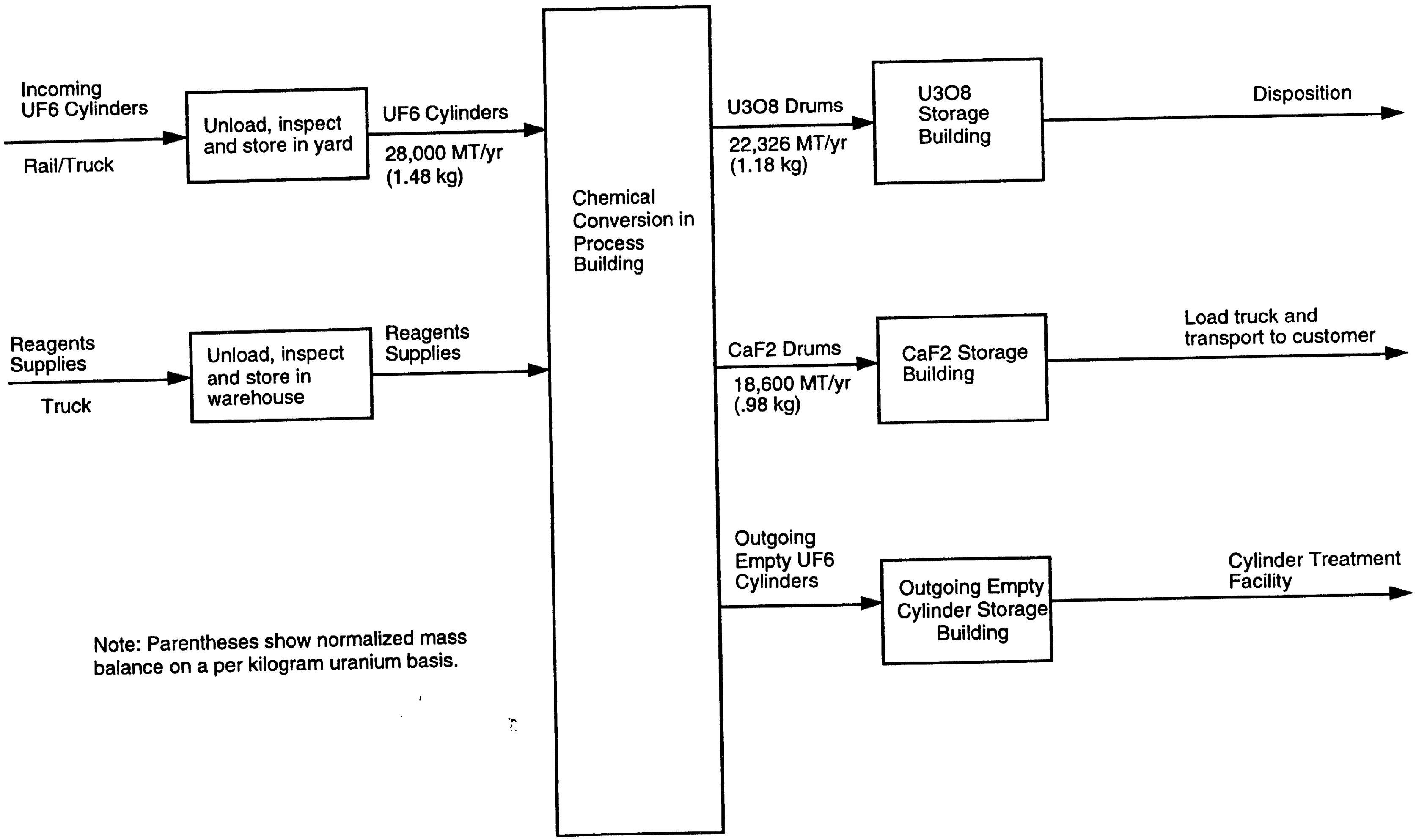

Figure 2-1 Defluorination / HF Neutralization Material Flow Diagram

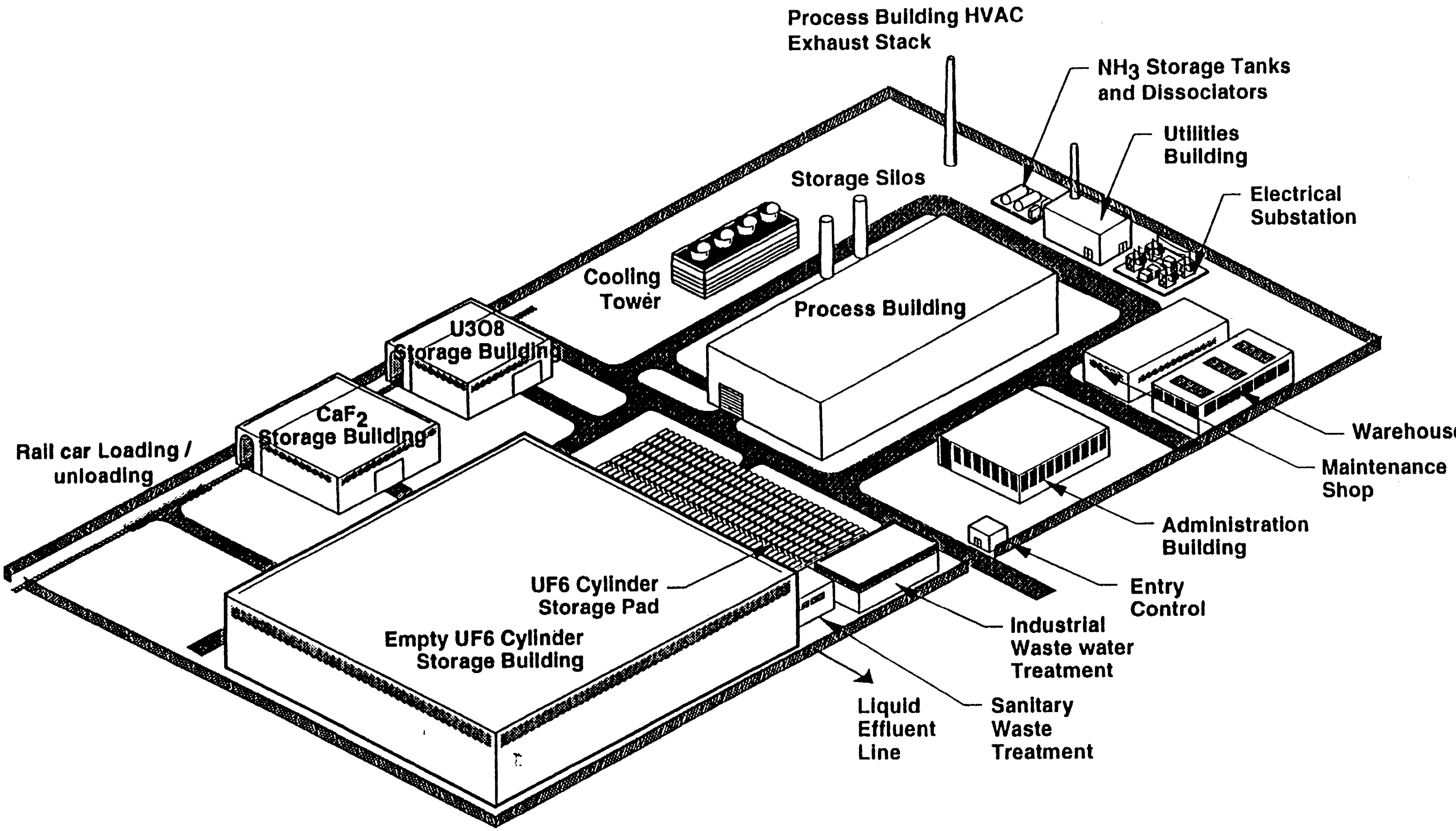

Figure 2-2 Plot Plan
Defluorination / HF Neutralization Facility

2.1.3 Building Descriptions

Facilities building data is summarized in Table 2-1

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	40,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
U_3O_8 Storage Building	8,000	1	Yes	Yes	HC2 / MH	Metal Frame
CaF_2 Storage Building	14,000	1	No	No	N/A	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	6,000	1	No	Yes	General	Metal Frame
Administration Building	8,000	1	No	No	General	Metal Frame
Maintenance Shop	5,000	1	No	Yes	General	Metal Frame
Warehouse	5,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	1,500	1	No	No	General	Metal Frame
Cooling Tower	7,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The Process Building layout and section is shown in Figures 2-3, 2-4 and 2-5. The building is a two-story reinforced concrete structure classified

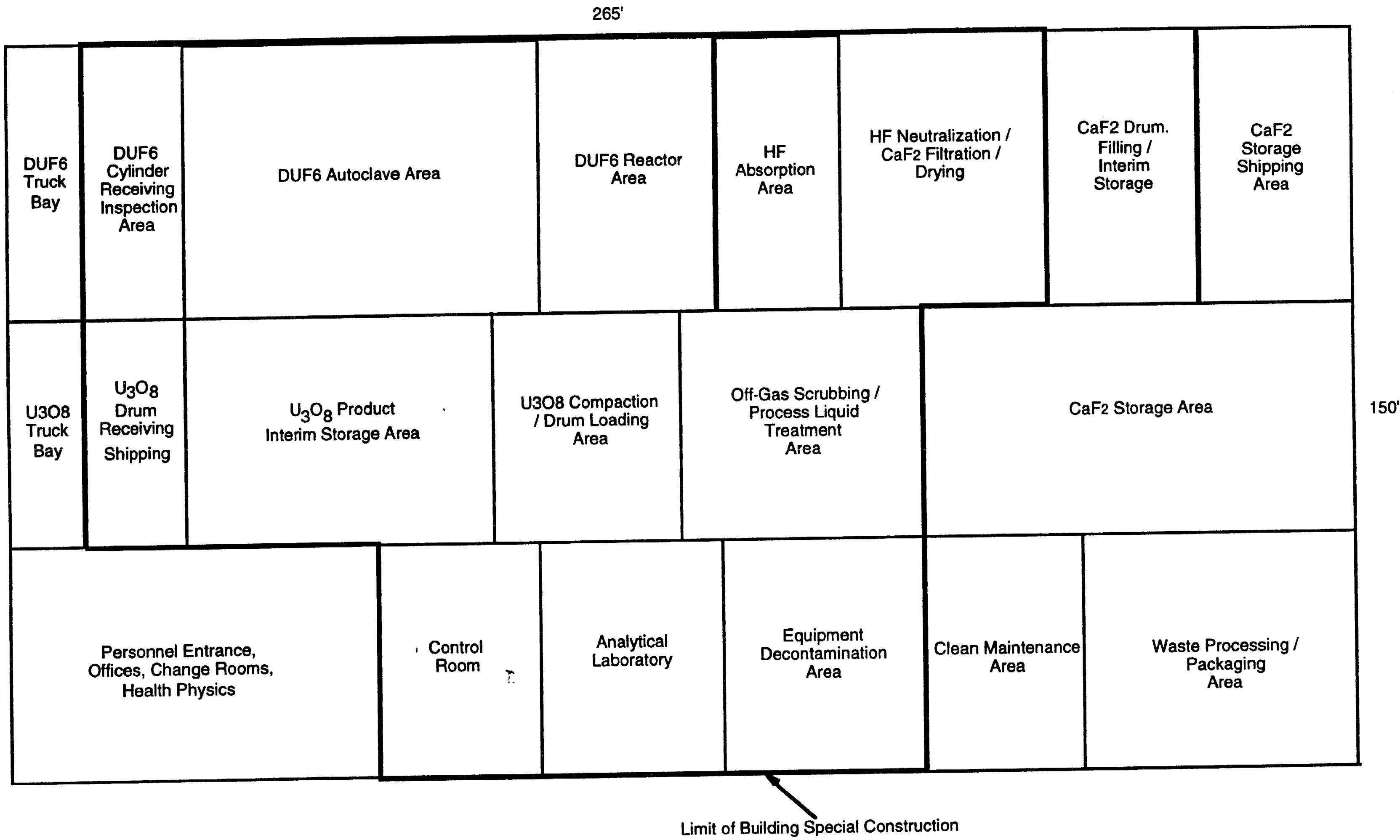

FIGURE 2-3 PROCESS BUILDING LAYOUT DEFLUORINATION / HF NEUTRALIZATION

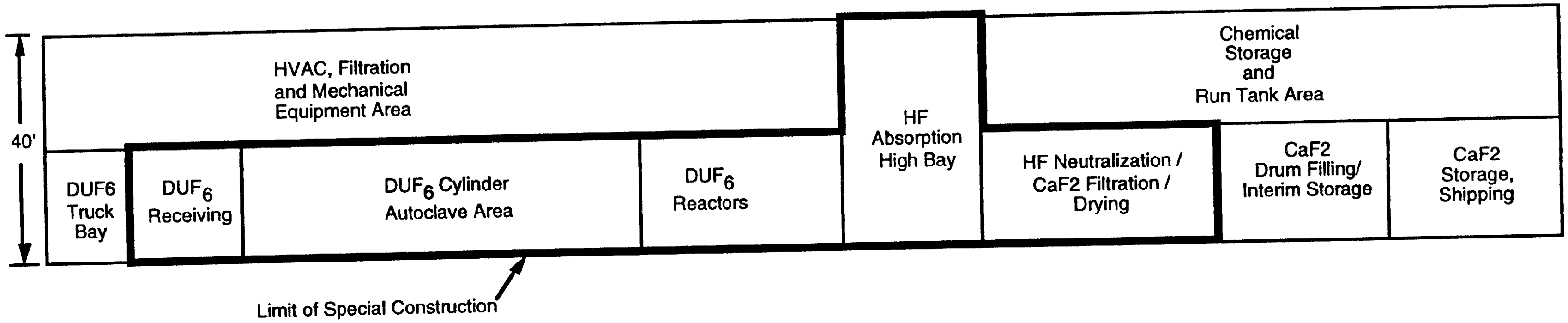

FIGURE 2-4 PROCESS BUILDING SECTION
DEFLUORINATION/HF NEUTRALIZATION

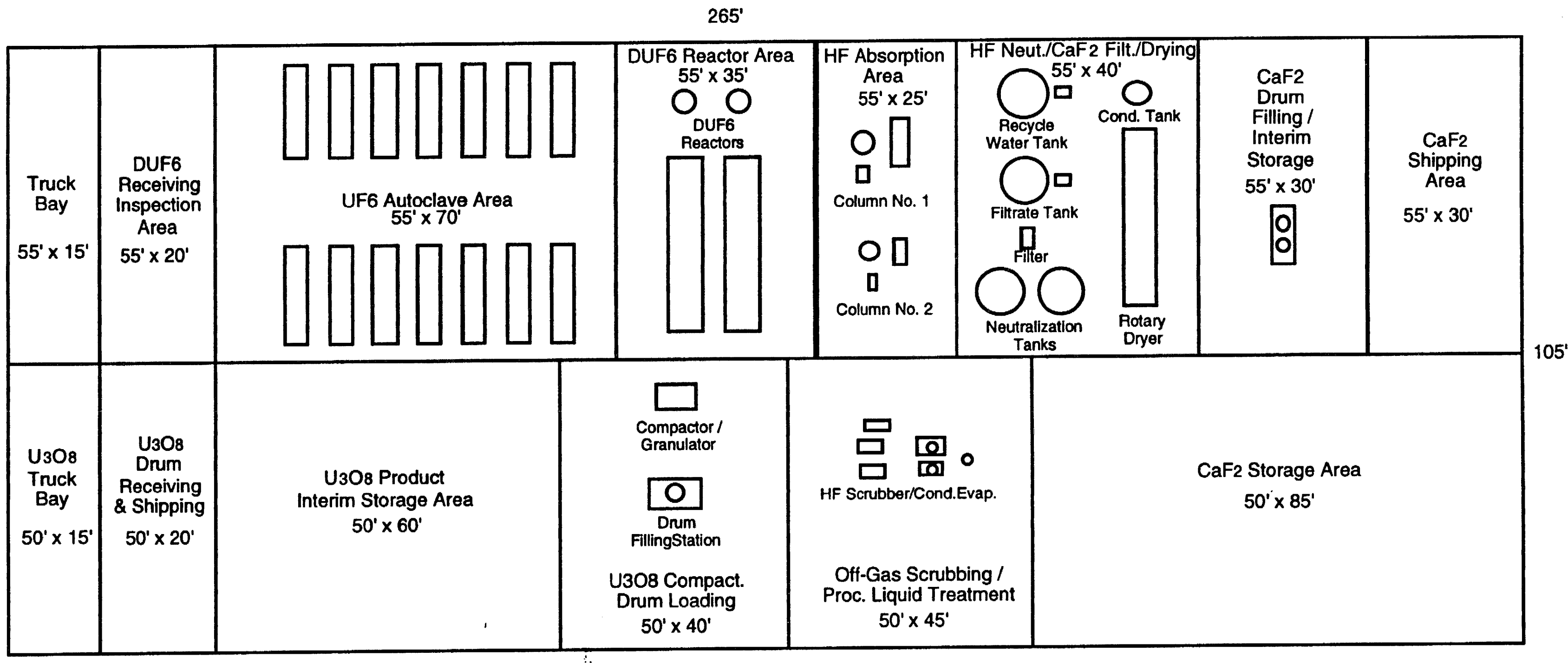

FIGURE 2-5 PROCESS EQUIPMENT ARRANGEMENT DEFLUORINATION / HF NEUTRALIZATION

radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of UF_6 and HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems such as the heating, ventilating and air conditioning systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

2.1.3.2 U_3O_8 Storage Building

The U_3O_8 Storage Building is a one-story metal frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for one months production of U_3O_8. A zone 2 HVAC system with filtered exhaust air is provided (See also Section 2.2.5).

2.1.3.3 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.4 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the DUF_6 Defluorination / HF Neutralization Facility includes the following facilities and systems: (Facilities are shown on Site Map Fig. 3-1.)

A metal frame CaF_2 Storage Building for storage of one months production of CaF_2.

A metal frame general use Utilities Building housing raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal frame or masonry Administration Building to house the facility support personnel.

A metal framed general use Maintenance Shops Building for housing clean maintenance and repair shops.

An 26 MM BTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 2,600 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility for the receipt, treatment and disposal of noncontaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility with a capacity of approximately 3,300 gpd.

Compressed air systems including plant air, instrument air and breathing air. A single set of two redundant 300 cfm reciprocating air compressors provide compressed air to both systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in dessicant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

A 600 cfm air compressor and membrane separation unit to provide 300 cfm of nitrogen to the UF_6 process reactors.

A 4000 cfh hydrogen/nitrogen supply system including two 7,000 gal ammonia storage tanks and a dissociator to provide hydrogen and nitrogen to Reactor No. 2.

Two 6,000 ft^3 lime storage silos located in the yard.

Building heating, ventilating and air conditioning (HVAC) systems use a central chilled water system for building cooling. Three 50% capacity, 275 ton centrifugal water chillers, and three 450 gpm circulating pumps are provided. A steel stack serves the Process Building HVAC exhaust systems. The steam plant boiler vents through a dedicated steel stack (see Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 15,000 lb/hr of 50 psig steam which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration and chlorination. The demineralized water is used in the process and for steam boiler feedwater (See also Fig. 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a design capacity of 1400 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 300 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas which require special lighting for nightime operation include the UF_6 cylinder storage pad areas, the railcar spur area, the utility area and the site entry control area.

Site security fencing as shown on Site Map, Figure 3-1, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventive systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSC's) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety class systems, structures, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Condensation Areas
U_3O_8 Storage Building	Zone 2 - Moderate Hazard Bldg	Single HEPA Filters	PC-3 for DBE & DBT	
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1.2 Tornadoes

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Floods

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480.7. This criteria requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

2.2.3 Materials Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., U_3O_8 drum loading operations, UF_6 sampling stations, etc.).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will utilize a combination of dividing the buildings into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize gloveboxes and fume hoods for confinement of uranium powders, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing autoclaves and other uranium processing areas. The ventilation system for these rooms utilize once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard. The U_3O_8 Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting area, CaF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a higher pressure than the rest of the building. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor and HF absorption areas and the off-gas scrubbing area of the Process Building have high chemical hazard potential and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a HF leak.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on the Site Map, Figure 3-1. This figure also shows the effluent air release point ventilation and boiler stacks.

Table 2-3 summarizes the characteristics of the effluent air release points.

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	90	80	60
Boiler	100	24	500	60

3.0 Site Map and Land Use Requirements

3.1 SITE MAP

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and U_3O_8 and CaF_2 from the facility. Air emission points are shown from the Process Building exhaust stack and the boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 LAND AREA REQUIREMENTS DURING OPERATION

As shown in Figure 3-1, the total land area required during operations is approximately 560,000 ft^2 or about 12.9 acres.

3.3 LAND AREA REQUIREMENTS DURING CONSTRUCTION

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 19.7 acres. Construction areas required in addition to the site structures and facilities include:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

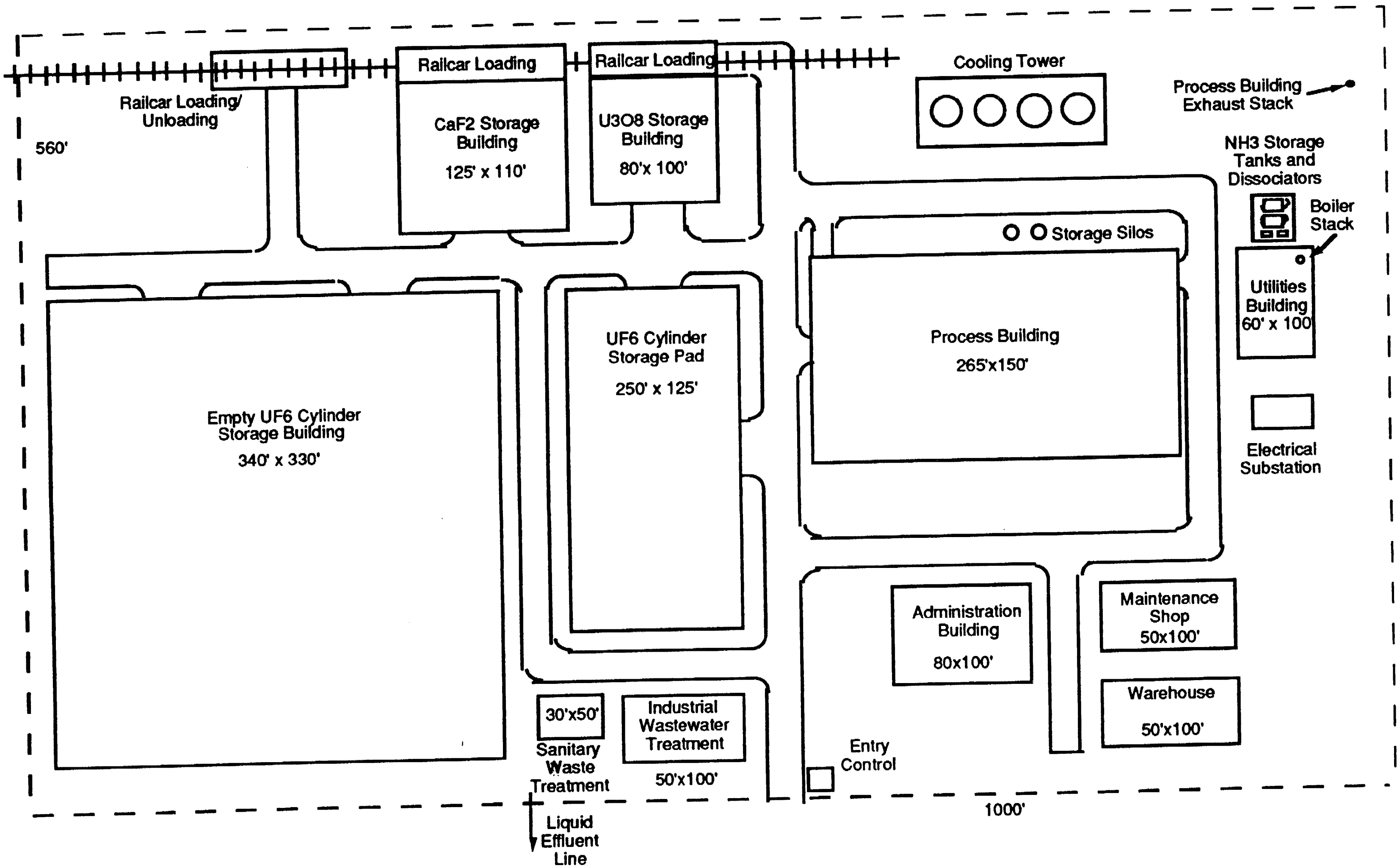

FIGURE 3-1 SITE MAP
DEFLUORINATION / HF NEUTRALIZATION

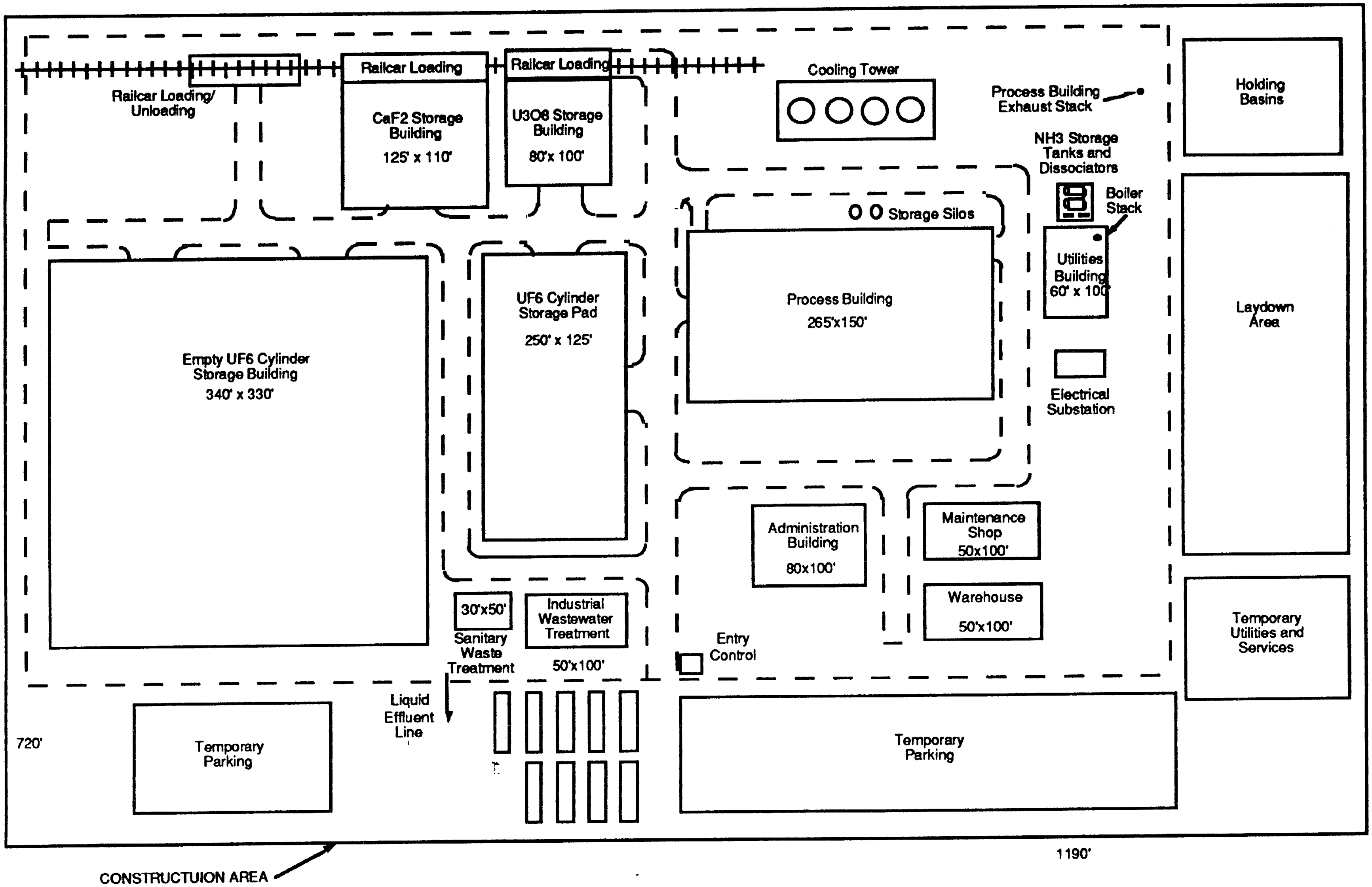

FIGURE 3-2 SITE MAP DURING CONSTRUCTION
DEFLUORINATION / HF NEUTRALIZATION

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is processed to produce uranium oxide (U_3O_8) and calcium fluoride (CaF_2). The process is shown in Figures 4-1 and 4-2. Annual and hourly material balances are given in Appendix A.

The UF_6 is converted to U_3O_8 in a two-step process. The UF_6 is vaporized using steam heated autoclaves and fed to Reactor No. 1, where it is mixed with steam and nitrogen. Solid UO_2F_2 is produced and flows to Reactor No. 2. Vapor containing HF, nitrogen and water flows to the HF absorption column. In the second reactor, the UO_2F_2 is mixed with steam and hydrogen to produce solid U_3O_8. Vapor containing HF and water flows to the HF absorption column. The U_3O_8 is discharged from the reactor, cooled, compacted and packaged in drums.

The HF absorption columns receive off-gas from Reactors No. 1 and 2. Two columns in series absorb the HF to produce a 20 wt% HF solution. The HF solution is neutralized with slaked lime, and the resulting CaF_2 precipitate is separated by filtering, washed with water, dried and packaged in drums.

Uncondensed off-gas from the second absorption column flows to the scrubber system. The HF in the off-gas is removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution. The CaF_2 precipitate is sent to drying.

The facility has two reactor trains of defluorination process equipment. Critical equipment such as a blowers or filters have spares installed in parallel. The process chemistry for the conversion of UF_6 to U_3O_8 is based on a Cogema facility in Tricastin, France.

4.1 UF6 CONVERSION REACTIONS

Reactor No. 1 converts UF_6 feed into UO_2F_2 and HF by hydrolysis in a fluidized bed. The chemical reaction is $UF_6 + 2H_2O \longrightarrow UO_2F_2 + 4HF$. This system is shown in Figure 4-3.

Depleted UF6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in steam-heated autoclaves and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is heated and vaporized (sublimed) at 140°F. Gaseous UF_6 flows out of the cylinder and is fed by compressor into a fluidized bed or spray tower reactor containing UO_2F_2 particles. Eleven UF_6 cylinders feed simultaneously to provide the required feed rate of 8,800 lb/hr.

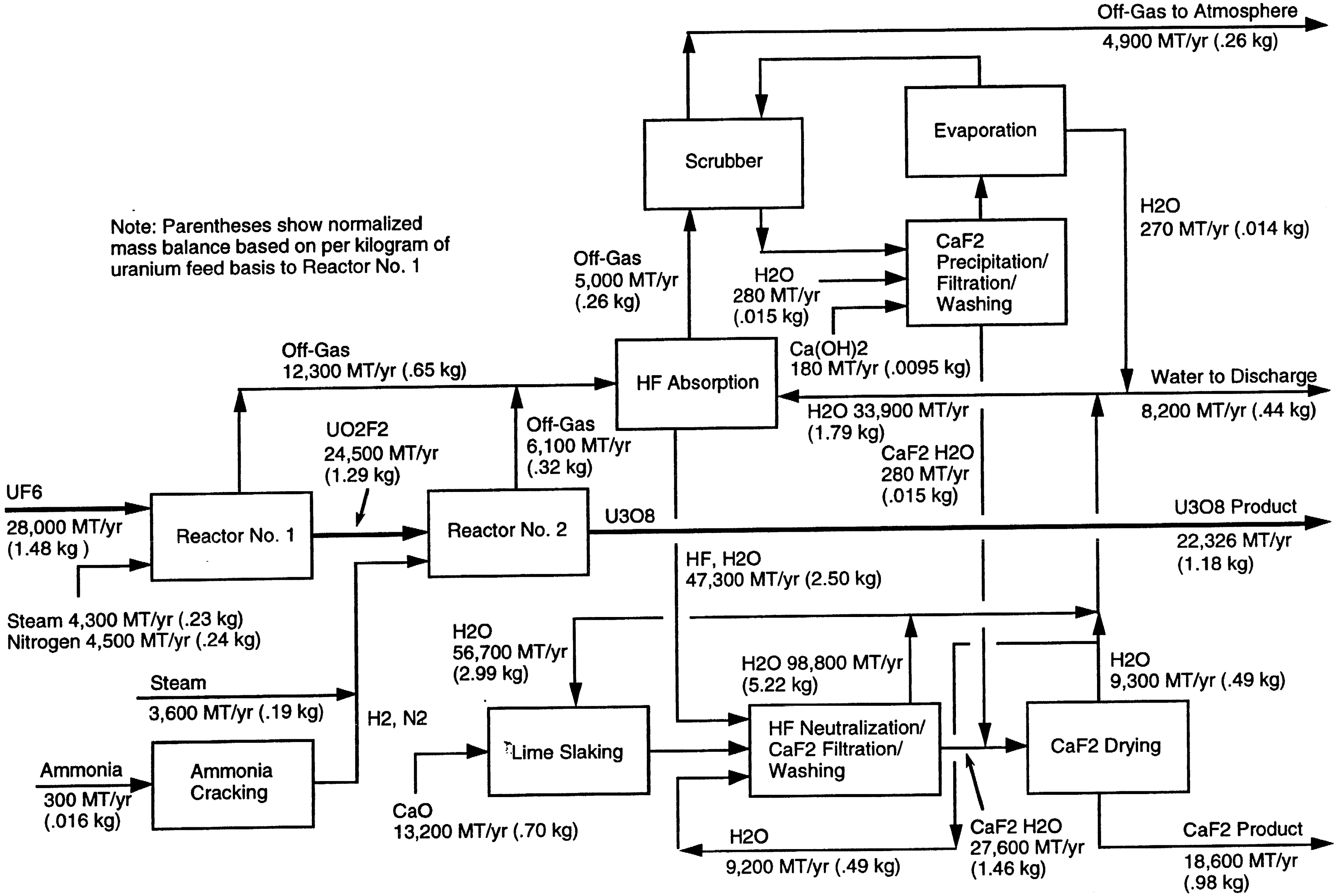

Figure 4-1 Defluorination/HF Neutralization Block Flow Diagram

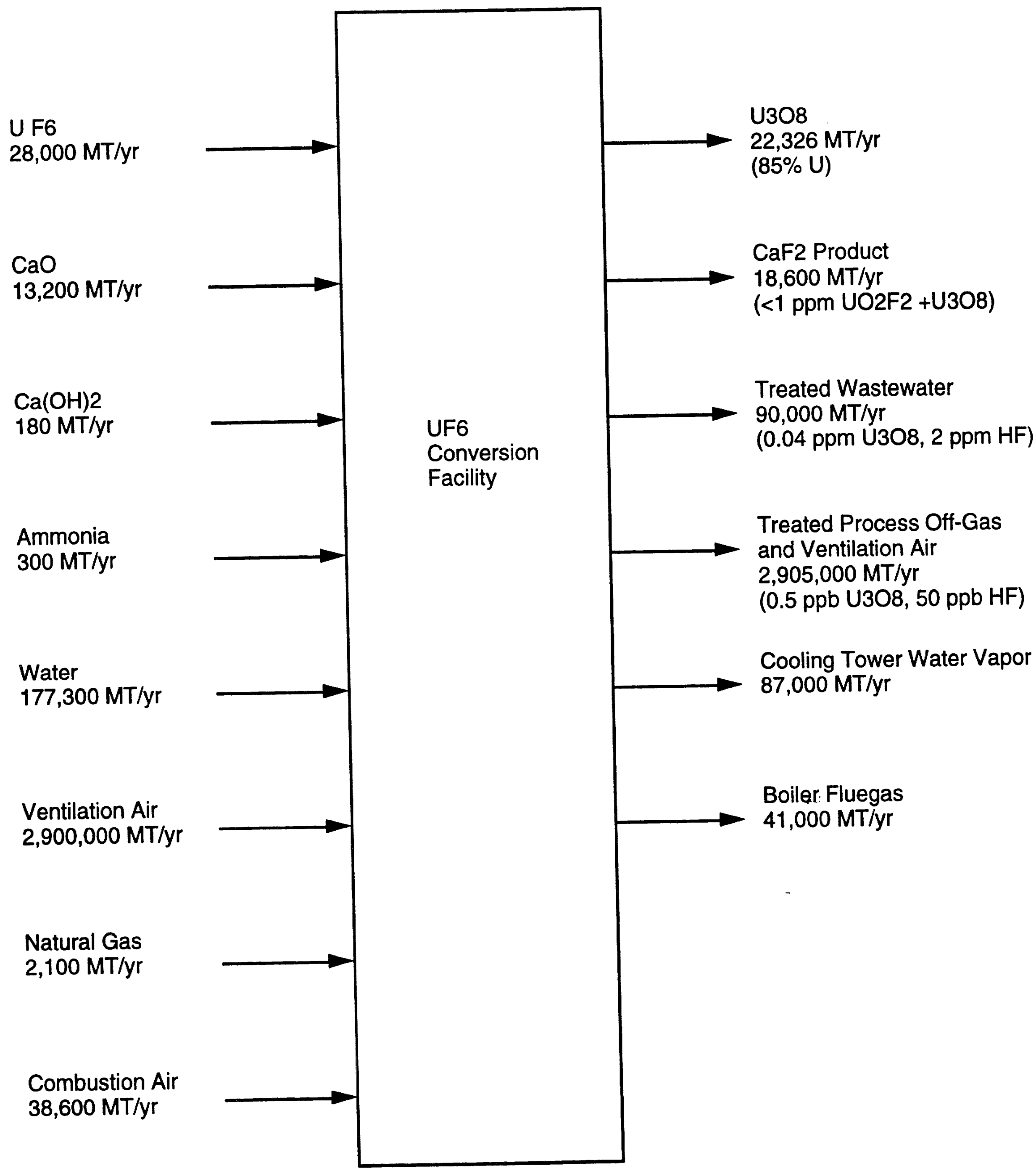

**Figure 4-2 Defluorination / HF Neutralization
Input / Output Diagram**

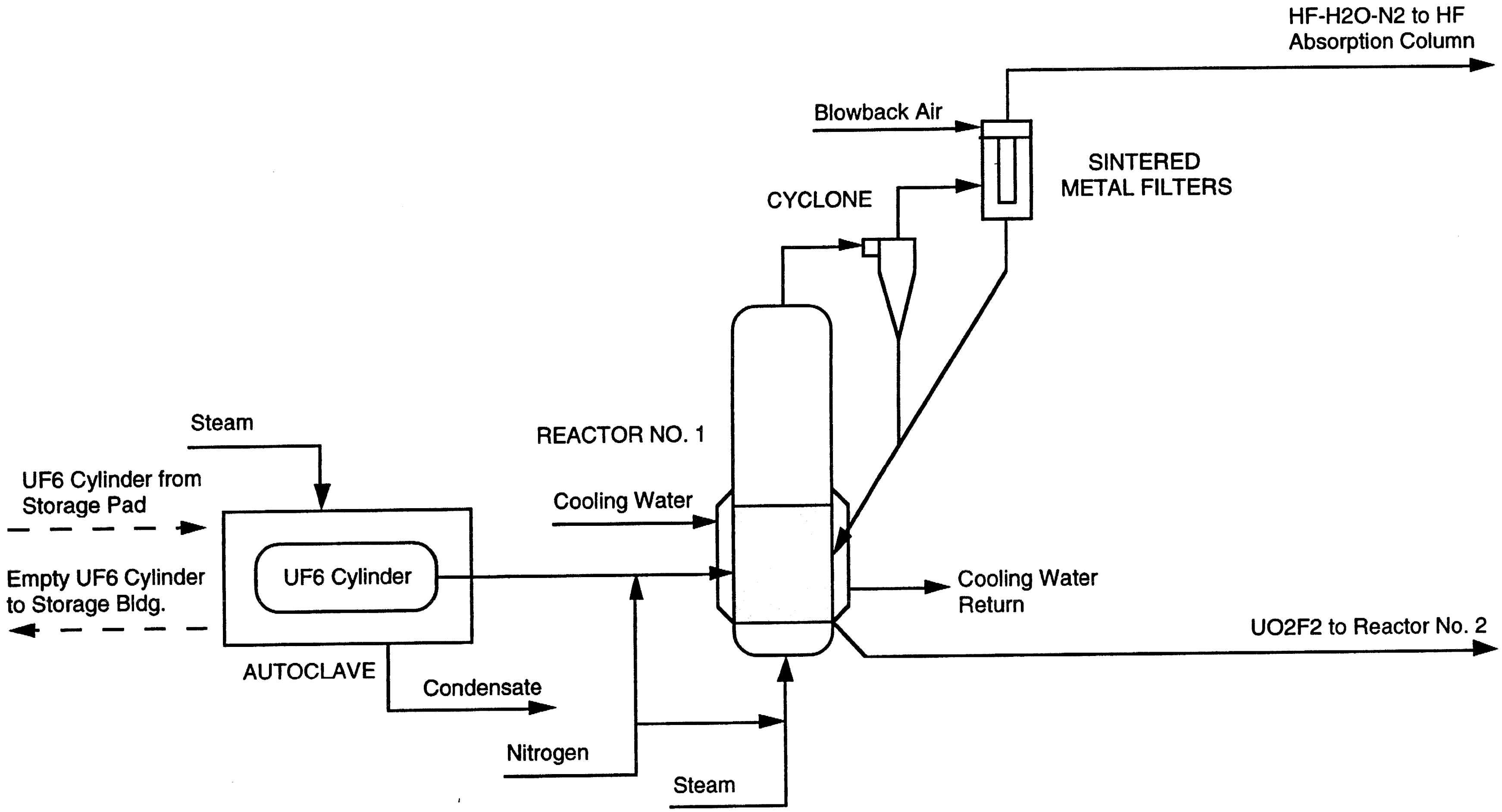

Figure 4-3 Reactor No. 1 Process Flow Diagram

Steam and nitrogen act as the fluidizing gas. Steam reacts with the UF_6 to form solid UO_2F_2 and gaseous HF. The reaction is exothermic, and cooling water is provided to maintain the reactor at about 480°F. The nitrogen also removes heat produced from the reaction.

The solid UO_2F_2 flows from this reactor to Reactor No. 2. The HF-water vapor flows through a cyclone and sintered metal filter to remove UO_2F_2 particulates, which are discharged back into the reactor. The HF-water vapor flows to the HF absorption column. After cooling, the empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

Reactor No. 2 converts UO_2F_2 into U_3O_8 and HF in a rotary kiln. The chemical reaction is $3UO_2F_2 + 3H_2O \text{--->} U_3O_8 + 6HF + 0.5O_2$. A stoichiometric amount of hydrogen is added to react with the oxygen, so the overall reaction is $3UO_2F_2 + 2H_2O + H_2 \text{--->} U_3O_8 + 6HF$. This system is shown in Figure 4-4.

Solid UO_2F_2 from Reactor No. 1 flows into the rotary kiln, where it reacts with steam and hydrogen to form solid U_3O_8 and gaseous HF. The reaction is endothermic, and the kiln is indirectly heated with natural gas to maintain the temperature at about 1380°F. Solid U_3O_8 is discharged from the reactor, cooled, compacted, granulated and loaded into drums. It is assumed that the compaction and granulation result in a final U_3O_8 bulk density of 3 g/cm^3. After filling, the drums are cleaned and transported to the storage building.

The HF and water vapor flow through a cyclone and sintered metal filter to remove U_3O_8 particulates, which are discharged back into the reactor. The off-gas vapor flows to the HF absorption column.

Hydrogen is provided from a packaged ammonia dissociator unit. The chemical reaction is $2NH_3 \text{--->} N_2 + 3H_2$. Liquid ammonia is vaporized and fed to the dissociator, which decomposes the ammonia at 1600°F in a catalyst bed. The hydrogen/nitrogen mixture is fed to Reactor No. 2.

Preliminary major equipment descriptions for the conversion process include 14 autoclaves and UF_6 compressors, two 3 ft-6 in. diameter by 10 ft high Monel fluidized bed reactors, two 6 ft by 30 ft long Inconel rotary kilns, two 12 in. by 10 ft long screw conveyor/coolers, a solids compactor / granulator, and a drum loading station.

4.2 HF ABSORPTION

The hot off-gas from the reactors, containing 70% HF/30% water vapor plus nitrogen gas, flows to a series of two absorption columns for HF recovery. The system is shown in Figure 4-5.

The vapor enters the first column, where it is contacted with aqueous HF solution. The HF and water condense, which increases the solution temperature by the heat of condensation and heat of solution. The liquid drains to the bottom of the column, where it mixes with liquid from the second absorber column. The resulting 20% HF solution is pumped through

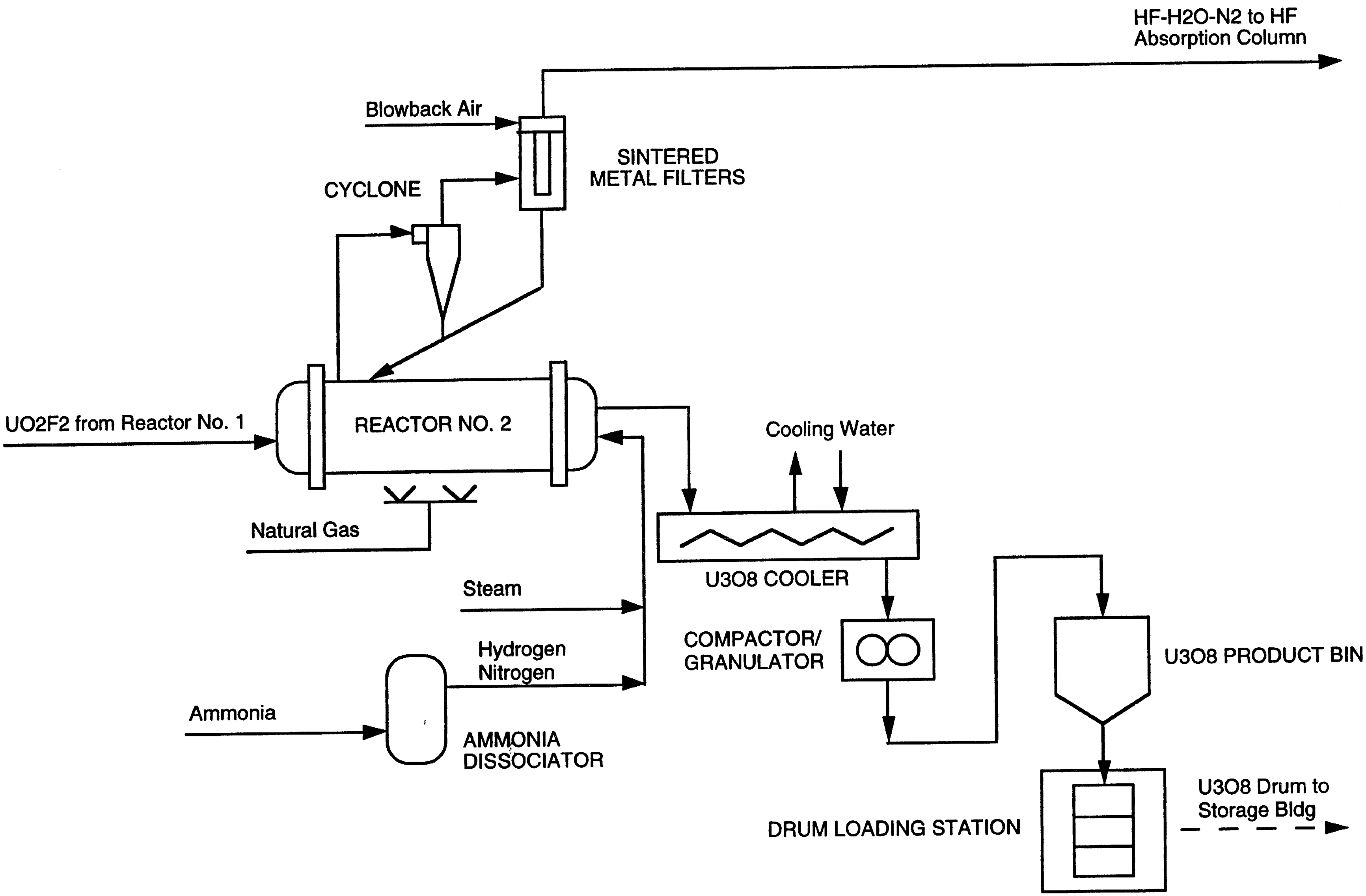

Figure 4-4 Reactor No. 2 Process Flow Diagram

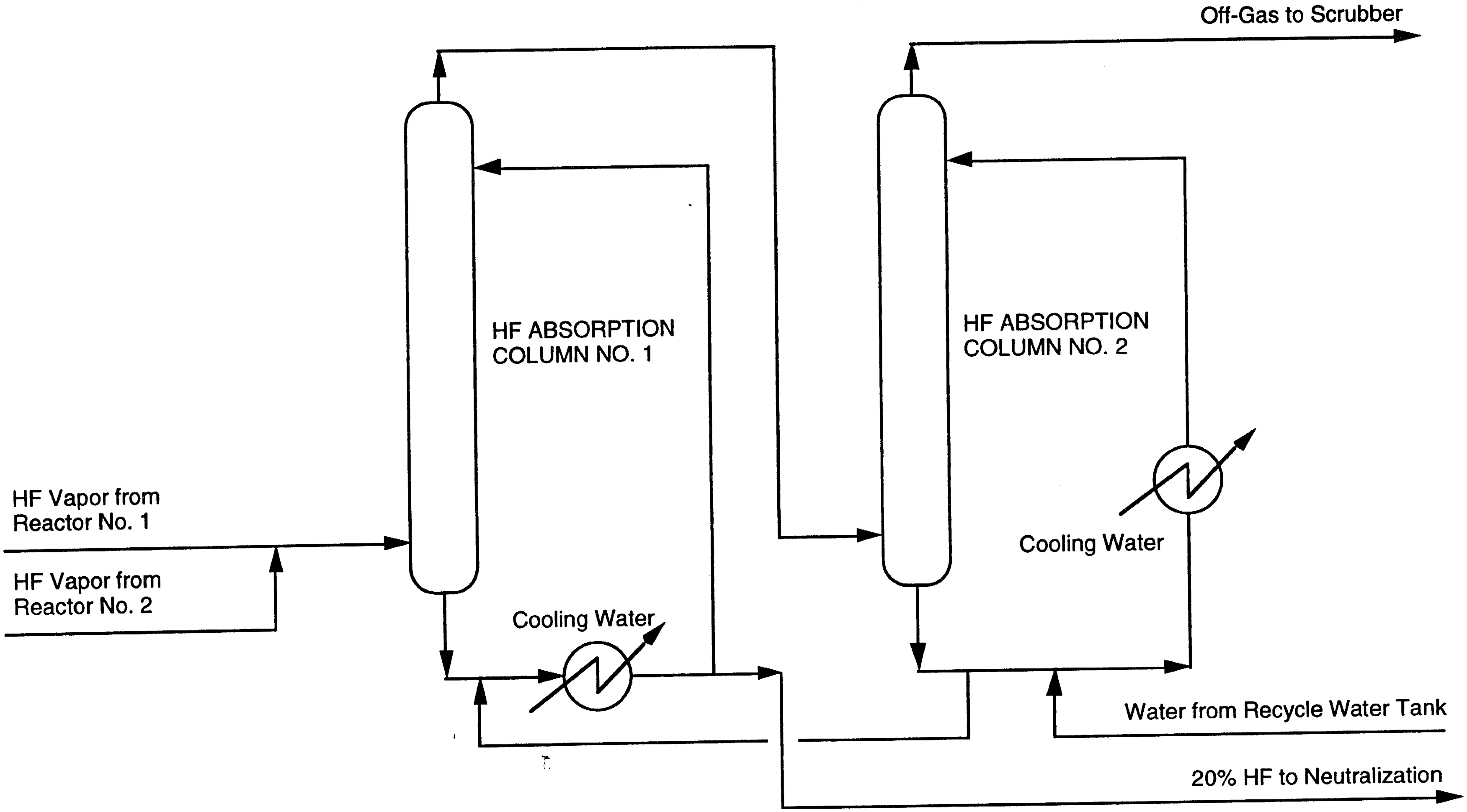

Figure 4-5 HF Absorption Process Flow Diagram

a heat exchanger for cooling and is recirculated to the top of the absorber column. A portion of the circulating liquid is continuously withdrawn and discharged to the HF neutralization system.

The vapor leaving the first column flows to the second column for additional HF removal. Fresh water is added to the second column to make up for the liquid that was discharged to the first column.

Major process equipment for the HF absorption process includes a 4 ft diameter by 21 ft high Monel absorption column, a 3 ft diameter by 8 ft long 1,200 ft^2 Monel cooler, a 2 ft-6 in. diameter by 19 ft high Monel absorption column, a 1 ft-6 in. diameter by 8 ft long 300 ft^2 Monel cooler, and associated circulation pumps.

4.3 HF SCRUBBING SYSTEM

Off-gas from HF Absorption is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The system is shown in Figure 4-6.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction HF + KOH ---> KF + H_2O. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction 2KF + $Ca(OH)_2$ ---> CaF_2 + 2KOH. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter or pressure filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities, and transferred to the CaF_2 dryer in the HF neutralization system.

The KOH filtrate and spent wash water are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The scrub solution is then cooled and pumped back to the scrubber. The treated off-gas is filtered and discharged to atmosphere.

Major equipment includes a 2 ft diameter by 10 ft high Monel HF scrubber with plastic packing, 7 ft diameter by 7 ft high 2,000 gallon Monel precipitation and filtrate tanks, a 6 ft diameter by 8 ft long Monel rotary drum filter, a 1 ft-6 in. diameter by 4 ft Monel evaporator/condenser unit, and associated tanks and pumps.

4.4 HF NEUTRALIZATION SYSTEM

The 20% HF solution from absorption is neutralized with slaked lime to form CaF_2. The system is shown in Figure 4-7.

Pebble lime (CaO) is mixed with water and milled in a vertical attritor to

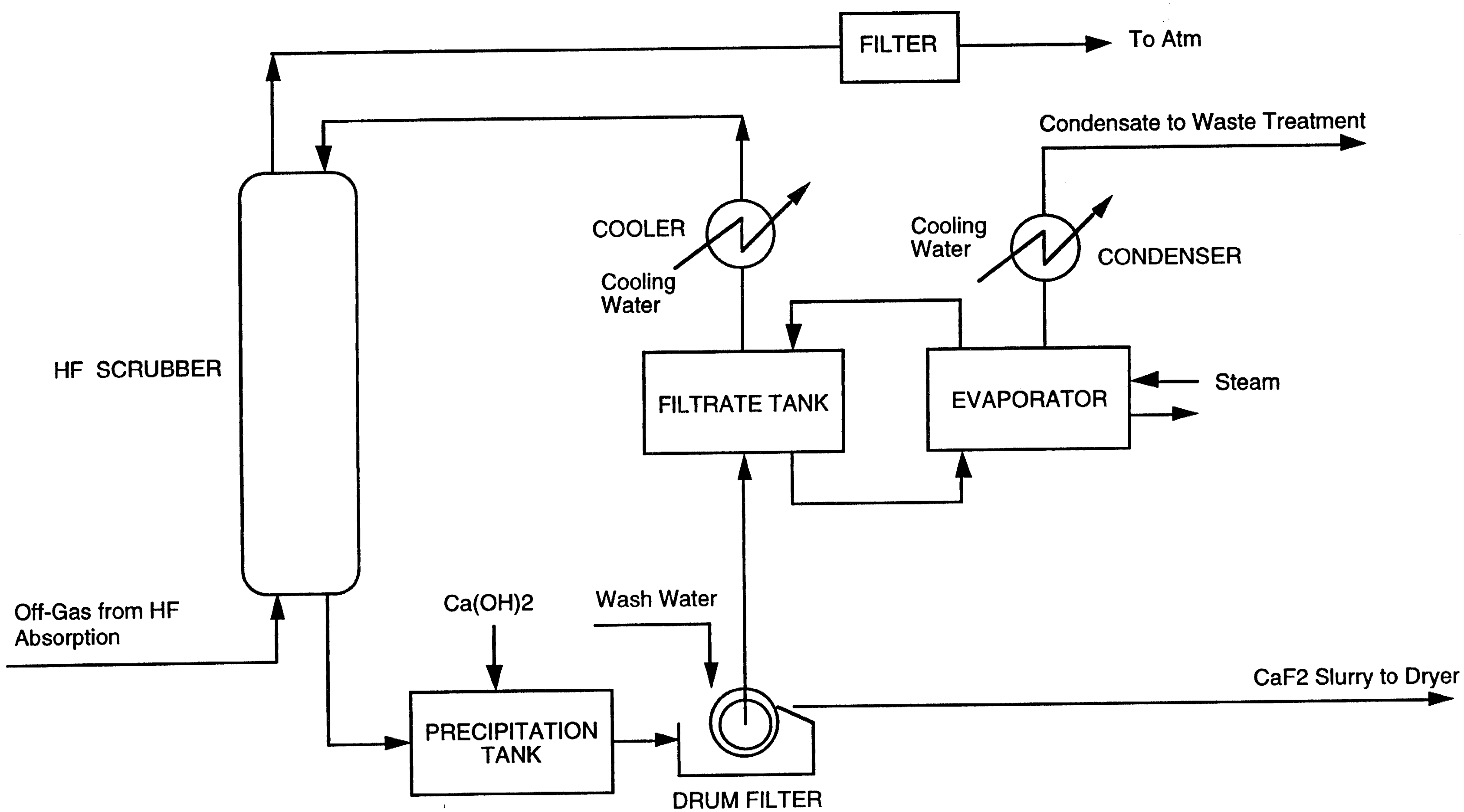

Figure 4-6 HF Scrubber Process Flow Diagram

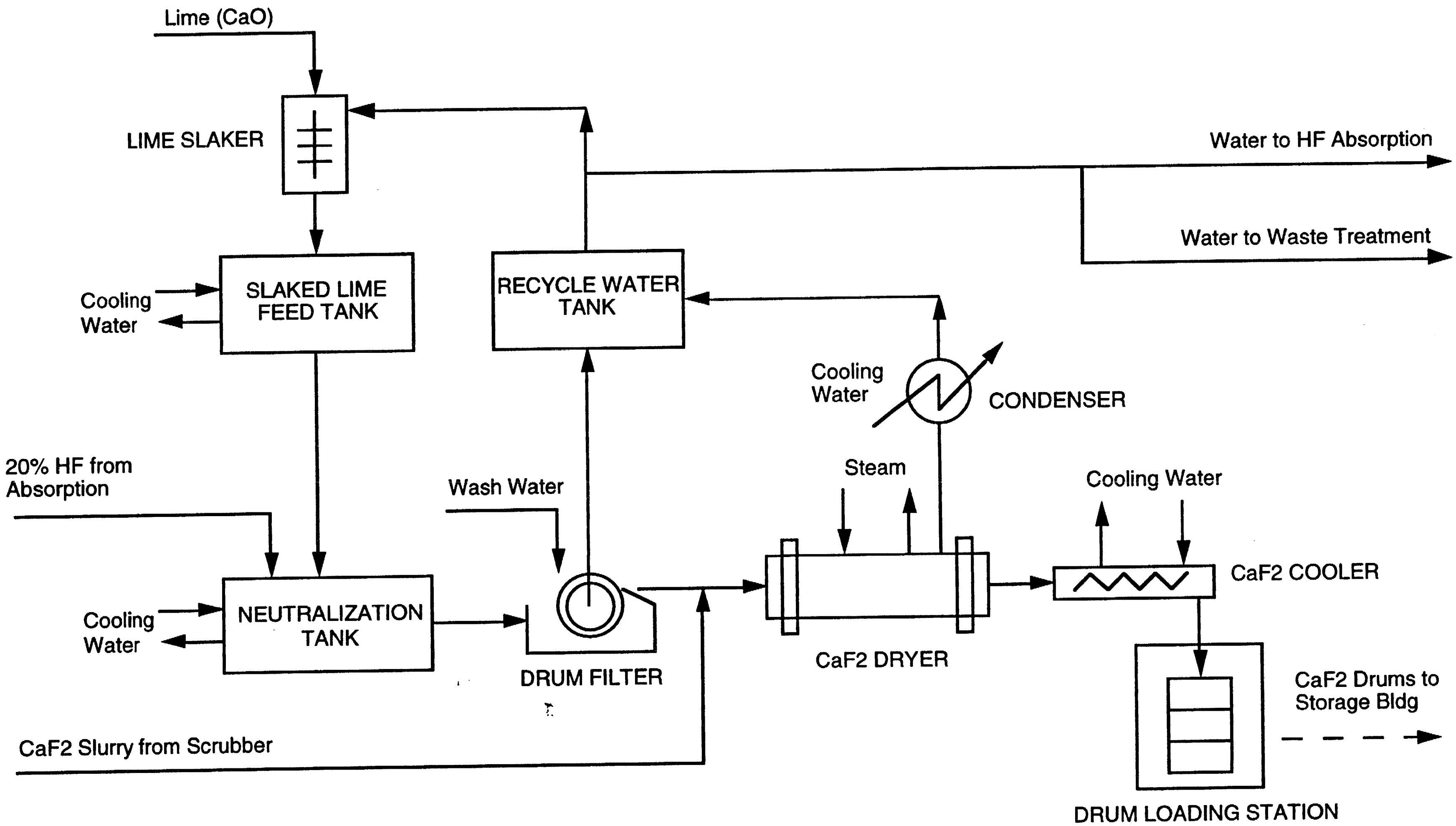

Figure 4-7 HF Neutralization Process Flow Diagram

form a 25 wt% $Ca(OH)_2$ slaked lime slurry. The chemical reaction is $CaO + H_2O \rightarrow Ca(OH)_2$. The slurry is collected in a feed tank with cooling coils, which cools the hot slurry to near ambient temperature.

The HF solution is mixed with slaked lime in a continuous neutralization tank. The chemical reaction is $2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O$. The reaction is exothermic and cooling coils are provided. The slurry then flows to a second neutralization tank for final pH adjustment.

The neutralized slurry, containing about 16 wt% solids, is filtered in a rotary drum vacuum filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities, and dried in a steam-heated rotary tube dryer. After cooling, the CaF_2 is packaged in drums and sent to the storage building. The filtrate and condensate are collected and reused in HF absorption and lime slaking. Excess water is sent to the industrial waste treatment facility.

Major equipment includes two 9 ft diameter by 10 ft high 4,500 gal Monel HF neutralization tanks (one with cooling coils), a 9 ft diameter by 10 ft high 4,500 gal steel filtrate tank, a 3 ft diameter by 4 ft long steel rotary drum filter, a 11 ft diameter by 12 ft high 8,500 gallon recycle water tank, a 6 ft diameter by 35 ft long rotary steam tube dryer, and associated pumps, conveyors and bins.

4.5 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.6 WASTE MANAGEMENT

The primary waste produced by the process is empty UF_6 cylinders. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	10.5 GWh	1.4 MW
Liquid Fuel	6,000 gals	NA
Natural Gas[2]	102×10^6 scf	NA
Raw Water	47×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5–1 is a preliminary conceptual DUF_6 Defluorination/HF Neutralization Facility Water Balance. This balance is based on the greenfield generic midwestern U.S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5–2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

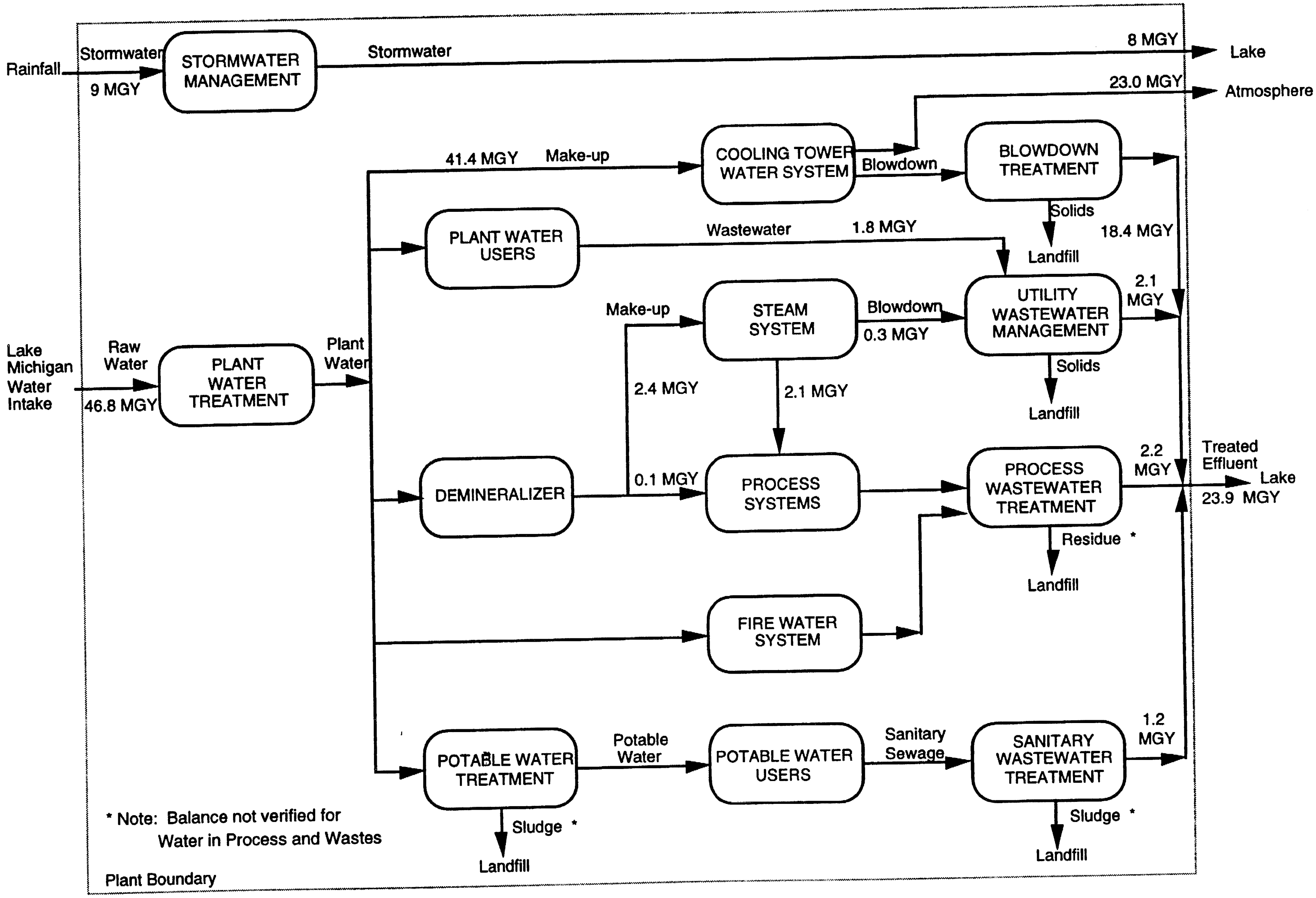

Figure 5-1 Preliminary Water Balance Defluorination / HF Neutralization

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6).

The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14 ton DOT approved carbon steel containers

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Calcium Oxide (Quicklime)	29,000,000
Calcium Hydroxide (Hydrated Lime)	388,000
Detergent	500
Liquid	
Ammonia (99.95% min. NH_3)	662,000
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	18,200
Sodium Hydroxide (50% NaOH)	14,400
Sodium Hypochlorite	4,300
Copolymers	7,700
Phosphates	800
Phosphonates	800
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 56 ft^3 boxes - see also Table 9-1)	568 drums 23 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5–3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	30,000 MWh	1.5 MW
Water	8×10^6 gal	600 gal
Solids		NA
Concrete	15,000 yd^3	
Steel (carbon or mild)	7,000 tons	
Electrical raceway	20,000 yd	
Electrical wire and cable	50,000 yd	
Piping	30,000 yd	
Steel decking	20,000 yd^2	
Steel siding	12,000 yd^2	
Built-up roof	13,500 yd^2	
Interior partitions	1,500 yd^2	
Lumber	4,000 yd^3	
HVAC ductwork	100 tons	
Asphalt paving	250 tons	
Liquids		
Fuel[2]	1.5×10^6 gals	
Gases		
Industrial Gases (propane)	4,000 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g. steel, etc.) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty materials used for equipment fabrication is approximately 30 tons of Monel and 10 tons of Inconel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 Employment Needs During Operation

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	6
Professionals	6
Technicians	29
Office and Clerical	20
Craft Workers (Maintenance)	10
Operators / Line Supervision	95/15
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	207

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 Employees at Risk of Radiological Exposure

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF, the operator will wear acid-resistant protective gear including a respirator.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4[1]
Process Building	35	25	25	25
U_3O_8 Storage Building	3	1	1	1
CaF_2 Storage Building	2	1	1	1
Cylinder Storage Pad and Building	7	3	3	3
Utilities/Services/Admin Areas	40	10	10	10
TOTAL EMPLOYEES	87	40	40	40

1 The fourth shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	250	420	170
Construction Management and Support Staff	30	50	80	30
TOTAL EMPLOYEES	200	300	500	200

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITICIA POLLUTANTS		**Boiler/Other**[1]
Sulfur Dioxide	Boiler Stack / Grade	60/50
Nitrogen Dioxide	Boiler Stack / Grade	8,300/380
Hydrocarbons	Boiler Stack / Grade	180/310
Carbon Monoxide	Boiler Stack / Grade	4,100/2,500
Particulate Matter PM-10	Boiler Stack / Grade	310/80
OTHER POLLUTANTS		
HF	Process Bldg. Stack	300
U_3O_8	Process Bldg. Stack	3.3
Copolymers	Cooling Tower	1,600
Phosphonates	Cooling Tower	150
Phosphates	Cooling Tower	150
Calcium	Cooling Tower	2,700
Magnesium	Cooling Tower	700
Sodium and Potassium	Cooling Tower	280
Chloride	Cooling Tower	500
Dissolved Solids	Cooling Tower	14,900

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	5.0×10^{-4}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	1.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generation During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	216,000	100	26 lb U3O8	370 55-gal drums
Metal, surface contaminated	Failed equipment	65,000	40	77 lb U3O8	148 55-gal drums
Noncombustible, compactible solid	HEPA filters	8,600	47	637 lb U3O8	23 4x2x7 ft boxes (3/4" plywood)
Other	LabPack (chemicals plus absorbent)	3,500	2.2	4 lb U3O8	8 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint	4,500	3 (600 gal)	See description	11 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	8,100	5	8 lb HF 8 lb NaOH	19 55-gal drums
Combustible debris	Wipes, etc.	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb U3O8 0.1 lb Acetone	2 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.2×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	520	22.7×10^6
Recyclable Wastes	210	-

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 WASTES AND EMISSIONS GENERATED DURING CONSTRUCTION

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2
Nitrogen Dioxide	28
Hydrocarbons	8
Carbon Monoxide	190
Particulate Matter PM-10	40

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7–6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction since it has been assumed that the facility will be located on a greenfield site.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	50 yd^3
Hazardous Liquids	20,000 gals
Nonhazardous Solids	
Concrete	100 yd^3
Steel	30 tons
Other	800 yd^3
Nonhazardous Liquids	
Sanitary	3×10^6 gals
Other	1×10^6 gals

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The DUF_6 Conversion Facility buildings include areas with hazard categories of chemically high hazard (HH) for buildings containing DUF_6 and HF and radiologically moderate hazard (HC2) for buildings containing U_3O_8. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgement and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario,
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques,
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following systems, structures and components (SSC's) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant inventories of gaseous HF or liquid NH_3 because their rupture could release HF or NH_3 with unacceptable consequences.
- Vessels containing significant inventories of UF_6 at elevated temperatures because their rupture could release HF or UF_6 (UO_2F_2) with unacceptable consequences.
- The Process Building and U_3O_8 Building structures because they house large gaseous HF and uranium inventories or UF_6 at elevated temperatures, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	41 lb U_3O_8
Tornado	Extremely Unlikely	69 lb U_3O_8
Flood	Incredible	No Release
HF System Leak	Anticipated	10 lb HF
U_3O_8 Drum Spill	Anticipated	1.4×10^{-4} lb U_3O_8
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	19 lb HF
Hydrogen Explosion	Extremely Unlikely	0.27 lb U_3O_8 7 lb HF
Ammonia Release	Unlikely	255 lb NH_3

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	205,000 lb U_3O_8	2.0×10^{-4} (a)	1.0	30 min
Tornado	1,380 lb U_3O_8	0.05 (b)	1.0	30 sec
Flood	No Release	NA	NA	NA
HF System Leak	25 lb HF	1.0	0.4 (c)	15 min
U_3O_8 Drum Spill	690 lb U_3O_8	2.0×10^{-4} (a)	1.0×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	19 lb HF	1.0	1.0	2 min
Hydrogen Explosion	5,250 lb U_3O_8 7 lb HF	0.05 (d) 1.0	1×10^{-3} 1.0	30 min
Ammonia Release	255 lb NH_3	1.0	1.0	1 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).

2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).

3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on powder spill in NUREG-1320, *Nuclear Fuel Cycle Accident Analysis Handbook*, May 1988, p. 4.71. Also consistent with free-fall spill of powders in DOE-HDBK-0013-93, *Recommended Values and Technical Bases for Airborne Release Fractions, Airborne Release Rates and Respirable Fractions at DOE Non-Reactor Nuclear Facilities*, July 1993, p. 4-5.

b. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

c. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

d. Based on deflagration of large volume of flammable mixture above powder in DOE-HDBK-0013-93, p. 4-5. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234, Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium and hydrofluoric acid are the primary hazardous materials handled in this facility. Uranium is toxic and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where high inventory of HF or UF_6 at elevated temperatures is present. Therefore, it would be incredible if these structures failed in the event of the DBE.

The U_3O_8 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,974 drums each containing 1,380 lb of U_3O_8. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum cover is lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Approximately 0.02% of this powder could be expected to become respirable airborne. Thus, approximately 41 lb of U_3O_8 is released to the environment. The release point is at grade.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are performance category PC-4 for structures for chemically high hazard facilities. These building areas are designed to resist the DBT for high hazard facilities. The DBTs defined for these structures would not result in a significant release from these structures. The U_3O_8 Storage Building is a category PC-3 structure for moderate hazard facilities. The DBT defined for this structure would withstand the DBT and not result in a significant release. However, in the extremely unlikely event of a DBT exceeding the PC-3 defined DBT or failure of PC-3 SSCs, a tornado wind-driven missile could impact a U_3O_8 storage drum and release the 1,380 lb inventory of the drum. It is assumed that all of the powder becomes airborne and 5% is in the respirable size range. Therefore, approximately 69 lb of respirable U_3O_8 is released during this extremely unlikely event. However, the powder will be highly dispersed due to tornado wind conditions.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF_6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF System Leak

Gaseous HF is produced from the conversion reactions. The HF is absorbed in a series of two columns to form 20% HF / 80% water solution. After absorption, the HF hazard is diminished because the vapor pressure of 20% HF is low at room temperature. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the off-gas line from the reactors to the absorbers leaks 5% of its flowing contents for 10 minutes, thus releasing 25 lb of HF into the process building. After the leak is detected by air monitoring instruments, the reactor feed is halted to stop the leak. It is assumed that the 40% of the HF vapor (10 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 U_3O_8 Drum Spill

Solid U_3O_8 is produced and packaged in drums in the process building. The drums are transported and stored in the U_3O_8 Storage Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the storage building floor. A drum contains 1,380 lb U_3O_8 . It is assumed that 50% of the U_3O_8 is released from the drum and 0.02% becomes respirable airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne U_3O_8. Thus 0.00014 lb of U_3O_8 is discharged through the U_3O_8 Building exhaust to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.4 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a significant release to the environment.

8.1.3.5 Loss of Cooling Water

Pressure relief valves are provided to protect the reactors, vessels and equipment. Loss of cooling water to the absorption column coolers would cause the absorber liquid to boil and the relief valve to open.

It is postulated that cooling water is lost and hot off-gas continues to flow into the column for 1 minute, vaporizing 19 lb of HF and 75 lb of water. High temperature and pressure alarms and interlocks would shut down the feed input to the columns to stop the release. About 19 lb of HF would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.6 Hydrogen Explosion

Hydrogen is fed to Reactor No. 2 as a reagent, where it reacts with oxygen to form water. Oxygen is produced in the reactor because it is a product of the reaction of UO_2F_2 with steam. The hydrogen flowrate is controlled such that all the hydrogen and oxygen react.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. An excess of steam is also fed to the reactor. The reactor vapor space normally contains steam, HF and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions and operator errors causes a large amount of hydrogen and air to accumulate in the reactor and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

The reactor is assumed to contain about 10,500 lb of U_3O_8 during normal operation (3 hour residence time). It is assumed that 50% of the material is released into the room, of which 100% becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the material. Thus 0.27 lb of U_3O_8 is discharged through the Process Building exhaust stack. The reactor also contains 7 lb of HF which is released to the stack. This accident is judged to be extremely unlikely.

8.1.3.7 Ammonia Release

Ammonia is stored as a liquid in two 7,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so it will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia", Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is considered unlikely.

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

9.0 Transportation

9.1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, U_3O_8 product in 55 gallon drums from the Process Building to the U_3O_8 Storage Building, and low level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of U_3O_8 to the plant boundary. Hazardous waste materials such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, laboratory wastes, etc. requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary for shipment to off-site hazardous waste treatment, storage and disposal facilities.

9.2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product, and waste materials are shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), hydrochloric acid (HCl), and ammonia (NH_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium oxide (U_3O_8), low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

The U_3O_8 product is packaged in 55 gallon steel drums that are 35 inches high by 22.5 inches outside diameter. The empty drum weighs 75 lbs and has a wall thickness of 0.053 inches (16 gage). Each drum contains 1,380 lbs of U_3O_8.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4
Transported Materials				
Type	UF_6	HCl	NaOH	NH_3
Physical Form	Solid	Liquid	Liquid	Liquid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	NH_3 / 100°F, 197 psig (max.)
Packaging				
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	Tank Truck 5,500 gal
Certified by	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	MC-330, 331
Container Weight (lb)	2,600	50	50	TBD
Material Weight (lb)	27,000	540	660	26,000
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% NH_3
Shipments				
Average Volume (ft^3)/Year	323,000	243	147	19,100
Packages/Year	2,322	33	20	26
Packages/Life of Project	46,440	660	400	520
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	17	10	1
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	26
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	520
Form of Transport/Routing				
Form of Transportation	Truck/Rail	Truck	Truck	Truck
Destination - Facility Type	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	Uranium Oxide	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	U_3O_8 / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	55 Gallon Drum	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	TBD	Varies	Varies	Varies	48G
Container Weight (lb)	75	50/300	50	50	2,600
Material Weight (lb)	1,380	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% U_3O_8	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	262,400	5,200	265	44	323,000
Packages/Year	35,700	526/23	36	6	2,322
Packages/Life of Project	714,000	10,520/460	720	120	46,440
Packages/Shipment	28 (truck) or 80 (railcar), 4 cars/train	40/12	18	6	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	1,275 (truck) or 112 (rail)	14/2	2	1	387 (truck) or 49 (rail)
Shipments/Life of Project	25,500 (truck) or 2,240 (rail)	280/40	40	20	7,740 (truck) or 980 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	TBD	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

10.0 References

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
atm	atmosphere
CaF_2	calcium fluoride
CAR	Cost Analysis Report
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft^2	square feet
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt hour(s) (1×10^9 watt-hour)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement

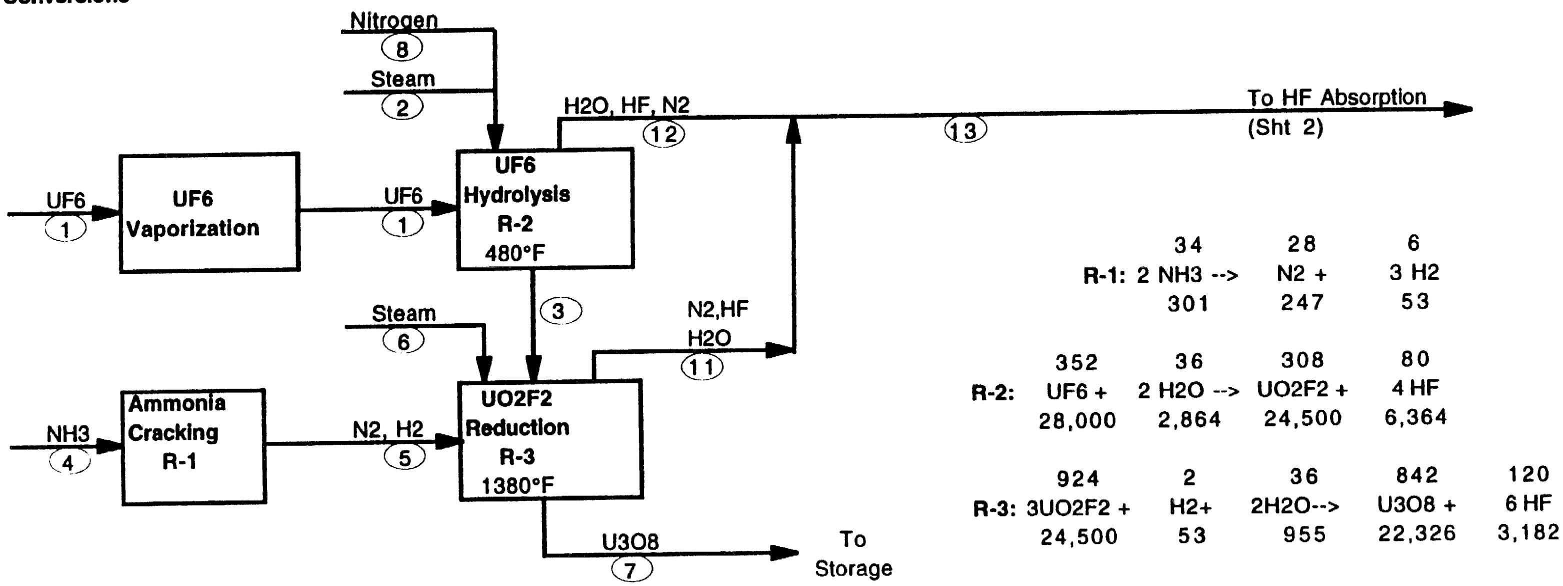
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

2-Mass Balance MT/yr

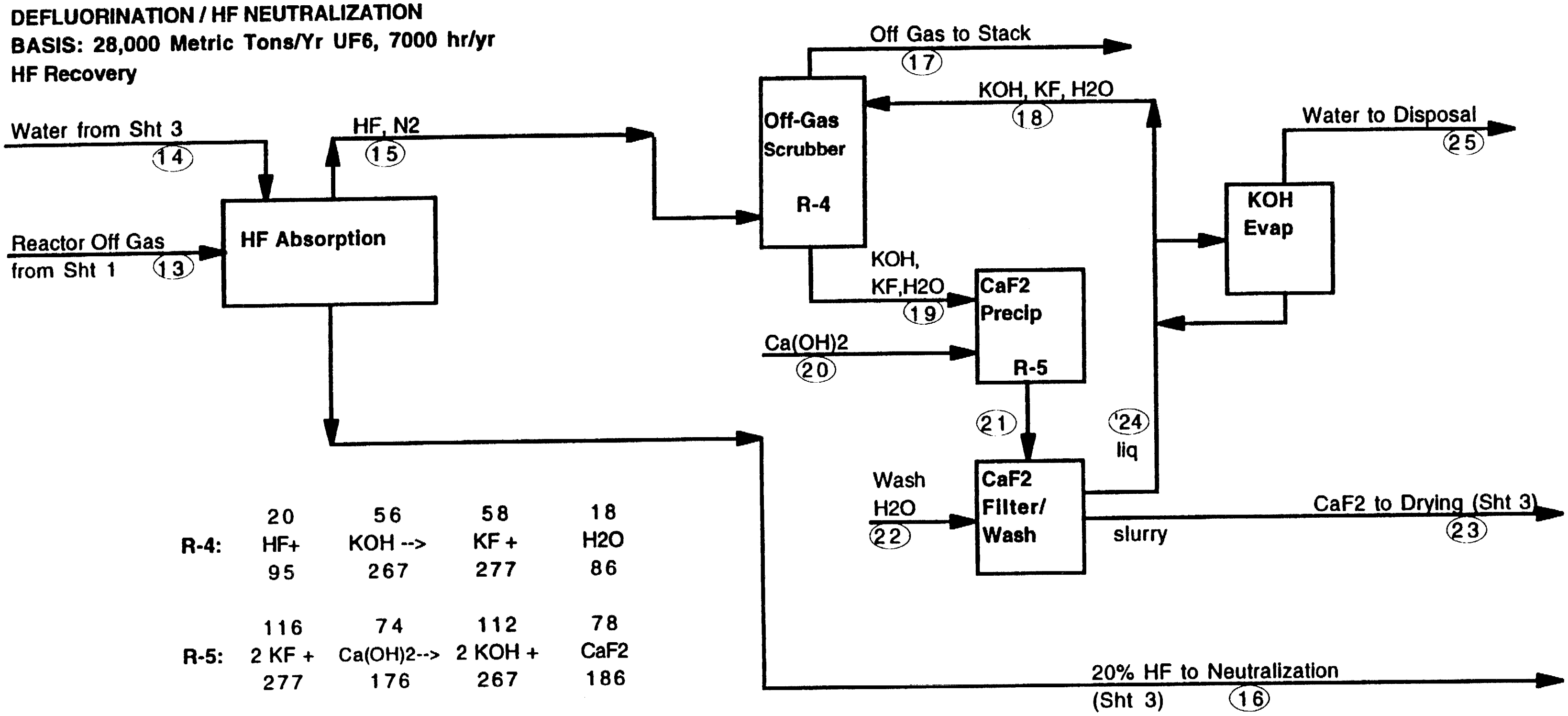
DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions



	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13
UF6	352	28,000												
UO2F2	308			24,500										
UO2	270													
U3O8	842							22,326						
HF	20											3,182	6,364	9,545
H2O	18		4,295				3,614					2,659	1,432	4,091
NH3	17				301									
H2	2					53						0		0
N2	28					247			4,480			247	4,480	4,727
O2	32													
Total MT/yr		28,000	4,295	24,500	301	301	3,614	22,326	4,480	0	0	6,089	12,275	18,364
kg/kg U		1.48	0.23	1.29	0.016	0.016	0.19	1.18	0.24	0.00	0.00	0.32	0.65	0.97

2-Mass B[illegible] MT/yr

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery



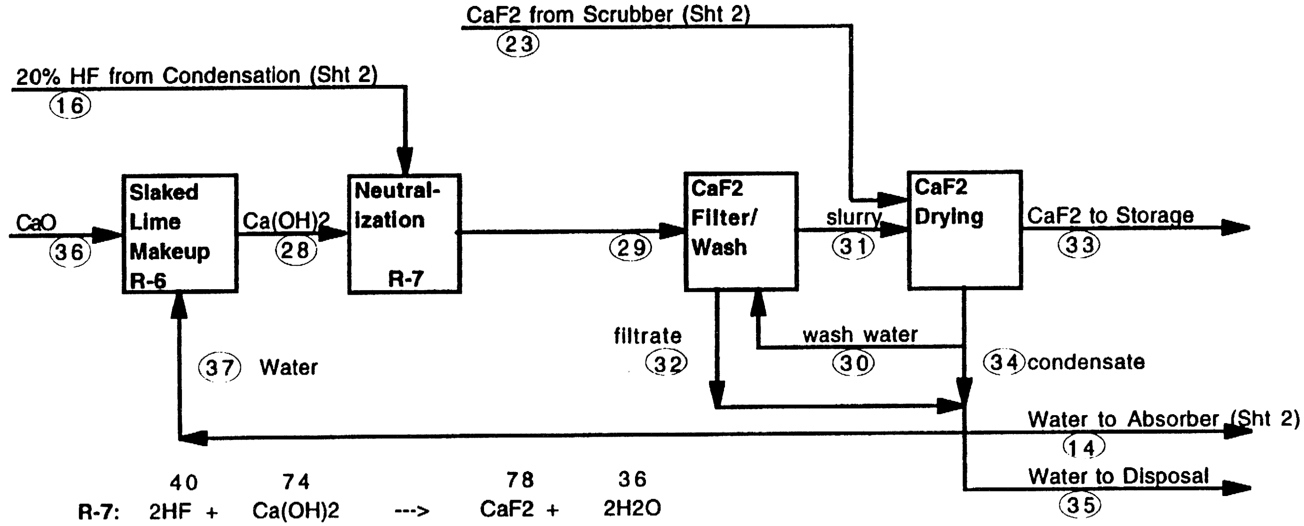
	20	56	58	18
R-4:	HF+	KOH -->	KF +	H2O
	95	267	277	86

	116	74	112	78
R-5:	2 KF +	Ca(OH)2-->	2 KOH +	CaF2
	277	176	267	186

	Mol Wt	14	15	16	17	18	19	20	21	22	23	24	25	26
Ca(OH)2	74							176	0					
CaF2	78								186		186			
KOH	56					334	67		334			334		
KF	58					28	304		28			28		
HF	20		95.5	9,450	0.10									
H2O	18	33,907	198	37,800	198	47,680	47,766		47,766	279	93	47,952	272	
H2	2		0		0									
N2	28		4,727		4,727									
O2	32													
Total MT/yr		33,907	5,021	47,250	4,926	48,042	48,137	176	48,314	279	279	48,314	272	0
kg/kg U		1.79	0.27	2.50	0.26	2.54	2.54	0.0093	2.55	0.015	0.015	2.55	0.014	0.00

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Neutralization

Overall Balance
Mass In 54,375
Mass Out 54,375



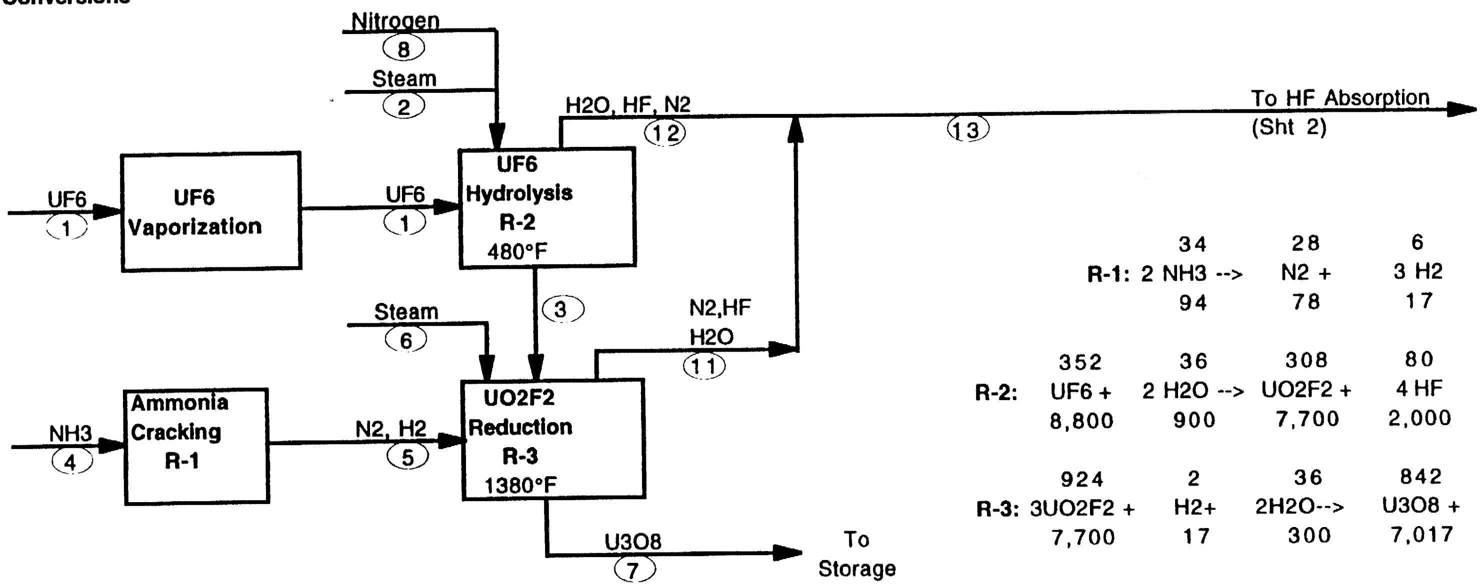
	40	74		78	36
R-7:	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
	9,450	17,483		18,428	8,505

	56	18		74
R-6:	CaO +	H2O	--->	Ca(OH)2
	13,230	4,253		17,483

	Mol Wt	27	28	29	30	31	32	33	34	35	36	37
Ca(OH)2	74		17,483	0								
CaF2	78			18,428		18,428		18,613				
KOH	56											
KF	58											
HF	20			0								
H2O	18		52,448	98,753	9,214	9,214	98,753		93	8,238		56,700
CaO	56										13,230	
H2	2											
N2	28											
O2	32											
Total MT/yr		0	69,930	117,180	9,214	27,641	98,753	18,613	93	8,238	13,230	56,700
kg/kg U		0.00	3.69	6.19	0.49	1.46	5.22	0.98	0.0049	0.44	0.70	2.99

2-Mass Balance lb/hr

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions

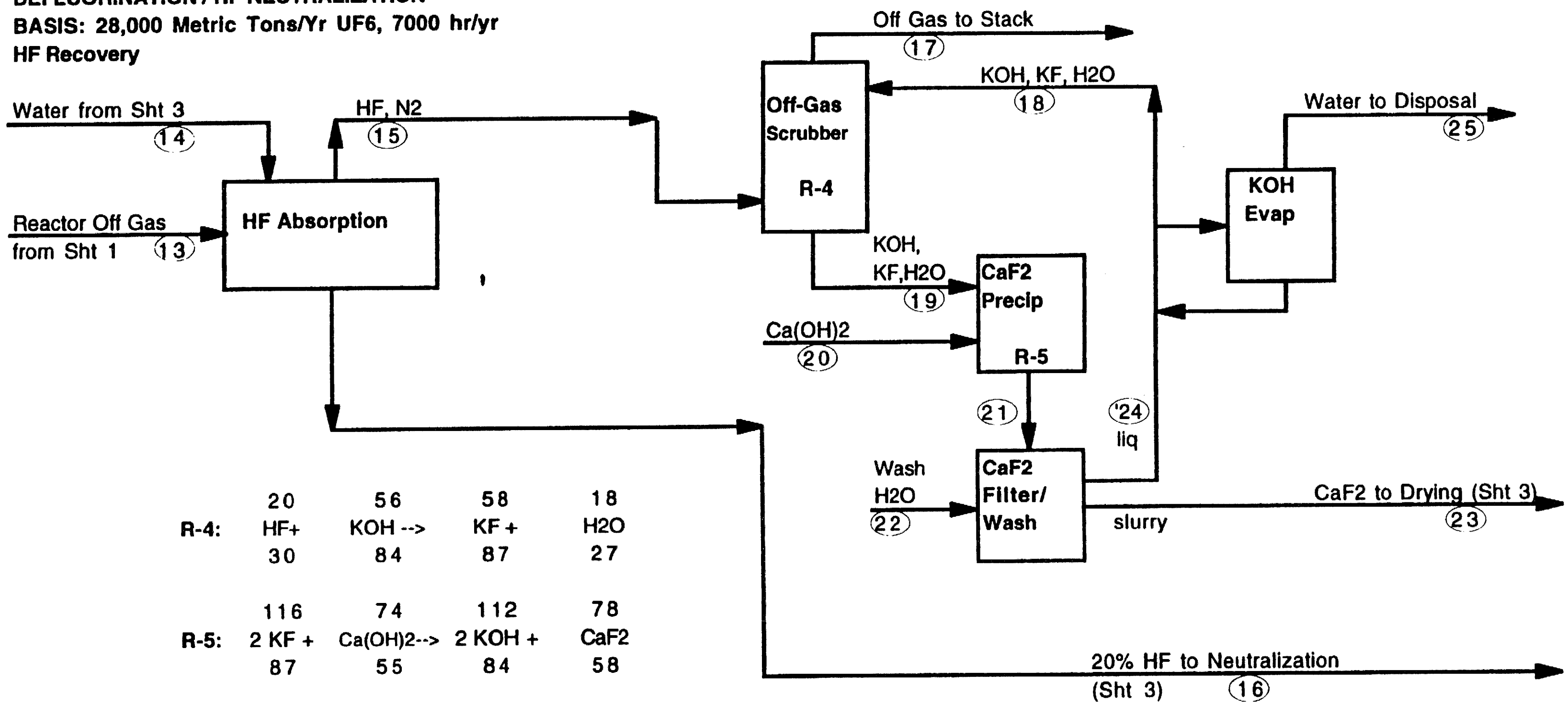


		34	28	6	
R-1:		2 NH3 -->	N2 +	3 H2	
		94	78	17	
	352	36	308	80	
R-2:	UF6 +	2 H2O -->	UO2F2 +	4 HF	
	8,800	900	7,700	2,000	
	924	2	36	842	120
R-3:	3UO2F2 +	H2+	2H2O-->	U3O8 +	6 HF
	7,700	17	300	7,017	1,000

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13
UF6	352	8,800												
UO2F2	308			7,700										
UO2	270													
U3O8	842							7,017						
HF	20											1,000	2,000	3,000
H2O	18		1,350				1,136					836	450	1,286
NH3	17				94									
H2	2					17						0		0
N2	28					78			1,408			78	1,408	1,486
O2	32													
Total lb/hr		8,800	1,350	7,700	94	94	1,136	7,017	1,408	0	0	1,914	3,858	5,772
kg/kg U		1.48	0.23	1.29	0.016	0.016	0.19	1.18	0.24	0.00	0.00	0.32	0.65	0.97

2-Mass Balance lb/hr

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery



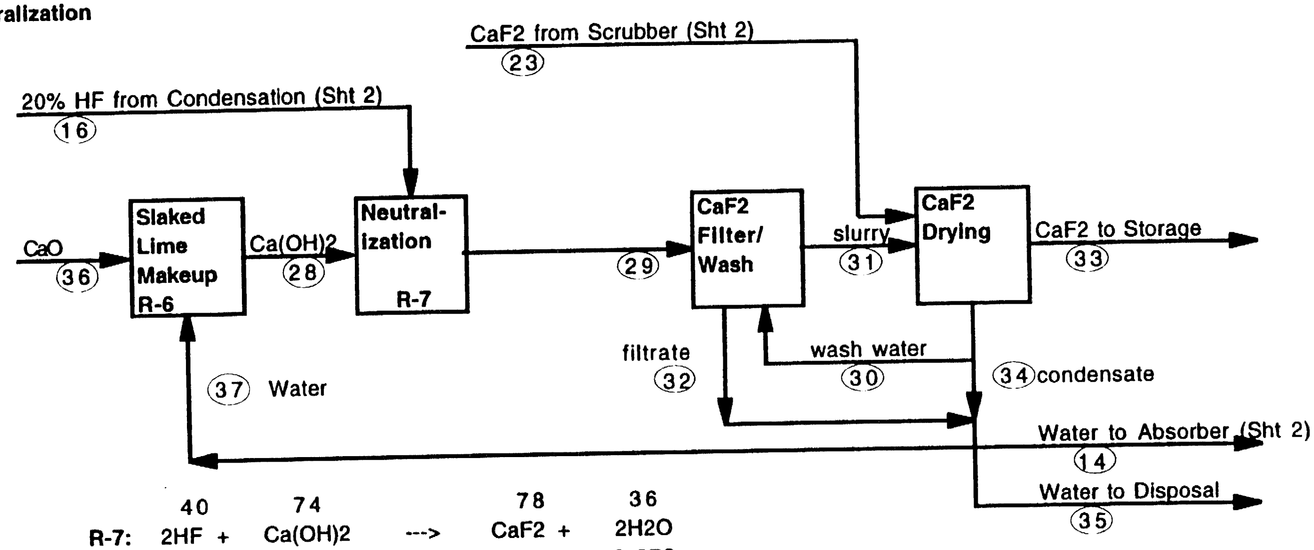
	20	56	58	18
R-4:	HF+	KOH -->	KF +	H2O
	30	84	87	27
	116	74	112	78
R-5:	2 KF +	Ca(OH)2-->	2 KOH +	CaF2
	87	55	84	58

	Mol Wt	14	15	16	17	18	19	20	21	22	23	24	25	26
Ca(OH)2	74							55	0					
CaF2	78								58		58			
KOH	56					105	21		105			105		
KF	58					9	96		9			9		
HF	20		30.0	2,970	0.03									
H2O	18	10,656	62	11,880	62	14,985	15,012		15,012	88	29	15,071	85	
H2	2		0		0									
N2	28		1,486		1,486									
O2	32													
Total lb/hr		10,656	1,578	14,850	1,548	15,099	15,129	55	15,184	88	88	15,184	85	0
kg/kg U		1.79	0.27	2.50	0.26	2.54	2.54	0.0093	2.55	0.015	0.015	2.55	0.014	0.00

2-Mass Balance lb/hr

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Neutralization

Overall Balance
Mass In 17,089
Mass Out 17,089



	40	74		78	36
R-7:	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
	2,970	5,495		5,792	2,673

	56	18		74
R-6:	CaO +	H2O	--->	Ca(OH)2
	4,158	1,337		5,495

	Mol Wt	27	28	29	30	31	32	33	34	35	36	37
Ca(OH)2	74		5,495	0								
CaF2	78			5,792		5,792		5,850				
KOH	56											
KF	58											
HF	20			0								
H2O	18		16,484	31,037	2,896	2,896	31,037		29	2,589		17,820
CaO	56										4,158	
H2	2											
N2	28											
O2	32											
Total lb/hr		0	21,978	36,828	2,896	8,687	31,037	5,850	29	2,589	4,158	17,820
kg/kg U		0.00	3.69	6.19	0.49	1.46	5.22	0.98	0.0049	0.44	0.70	2.99

Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Defluorination / HF Neutralization Process

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressor (14)	800 lb/hr UF6, 15 psig discharge	Proc. Bldg
Reactor No. 1 (2)	3'6"Dx10'H, fluidized bed, cooling jacket, Monel	Proc. Bldg
Screw Conveyor (2)	6"Dx10'L, 40 cfh, Monel	Proc. Bldg
Reactor No. 2 (2)	6'Dx30'L rotary kiln, indirect heating, Inconel	Proc. Bldg
Off-Gas System	Cyclone and sintered metal filters	Proc. Bldg
U3O8 Product Cooler (2)	12"Dx10'L, screw conveyor with cooling water, steel, 40 cfh	Proc. Bldg
U3O8 Bucket Elevator No. 1 (2)	20'H, 40 cfh	Proc. Bldg
U3O8 Raw Product Bin	4'Dx8'H, 80 cf, steel	Proc. Bldg
U3O8 Roller Compactor	80 cfh	Proc. Bldg
U3O8 Granulator	40 cfh	Proc. Bldg
U3O8 Bucket Elevator No. 2	20'H, 40 cfh	Proc. Bldg
U3O8 Compacted Product Bin	4'Dx8'H, 80 cf, steel	Proc. Bldg
U3O8 Drum Filling Station	5.1 drums/hr, glovebox	Proc. Bldg
U3O8 Dust Collector	baghouse	Proc. Bldg
HF Absorber Column No. 1	4'Dx21'H, plastic packing, Monel shell	Proc. Bldg
Absorber No. 1 Pump	175 gpm, Monel	Proc. Bldg
Absorber No. 1 Cooler	3'Dx8'L, 1200 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Absorber Column No. 2	2.5'Dx19'H, plastic packing, Monel shell	Proc. Bldg
Absorber No. 2 Pump	50 gpm, Monel	Proc. Bldg
Absorber No. 2 Cooler	1'6"Dx8'L, 300 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Neutralization Tank No. 1	9'Dx10'H, 4500 gal, Monel, 1300 sq ft cooling coil	Proc. Bldg
HF Neutralization Tank No. 2	9'Dx10'H, 4500 gal, Monel, no coils	Proc. Bldg
Drum Filter	3'Dx4'L, 40 sq ft, steel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	9'Dx10'H, 4500 gal, steel	Proc. Bldg
Filtrate Transfer Pump	70 gpm, cast iron	Proc. Bldg
Recycle Water Tank	11'Dx12'H, 8500 gal, steel	Proc. Bldg
Recycle Water Transfer Pump	70 gpm, cast iron	Proc. Bldg
CaF2 Rotary Dryer	6'Dx35'L, 1800 sq ft steam tubes, steel	Proc. Bldg
CaF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
CaF2 Dryer Condensate Tank	4'Dx4'H, 400 gal, steel	Proc. Bldg
CaF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water, steel, 60 cfh	Proc. Bldg
CaF2 Bucket Elevator	20'H, 60 cfh, steel	Proc. Bldg
CaF2 Product Bin	4'Dx11'H, 120 cf, steel	Proc. Bldg
CaF2 Drum Filling Station	7.3 drums/hr, glovebox	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / HF Neutralization Process

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
Off-Gas Scrubber	2'Dx10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	2.5 kw electric heater	Proc. Bldg
Off-Gas HEPA Filter (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhauster (2)	100 scfm	Proc. Bldg
Lime Feed Bin	4'Dx6'H, 60 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 0.8 cfh, steel	Proc. Bldg
Precipitation Tank	7'Dx7'H, 2000 gal, Monel	Proc. Bldg
Drum Filter	6'Dx8'L, 150 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	7'Dx7'H, 2000 gal, Monel	Proc. Bldg
Scrub Solution Cooler	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Scrub Solution Pump	30 gpm, Monel	Proc. Bldg
Evaporator	1'6"Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	3'Dx3'H, 100 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
Lime Silo (2)	12'Dx58'H, 6000 cf, steel	Yard
Lime Pneumatic Conveyor	16 tons/hr	Proc. Bldg
Lime Feed Bin	7'Dx17'H, 600 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 70 cfh, steel	Proc. Bldg
Lime Slaker	5'Dx23'H, 20 hp, steel, 2.1 tons lime/hr	Proc. Bldg
Slaked Lime Transfer Pump	40 gpm, cast iron	Proc. Bldg
Slaked Lime Feed Tank	9'Dx11'H, 5000 gal, steel, 500 sq ft cooling coil	Proc. Bldg
Slaked Lime Feed Pump	40 gpm, cast iron	Proc. Bldg
Ammonia Storage Tank (2)	7'Dx25'L, 7000 gal, steel, 250 psig design	Yard
Ammonia Dissociator (1)	4000 cfh N2+H2, 66 kw	Proc. Bldg
Nitrogen Generator	320 scfm, membrane separation	Proc. Bldg
Air Compressor	600 cfm, 150 psi, 172 bhp	Proc. Bldg
Nitrogen Receiver (2)	4'Dx13'H, 1200 gal, 150 psig design, steel	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / HF Neutralization Process

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Process Material Handling Systems	DUF_6 cylinder handling:	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated carbon steel storage racks for 14-ton DUF_6 cylinders	Proc. Bldg
	Two(2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	U_3O_8 drum handling:	
	-3 flatbed trucks	Yard
	-3 55 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg/ U_3O_8 Bldg
	-3 forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ U_3O_8 Bldg
	CaF_2 handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ CaF_2 Bldg
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U_3O_8 drum / LLW CaF_2 packaging and drum handling areas	Proc. Bldg
Sampling / Analytical Systems	-6 local sampling glove boxes with laboratory liquid / powder sample hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / HF Neutralization Process

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Low Level Radioactive & Hazardous Waste Management System	Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U_3O_8 drums	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U_3O_8 tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc,Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2, - 270,000 gal Fire system piping Sprinkler System Alarm system	
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg

MAJOR EQUIPMENT LIST (Continued)
Defluorination / HF Neutralization Process

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 15,000 lb/hr, 50 psig gas fired	Util. Bldg
	Air compressors - 2@ 300 cfm 150 psig	Util. Bldg
	Breathing Air Compressors-2 @ 100 cfm	Util. Bldg
	Air Dryers - desiccant, -40°F dew point	Util. Bldg
	Demineralized water system - 7000 gpd	Util. Bldg
	Sanitary water treatment system - 3300 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 70,000 gpd	Wastewater Treatment area
	Electrical substation - 1400 kW	Substation
	Emergency generators - 2 @ 300kW	Substation
	Uninterruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 26 MM Btu/hr, 2600 gpm	Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-2000 cfm, 5 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-50,000 cfm, 120 HP exhaust fans, 2-50,000 cfm 60 HP supply air units	U_3O_8 Areas DUF_6 Areas Analytical Lab HF Absorption
Zone 3 HVAC System	2-30,000 cfm, 25 HP supply air units, 2-15,000 cfm, 10 HP exhaust fans, 2-15,000 cfm, 15 HP supply air units	CaF_2 Areas Waste Proc'g Control Room Support Areas
HVAC Chillers	3-275 ton chillers	Proc. Bldg
Circulating Pumps	3-450 gpm, 15 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

DEFLUORINATION / HF NEUTRALIZATION - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	21	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	21	6	Steel	1/4"	3483.0
UO2F2 reactor surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
U3O8 reactor surveillance	1	0.50	1752	7	3	Inconel	1.5"	876.0
U3O8 compactor surveillance	1	0.50	1752	8,9	3	Steel	1/4"	876.0
Transfer U3O8 drums to interim storage	2	0.50	7137	10,11	3	Steel	0.06"	7137.0
Transfer U3O8 drums to storage building	2	0.50	7137	10,11	3	Steel	0.06"	7137.0
Load U3O8 drums for shipment offsite	2	1.00	1200	10,13	3	Steel	0.06"	2400.0
U3O8 interim storage surveillance	1	0.50	2190	10,14	3	Steel	0.06"	1095.0
U3O8 storage building surveillance	1	0.50	2190	10,15	3	Steel	0.06"	1095.0
HF absorption surveillance	1	0.50	1752	6,7	20	Monel,Inconel	3/4",1.5"	876.0
Off-gas Scrubbing / Process Liquid Treat. surveillance	1	0.50	1752	8,9	20	Steel	1/4"	876.0
HF Neutralization / CaF2 Processing surveillance	1	0.50	1752	6,7	60	Monel,Inconel	3/4",1.5"	876.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS
Transfer CaF2 drums to interim storage	2	0.50	7288	6,7,16	100	Monel,Inconel	3/4",1.5"	7286.0
Transfer CaF2 drums to storage area	2	0.50	7286	8,9,16	60	Steel	1/4"	7286.0
Load CaF2 drums for shipment offsite	1	1.00	1275	10,15,17	30	Steel	0.06"	1275.0
CaF2 interim storage surveillance	1	0.25	2190	8,9	60	Steel	1/4"	547.5
CaF2 storage building surveillance	1	0.50	2190	10,15	30	Steel	0.06"	1095.0
LLW processing, packaging, and shipping	2	8.00	1100	20	3	Steel	0.06"	17600.0
Process control room operations	8	8.00	1100	10,14	30	Steel	0.06"	70400.0
Laboratory operations	4	8.00	1100	8,9	30	Steel	1/4"	35200.0
HP	2	8.00	1100	10,14	30	Steel	0.06"	17600.0
Management / Professionals	12	8.00	250	6,7	30	Monel,Inconel	3/4",1.5"	24000.0
Accountability	2	2.00	1100	3,4,15	3	Steel	1/4",0.06"	4400.0
Industrial and sanitary waste treatment	4	8.00	1100	2,5	50	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	6,7	120	Monel,Inconel	3/4",1.5"	35200.0
Administration	20	8.00	250	2,5	100	Steel	1/4"	40000.0
Guardhouses / Proc. Bldg	5	8.00	1100	2,5	100	Steel	1/4"	44000.0
Maintenance								14232.0
								409535.1

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 19)	THICKNESS	PERSON HOURS

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) Compactor feed bin; there are 2 bins.
9) Drum fill bin.
10) Drum of U3O8.
11) Each transfer consists of 5 U3O8 drums.
12)
13) There are 30 U3O8 drums per shipment.
14) There are 120 U3O8 drums in interim storage
15) There are 3,000 U3O8 drums in the storage building.
16) Each transfer consists of 7 CaF2 drums
17) There are 40 CaF2 drums per shipment
18) 2322 UF6 cylinders per year
365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
35683 U3O8 drums/yr / 5 drums per transfer = 7137 transfers per year
35683 U3O8 drums/yr / 30 drums per transfer = 1200 shipments per year
51000 CaF2 drums/yr / 7 drums per transfer = 7286 transfers per year
51000 CaF2 drums/yr / 40 drums per shipment = 1275 transfers per year
365 days per year x 3 shifts per day x 1 per shift = 1100 per year
2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
19) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
20) Batch of LLW
21) A single 3 mo. old empty UF6 cylinder

DEFLUORINATION / HF NEUTRALIZATION - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UO2F2 reactor (Reactor No. 1) (2)	2	26	2	6	3	Monel	3/4"	104
UO2F2 screw conveyor (2)	2	104	2	6	3	Monel	3/4"	416
UO2F2 sintered metal filter (2)	2	4	2	15	1			16
U3O8 reactor (Reactor No. 2) (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 product cooler (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 sintered metal filter (2)	2	4	2	15	1			16
U3O8 bucket elevator No. 1 (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 compactor (1)	2	52	1	8,9	3	Steel	1/4"	104
U3O8 granulator (1)	2	52	1	8,9	3	Steel	1/4"	104
U3O8 bucket elevator No. 2 (1)	2	104	1	8,9	3	Steel	1/4"	208
U3O8 dust collector (1)	2	4	1	15	1			8
HF absorber columns (2)	2	26	2	6,7	20	Monel, Inconel	3/4",1.5"	104
HF absorber coolers (2)	2	26	2	6,7	20	Monel, Inconel	3/4",1.5"	104
HF absorber pumps (2)	2	52	2	6,7	20	Monel, Inconel	3/4",1.5"	208
CaF2 drum filter (1)	2	26	1	6,7	45	Monel, Inconel	3/4",1.5"	52
vacuum pump (1)	2	52	1	6,7	45	Monel, Inconel	3/4",1.5"	104
filtrate transfer pump (1)	2	52	1	6,7	45	Monel, Inconel	3/4",1.5"	104
recycle water transfer pump (1)	2	52	1	6,7	45	Monel, Inconel	3/4",1.5"	104
CaF2 rotary dryer (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
CaF2 dryer condenser (1)	2	26	1	6,7	60	Monel, Inconel	3/4",1.5"	52
CaF2 solids cooler (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
CaF2 bucket elevator (1)	2	104	1	6,7	60	Monel, Inconel	3/4",1.5"	208
CaF2 dust collector (baghouse) (1)	2	4	1	6,7	120	Monel, Inconel	3/4",1.5"	8
Off-gas HEPA filters (2)	2	4	2	8,9	20	Steel	1/4"	16

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR
Off-gas exhausters (2)	2	52	2	8,9	20	Steel	1/4"	208
Off-gas scrubber (1)	2	26	1	8,9	20	Steel	1/4"	52
Off-gas heater (1)	2	26	1	8,9	20	Steel	1/4"	52
Lime feeder (1)	2	104	1	6,7	60	Monel, Inconel	3/4",1.5"	208
Drum filter (1)	2	26	1	6,7	60	Monel, Inconel	3/4",1.5"	52
Vacuum pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
Scrub pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
Evaporator (1)	2	26	1	6,7	60	Monel, Inconel	3/4",1.5"	52
Condenser (1)	2	26	1	6,7	60	Monel, Inconel	3/4",1.5"	52
Condensate pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
Lime feeder (1)	2	104	1	6,7	60	Monel, Inconel	3/4",1.5"	208
Lime slaker (1)	2	104	1	6,7	60	Monel, Inconel	3/4",1.5"	208
Slaked lime transfer pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
Slaked lime feed pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4",1.5"	104
Ammonia dissociator (1)	2	26	1	6,7	200	Monel, Inconel	3/4",1.5"	52
Nitrogen generator (1)	2	26	1	6,7	200	Monel, Inconel	3/4",1.5"	52
Air compressor (1)	2	52	1	6,7	200	Monel, Inconel	3/4",1.5"	104
Boiler, Water Systems, Other Utilities	2	52	3	6,7	200	Monel, Inconel	3/4",1.5"	312
HVAC equipment	2	520	1	6,7	30	Monel, Inconel	3/4",1.5"	1040
Waste water treatment equipment	1	2190	1	2,5	50	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	6,7	120	Monel, Inconel	3/4", 1.5"	2190
Admin building	1	1000	1	2,5	50	Steel	1/4"	1000
								14232

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 13)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 14)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) Compactor feed bin; there are 2 bins.
9) Drum fill bin.
10) Drum of U3O8.
11) Each transfer consists of 5 U3O8 drums.
12)
13) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - Includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - Includes instrumentation
    10 hours per week on HVAC components
    6 hours per day on waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
14) Materials do not include walls between operating areas.
15) Loaded filter/bag.

Section 6.6

UO_2: Ceramic UO_2 / Anhydrous HF Facility

Section 6.6
UO2: Ceramic UO2 / Anhydrous HF Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into uranium dioxide (UO_2) and anhydrous hydrofluoric acid (HF). Due to its high density and chemical stability, UO_2 is a principal option for uranium use, long term storage or disposal. Anhydrous HF is assumed to be a salable material to industry. UF_6 defluorination is achieved through a steam/hydrogen, hydrolysis/pyrohydrolysis route. UO_2 powder is pressed and sintered to form high density pellets. Upgrading of the aqueous HF to anhydrous HF is accomplished by conventional distillation. Specific process aspects for flowsheet modeling were based on the Allied Signal/General Atomic/Sequoyah Fuels patent and processes used in the nuclear fuel fabrication industry.

Process Summary

Depleted uranium hexafluoride (UF_6) is processed to produce sintered uranium dioxide (UO_2) pellets and hydrofluoric acid (HF). The conversion of UF_6 to UO_2F_2 with HF recycle is based on a Sequoyah Fuels patent. The conversion of UO_2F_2 to UO_2 pellets is based on processes used in the nuclear fuel fabrication industry.

The UF_6 is converted to UO_2 in two steps. The UF_6 is vaporized using steam-heated autoclaves and fed to a reactor, where it is mixed with HF-water vapor. Solid UO_2F_2 is produced and flows to a second reactor, where the UO_2F_2 is mixed with hydrogen, nitrogen and steam to produce solid UO_2. Vapor containing HF, hydrogen and water flows to the HF distillation column. Distillation of the HF stream produces anhydrous HF which can be sold commercially. Uncondensed off-gas from the distillation process flows to the scrubber system. The UO_2 is discharged from the reactor, cooled, and sent to powder processing.

The UO_2 powder is milled, compacted and granulated, then mixed with a dry lubricant in a blender. The granules are fed to a high-speed press that produces cylindrical pellets. The pellets are sintered in a continuous tunnel kiln operating at 1700°C under a reducing gas atmosphere. The sintered UO_2 pellets are loaded into drums for storage and shipment.

1.0 DUF_6 Conversion Facility - Missions, Assumptions, and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Ceramic UO_2 /Anhydrous Hydrofluoric Acid Conversion Facility converts depleted UF_6 into uranium dioxide (UO_2) for use (shielding), long-term storage, or disposal.

1.2 ASSUMPTIONS AND DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure with an average isotopic composition as follows: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinders, the short-lived daughter products of U-238, Th-234 and Pa-234m, are in equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is 7,000 hours based on a plant availability factor of 0.8.
- For the conversion process, two reactor trains are needed for the conversion from UF_6 to UO_2 and three furnace trains are needed for UO_2 pellet sintering. Other systems can be accomplished with a single train.
- The anhydrous HF produced in the process is shipped off-site in rail tank cars or tanker trucks. Indoor storage of one month's production is provided on site.

- Sintered UO_2 pellets are packaged in 30 gallon drums. Grout and CaF_2 products are packaged in 55-gallon drums. Since the weight of UO_2 in a full drum exceeds the maximum weight limitations for a standard drum, it is assumed that specially engineered drums are used for UO_2. Indoor storage space for one month's production is provided on site.
- On-site storage of one month's supply of ammonia, cement, and lime is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities", as defined in DOE Order 6430.1A, and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- HF Storage Building
- UO_2 Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility including the following:

- CaF_2 Storage Building
- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20-year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

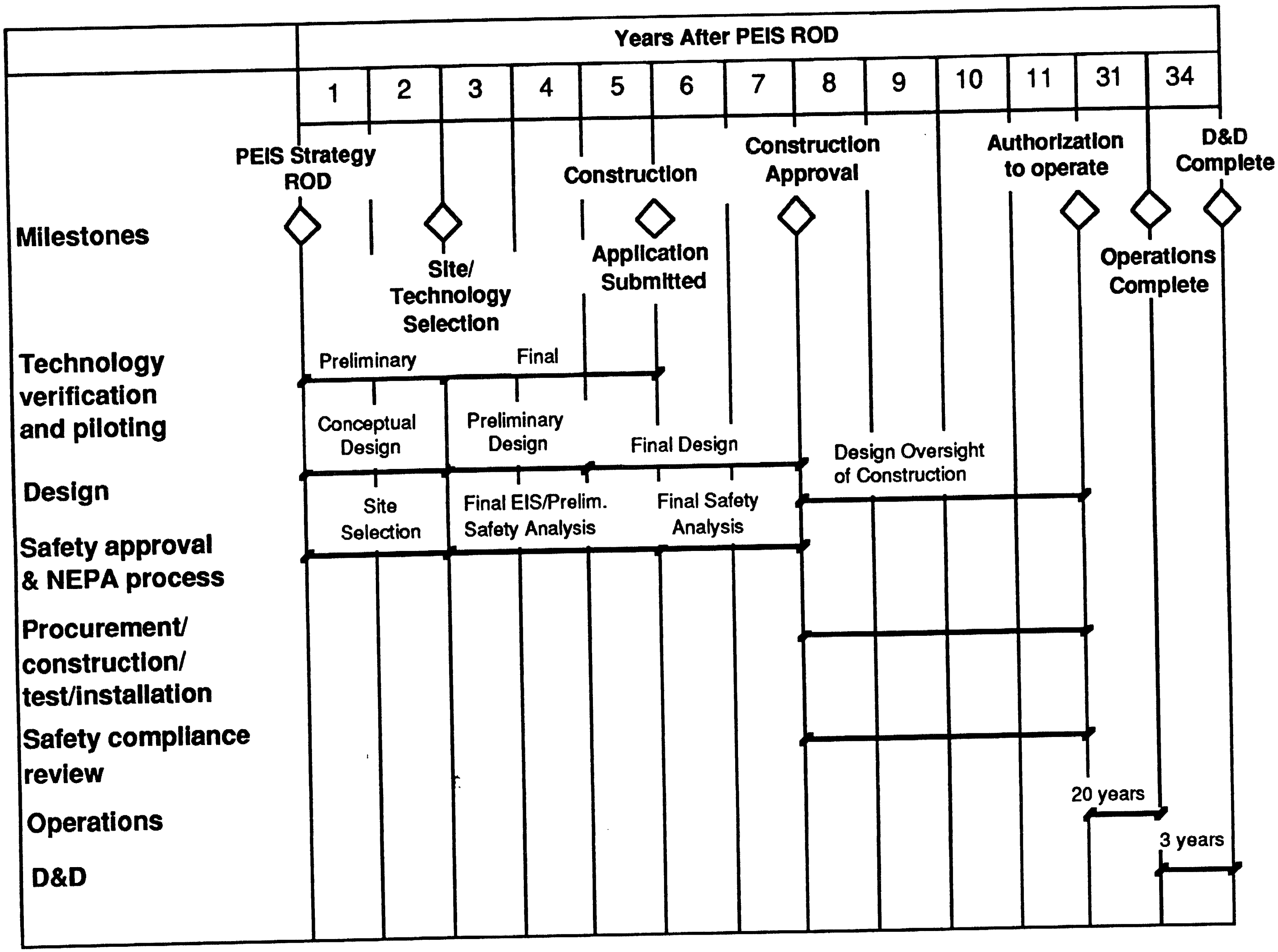


Figure 1-1 Preliminary Project Schedule

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502, *Environmental Impact Statement*, 10 CFR 1021, *National Environmental Policy Act Implementing Procedures (for DOE)*, and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program.*

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, and guidelines, as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*, DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act*. Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection*.

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements*; the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions, - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the facility and process include the following:

- This process has not been demonstrated on a throughput scale assumed for this study (28,000 MT/yr UF_6). Primary concern is direct scaleup of the conversion reactors.
- Sintering furnaces combining high temperature, special gas atmosphere and high capacity are required. Furnaces with one or two of these features are common, but a furnace combining all of these will require some engineering and development. However, it is believed that the furnace design is technically feasible.
- The optimum material of construction for reactor system process equipment and components exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.
- The ultimate use, storage or disposal form of the UO_2 product has not been finalized. Also, the viability of shipment of UO_2 in 30 gallon drums has not been determined.
- The relative hazards and economics of on-site storage of large quantities of hydrofluoric acid (HF) in tanks versus on-site storage of HF in rail tank cars has not been fully assessed.
- Due to the pre-conceptual nature of the facility design, design details of process and support system equipment and components as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment, system, and facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium dioxide (UO_2) and anhydrous hydrofluoric acid (AHF) by defluorination with steam and hydrogen. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a series of two reactors, to solid UO_2 product which is then milled, compacted, granulated, and screened. The UO_2 is pressed into pellets, sintered and packaged in 30 gallon drums. The UO_2 product is stored on-site until it is transported to another site for subsequent disposition; long term storage, use or disposal. Hydrofluoric acid produced in the reaction is recovered as AHF by distillation and is assumed to be sold.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- HF Storage Building
- UO_2 Storage Building
- CaF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings, including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

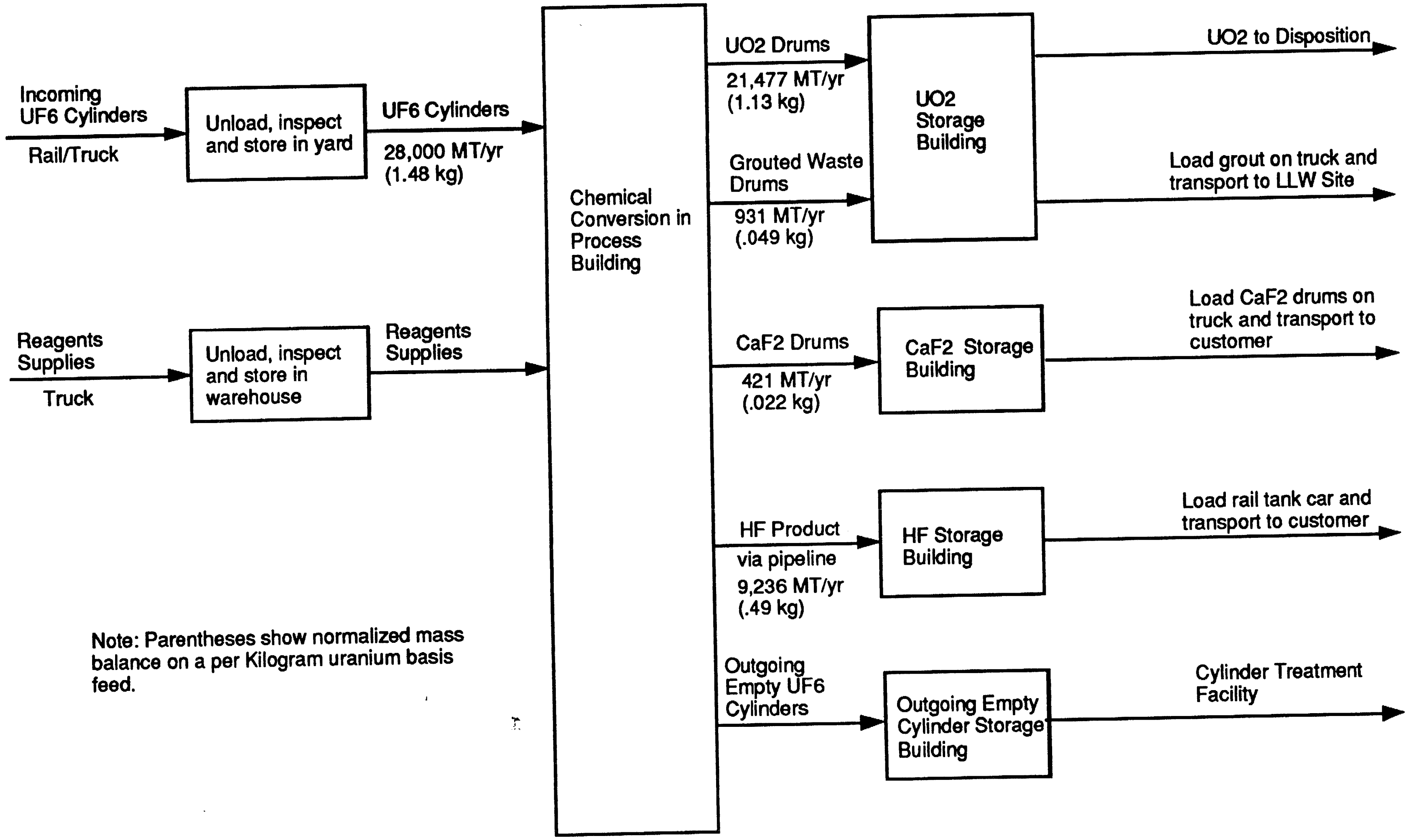


Figure 2-1 Ceramic UO2 / Anhydrous HF Material Flow Diagram

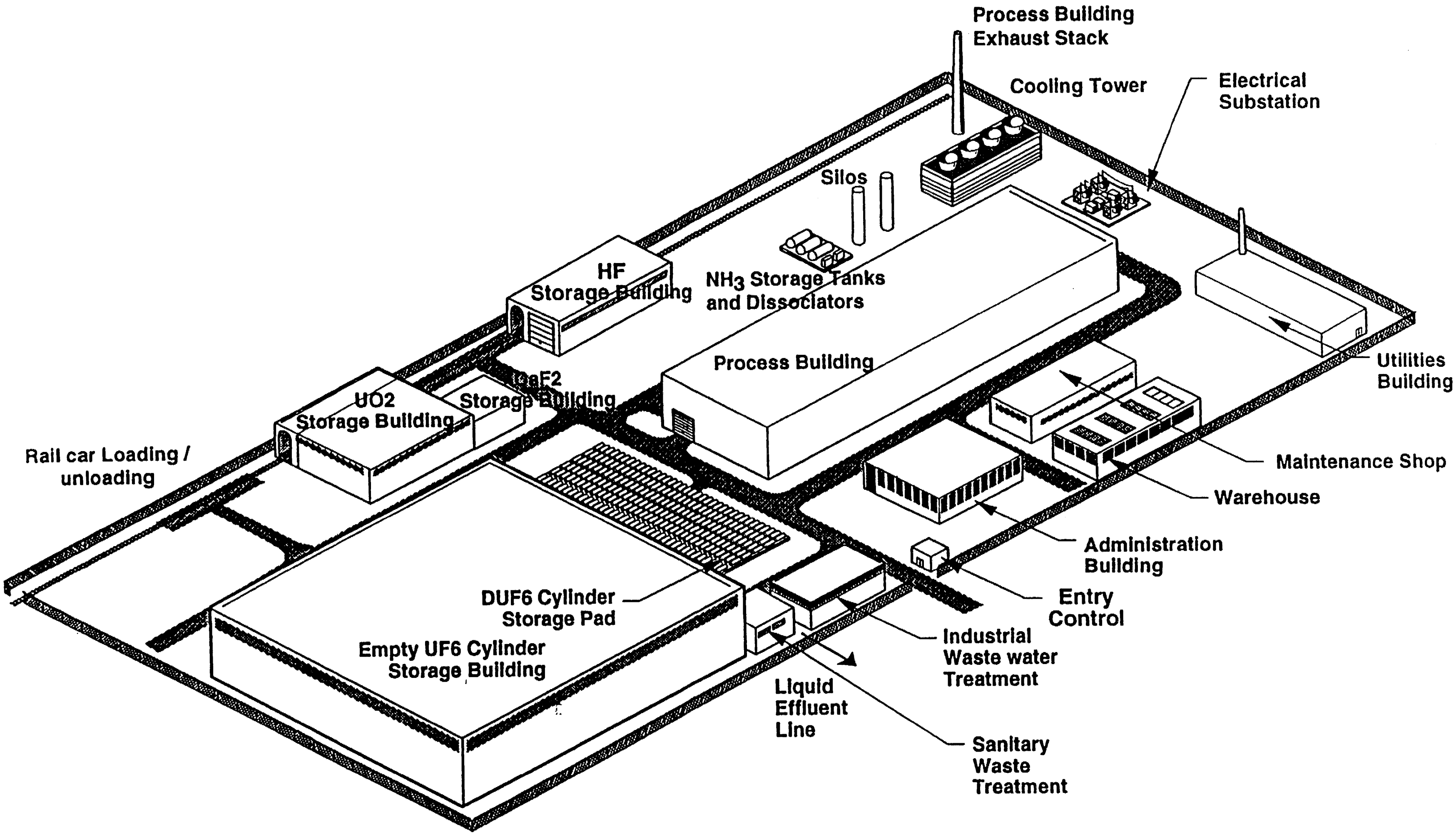


Figure 2-2 Plot Plan
Ceramic UO2 / Anhydrous HF

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	53,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
HF Storage Building	10,500	1	No	Yes	NA / HH	Reinforced Concrete
UO_2 Storage Building	11,250	1	Yes	Yes	HC2 / MH	Metal Frame
CaF_2 Storage Building	1,800	1	No	No	General	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	8,000	1	No	Yes	General	Metal Frame
Administration Building	10,000	1	No	No	General	Metal Frame
Maintenance Shop	6,000	1	No	Yes	General	Metal Frame
Warehouse	7,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	2,000	1	No	No	General	Metal Frame
Cooling Tower	7,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The layout, sections, and equipment arrangements for the Process Building are shown in Figures 2-3 through 2-6. The building is a two-story

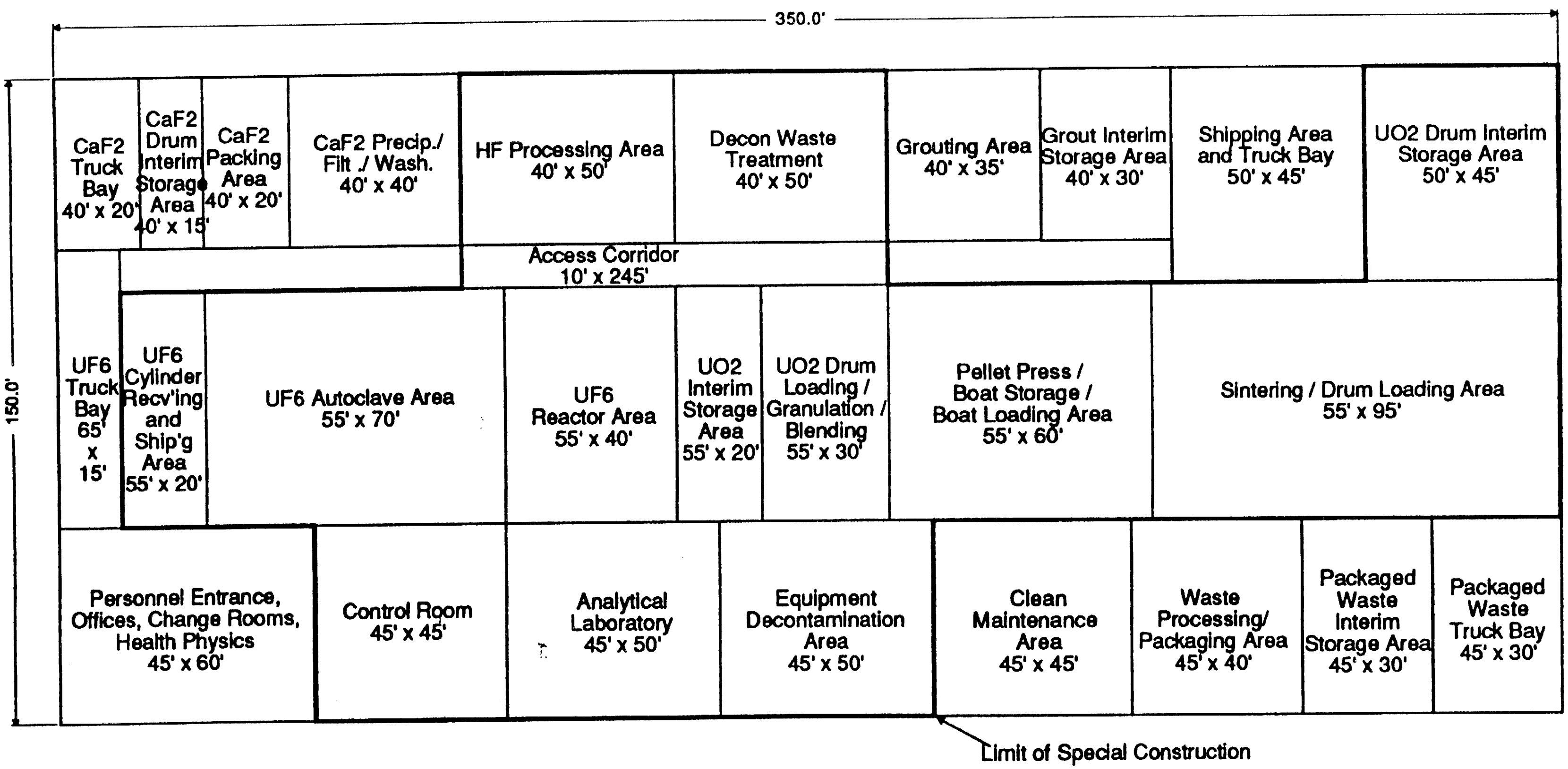


Figure 2-3 Process Building Layout
Ceramic UO2 / Anhydrous HF

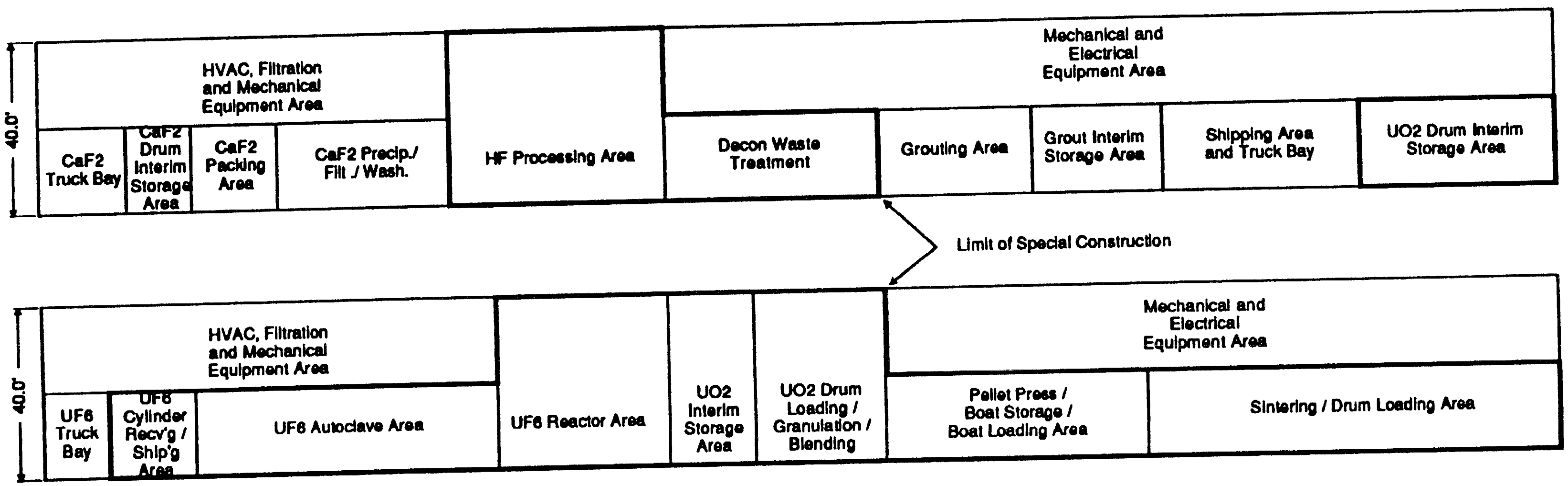


Figure 2-4 Process Building Sections
Ceramic UO2 / Anhydrous HF

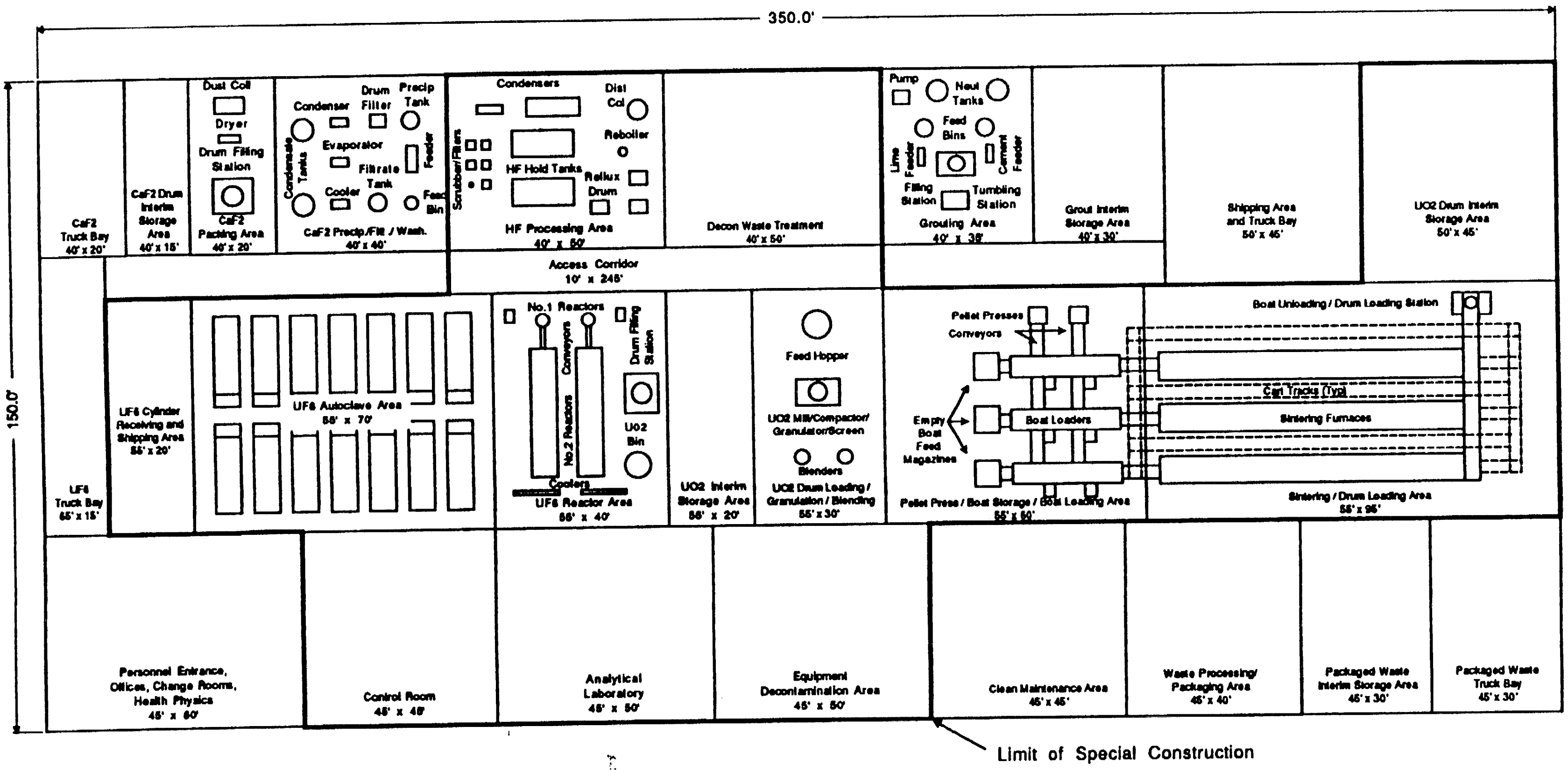


**Figure 2-5 Process Equipment Arrangement - Plan
Ceramic UO2 / Anhydrous HF**

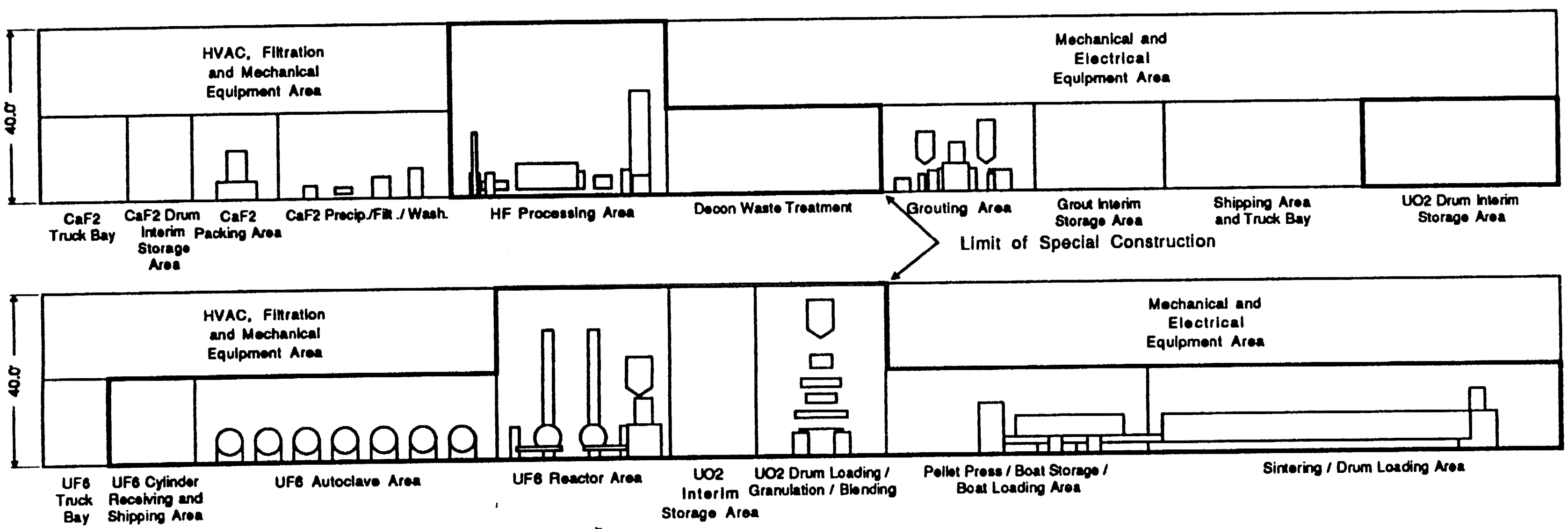


Figure 2-6 Process Equipment Arrangement - Sections Ceramic UO2 / Anhydrous HF

reinforced concrete structure classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas, and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems, such as the heating, ventilating, and air conditioning (HVAC) systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

2.1.3.2 HF Storage Building

Due to the presence of a large inventory of HF, the HF Storage Building is classified as a nonradiological, chemically high hazard (HH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is a one-story reinforced concrete structure providing space for tanks that store one month's production of HF. The facility is provided with a rail car loading bay and space for the required storage tanks. An air refrigeration system is provided to maintain temperatures in the building in the range of 45 to 55°F to limit vaporization of HF in the event of a spill. Also, a water spray system and floors surrounded by dikes are provided to mitigate the effects of an HF spill.

2.1.3.3 UO_2 Storage Building

The UO_2 Storage Building is a one-story metal-frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility, as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse that provides space for one month's production of UO_2 product and grouted waste. A zone 2 HVAC system with filtered exhaust air is provided (See also Section 2.2.5).

2.1.3.4 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.5 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the Conversion Facility includes the following facilities and systems (facilities are shown on Figure 3-1, Site Map):

A metal-frame CaF_2 Storage Building providing storage for one month's supply of CaF_2 product.

A metal-frame general-use Utilities Building houses raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling, and steam heating boiler systems.

A metal-frame or masonry Administration Building houses the facility support personnel.

A metal-frame general-use Maintenance Shops Building for housing clean maintenance and repair shops.

A 26 MM BTU/hr multiple cell, wood construction, induced-draft, crossflow-type cooling tower and a 2,600 gpm cooling tower water circulation system provides cooling for both the process and HVAC systems

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility accommodates the receipt, treatment, and disposal of noncontaminated chemical, liquid, and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown, and cold chemical area liquid effluents, will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility is provided with a capacity of approximately 4,100 gpd.

Compressed air systems, including plant air, instrument air, and breathing air include a single set of two redundant 300 cfm reciprocating air compressors for the plant and instrument air systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in desiccant-type air dryers to a dew point of -40°F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

An 800 cfm air compressor and membrane separation unit to provide 380 cfm of nitrogen to the sintering furnaces.

An 18,000 cfh hydrogen/nitrogen supply system consisting of two 25,000 gal steel ammonia storage tanks and three ammonia dissociators to supply hydrogen and nitrogen to the UF_6 reduction reactors and to the UO_2 pellet sintering furnaces.

Building HVAC systems use a central chilled water system for building cooling. Three 50% capacity, 350 ton centrifugal water chillers, and three 600 gpm circulating pumps are provided. A steel stack serves the Process

Building HVAC exhaust systems. The steam plant boiler vents through a dedicated steel stack (see Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant in the Support Utilities Building produces steam for process uses and for building heating by the HVAC systems. The plant produces 22,000 lb/hr of 50 psig steam, which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration, and chlorination. The demineralized water is used in the process and for steam boiler feedwater (see also Figure 5-1).

A 700 ft^3 cement storage silo and a 1,600 ft^3 lime storage silo are located outdoors in the yard area.

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The electrical substation has a design capacity of 4,000 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 500 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas that require special lighting for night-time operation include the UF_6 cylinder storage pad areas, the rail spur area, the utility area, and the site entry control area.

Site security fencing as shown on Figure 3-1, Site Map, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control, and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public, and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as the following:

- Barriers to contain uncontrolled hazardous material or energy release
- Preventive systems to protect those barriers
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Distillation Areas
UO_2 Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
HF Storage Building	Zone 1 - High Chemical Hazard	Conventional	PC-4 for High Hazard Areas	Automatic water spray and shutdown of HVAC system upon HF leak
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class structures, systems, and components (SSCs) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety-class structures, systems, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornado

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Flood

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety-class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480.7. These criteria require that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire-rated barriers to limit the maximum possible fire loss and to protect life by providing fire-rated escape routes for operating personnel.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.
- Automatic fire sprinkler systems are used throughout the facilities.

2.2.3 Materials Accountability and Plant Security

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3), and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., UO_2 handling, container loading operations, and UF_6 sampling stations).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will use a combination of dividing the buildings into zones according to level of hazard, space pressure control, and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate, or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breeched or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing gloveboxes and other uranium processing areas. The ventilation system for these rooms uses once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters, and pressure control to assure air flow from areas of low hazard to areas of high hazard. The UO_2 Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting area, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a higher pressure than the rest of the building. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor and HF distillation areas and the off-gas scrubbing area of the Process Building have high chemical hazard potential, and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a leak of HF.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on Figure 3-1, Site Map. This figure also identifies the effluent air release points (ventilation and boiler stacks).

Table 2-3 summarizes the characteristics of the effluent air release points.

Table 2-3, Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	104	80	60
Boiler	100	27	500	60

3.0 Site Map and Land Use Requirements

3.1 Site Map

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and UO_2, HF, grout, and CaF_2 from the facility. Air emission points are from the Process Building ventilation exhaust stack and the facility boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 Land Area Requirements During Operation

As shown in Figure 3-1, the total land area required during operations is approximately 636,000 ft^2 or about 14.6 acres.

3.3 Land Area Requirements During Construction

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 24.0 acres. Construction areas required in addition to the site structures and facilities are as follows:

- A construction laydown area for temporary storage of construction materials, such as structural steel, pipe, lumber for concrete forms, and electrical conduit
- Temporary construction offices for housing onsite engineering support, construction supervision, and management personnel
- Temporary parking for construction craft workers and support personnel
- Temporary holding basins for control of surface water runoff during construction
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

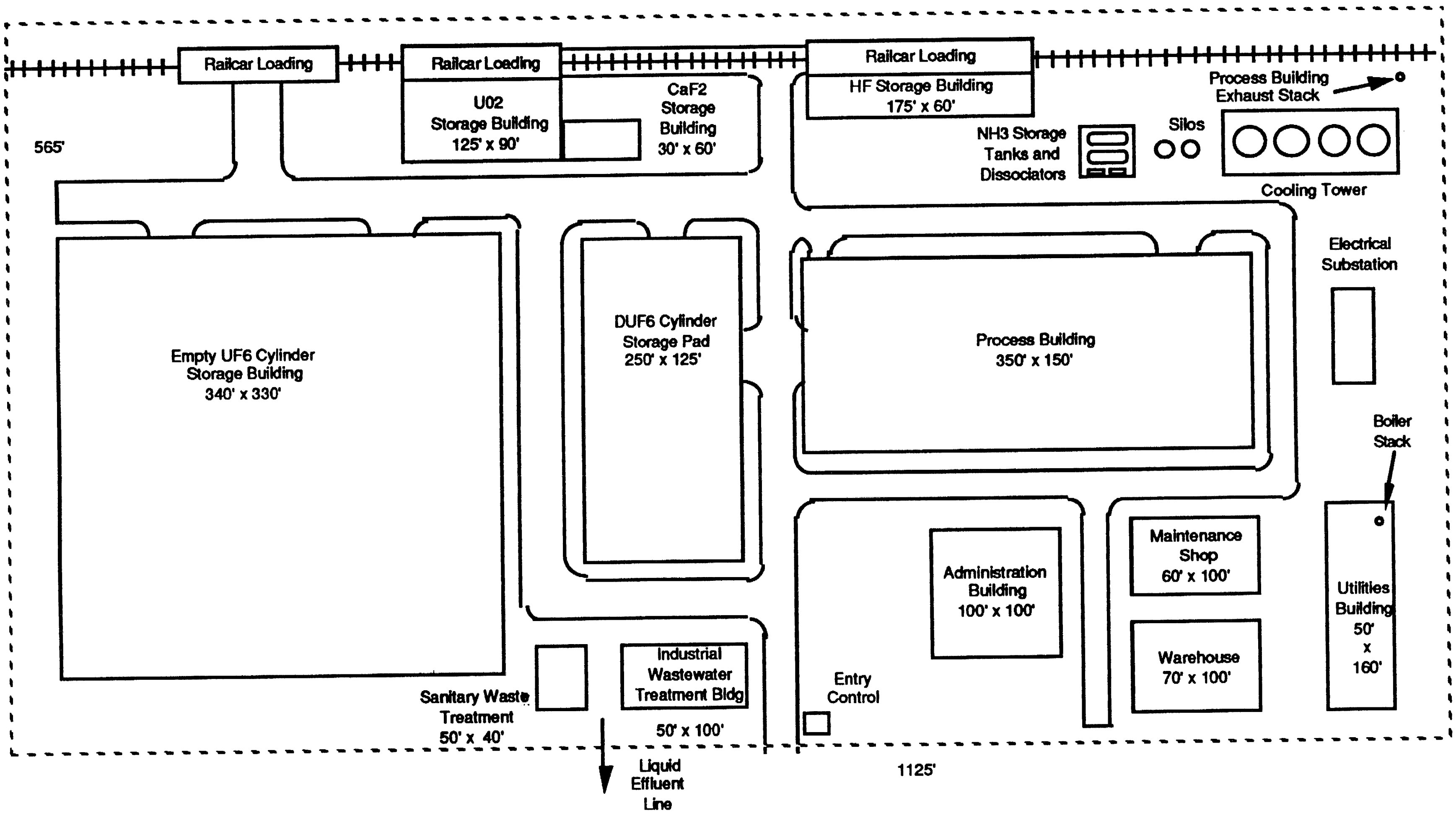


FIGURE 3-1 SITE MAP
CERAMIC UO2 / ANHYDROUS HF

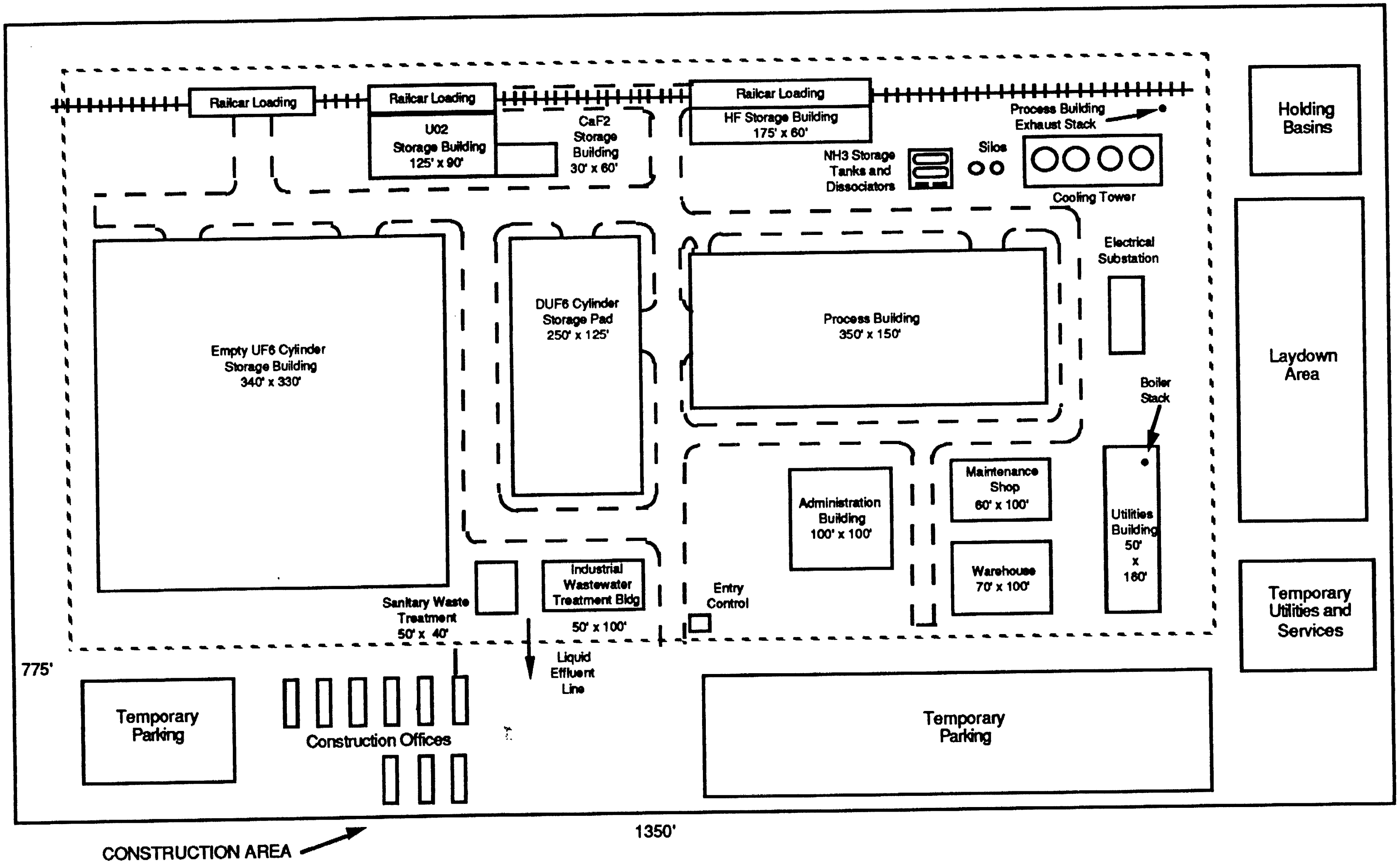


FIGURE 3-2 SITE MAP DURING CONSTRUCTION
CERAMIC UO2 / ANHYDROUS HF

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is processed to produce sintered uranium dioxide (UO_2) pellets and hydrofluoric acid (HF). The process is shown in Figures 4-1 to 4-3. Annual and hourly material balances are given in Appendix A.

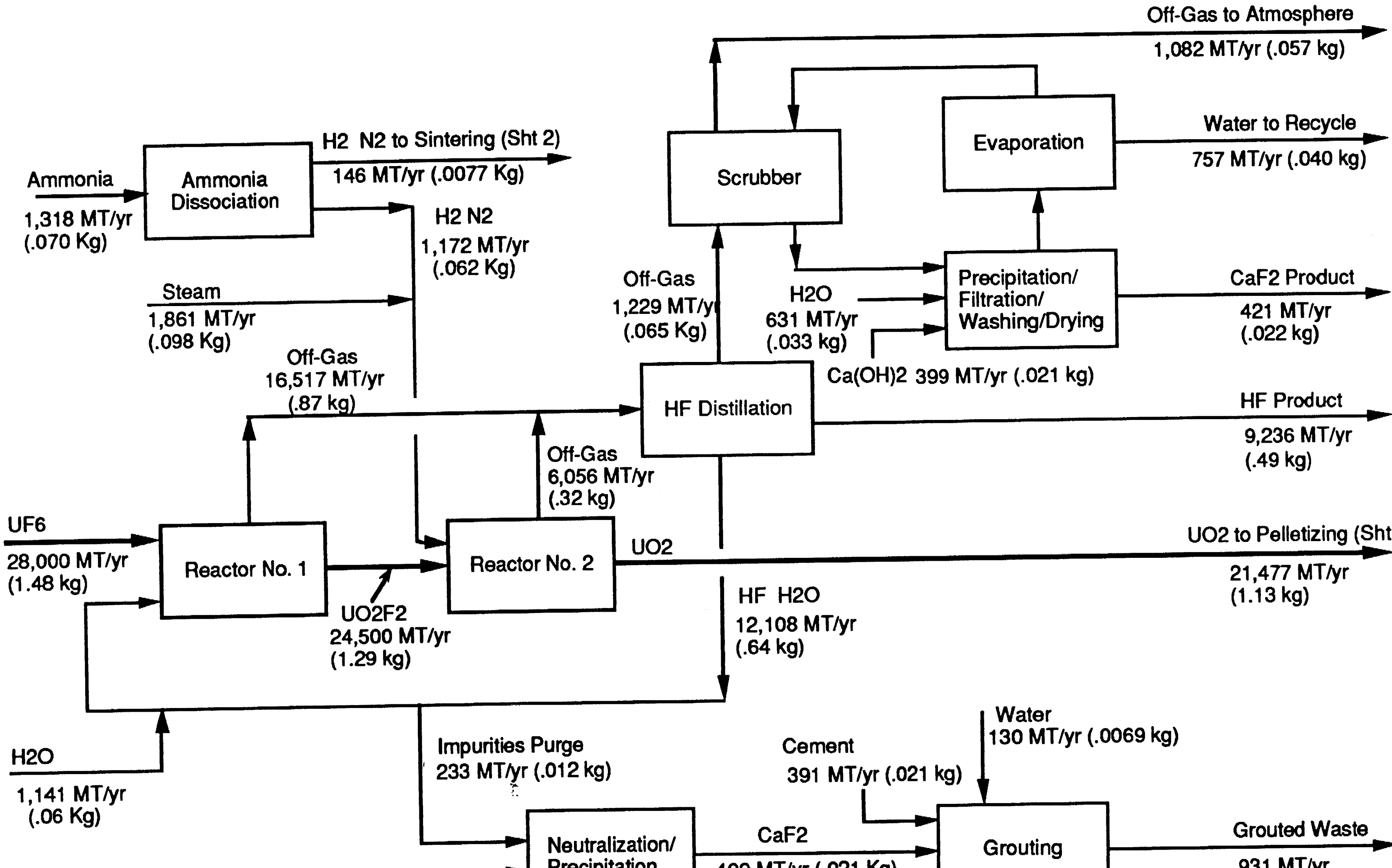
The UF_6 is converted to UO_2 in a two-step process. The UF_6 is vaporized using steam-heated autoclaves and fed to Reactor No. 1, where it is mixed with 45% HF-water vapor. Solid UO_2F_2 is produced and flows to Reactor No. 2. The UO_2F_2 is mixed with a hydrogen, nitrogen and steam mixture to produce solid UO_2. Vapor containing HF, hydrogen and water flows to the HF distillation column. The UO_2 is discharged from the reactor, cooled, and sent to powder processing.

The HF distillation column receives feed from Reactors No. 1 and 2. The column purifies the HF to produce anhydrous HF. The HF product is pumped to storage tanks and loaded into railroad tank cars for delivery to customers. The distillation column bottoms stream is collected, vaporized and recycled to Reactor No. 1. Uncondensed off-gas from the distillation column flows to the scrubber system.

The UO_2 powder is milled in a hammer mill to eliminate agglomerates, and is compacted in a press to form sheets, which are then size reduced in a granulator. After screening to recycle oversize and undersize particles, the product granules are mixed with a dry lubricant in a blender. The granules are fed to a high-speed press that produces cylindrical pellets. The pellets are sintered at 1700°C in a continuous tunnel kiln under a reducing gas atmosphere. The sintered pellets are about 0.82 in. diameter by 0.82 in. long and have a density of about 9.8 g/cc (90% of theoretical). The UO_2 pellets are loaded into drums for storage and shipment.

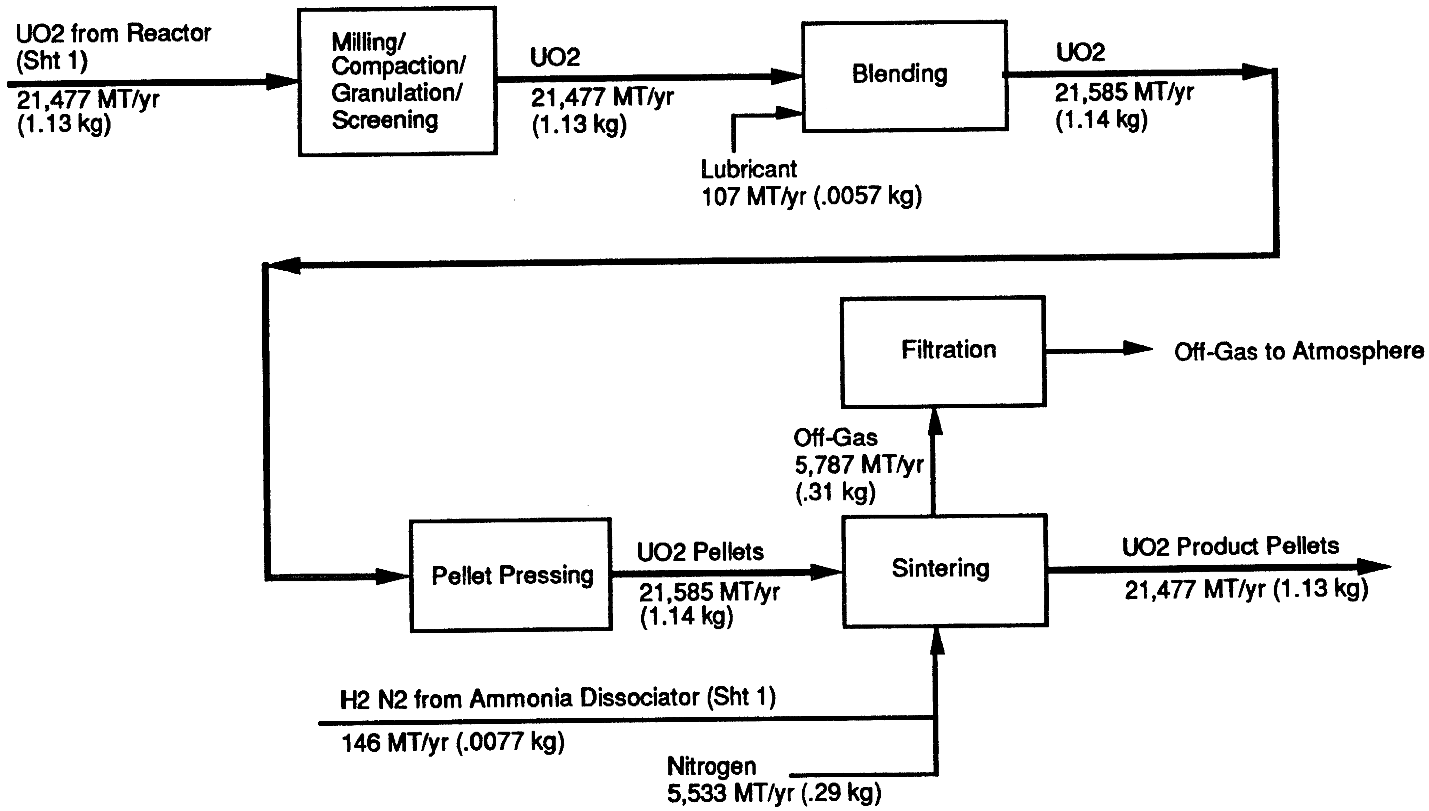
Uncondensed off-gas from the distillation column flows to the scrubber system. The remaining traces of HF in the off-gas are removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution. The CaF_2 precipitate is dried and packaged in drums for shipment.

To prevent the buildup of uranium and other impurities in the HF distillation column bottoms stream that is recycled to Reactor No. 1, a small purge stream is continuously withdrawn. This purge stream is neutralized with hydrated lime, and mixed with cement and water to form a grout. The solid waste grout is packaged in drums and disposed as low level waste.



Note: Parentheses show normalized mass balance based on a per Kilogram uranium basis feed to Reactor No. 1

Figure 4-1 Ceramic UO2 / Anhydrous HF Block Flow Diagram - Sheet 1



Notes:
1. Parentheses show normalized mass balance on a per kilogram uranium basis feed to Reactor No. 1.
2. Process operations shown in this figure are located primarily in gloveboxes or ventilated enclosures.

Figure 4-2 Ceramic UO2 / Anhydrous HF Block Flow Diagram - Sheet 2

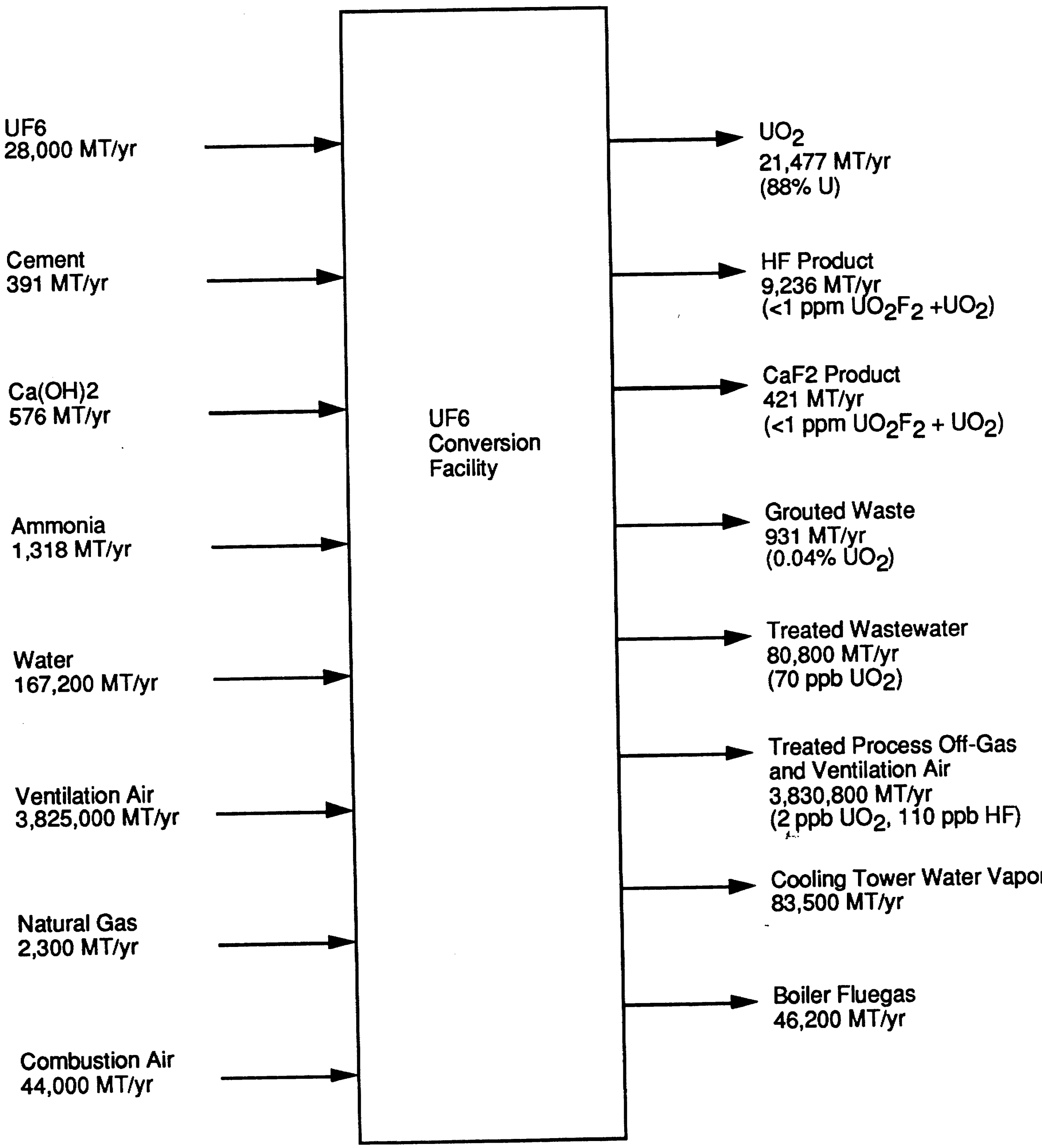


Figure 4-3 Ceramic UO2 / Anhydrous HF Input/Output Diagram

The facility has two trains of defluorination reactors. Multiple pelletizing presses and sintering furnaces are provided to meet the required throughput. The hydrofluoric acid distillation system is a single train. Critical equipment such as a blowers or filters have spares installed in parallel. The conversion of UF_6 to UO_2F_2 with HF recycle is based on a Sequoyah Fuels patent. The conversion of UO_2F_2 to UO_2 pellets is based on processes used in the nuclear fuel fabrication industry.

4.1 UF_6 CONVERSION REACTION

Reactor No. 1 converts UF_6 feed into UO_2F_2 and HF by hydrolysis in a fluidized bed. The chemical reaction is $UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$. This system is shown in Figure 4-4.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in steam-heated autoclaves and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is heated and vaporized (sublimed) at 140°F.

Gaseous UF_6 flows out of the cylinder and is fed by a compressor into a fluidized bed reactor containing UO_2F_2 particles. Eleven UF_6 cylinders feed simultaneously to provide the required feed rate of 8,800 lb/hr. The 49% HF bottoms stream from HF distillation and makeup water are vaporized in a steam-heated exchanger. The resulting 45% HF-water vapor stream enters the bottom of the reactor and acts as the fluidizing gas. Water vapor reacts with the UF_6 to form solid UO_2F_2 and gaseous HF. The reaction is exothermic, and cooling water is provided to maintain the reactor at about 550°F.

The solid UO_2F_2 flows from this reactor to Reactor No. 2. The HF-water vapor flows through a cyclone and sintered metal filter to remove UO_2F_2 particulates, which are discharged back into the reactor. The HF-water vapor then flows to the HF distillation column. A small purge stream is discharged from the vaporizer to prevent buildup of uranium and impurities. This stream is sent to the impurities neutralization system. After cooling, the empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

Preliminary major equipment descriptions for the conversion process include 14 autoclaves and UF_6 compressors and two 3 ft-6 in. diameter by 10 ft high Monel fluidized bed reactors.

4.2 UO_2F_2 CONVERSION REACTION

Reactor No. 2 converts UO_2F_2 into UO_2 and HF in a rotary kiln. The overall chemical reaction is $UO_2F_2 + H_2 \rightarrow UO_2 + 2HF$. This system is shown in Figure 4-5.

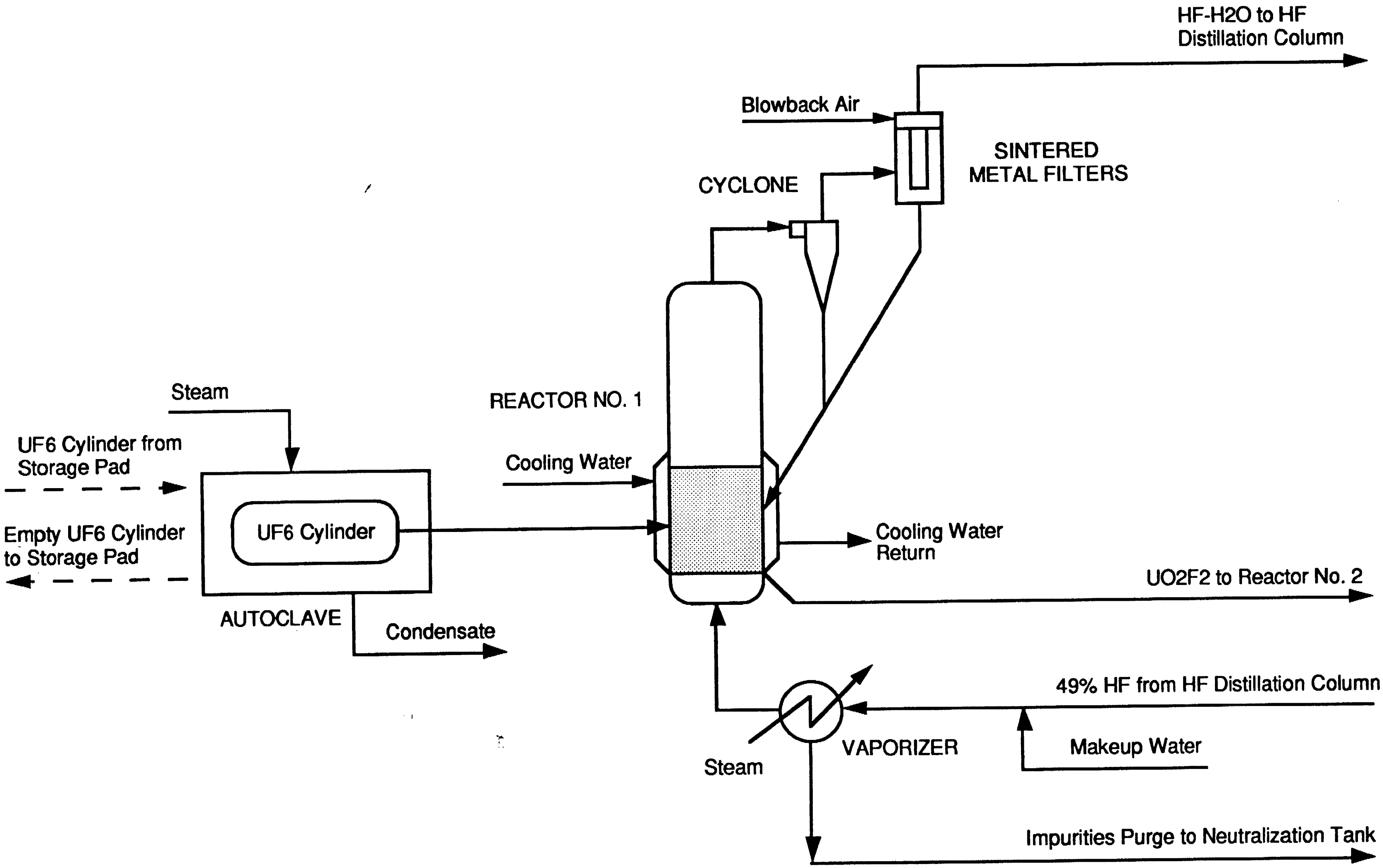


Figure 4-4 Reactor No. 1 Process Flow Diagram

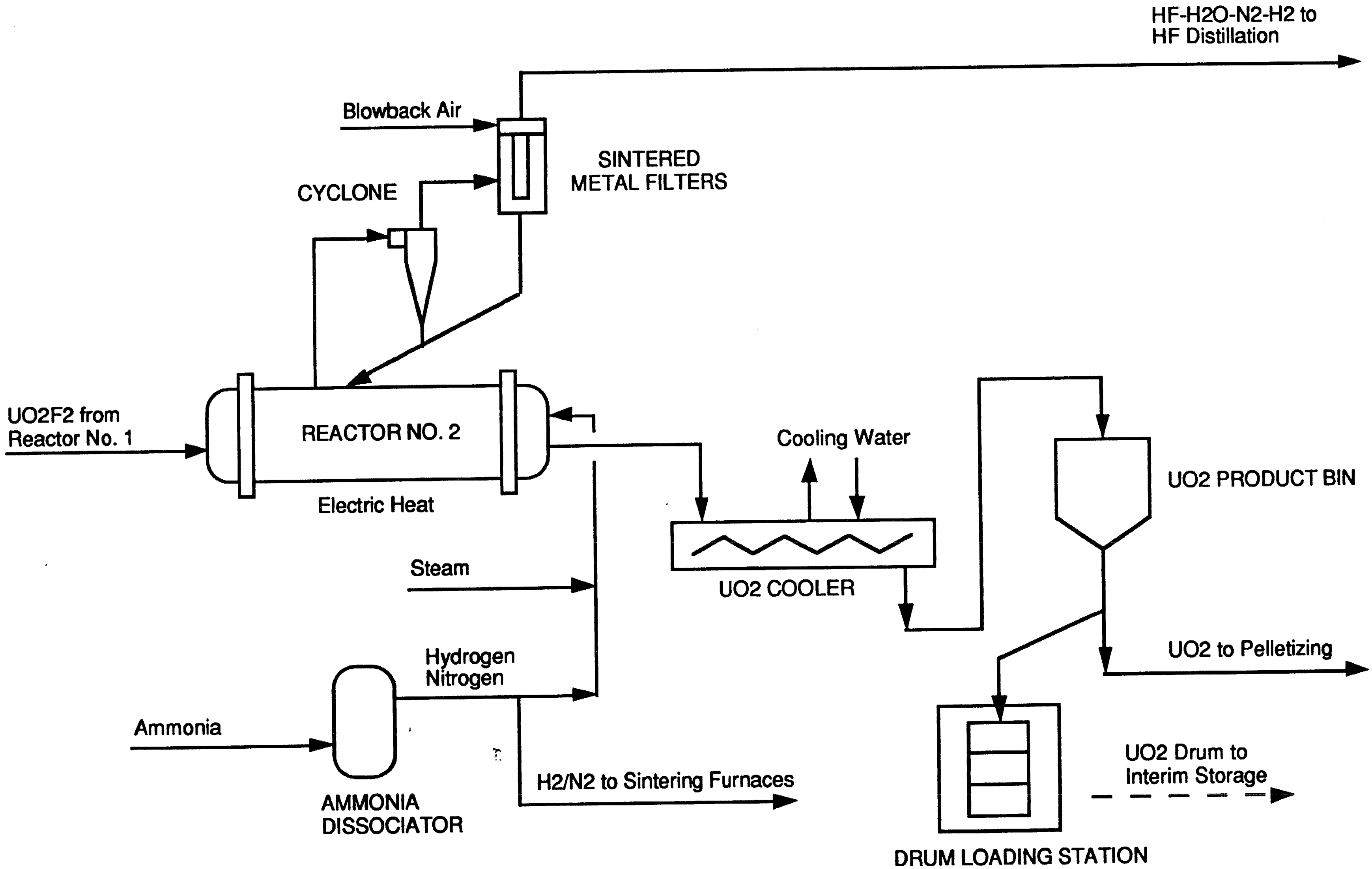


Figure 4-5 Reactor No. 2 Process Flow Diagram

Solid UO_2F_2 from Reactor No. 1 flows into the rotary kiln, where it reacts with hydrogen and steam to form solid UO_2 and gaseous HF. The reaction is endothermic, and the kiln is electrically-heated to maintain the temperature at about 1200°F. Solid UO_2 is discharged from the reactor, cooled, and conveyed to the granulation area. There is also a drum loading station to provide interim storage of UO_2 in drums as necessary.

The HF and water vapor flow through a cyclone and sintered metal filter to remove UO_2 particulates, which are discharged back into the reactor. The off-gas vapor flows to the HF distillation column.

Hydrogen is provided from a packaged ammonia dissociator unit. The chemical reaction is $2NH_3 \rightarrow N_2 + 3H_2$. Liquid ammonia is vaporized and fed to the dissociator, which decomposes the ammonia at 1600°F in a catalyst bed. The hydrogen/nitrogen mixture is fed to Reactor No. 2.

Preliminary major equipment descriptions include two 6 ft by 30 ft long Inconel rotary kilns, two 12 in. by 10 ft long screw conveyor/coolers, and a drum loading station.

4.3 HF DISTILLATION

The hot off-gas and vapor from the reactors flow to a distillation column for HF recovery and purification. The system is shown in Figure 4-6.

The vapor is first quenched with distillation column bottoms to cool the superheated vapor to its saturation temperature. The saturated vapor is fed to the column, which produces an anhydrous HF overhead product at 67°F containing about 200 ppm water, and a 49 wt% HF bottoms stream at 233°F that is recycled to Reactor No. 1.

The overhead product is condensed in a chilled water condenser at 40°F, collected and sampled. Upon satisfactory analysis, the HF is pumped through an underground pipeline to storage tanks in the HF storage building. The HF is then loaded into railroad tank cars or tank trucks for shipment to customers.

The noncondensible gases, primarily nitrogen and hydrogen, pass through a -70°F refrigerated condenser to recover additional HF. The gases then flow to the HF scrubbing system.

Major process equipment for the HF distillation process includes a 4 ft-six in diameter by 23 ft high Monel distillation column, equipped with a 2 ft diameter by 6 ft high shell and tube reboiler, a 4 ft diameter by 12 ft long 3,500 ft^2 40°F condenser, a 2 ft diameter by 6 ft long 150 ft^2 -70°F condenser, and two 6 ft diameter by 14 ft long 3000 gallon hold tanks equipped with cooling coils, and six 12 ft diameter by 45 ft long 38,000 gallon storage tanks.

4.4 HF SCRUBBING SYSTEM

Off-gas from HF distillation is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The system is shown in Figure 4-7.

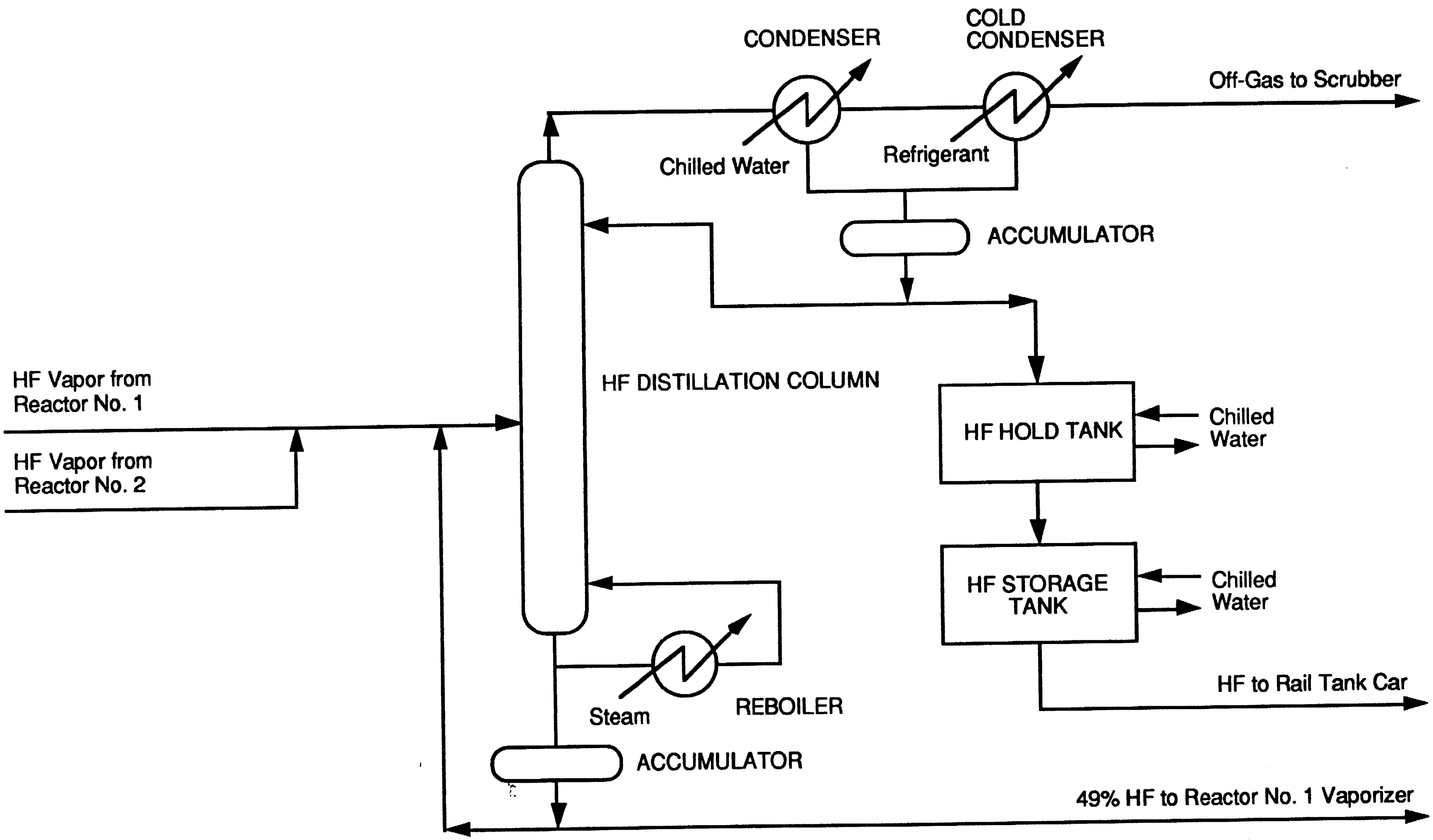


Figure 4-6 HF Distillation Process Flow Diagram

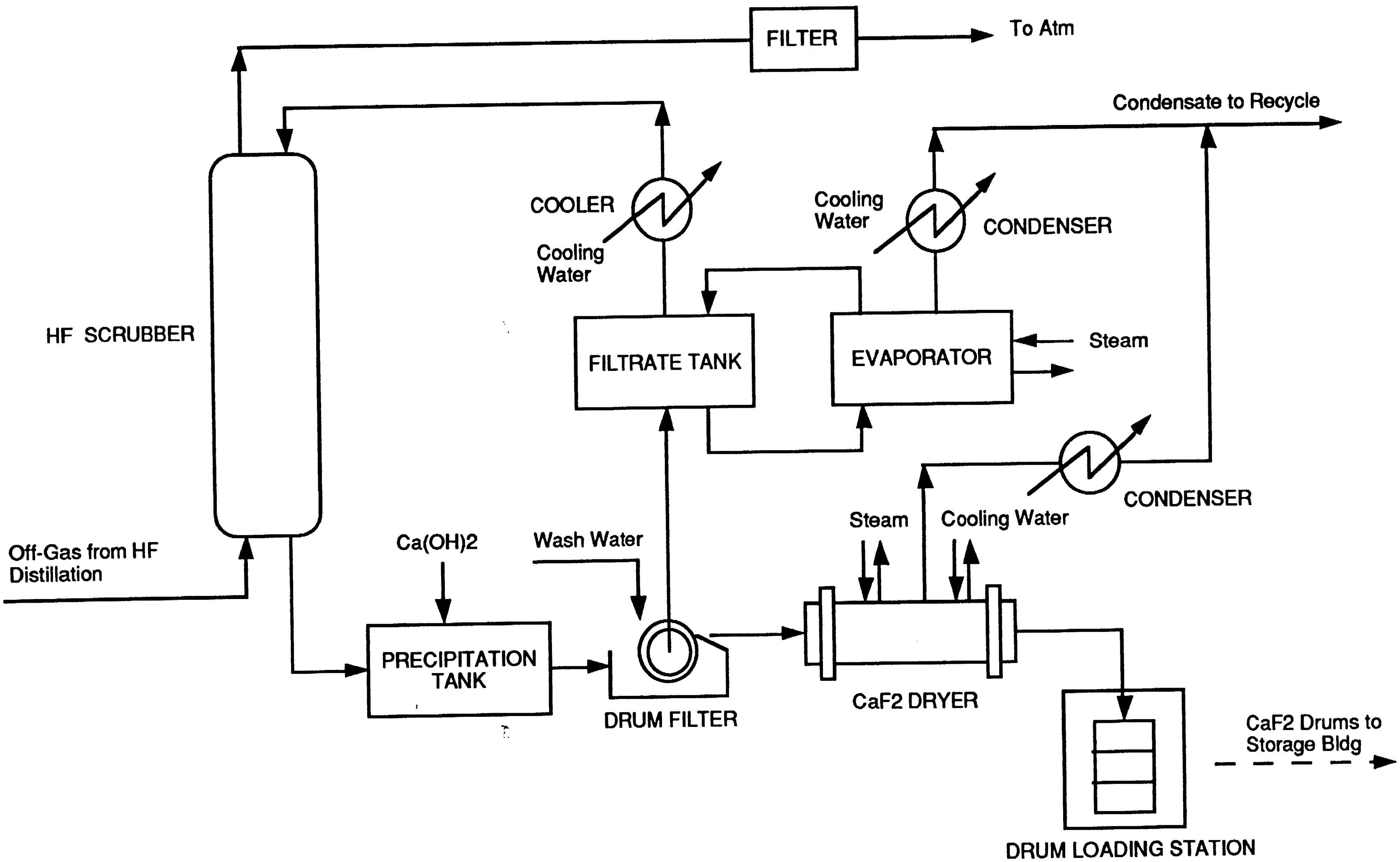


Figure 4-7 HF Scrubber Process Flow Diagram

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \longrightarrow KF + H_2O$. The treated off-gas is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2KF + Ca(OH)_2 \longrightarrow CaF_2 + 2KOH$. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter or a pressure filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities, and dried in a steam-heated rotary dryer. After cooling, the CaF_2 is packaged in drums and sent to the storage building.

The KOH and wash water filtrate are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The filtrate is then cooled and pumped back to the scrubber as scrub solution.

Major equipment includes a 1 ft diameter by 10 ft high Monel HF scrubber with plastic packing, 4 ft diameter by 5 ft high 450 gallon Monel precipitation and filtrate tanks, a 2 ft diameter by 6 ft long Monel drum filter, a 2 ft diameter by 4 ft high Monel evaporator/ condenser unit, a 1 ft-6 in diameter by 5 ft long rotary dryer and associated tanks and pumps.

4.5 UO_2 GRANULATION

The UO_2 powder is processed to form free-flowing granules that enable precise and reproducible feeding of the pellet presses. This system is shown in Figure 4-8.

The raw UO_2 powder is fed to a hammer mill to eliminate any lumps or agglomerates. The milled powder is fed to a roller compactor, which compresses the powder to about 40% of theoretical density. The compacted powder sheets are then size-reduced in a granulator.

The UO_2 granules are then screened, with oversize particles recycled to the granulator and undersize particles recycled to the compactor. The product granules, with a particle size between -20 and +60 mesh, are blended with a dry lubricant in a double-cone mixer or ribbon mixer to produce granules containing 0.5 wt% Sterotex lubricant (powdered hydrogenated cottonseed oil by Capital City Products). The granules are conveyed to the pelletizing area. There is also a drum loading station to provide interim storage of UO_2 granules in drums as necessary.

Major process equipment includes a hammer mill, roller compactor, granulator, a vibrating screen separator, two 15 ft^3 double-cone blenders, a drum loading station, and a dust collection system.

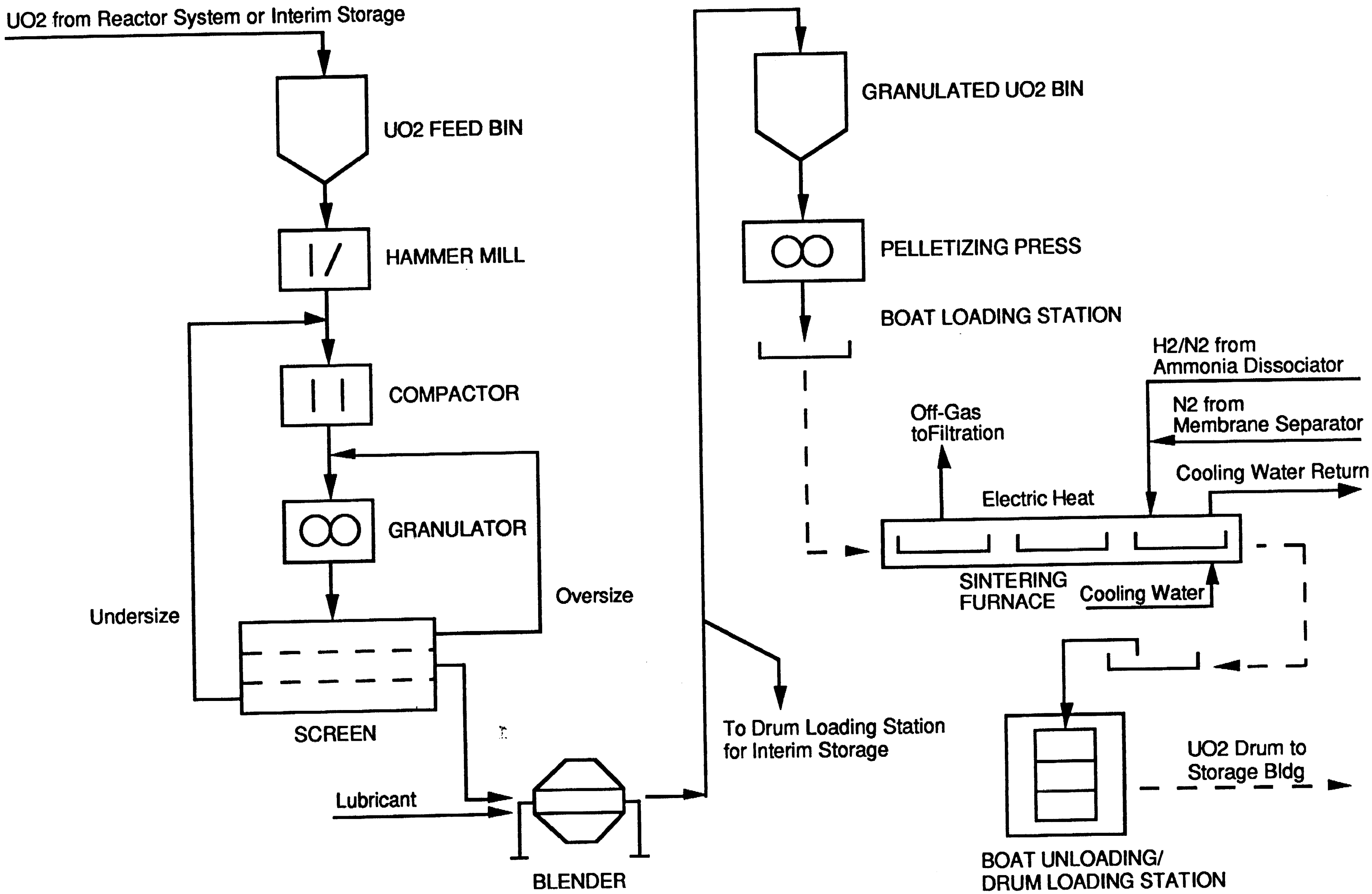


Figure 4-8 UO2 Pelletizing/Sintering Process Flow Diagram

4.6 UO_2 PELLETIZING AND SINTERING

The granulated UO_2 is pressed to form pellets, which are sintered at high temperature to increase their density. This system is shown in Figure 4-8.

The UO_2 granules are fed to an automatic, high-speed, rotary powder compacting press operating at 20,000 to 60,000 psi. Cylindrical pellets about 1 in. diameter by 1 in. long with a density of about 50% of theoretical are produced. These "green" (unsintered) pellets are automatically loaded into molybdenum boats (trays), which are conveyed to the sintering area.

The sintering furnace is a continuous, tunnel kiln with separate zones for heatup, soak (sinter) and cooldown. The furnace atmosphere is 6% hydrogen and 94% nitrogen to provide a reducing environment. Boats containing pellets are placed on carts which enter the furnace through a double-door airlock. The airlock has a nitrogen purge to keep air out of the furnace and a flame curtain to destroy any hydrogen that leaks out of the furnace. The carts slowly move through the kiln. Total cycle time in the furnace is about 8 hours, which includes a 3 hour heatup, 3 hour soak at 1700°C, and 2 hour cooldown. If later development work shows a lower sintering temperature is feasible, the furnace design and materials of construction would be simpler and less costly.

Off-gas from the furnace is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. Hydrogen is provided from the ammonia dissociator and nitrogen is provided from a membrane separation unit or cryogenic tank.

The sintered pellets have a density of about 9.8 g/cc (90% of theoretical), and are about 0.82 in diameter by 0.82 in. long. The boats and carts exit the furnace through a second airlock, and the sintered pellets are removed from the boats and loaded into 30 gallon drums in a drum filling station. The drum is sealed, cleaned and transported to the storage building.

Major process equipment includes two 365 pellets/min rotary powder compacting presses, three 6 ft wide by 6 ft high by 70 ft long 400 kW sintering furnaces, an off-gas treatment system, a dust collection system, a drum loading station, and conveyors for the pellet boats.

4.7 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4.8 WASTE MANAGEMENT

The primary wastes produced by the process are empty UF_6 cylinders and vaporizer blowdown liquid. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment. The treatment of blowdown wastes is shown in Figure 4-9.

The blowdown stream from the vaporizer to Reactor No. 1 is converted into a solid grout for disposal. The blowdown stream, containing HF, water, uranium and impurities, is neutralized with hydrated lime. The main reaction is $HF + Ca(OH)_2 \dashrightarrow CaF_2 + 2H_2O$. The slurry is then mixed with cement and water in a drum to form a grout. After solidification, the waste drums are transported to the warehouse for storage, and then sent to a low level waste disposal site. The composition of the grout is 42% cement, 38% H_2O, 20% CaF_2, and 0.04% U_3O_8.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing, packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

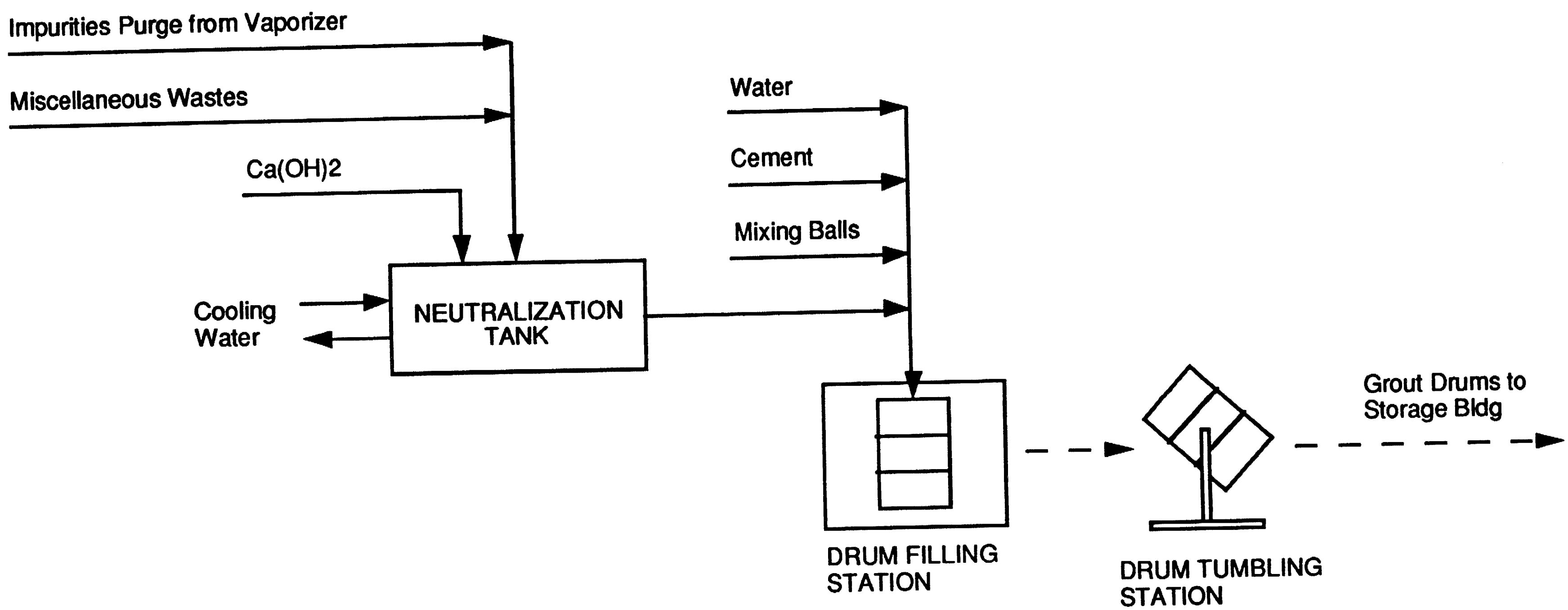


Figure 4-9 Waste Grouting Process Flow Diagram

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	30 GWh	4.0 MW
Liquid Fuel	7,000 gals	NA
Natural Gas[2]	116×10^6 scf	NA
Raw Water	44×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance for the facility. This balance is based on the greenfield generic midwestern U.S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

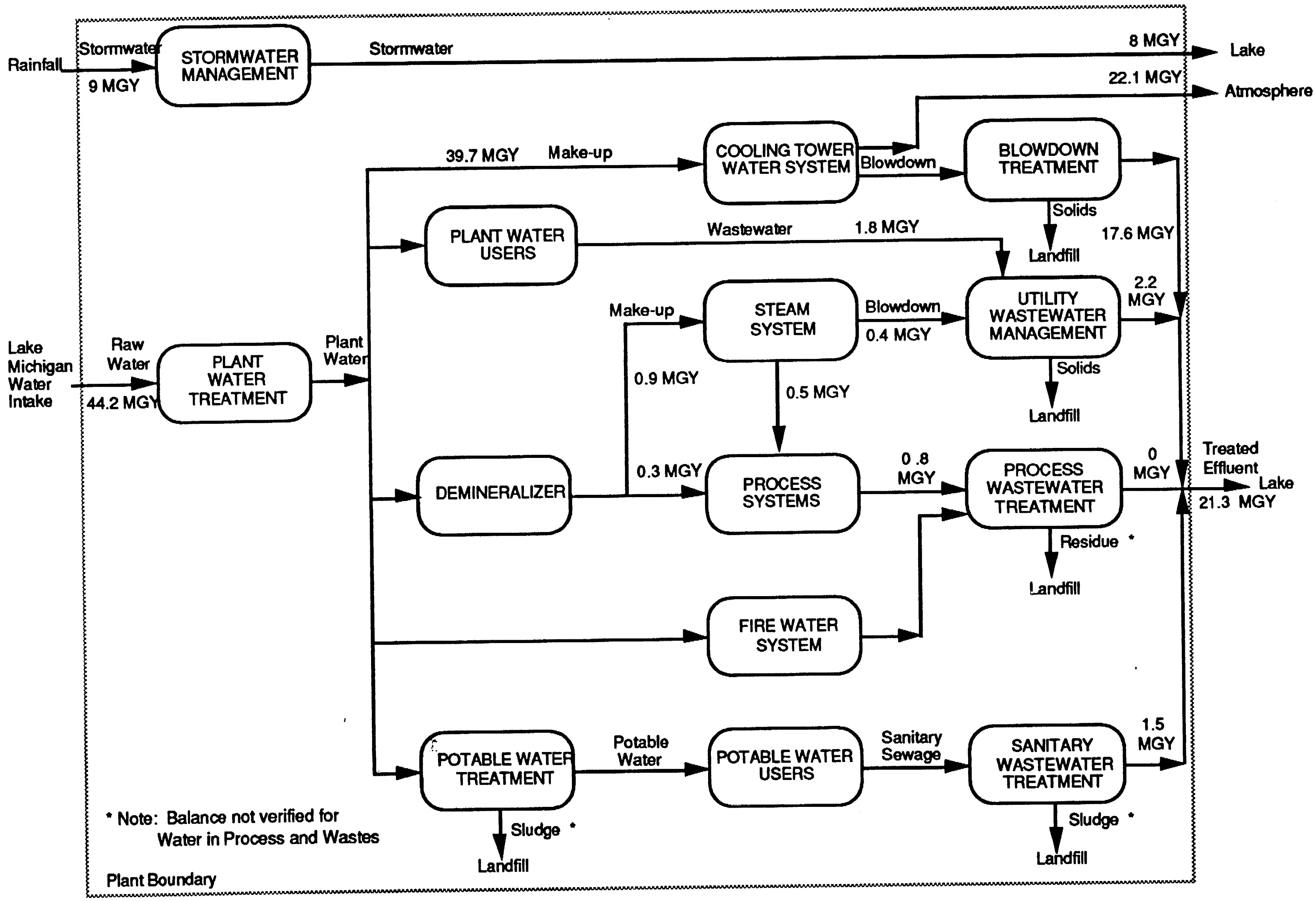


Figure 5-1 Preliminary Water Balance
Ceramic UO2/Anhydrous HF

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Pelletizing Lubricant	236,000
Calcium Hydroxide (Hydrated Lime)	1,270,000
Cement	862,000
Detergent	600
Liquid	
Ammonia (99.95% min. NH_3)	2,900,000
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	8,900
Sodium Hydroxide (50% NaOH)	7,000
Sodium Hypochlorite	4,300
Copolymers	7,300
Phosphates	730
Phosphonates	730
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 56 ft^3 boxes - see also Table 9-1)	2,877 drums 30 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6).

The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14-ton DOT approved carbon steel containers.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5-3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	35,000 MWh	1.5 MW
Water	10×10^6 gal	700 gal
Solids		NA
Concrete	21,000 yd^3	
Steel (carbon or mild)	8,000 tons	
Electrical raceway	25,000 yd	
Electrical wire and cable	60,000 yd	
Piping	40,000 yd	
Steel decking	25,000 yd^2	
Steel siding	13,000 yd^2	
Built-up roof	19,500 yd^2	
Interior partitions	1,500 yd^2	
Lumber	5,400 yd^3	
HVAC ductwork	170 tons	
Special coatings	4,000 yd^2	
Asphalt paving	270 tons	
Liquids		
Fuel[2]	1.6×10^6 gals	
Gases		
Industrial Gases (propane)	4,400 gal	

1 Peak demand is the maximum rate expected during any hour.

2 Fuel is 50% gasoline and 50% diesel fuel.

The total quantities of commonly used construction material (e.g., steel,) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 25 tons of Monel and 10 tons of Inconel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 Employment Needs During Operation

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	8
Professionals	8
Technicians	34
Office and Clerical	22
Craft Workers (Maintenance)	11
Operators / Line Supervision	103/17
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	229

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 Employees at Risk of Radiological Exposure

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF (e.g., connecting the tank car loading hose), the operator will wear acid-resistant protective gear including a respirator.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4 [1]
Process Building	47	28	28	28
HF Storage Building	2	1	1	1
UO_2 Storage Building	3	1	1	1
CaF_2 Storage Building	1	0	0	0
Cylinder Storage Pad and Building	7	3	3	3
Utilities/Services/Admin Areas	40	10	10	10
TOTAL EMPLOYEES	100	43	43	43

1 The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	290	510	250
Construction Management and Support Staff	30	60	90	50
TOTAL EMPLOYEES	200	350	600	300

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides estimates of the annual emissions, effluents, waste generation, and radiological and hazardous emissions from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility work force.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	70/54
Nitrogen Dioxide	Boiler Stack / Grade	9,300/460
Hydrocarbons	Boiler Stack / Grade	200/410
Carbon Monoxide	Boiler Stack / Grade	4,600/2,700
Particulate Matter PM-10	Boiler Stack / Grade	350/92
OTHER POLLUTANTS		
HF	Process Bldg. Stack	900
UO_2	Process Bldg. Stack	12
Copolymers	Cooling Tower	1,500
Phosphonates	Cooling Tower	150
Phosphates	Cooling Tower	150
Calcium	Cooling Tower	2,600
Magnesium	Cooling Tower	700
Sodium and Potassium	Cooling Tower	300
Chloride	Cooling Tower	500
Dissolved Solids	Cooling Tower	14,300

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	2×10^{-3}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	2×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	248,000	115	28 lb UO2	425 55-gal drums
Metal, surface contaminated	Failed equipment	73,000	45	82 lb UO2	166 55-gal drums
Noncombustible, compactible solid	HEPA filters	13,000	62	2,500 lb UO2	30 4x2x7 ft boxes (3/4" plywood)
Noncombustible, noncompactible solid	Grouted waste See Sect. 4-8	2,053,000	609	821 lb U3O8	2,236 55-gal drums
Other	LabPack (chemicals plus absorbent)	3,500	2.2	4 lb UO2	8 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint	4,500	3 (600 gal)	See description	11 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	8,100	5	8 lb HF 8 lb NaOH	19 55-gal drums
Combustible debris	Wipes, etc.	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb UO2 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb UO2 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb UO2 0.1 lb Acetone	2 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.5×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	570	19.8×10^6
Recyclable Wastes	230	-

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities, and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to an offsite waste facility for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, and other items generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 Wastes and Emissions Generated During Construction

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	1.8
Nitrogen Dioxide	30
Hydrocarbons	8.2
Carbon Monoxide	200
Particulate Matter PM-10	50

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the facility since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil and lubricants for construction vehicles, will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	60 yd^3
Hazardous Liquids	25,000 gals
Nonhazardous Solids	
Concrete	130 yd^3
Steel	40 tons
Other	1,000 yd^3
Nonhazardous Liquids	
Sanitary	3.5×10^6 gals
Other	1.5×10^6 gals

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities (e.g., construction debris and rock cuttings) are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The facility includes areas with hazard categories of chemically high hazard (HH) for buildings containing HF and radiologically moderate hazard (HC2) for buildings containing DUF_6 and UO_2 product. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment (because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques)
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following structures, systems, and components (SSCs) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of liquid HF or NH_3 because their rupture could release HF or NH_3 with unacceptable consequences.
- Vessels containing significant inventories of gaseous HF or UF_6 because their rupture could release HF or UF_6 (UO_2F_2) with unacceptable consequences.
- The Process Building, HF Storage Building and UO_2 Storage Building structures because they house large HF and uranium inventories or gaseous UF_6, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	9.8 lb UO_2
Tornado	Extremely Unlikely	3.7 lb UO_2
Flood	Incredible	No Release
HF System Leak	Anticipated	216 lb HF
HF Pipeline Rupture	Unlikely	500 lb HF to Soil
HF Storage Tank Overflow	Unlikely	45 lb HF
UO_2 Drum Spill	Anticipated	3.7×10^{-5} lb UO_2
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	22 lb HF
Hydrogen Explosion	Extremely Unlikely	0.25 lb UO_2 7 lb HF
Ammonia Release	Unlikely	255 lb NH_3

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	197,000 lb UO_2	5×10^{-5} (a)	1	30 min
Tornado	1,470 lb UO_2	2.5×10^{-3} (b)	1	30 sec
Flood	No Release	NA	NA	NA
HF System Leak	540 lb HF	1	.4 (c)	15 min
HF Pipeline Rupture	500 lb HF	(d)	(d)	10 min
HF Storage Tank Overflow	830 lb HF	.22 (e)	.25 (f)	15 min
UO_2 Drum Spill	735 lb UO_2	5×10^{-5} (a)	1×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	22 lb HF	1	1	2 min
Hydrogen Explosion	5,000 lb UO_2 7 lb HF	.05 (g) 1	1×10^{-3} 1	30 min
Ammonia Release	255 lb NH_3	1	1	1 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).
2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).
3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

b. Respirable airborne fraction is assumed to be 50 times greater than that for free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

c. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

d. Assume 100% of the HF drains into the ground at a point 3 ft below grade during a 10 minute period. The contaminated soil is removed after 48 hrs.

e. Airborne release fraction is .22 based on 0.06 lb/min-sq ft evaporation rate, 200 sq ft spill area and 15 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*, American Industrial Hygiene Association Journal, November 1974. Fraction in respirable range is 1.

f. Based on 3 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

g. Based on deflagration of large volume of flammable mixture above powder in DOE-HDBK-0013-93, p. 4-5. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234, Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium, hydrofluoric acid and ammonia are the primary hazardous materials handled in this facility. Uranium and ammonia are toxic and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

The HF Storage Building and selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where high inventory of HF or UF_6 at elevated temperatures is present. Therefore, it would be incredible that these structures fail in the event of the DBE.

The UO_2 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,680 drums each containing 1,470 lb of UO_2. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum cover is lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Assuming a conservative average fall height of 8 ft, approximately 0.005% of the pellets are fractured into respirable particles which are assumed to subsequently exhibit powder-like behavior and could be expected to become airborne. Thus, approximately 9.8 lb of UO_2 is released to the environment. The release point is at grade.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

The HF Storage Building and selected areas of the Process Building are performance category PC-4 for structures for chemically high hazard facilities. These building areas are designed to resist the DBT for high hazard facilities. The DBTs defined for these structures would not result in a significant release. The UO_2 Storage Building is a category PC-3 structure for moderate hazard facilities. This structure would withstand the DBT and would not enable a significant release. However, in the extremely unlikely event of a

DBT exceeding the PC-3 defined DBT or failure of PC-3 SSCs, a tornado wind-driven missile could impact a UO_2 storage drum and release the 1,470 lb inventory of the drum. It is assumed that, due to the high wind conditions, all of the pellets become airborne and some fraction of these are pulverized into respirable fragments. This fraction is estimated to be fifty times greater than the pulverizing fraction associated with a drum spill as described above or 0.25%. Therefore, approximately 3.7 lb of respirable UO_2 is released during this extremely unlikely event. However, the particles will be highly dispersed due to tornado wind conditions.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF Distillation System Leak

Gaseous HF is produced from the conversion reactions. The HF is separated in a distillation column to form anhydrous (~100%) HF and 49 wt% HF in water. The boiling point of anhydrous HF is 67°F and that of 49 wt% HF is 233°F. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the distillation column overhead vapor line carrying anhydrous HF leaks 5% of its flowing contents for 10 minutes, thus releasing 540 lb of HF into the Process Building. After the leak is detected by air monitoring instruments, the distillation column operation and reactor feed are halted to stop the leak. It is assumed that 40% of the HF vapor (216 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 HF Pipeline Rupture

Anhydrous HF is pumped from the Process Building to the HF Storage Building through an underground pipeline. The pipe is double-walled to contain possible leakage and has a leak detection alarm. It is postulated that an earthquake ruptures the pipeline and its outer pipe. Assuming it takes 5 minutes to stop the HF pump, the pipeline is 200 ft of 1" pipe, and the pump runs at 10 gpm, it is estimated that approximately 60 gallons (500 lb) of anhydrous HF is released into the ground in a ten minute period. The contaminated soil is removed after 48 hours. This accident has been judged to be unlikely.

8.1.3.4 HF Storage Tank Overflow

Anhydrous HF is stored in six 38,000-gallon tanks in the HF Storage Building. Each tank contains about 282,000 lb of HF. The tanks and building are cooled to about 50°F to minimize the HF that vaporizes if a spill should occur. The tanks are performance category PC-4, have high level alarms and interlocks that stop the transfer pump, and are diked to contain spillage. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

It is postulated that during filling, a storage tank overflows at 10 gpm for 10 minutes and releases 100 gallons (830 lb) of HF. The HF spills onto the floor and drains to a covered sump. The HF evaporates at a rate of 12 lb/min for 15 minutes, based on an evaporation rate of 0.06 lb/min-sq ft and a spill area of 200 sq ft. The building HVAC system discharges 25% of the HF vapor (45 lb) to atmosphere in a 15 minute period, based on 3 air changes/hr and a mixing factor of 0.33. The building HVAC system is then shut down to stop further releases to atmosphere and the building water spray system is activated to absorb HF vapor remaining in the building. The release point is the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.5 UO_2 Drum Spill

Solid UO_2 is produced and packaged in drums in the process building. The drums are transported and stored in the UO_2 Storage Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the storage building floor. A drum contains 1,470 lb of UO_2. It is assumed that 50% of the UO_2 is released from the drum and fall to the floor. The pulverizing fraction for this scenario is 0.005% meaning that this proportion of the pellets are fractured into respirable particles which become airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne UO_2. Thus 3.7×10^{-5} lb of UO_2 is discharged through the UO_2 Building exhaust to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.6 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

8.1.3.7 Loss of Cooling Water

The HF distillation column and conversion reactors operate at pressures up to 15 psig. Pressure relief valves are provided to protect vessels and equipment. Loss of cooling water to the distillation column condenser would cause the pressure in the column to rise and the relief valve to open. The relief valve outlet is piped to a bed of limestone to neutralize the HF vapor (or a water quench tank to absorb the vapor) before discharging to atmosphere.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 1100 lb of HF. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. Assuming that the limestone bed has a 98% removal efficiency for HF, about 22 lb of HF would be released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.8 Hydrogen Explosion

Hydrogen is fed to Reactor No. 2 as a reagent, to react with UO_2F_2. There are two reactors in parallel, and each reactor receives about 33 lb/hr of hydrogen.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. Steam is also fed to the reactor. The reactor vapor space normally contains excess unreacted hydrogen, steam, HF and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

The reactor is assumed to contain about 10,000 lb of UO_2 during normal operation (3 hour residence time). It is assumed that 50% of the material is released into the room, of which 100% becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the material. Thus 0.25 lb of UO_2 is discharged through the Process Building exhaust stack. The reactor also contains 7 lb of HF that is released through the stack. This accident is judged to be extremely unlikely.

8.1.3.9 Sintering Furnace Explosion

A 6% hydrogen / 94% nitrogen gas mixture is fed to the sintering furnaces. There is normally no air in the furnaces. Each furnace receives about 2.7 lb/hr of hydrogen. The furnaces contain uranium pellets, which are much less dispersible than powder. The consequences of a furnace hydrogen explosion will be bounded by the reactor explosion described previously.

8.1.3.10 Ammonia Release

Ammonia is stored as a liquid in two 25,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so it will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia", Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is judged to be unlikely .

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

9.0 Transportation

9.1 Intrasite Transportation

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, UO_2 product in 30 gallon drums from the Process Building to the UO_2 Storage Building, and low-level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of uranium product to the plant boundary. Hazardous waste materials, such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, and laboratory wastes, requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary (for further transport to off-site hazardous waste treatment, storage, and disposal facilities).

9.2 Intersite Transportation

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product, and waste materials are shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), hydrochloric acid (HCl), and ammonia (NH_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium dioxide, hydrofluoric acid (HF), low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

The UO_2 product is packaged in 30 gallon steel drums that are 29 inches high by 18.2 inches outside diameter. The empty drum weighs 50 lbs and has a wall thickness of 0.053 inches (16 gage). Each drum contains 1,470 lbs of UO_2.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Output Material #1
Transported Materials					
Type	UF_6	HCl	NaOH	NH_3	Uranium Dioxide
Physical Form	Solid	Liquid	Liquid	Liquid	Solid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	NH_3 / 100°F, 197 psig (max.)	UO_2 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	Rail Car 11,000 gal	30 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	105S-300-W	TBD
Container Weight (lb)	2,600	50	50	TBD	50
Material Weight (lb)	27,000	540	660	52,000	1,470
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% NH_3	100% UO_2
Shipments					
Average Volume (ft^3)/Year	323,000	117	73	82,400	129,000
Packages/Year	2,322	16	10	56	32,150
Packages/Life of Project	46,440	320	200	1120	642,900
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	8	5	1	24 (truck) or 76 (railcar), 4 cars/train
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	56	1,340 (truck) or 106 (rail)
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	1120	26,800 (truck) or 2,120 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Rail	Truck/Rail
Destination - Facility Type	NA	NA	NA	NA	TBD

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #2	Output Material #3	Output Material #4	Output Material #5	Output Material #6
Transported Materials					
Type	Hydrofluoric Acid	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Liquid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	HF / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	Rail Tankcar 11,000 gal	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	105A-300-W	Varies	Varies	Varies	48G
Container Weight (lb)	TBD	50	50	50	2,600
Material Weight (lb)	84,000	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% HF	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	358,000	22,500	265	44	323,000
Packages/Year	243	2,835/30	36	6	2,322
Packages/Life of Project	4,860	56,700/600	720	120	46,440
Packages/Shipment	12 railcars/ train	40/10	18	6	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	20	71/3	2	1	387 (truck) or 49 (rail)
Shipments/Life of Project	400	1,420/60	40	20	7,740 (truck) or 980 (rail)
Form of Transport/Routing					
Form of Transportation	Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	Customer	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

10.0 References

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt ($1x10^6$ kW) hour(s)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

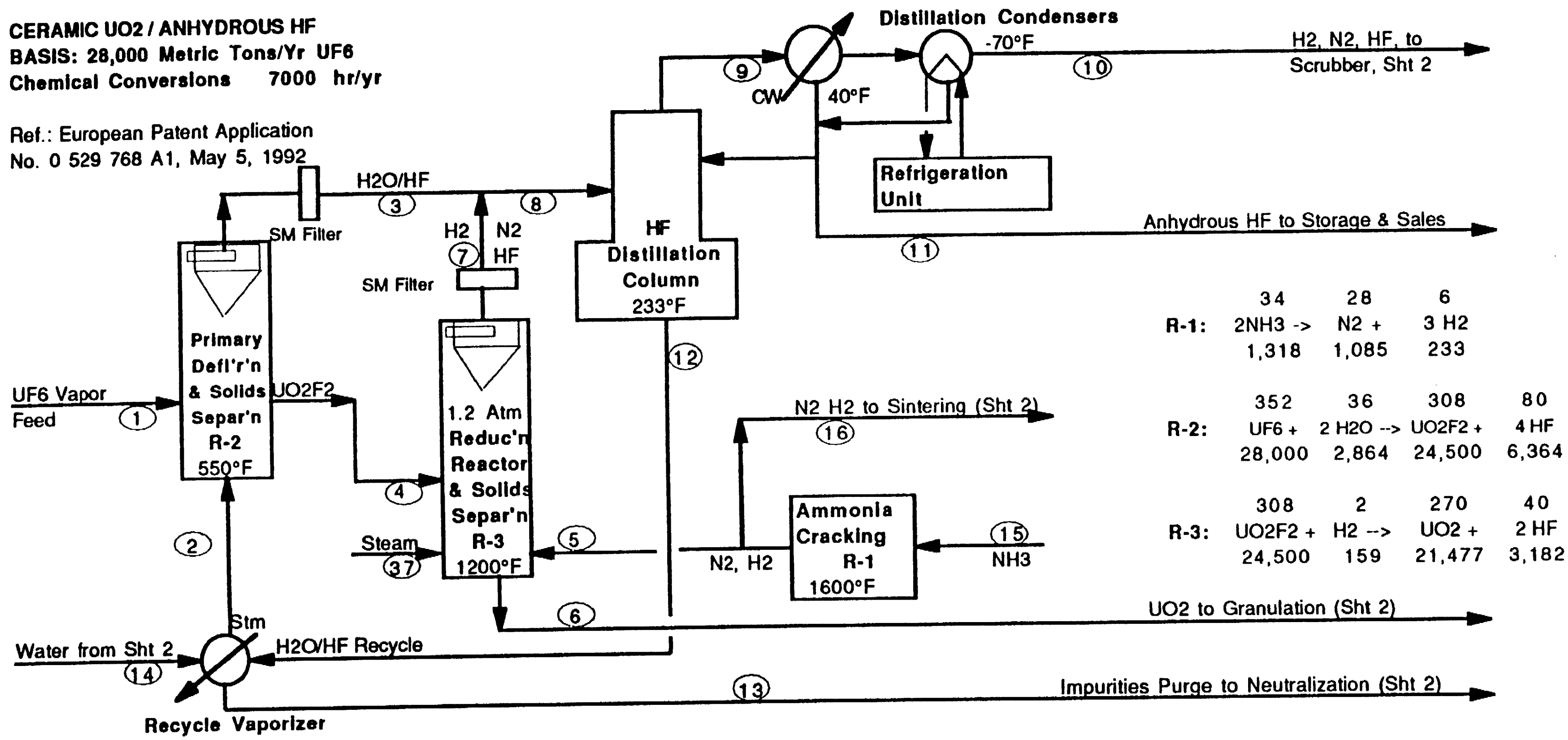
ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

CERAMIC UO2 / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Chemical Conversions 7000 hr/yr

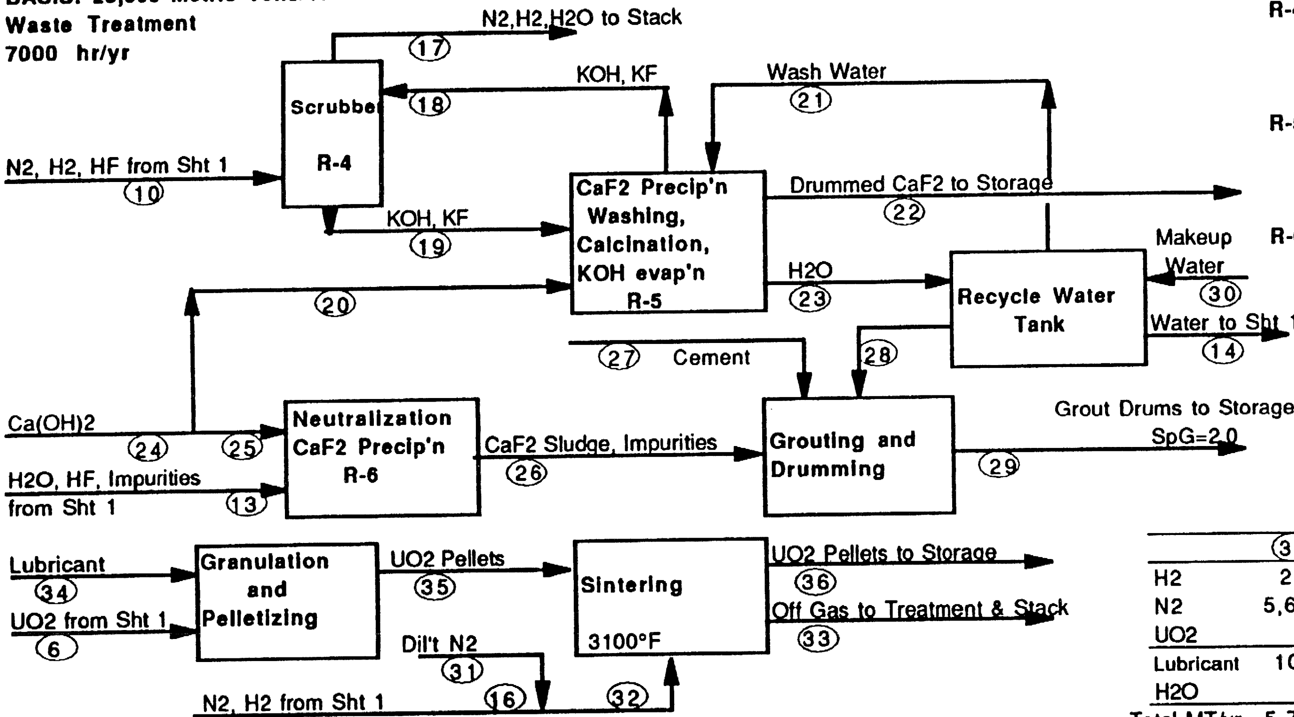
Ref.: European Patent Application
No. 0 529 768 A1, May 5, 1992



Does not include reflux (stream 9)

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
UF6	352	28,000															
UO2F2	308				24,500												
UO2	270						21,477										
HF	20		5,857	12,221				3,182	15,403	9,450	216	9,234	5,953	95			
H2	2					207		48	48	48	48						26
N2	28					965		965	965	965	965						120
NH3	17															1,318	
H2O	18		7,159	4,295				1,861	6,157	1.8	0	1.85	6,155	137	1,141		
Total MT/yr		28,000	13,017	16,517	24,500	1,172	21,477	6,056	22,573	10,465	1,229	9,236	12,108	233	1,141	1,318	146
kg/kgU		1.48	0.69	0.87	1.29	0.062	1.13	0.32	1.19	0.55	0.065	0.49	0.64	0.012	0.060	0.070	0.0077

CERAMIC UO2 / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Waste Treatment
7000 hr/yr



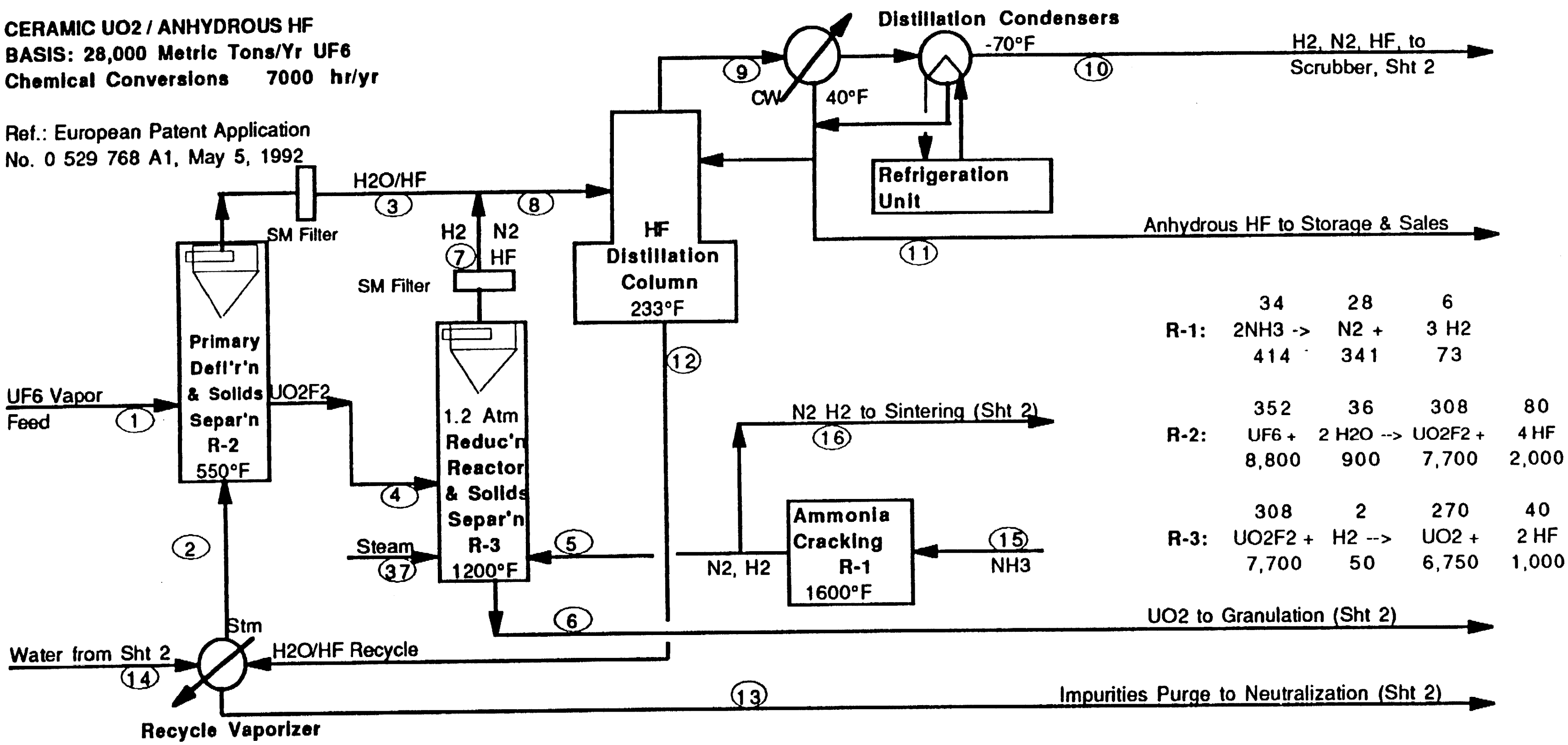
	20	56	58	18
R-4:	HF +	KOH -->	KF +	H2O
	216	604	626	194
	116	74	78	112
R-5:	2 KF +	Ca(OH)2-->	CaF2 +	2 KOH
	626	399	421	604
	40	74	78	36
R-6:	2 HF +	Ca(OH)2-->	CaF2 +	2 H2O
	95	177	186	86

	33	34	35	36	37
H2	26				
N2	5,654				
UO2			21,477	21,477	
Lubricant	107	107	107		
H2O					1,861
Total MT/yr	5,787	107	21,585	21,477	1,861
kg/kgU	0.31	0.0057	1.14	1.13	0.098

	Mol Wt	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Cement												391		391			
KOH	56		755	151													
KF	58		63	688													
CaF2	78						421				186			186			
HF	20	0.216												0			
H2	2	48															26
N2	28	965														5,533	5,654
Ca(OH)2	74				399				576	177							
H2O	18	68	10,129	10,255		631		757			223		130	354	1,146		
Total MT/yr		1,082	10,947	11,094	399	631	421	757	576	177	409	391	130	931	1,146	5,533	5,680
kg/kgU		0.057	0.58	0.59	0.021	0.033	0.022	0.040	0.030	0.0093	0.022	0.021	0.0069	0.049	0.061	0.29	0.30

CERAMIC UO2 / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Chemical Conversions 7000 hr/yr

Ref.: European Patent Application No. 0 529 768 A1, May 5, 1992

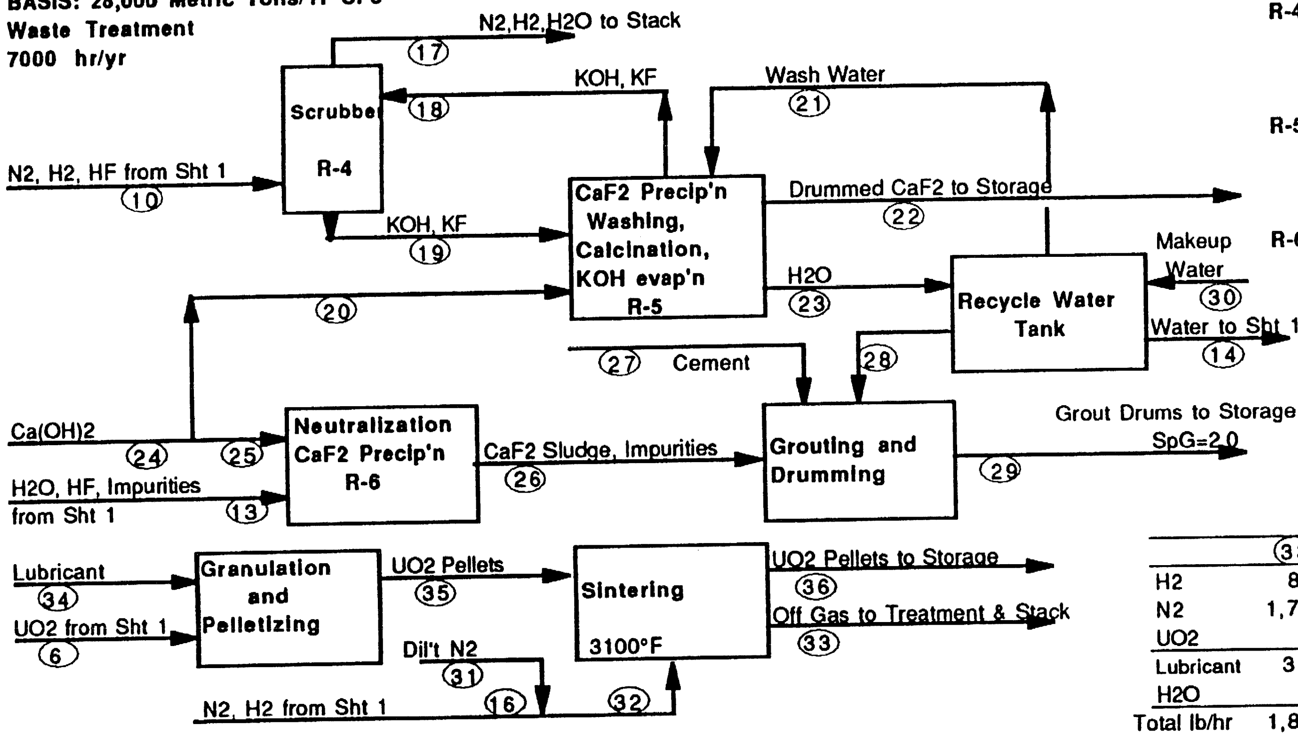


Does not include reflux (→ stream 9)

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
UF6	352	8,800															
UO2F2	308				7,700												
UO2	270						6,750										
HF	20		1,841	3,841				1,000	4,841	2,970	68	2,902	1,871	30			
H2	2					65		15	15	15	15						8
N2	28					303		303	303	303	303						38
NH3	17															414	
H2O	18		2,250	1,350				585	1,935	0.6	0	0.58	1,934	43	359		
Total lb/hr		8,800	4,091	5,191	7,700	368	6,750	1,903	7,094	3,289	386	2,903	3,805	73	359	414	46
kg/kgU		1.48	0.69	0.87	1.29	0.062	1.13	0.32	1.19	0.55	0.065	0.49	0.64	0.012	0.060	0.070	0.0077

5-Mass Balance lb/hr

CERAMIC UO2 / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Waste Treatment
7000 hr/yr



	20	56	58	18
R-4:	HF +	KOH -->	KF +	H2O
	68	190	197	61
	116	74	78	112
R-5:	2 KF +	Ca(OH)2-->	CaF2 +	2 KOH
	197	125	132	190
	40	74	78	36
R-6:	2 HF +	Ca(OH)2-->	CaF2 +	2 H2O
	30	56	59	27

	33	34	35	36	37
H2	8				
N2	1,777				
UO2			6,750	6,750	
Lubricant	34	34	34		
H2O					585
Total lb/hr	1,819	34	6,784	6,750	585
kg/kgU	0.31	0.0057	1.14	1.13	0.098

	Mol Wt	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Cement												123		123			
KOH	56		237	47													
KF	58		20	216													
CaF2	78						132				59			59			
HF	20	0.068												0			
H2	2	15															8
N2	28	303														1,739	1,777
Ca(OH)2	74				125				181	56							
H2O	18	22	3,183	3,223		198		238			70		41	111	360		
Total lb/hr		340	3,440	3,487	125	198	132	238	181	56	129	123	41	293	360	1,739	1,785
kg/kgU		0.057	0.58	0.59	0.021	0.033	0.022	0.040	0.030	0.0093	0.022	0.021	0.0069	0.049	0.061	0.29	0.30

Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressor (14)	800 lb/hr UF6, 15 psig discharge	Proc. Bldg
Reactor No. 1 (2)	3'6"Dx10'H, fluidized bed, cooling jacket, Monel	Proc. Bldg
Screw Conveyor (2)	Monel, 6"Dx10'L, 40 cfh	Proc. Bldg
Reactor No. 2 (2)	6'Dx30'L rotary kiln, 66 kw, Inconel	Proc. Bldg
Vaporizer (2)	2'Dx6'L, 150 sq ft, Monel tubes, stl shell	Proc. Bldg
Reactor Off-Gas System	Cyclone, sintered metal filter	Proc. Bldg
UO2 Product Cooler (2)	12"Dx10'L, screw conveyor with cooling water, steel, 33 cfh	Proc. Bldg
UO2 Bucket Elevator No. 1 (2)	20'H, 33 cfh	Proc. Bldg
UO2 Product Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
UO2 Drum Filling Station	4.5 drums/hr, glovebox	Proc. Bldg
UO2 Dust Collector	baghouse	Proc. Bldg
HF Distillation Column	4'6"Dx24'H, Monel	
Reboiler	2'Dx6'H, 150 sq ft, Monel tubes, steel shell	Proc. Bldg
40°F Condenser	4'Dx12'L, 3500 sq ft, Monel tubes, steel shell	Proc. Bldg
-70°F Condenser	2'Dx6'L, 150 sq ft, Monel tubes, steel shell	Proc. Bldg
Reflux Drum	3'Dx4'L, Monel	Proc. Bldg
Reflux Pump	135 gpm, Monel	Proc. Bldg
30°F Chiller	9.3 MMBTU/hr, 750 hp	Proc. Bldg
-80°F Chiller	60,000 BTU/hr, 15 hp	Proc. Bldg
Bottoms Pump	10 gpm, Monel	Proc. Bldg
HF Hold Tanks (2)	6'Dx14'L, 3000 gal, cooling coils, steel	Proc. Bldg
HF Transfer Pump	10 gpm, bronze	Proc. Bldg
HF Bulk Storage Tanks (6)	12'Dx45'L, 38,000 gal, cooling coils, steel	HF Bldg
HF Loading Pump	25 gpm, bronze	HF Bldg
Off-Gas Scrubber	1'Dx10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
Off-Gas HEPA Filter (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhauster (2)	100 scfm	Proc. Bldg
Lime Feed Bin	3'Dx7'H, 40 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 132 lb/hr	Proc. Bldg
Precipitation Tank	4'Dx5'H, 450 gal, Monel	Proc. Bldg
Drum Filter	2'Dx6'L, 40 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 scfm	Proc. Bldg
Filtrate Tank	4'Dx5'H, 450 gal, steel	Proc. Bldg
Scrub Solution Cooler	2'Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Scrub Solution Pump	8 gpm, Monel	Proc. Bldg
Evaporator	2'Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	2'Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	5'Dx5'H, 750 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
CaF2 Screw Conveyor	6"Dx10'L	Proc. Bldg
CaF2 Rotary Dryer	1'6"Dx5'L, steel	Proc. Bldg
CaF2 Drum Filling Station	0.2 drums/hr, glovebox	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg
Impurities Neutralization Tank (2)	5'Dx5'H, 750 gal, cooling jacket, Monel	Proc. Bldg
Lime Feed Bin	3'6"Dx7'H, 50 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 2000 lb/hr	Proc. Bldg
Neutralized Waste Feed Pump	5 gpm, 316 SS	Proc. Bldg
Cement Feed Bin	4'Dx10'H, 90 cf, steel	Proc. Bldg
Cement Feeder	6"Dx6'L screw feeder, steel	Proc. Bldg
Drum Tumbling Station	0.3 drums/hr (avg)	Proc. Bldg
Feed Hopper	4'Dx7'H, 70 cf, steel	Proc. Bldg
UO2 Powder Mill	hammer mill, 33 cfh	Proc. Bldg
UO2 Compactor	33 cfh feed	Proc. Bldg
UO2 Granulator	20 cfh	Proc. Bldg
Vibrating Screen Separator	4'Dx5'H, stainless steel	Proc. Bldg
UO2 Blender (2)	Double-cone tumbler, 13 cf working cap.	Proc. Bldg
Lubricant Feed Tank	3'Dx3'H, 100 gal, steel	Proc. Bldg
Granulated UO2 Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
Pellet Press (2)	365 pellets/min	Proc. Bldg
Boat Loading Station (3)	33 1'x1' boats/hr, 3'x3'x30'L glovebox	Proc. Bldg
Sintering Furnace (3)	6'Wx6'Hx70'L, 400 kw, water jacketed	Proc. Bldg
Furnace Off-Gas Filters		Proc. Bldg
Boat Unload/Drum Load Station	4.6 drums/hr, glovebox	Proc. Bldg
Cement Silo	7'Dx23'H, 700 cf, steel	Yard
Cement Pneumatic Conveyor	4 tons/hr	Yard/Proc. Bldg
Lime Silo	8'Dx35'H, 1600 cf, steel	Yard
Lime Pneumatic Conveyor	2 tons/hr	Yard/ Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
Ammonia Storage Tank (2)	9'Dx53'L, 25,000 gal, steel, 250 psig	Yard
Ammonia Dissociator (3)	6000 cfh H2+N2, 90 kw	Yard
Nitrogen Generator	380 scfm, membrane separator	Proc. Bldg
Air Compressor	800 cfm, 150 psi, 230 bhp	Proc. Bldg
Nitrogen Receiver (2)	4'Dx13'H, 1200 gal, 150 psig, steel	Proc. Bldg
SUPPORT SYSTEMS		
Process Material Handling Systems	DUF_6 cylinder handling:	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated/ carbon steel storage racks for 400 14-ton DUF_6 cylinders	Proc. Bldg
	Two(2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	UO_2 drum interim handling:	
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg
	Grouted waste & UO_2 pellet drum handling:	
	-3 flatbed trucks	Yard
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg/ UO_2 Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg/ UO_2 Bldg
	CaF_2 handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ CaF_2 Bldg
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF_2 traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Process Control / Monitoring System	-Computer based distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, U_3O_8 drum handling, waste grouting / LLW packaging and CaF_2 drum handling areas	Proc. Bldg
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms and controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg & Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-6 local sampling glove boxes with laboratory liquid / powder sample hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste evaporator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U_3O_8 drums	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U_3O_8 tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/ Yard

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	Yard Yard Yard Yard/Buildings Buildings Buildings
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 22,000 lb/hr, 50 psig gas fired Air compressors - 2@ 300 cfm 150 psig Breathing air compressors - 2 @ 100 cfm Air Dryers - desiccant, minus 40°F dew point Demineralized water system - 3500 gpd Sanitary water treatment system - 4100 gpd Industrial wastewater treatment system - 60,000 gpd Electrical substation - 4000 kW Emergency generators - 2 @ 500kW Uninterruptible Power Supply - 100 kVA Cooling Tower - 26 MM Btu/hr, 2600 gpm	Util. Bldg Util. Bldg Util. Bldg Util. Bldg Util. Bldg Sanitary Treatment area Wastewater Treatment area Substation Substation Proc. Bldg Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-3000 cfm,7 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / Anhydrous HF

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
HVAC SYSTEMS		
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-80,000 cfm, 200 HP exhaust fans, 2-80,000 cfm 100 HP supply air units	UO_2 Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, Process'g 2-10,000 cfm, 15 HP supply air units	Grout Areas CaF_2 Areas Waste Control Room Support Areas
HF Area HVAC	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, Emergency shutdown on HF leak	HF Areas
HVAC Chillers	3-350 ton chillers	Proc. Bldg
Circulating Pumps	3-600 gpm, 20 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

CERAMIC UO2 / ANHYDROUS HF - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (see note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	26	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	26	6	Steel	1/4"	3483.0
UO2F2 reactor surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
UO2 reactor surveillance	1	0.50	1752	7	6	Inconel	1.5"	876.0
UO2 drum loading	1	0.50	715	9,10	6	Steel	0.06"	357.5
Transfer UO2 drums to interim storage	2	0.50	715	10,11	3	Steel	0.06"	715.0
Transfer UO2 drums to pelletizing	2	0.50	715	10,11	3	Steel	0.06"	715.0
UO2 interim storage surveillance	1	0.50	2190	10,12,14	3	Steel	0.06"	1095.0
UO2 pelletizing surveillance	2	7000.00	continuous	19,20	6	Steel	1/4"	14000.0
UO2 sintering surveillance	2	7000.00	continuous	21	6	Steel	1/4"	14000.0
Transfer UO2 pellets to interim storage	2	0.50	6400	12,11	3	Steel	0.06"	6400.0
Transfer UO2 pellets to storage building	2	0.50	6400	12,11	3	Steel	0.06"	6400.0
Load UO2 pellets for shipment offsite	1	1.00	1600	13,15	3	Steel	0.06"	1600.0
UO2 Storage Building surveillance	1	0.50	2190	15	3	Steel	0.06"	1095.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (see note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS
HF distillation surveillance	1	0.50	1752	6,7	20	Monel,Inconel	3/4",1.5"	876.0
Off-gas Scrubbing & CaF2 Processing surveillance	1	0.50	1752	1,2,3	35	Steel	1/4"	876.0
Waste Grouting & Decon Waste Treatment surveillance	1	0.50	1752	24	3	Steel	1/4"	876.0
Transfer grouted waste to interim storage area.	2	0.50	320	24	3	Steel	0.06"	320.0
Transfer grouted waste to storage building	2	0.50	320	24	3	Steel	0.06"	320.0
Load grouted drums for shipment offsite	1	1.00	56	25	3	Steel	0.06"	56.0
Transfer CaF2 drums to interim storage	2	0.50	160	1,2,3	35	Steel	1/4"	160.0
Transfer CaF2 drums to storage area	2	0.50	160	1,2,3	35	Steel	1/4"	160.0
Load CaF2 drums for shipment offsite	1	1.00	28	25	3	Steel	0.06"	28.0
CaF2 interim storage surveillance	1	0.25	2190	1,2,3	35	Steel	1/4"	547.5
CaF2 & Grouted Waste storage building surveillance	1	0.20	2190	25	3	Steel	0.06"	438.0
HF Storage Building surveillance	1	0.50	2190	4	150	Steel	1/4"	1095.0
Transfer HF for shipment offsite	2	10.00	243	4	150	Steel	1/4"	4860.0
LLW processing, packaging, and shipping	2	8.00	1100	24	3	Steel	0.06"	17600.0
Process control room operations	8	8.00	1100	1,2,3	30	Steel	1/4"	70400.0
Laboratory operations	5	8.00	1100	6,7	30	Monel,Inconel	3/4",1.5"	44000.0
HP	2	8.00	1100	1,2,3	30	Steel	1/4"	17600.0
Management / Professionals	16	8.00	250	20	3	Steel	1/4"	32000.0
Accountability	3	2.00	1100	3,4,15	3	Steel	1/4",0.06"	6600.0
Industrial and sanitary waste treatment	4	8.00	1100	2,5	100	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	21	120	Steel	1/4"	35200.0
Administration	22	8.00	250	7,19	120	Inconel,Steel	1.5",1/4"	44000.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (see note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS
Guardhouse / Process Bldg.	5	8.00	1100	2,5	150	Steel	1/4"	44000.0
Maintenance								15160.0
								450595.6

1) A single full UF6 cylinder.
2) A single empty UF6 cylinder.
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; There are 2 reactors.
7) UO2 reactor; There are 2 reactors.
8) Compactor feed bin; There are 2 bins.
9) Drum fill bin.
10) Drum of UO2 powder.
11) Each transfer consists of 5 UO2 drums.
12) Drum of UO2 pellets.
13) There are 20 drums UO2 pellets per shipment.
14) Assume up to 1 weeks production in interim storage = 690 drums
15) There are up to 2673 UO2 drums in the storage building.
16) Each transfer consists of 7 CaF2 drums
17) There are 40 CaF2 drums per shipment
18) 2322 UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    35683 UO2 powder drums/yr equivalent
    assume 2% of production is sent to interim storage in drums = .02* 35683 = 715
    32000 UO2 pellet drums/yr /5 drums per transfer = 6400 transfers
    32000 UO2 pellet drums/yr /20 drums per shipment = 1600 shipments
    243 railcars/yr of HF
    1100 CaF2 drums/yr / 7 drums per transfer = 160 transfers per year
    1100 CaF2 drums/yr / 40 drums per shipment = 28 transfers per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    2232 grouted waste drums/yr /7 drums per transfer = 320 transfers per year
    2232 grouted waste drums/yr /40 drums per shipment = 56 transfers per year
19) Cumulative inventory UO2 Feed Bin through Granulated UO2 Bin.

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (see note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS

20) Cumulative UO2 inventory Pellet Press and Boat Loading Station.

21) Sintering Furnace inventory.

22) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

23) Drum of grouted waste

24) Batch of LLW

25) There are up to 190 drums of grouted waste in the storage building.

26) A single 3 mo. old empty UF6 cylinder

CERAMIC UO2 / ANHYDROUS HF - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UO2F2 Reactor (Reactor No. 1) (2)	2	26	2	6	3	Monel	3/4"	104
UO2F2 screw conveyor (2)	2	108	2	6	3	Monel	3/4"	432
UO2F2 sintered metal filter (2)	2	4	2	23	1			16
UO2 reactor (Reactor No. 2) (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 product cooler (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 sintered metal filter (2)	2	4	2	23	1			16
UO2 bucket elevator No. 1 (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 dust collector (baghouse) (1)	2	4	1	23	1			8
UO2 powder mill (1)	2	52	1	19	2	Steel	1/4"	104
UO2 compactor (1)	2	52	1	19	2	Steel	1/4"	104
UO2 granulator (1)	2	52	1	19	2	Steel	1/4"	104
Vibrating screen separator (1)	2	52	1	19	2	Steel	1/4"	104
UO2 blender (1)	2	52	1	19	2	Steel	1/4"	104
Pellet press (1)	2	108	1	20	2	Steel	1/4"	216
Boat loading station (3)	2	26	3	20	2	Steel	1/4"	156
Sintering furnace (3)	2	26	3	21	2	Steel	1/4"	156
Sintering furnace off-gas filters	2	4	3	23	1			24
Boat unload / drum load station (1)	2	26	1	21	2	Steel	1/4"	52
HF distillation column (1)	2	26	1	6,7	40	Monel, Inconel	3/4",1.5"	52
HF distillation reboiler (1)	2	26	1	6,7	40	Monel,Inconel	3/4",1.5"	52
40 deg F condenser (1)	2	26	1	6,7	50	Monel,Inconel	3/4",1.5"	52
-20 deg F condenser (1)	2	26	1	6,7	50	Monel,Inconel	3/4",1.5"	52
HF distillation reflux pump (1)	2	52	1	6,7	30	Monel,Inconel	3/4",1.5"	104
30 deg F chiller (1)	2	52	1	6,7	50	Monel,Inconel	3/4",1.5"	104
-30 deg F chiller (1)	2	52	1	6,7	50	Monel,Inconel	3/4",1.5"	104
HF distillation bottoms pump (1)	2	52	1	6,7	30	Monel,Inconel	3/4",1.5"	104
HF transfer pump (1)	2	52	1	6,7	30	Monel,Inconel	3/4",1.5"	104

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR
Off-gas scrubber (1)	2	26	2	6,7	40	Monel,Inconel	3/4",1.5"	104
Off-gas heater (1)	2	26	2	6,7	40	Monel,Inconel	3/4",1.5"	104
Off-gas HEPA filters (2)	2	4	2	6,7	40	Monel,Inconel	3/4",1.5"	16
Off-gas exhausters (2)	2	52	2	6,7	40	Monel,Inconel	3/4",1.5"	208
Lime feeder (1)	2	104	1	1,2,3	30	Steel	1/4"+1/4"	208
Drum filter (1)	2	26	1	1,2,3	40	Steel	1/4"+1/4"	52
Vacuum pump (1)	2	52	1	1,2,3	40	Steel	1/4"+1/4"	104
Scrub solution cooler (1)	2	26	1	1,2,3	25	Steel	1/4"+1/4"	52
Scrub solution pump (1)	2	52	1	1,2,3	25	Steel	1/4"+1/4"	104
Evaporator (1)	2	26	1	1,2,3	30	Steel	1/4"+1/4"	52
Condenser (1)	2	26	1	1,2,3	40	Steel	1/4"+1/4"	52
Condensate pump (1)	2	52	1	1,2,3	40	Steel	1/4"+1/4"	104
CaF2 screw conveyor (1)	2	104	1	1,2,3	40	Steel	1/4"+1/4"	208
CaF2 rotary dryer (1)	2	104	1	1,2,3	40	Steel	1/4"+1/4"	208
CaF2 dust collector (1)	2	4	1	1,2,3	50	Steel	1/4"+1/4"	8
Lime feeder (1)	2	104	1	20	40	Steel	1/4"	208
Neutralized waste feed pump (1)	2	52	1	20	50	Steel	1/4"	104
Cement feeder (1)	2	104	1	20	40	Steel	1/4"	208
Grout mixing / drum tumbling station (1)	2	52	1	20	30	Steel	1/4"	104
Ammonia dissociator (3)	2	26	3	12,14	130	Steel	0.06"	156
Nitrogen generator	2	26	1	21	125	Steel	1/4"	52
Air compressor (1)	2	52	1	21	125	Steel	1/4"	104
Boiler, Water Systems, and other Utilities	2	52	3	21	125	Steel	1/4"	312
HVAC equipment	2	520	1	19	30	Steel	1/4"	1040
Waste water treatment equipment	1	2190	1	2,5	100	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	2,5	100	Steel	1/4"	2190

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR
Admin building	1	1000	1	19	120	Steel	1/4"	1000
								15160

1) A single full UF6 cylinder.
2) A single empty UF6 cylinder.
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; There are 2 reactors.
7) UO2 reactor; There are 2 reactors.
8) Compactor feed bin; There are 2 bins.
9) Drum fill bin.
10) Drum of UO2 powder.
11) Each transfer consists of 5 UO2 drums.
12) Drum of UO2 pellets.
13) There are 20 drums UO2 pellets per shipment.
14) Assume up to 1 weeks production in interim storage = 690 drums
15) There are up to 2673 UO2 drums in the storage building.
16) Each transfer consists of 7 CaF2 drums
17) There are 40 CaF2 drums per shipment
18) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HJVAC components
    6 hours per day of waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
19) Cumulative inventory UO2 Feed Bin through Granulated UO2 Bin.
20) Cumulative UO2 inventory Pellet Press and Boat Loading Station.
21) Sintering Furnace inventory.
22) Materials do not include walls between operating areas.
23) Loaded filter/bag.

Section 6.7

UO_2: Ceramic UO_2/HF Neutralization Facility

Section 6.7
UO2: Ceramic UO2/HF Neutralization Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into uranium dioxide (UO_2) and byproduct calcium fluoride (CaF_2). Due to its high density and chemical stability, UO_2 is a principal option for uranium use, long term storage or disposal. UF_6 defluorination is achieved through a steam/hydrogen, hydrolysis/ pyrohydrolysis route, with neutralization of the hydrofluoric acid (HF) produced with lime. UO_2 powder is pressed and sintered to form high density pellets. The process is based on processes used in the nuclear fuel fabrication industry.

Process Summary

Depleted uranium hexafluoride is processed to produce sintered uranium dioxide (UO_2) pellets and byproduct calcium fluoride. A dry process (steam hydrolysis/steam pyrohydrolysis) is used for conversion to uranium dioxide powder, which is then pelletized and sintered to the ceramic form.

The UF_6 is converted in two steps. The UF_6 is vaporized using steam heated autoclaves and fed to a reactor, where it is mixed with steam. Solid uranyl fluoride (UO_2F_2) is produced and it flows to a second reactor where it is mixed with hydrogen, nitrogen and superheated steam to produce solid UO_2. The UO_2 powder is milled, compacted and granulated, and then mixed with a dry lubricant. The granules are fed to a high-speed press that produces cylindrical pellets. The pellets are sintered in a continuous tunnel kiln operating at 1700°C under a reducing gas atmosphere. The sintered pellets are loaded into drums for storage and shipment.

Vapor containing HF and water vapor from both reactors flows to HF absorption columns. The resulting HF solution is neutralized with slaked lime (CaO). The resulting CaF_2 precipitate is separated, dried, and packaged in drums for sale.

1.0 DUF_6 Conversion Facility - Missions, Assumptions and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Ceramic UO_2 / Hydrofluoric Acid (HF) Neutralization Conversion Facility process converts depleted UF_6 into uranium dioxide (UO_2) for use (shielding), long-term storage, or disposal.

1.2 ASSUMPTIONS & DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or railcar. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three months supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure, and the assumed average isotopic composition is: 0.001% U-234, 0.25% U-235, and 99. 75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinder, the short lived daughter products of U-238, Th-234 and Pa-234, are in the same equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.
- Annual operating time is assumed to be 7,000 hours based on a plant availability factor of 0.8.
- A single train of process equipment is provided to produce the plant processing capacity, except in the UF_6 reactor systems, where two parallel trains are provided. Two pellet pressing lines and three custom-designed sintering furnaces provide the required pelletizing/sintering capacity.
- The hydrofluoric acid (HF) produced in the process is converted to CaF_2, which is sold.

- UO_2 is packaged in 30 gallon drums and and CaF_2 product is packaged in 55 gallon drums. Since the weight of UO_2 in a full drum exceeds the maximum weight limitations for a standard drum, it is assumed that specially engineered drums are used for UO_2. Indoor on-site storage space for 1 months production is provided.
- On-site storage of one weeks supply of lime (calcium oxide) and one months supply of ammonia is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities" as defined in DOE Order 6430. 1A and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- UO_2 Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility including the following:

- CaF_2 Storage Building
- Administration Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20 year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation

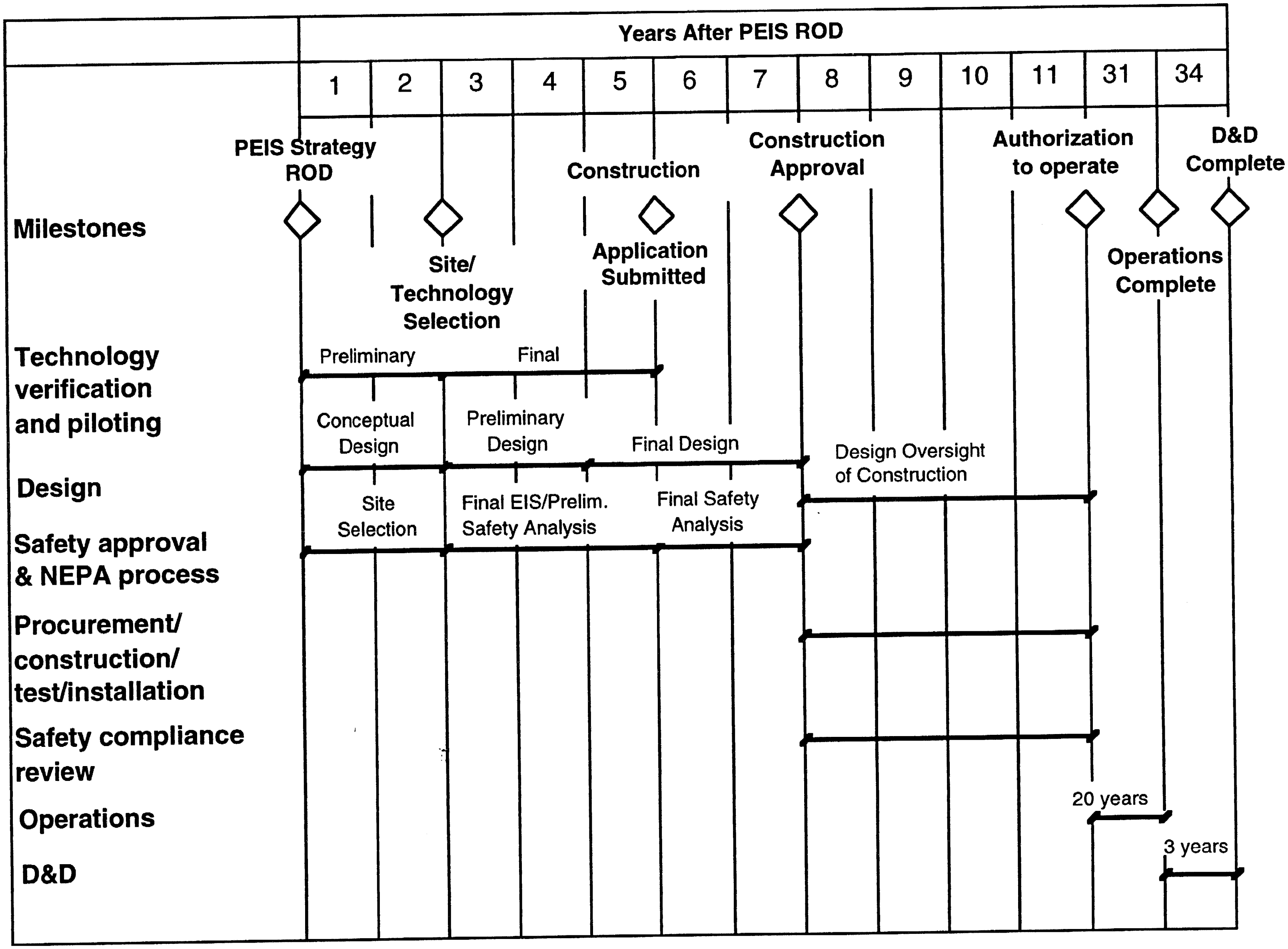


Figure 1-1 Preliminary Project Schedule

40 CFR 1502 - *Environmental Impact Statement*, 10 CFR 1021, *National Environmental Policy Act Implementing Procedures* (for DOE) and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program.*

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria.* Applicable codes, standards, guidelines, etc. as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable NRC regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards;* DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations;* and DOE Order 5440.1C, *National Environmental Policy Act.* Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection.*

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities. " Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements;* the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities. "

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400. 1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820. 2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process and facility include the following:

- This process has not been demonstrated on a throughput scale assumed for this study (28,000 MT/yr UF_6). Primary concern is direct scaleup of the conversion reactors.
- Sintering furnaces combining high temperature, special gas atmosphere and high capacity are required. Furnaces with one or two of these features are common, but a furnace combining all of these will

require some engineering and development. However, it is believed that the furnace design is technically feasible.

- The optimum material of construction for reactor system process equipment and components exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.
- The ultimate use or disposal form of the UO_2 product has not been finalized. Also, the viability of shipment of sintered UO_2 pellets in 30 gallon drums has not been determined.
- Due to the pre-conceptual nature of the facility design, development of process and support system equipment and component design details as well as facility building and site construction quantities has not been fully defined. With the exception of the major process equipment, current equipment / system / facility descriptions are based primarily on engineering judgement and comparisons with historical data from similar facilities.
- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium dioxide (UO_2) and calcium fluoride (CaF_2) by defluorination with steam and hydrogen. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the process building in a series of two reactors, to solid UO_2 product which is then milled, compacted, granulated, and screened. The UO_2 pellets are pressed, sintered and packaged in 30 gallon drums. The product uranium dioxide is stored on-site until it is transported to another site for subsequent disposition: long term storage, use or disposal. Hydrofluoric acid (HF) produced in the reaction is neutralized with lime (CaO) to produce the byproduct calcium fluoride, which is sold.

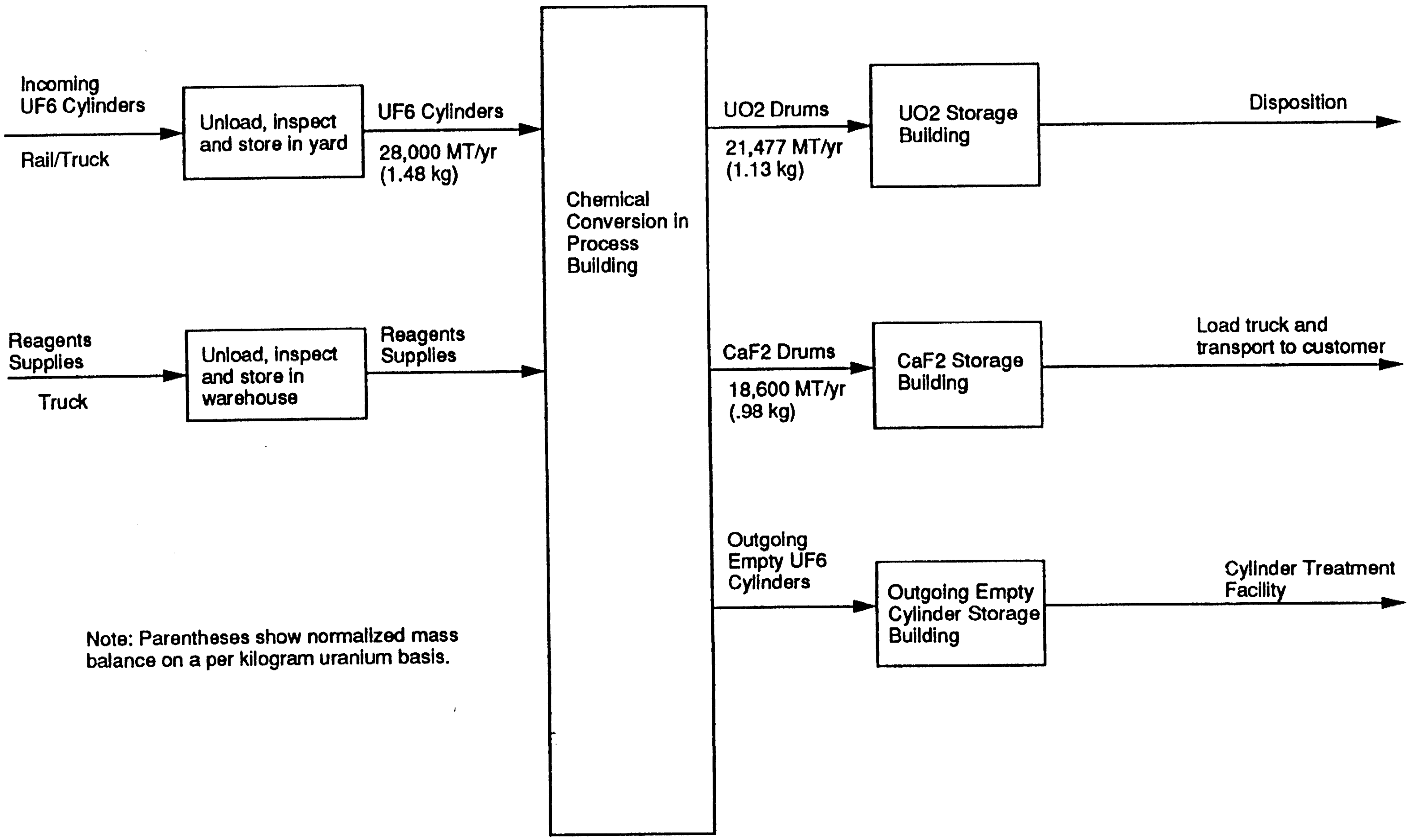
2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- UO_2 Storage Building
- CaF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Miscellaneous support buildings, including the Administration Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot plan conveys general layout information only and is based on the assumption of a generic, greenfield site.



Note: Parentheses show normalized mass balance on a per kilogram uranium basis.

Figure 2-1 Ceramic UO2 / HF Neutralization Material Flow Diagram

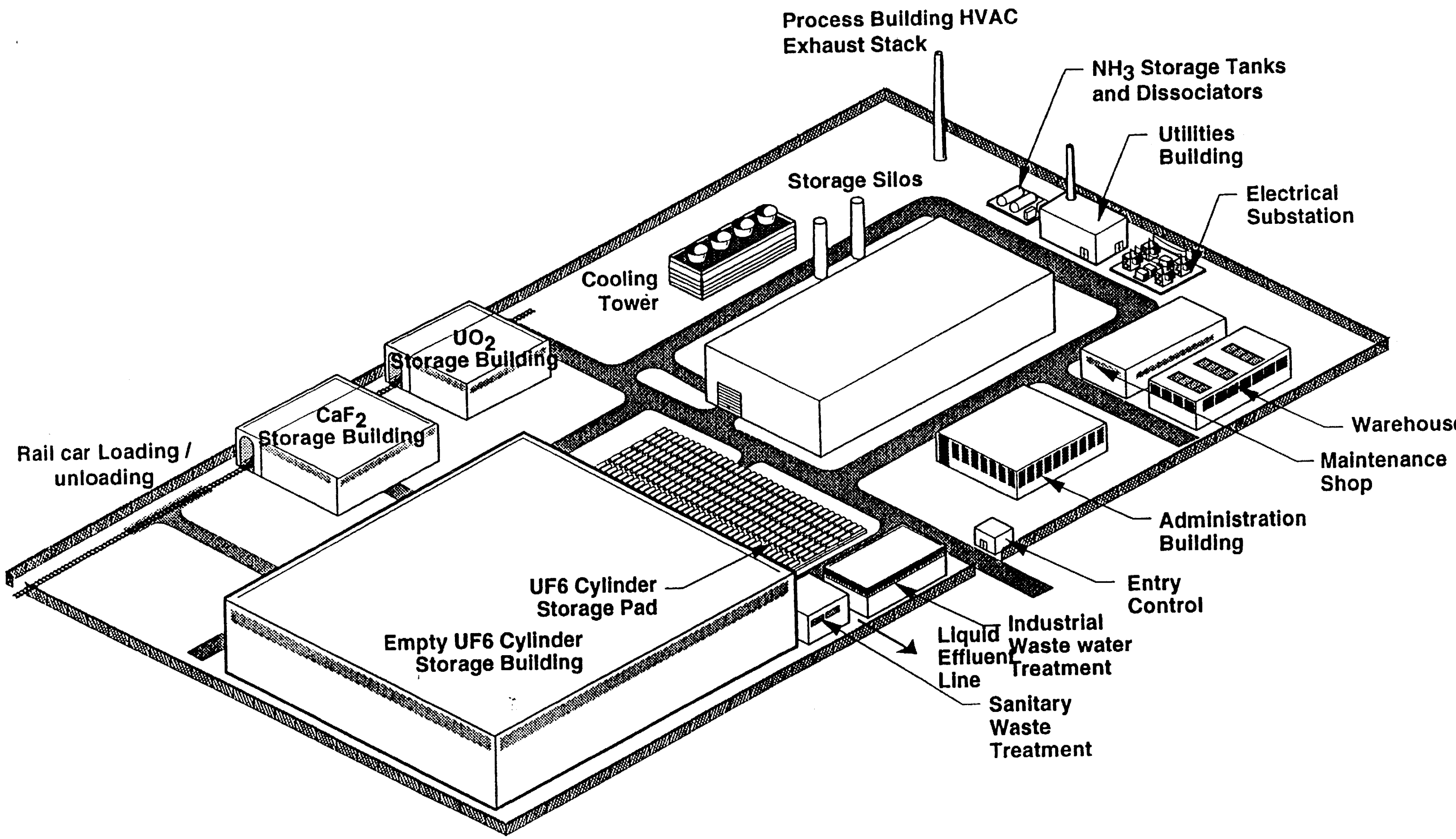


Figure 2-2 Plot Plan
Ceramic UO_2 / HF Neutralization Facility

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	54,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
UO_2 Storage Building	10,000	1	Yes	Yes	HC2 / MH	Metal Frame
CaF_2 Storage Building	14,000	1	No	No	General	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	8,000	1	No	Yes	General	Metal Frame
Administration Building	10,000	1	No	No	General	Metal Frame
Maintenance Shop	6,000	1	No	Yes	General	Metal Frame
Warehouse	7,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	5,000	1	No	Yes	General	Metal Frame
Sanitary Waste Building	2,000	1	No	No	General	Metal Frame
Cooling Tower	7,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The Process Building layout, section and equipment arrangement is shown in Figures 2-3, 2-4 & 2-5. The building is a two-story reinforced concrete structure classified radiologically as a category HC2 moderate hazard

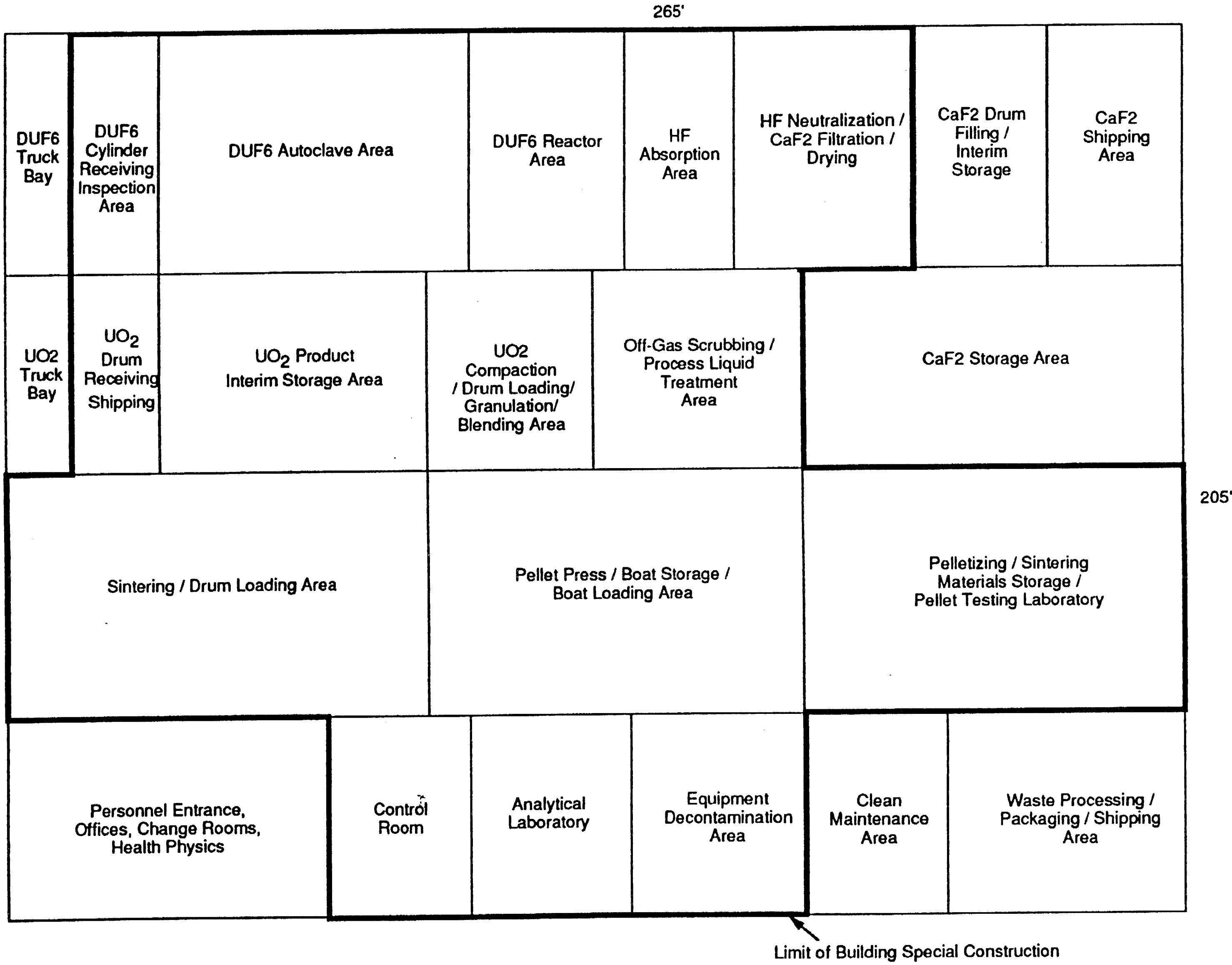


Figure 2-3 Process Building Layout Ceramic UO2 / HF Neutralization

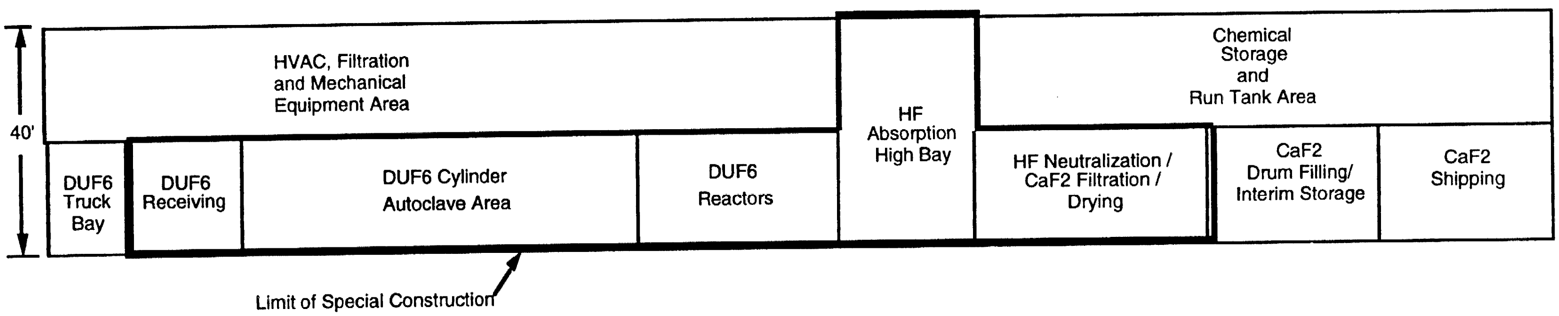


Figure 2-4 Process Building Section Ceramic UO2 / HF Neutralization

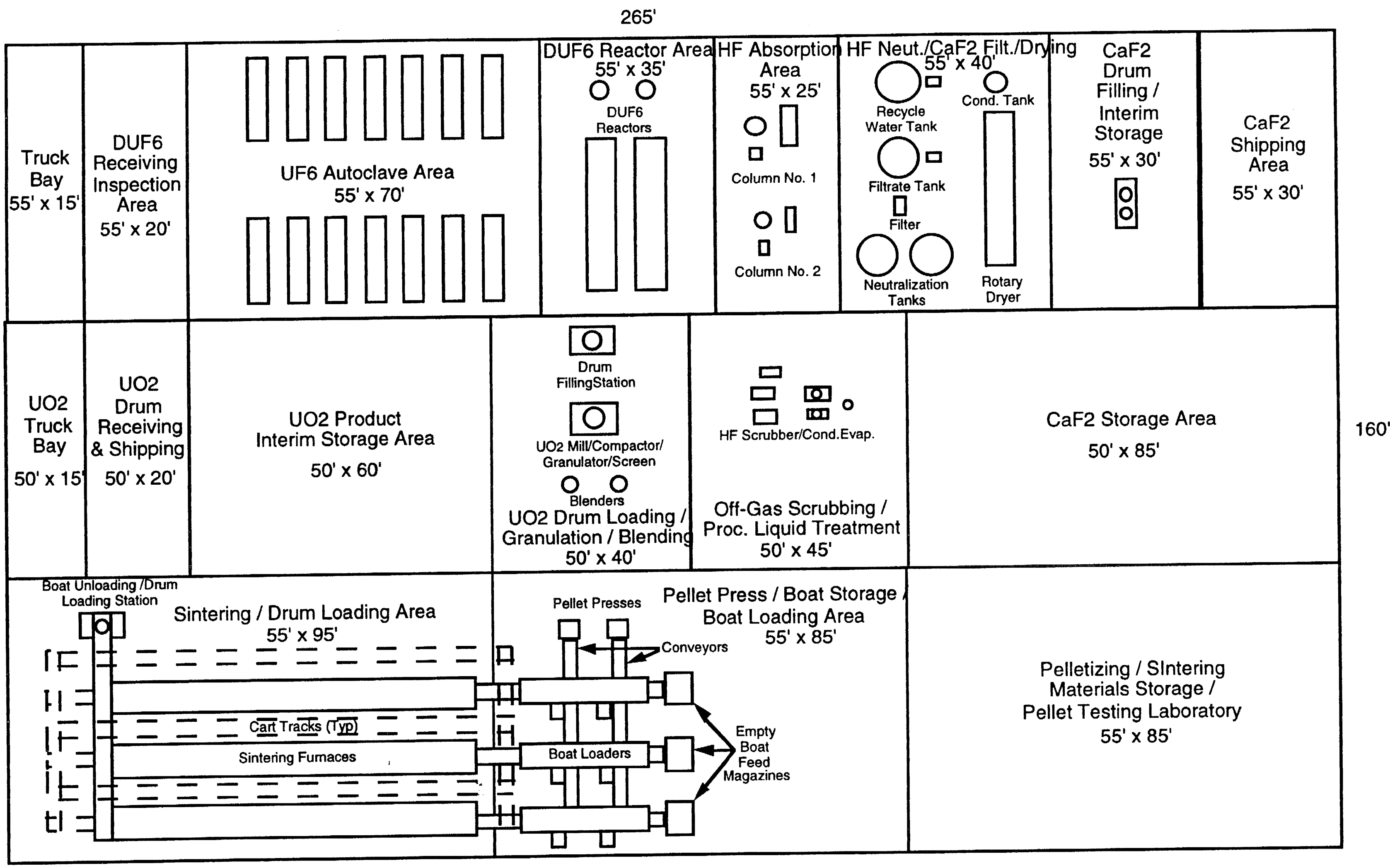


Figure 2-5 Process Equipment Arrangement
Ceramic UO2 / HF Neutralization

facility and chemically as a category HH high hazard facility where significant quantities of UF_6 and HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems such as the heating, ventilating and air conditioning systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

2.1.3.2 UO_2 Storage Building

The UO_2 Storage Building is a one-story metal frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for one months production of UO_2. A zone 2 HVAC system with filtered exhaust air is provided (See also Section 2.2.5).

2.1.3.3 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.4 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the Ceramic UO_2 / HF Neutralization Facility includes the following facilities and systems: (Facilities are shown on Site Map Fig. 3-1.)

A metal frame CaF_2 Storage Building for storage of one months production of CaF_2.

A metal frame general use Utilities Building housing raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal frame or masonry Administration Building to house the facility support personnel.

A metal framed general use Maintenance Shops Building for housing clean maintenance and repair shops.

An 31 MM BTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 3,100 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Facility for the receipt, treatment and disposal of noncontaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Facility with a capacity of approximately 4,100 gpd.

Compressed air systems including plant air, instrument air and breathing air. A single set of two redundant 300 cfm reciprocating air compressors provide compressed air to both systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in dessicant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

An 800 cfm air compressor and membrane separation unit to provide 380 cfm of nitrogen to the sintering furnaces.

An 18,000 cfh hydrogen/nitrogen supply system consisting of two 25,000 gal steel ammonia storage tanks and three ammonia dissociators to supply hydrogen and nitrogen to Reactor No. 2 and to the UO_2 pellet sintering furnaces.

Two 6,000 ft^3 lime storage silos located in the yard.

Building heating, ventilating and air conditioning (HVAC) systems use a central chilled water system for building cooling. Three 50% capacity, 360 ton centrifugal water chillers, and three 600 gpm circulating pumps are provided. A steel stack serving the Process Building HVAC exhaust systems is provided. The steam plant boiler vents through a dedicated steel stack. (See Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant is provided in the Support Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 20,000 lb/hr of 50 psig steam which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration and chlorination. The demineralized water is used in the process and for steam boiler feedwater (See also Figure 5-1).

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a design capacity of 3,200 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 500 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas which require special lighting for nightime operation include the UF_6 cylinder storage pad areas, the railcar spur area, the utility area and the site entry control area.

Site security fencing as shown on Site Map, Figure 3-1, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventive systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Condensation Areas
UO_2 Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSC's) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety class systems, structures, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornadoes

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Floods

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480. 7. This criteria requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

2.2.3 Materials Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., UO_2 pelletizing and drum loading operations, UF_6 sampling stations, etc.).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will utilize a combination of dividing the buildings into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breeched or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing gloveboxes, and other uranium processing areas. The ventilation system for these rooms utilize once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard. The UO_2 Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting areas, CaF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a positive pressure with respect to the rest of the building, but slightly negative with respect to the outside. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor and HF absorption areas and the off-gas scrubbing area of the Process Building have high chemical hazard potential and will be served by a separate once-through air conditioning system. HF monitors in these rooms will automatically shut down the ventilation system and isolate the room in the event of a HF leak.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment.

Due to the generic nature of the site, a single hypothetical liquid release point has been shown on the Site Map, Figure 3-1. This figure also shows the effluent air release point ventilation and boiler stacks.

Table 2-3 summarizes the facility effluent air release points.

Table 2-3 Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	105	80	60
Boiler	100	26	500	60

3.0 Site Map and Land Use Requirements

3.1 SITE MAP

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders to the facility and UO_2 and CaF_2 from the facility. Air emission points are shown from the Process Building ventilation exhaust stack and the facility boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 LAND AREA REQUIREMENTS DURING OPERATION

As shown in Figure 3-1, the total land area required during operations is approximately 590,000 ft^2 or about 13.6 acres.

3.3 LAND AREA REQUIREMENTS DURING CONSTRUCTION

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 22.1 acres. Construction areas required in addition to the site structures and facilities include:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

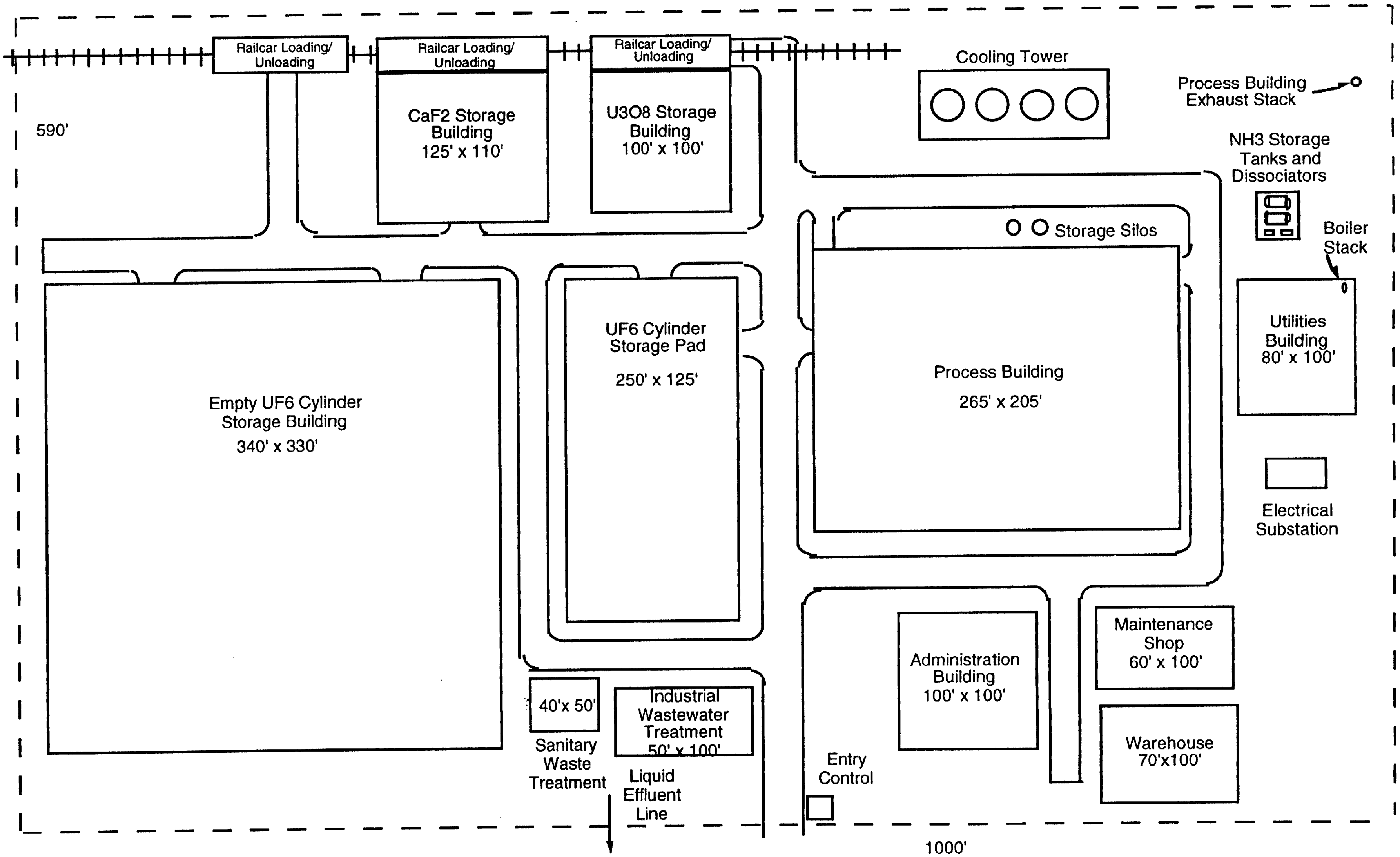


FIGURE 3-1 SITE MAP
CERAMIC UO_2 / HF NEUTRALIZATION FACILITY

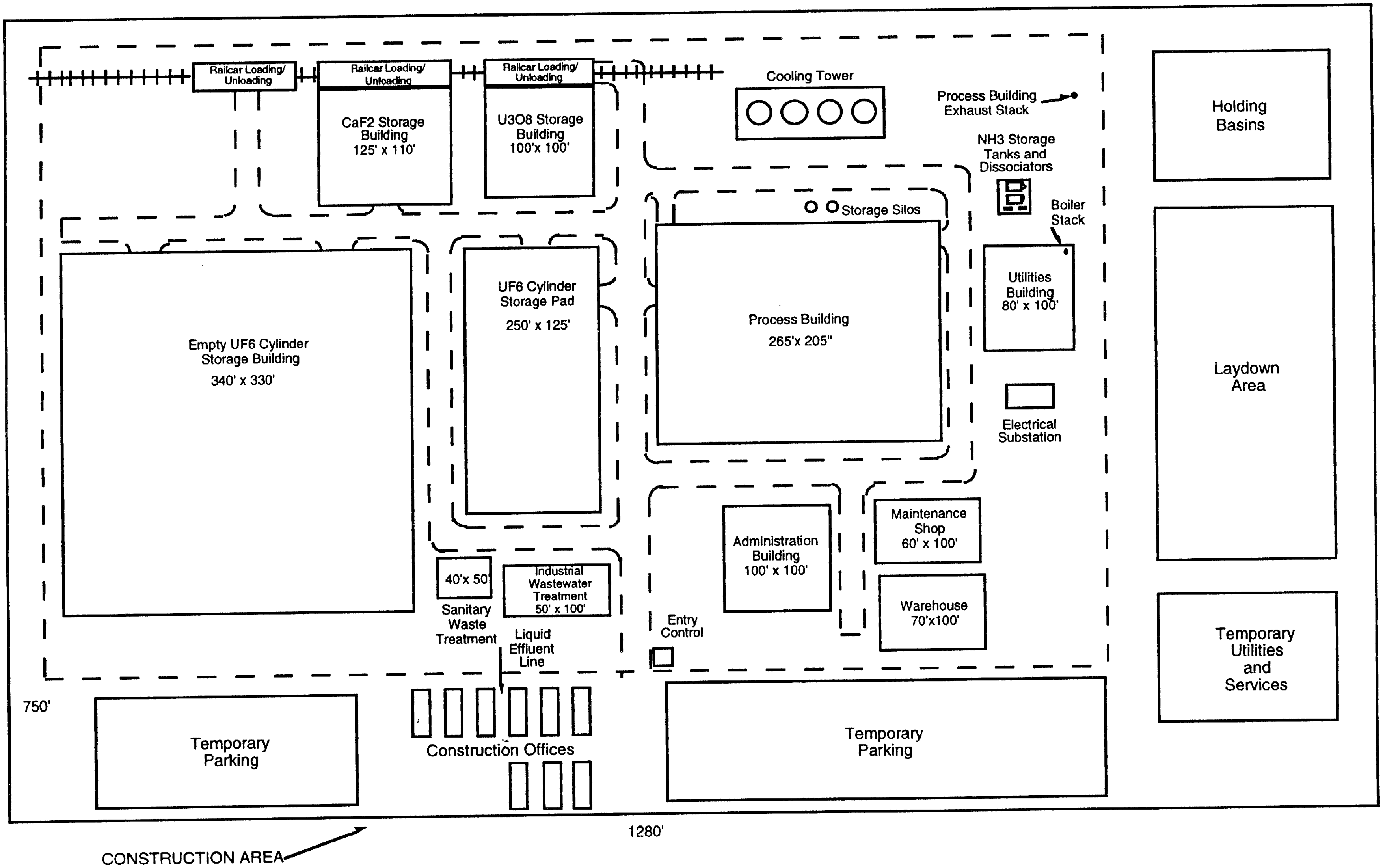


FIGURE 3-2 SITE MAP DURING CONSTRUCTION
CERAMIC UO_2 / HF NEUTRALIZATION FACILITY

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is processed to produce sintered uranium dioxide (UO_2) pellets and calcium fluoride (CaF_2). The process is shown in Figures 4-1 to 4-3. Annual and hourly material balances are given in Appendix A.

The UF_6 is converted to UO_2 in a two-step process. The UF_6 is vaporized using steam-heated autoclaves and fed to Reactor No. 1, where it is mixed with steam. Solid UO_2F_2 is produced and flows to Reactor No. 2. Vapor containing HF and water flows to the HF absorption column. In the second reactor, the UO_2F_2 is mixed with a hydrogen, nitrogen and steam mixture to produce solid UO_2. Vapor containing HF, hydrogen and water flows to the HF absorption column. The UO_2 is discharged from the reactor, cooled, and sent to powder processing.

The UO_2 powder is milled in a hammer mill to eliminate agglomerates, and is compacted in a press to form sheets, which are then size reduced in a granulator. After screening to recycle oversize and undersize particles, the product granules are mixed with a dry lubricant in a blender. The granules are fed to a high-speed press that produces cylindrical pellets. The pellets are sintered in a continuous tunnel kiln operating at 1700°C under a reducing gas atmosphere. The sintered pellets are about 0.82 in diameter by 0.82 in long and have a density of about 9.8 g/cc (90% of theoretical). The UO_2 pellets are loaded into drums for storage and shipment.

The HF absorption columns receive off-gas from Reactors No. 1 and 2. Two columns in series absorb the HF to produce a 20 wt% HF solution. The HF solution is neutralized with slaked lime, and the resulting CaF_2 precipitate is separated by filtering, washed with water, dried and packaged in drums.

Uncondensed off-gas from the second absorption column flows to the scrubber system. The remaining traces of HF in the off-gas are removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution. The CaF_2 precipitate is sent to drying.

The facility has two reactor trains of defluorination process equipment. Multiple pelletizing presses and sintering furnaces are provided to meet the required throughput. Critical equipment such as a blowers or filters have spares installed in parallel. The conversion of UF_6 to UO_2 pellets is based on processes used in the nuclear fuel fabrication industry.

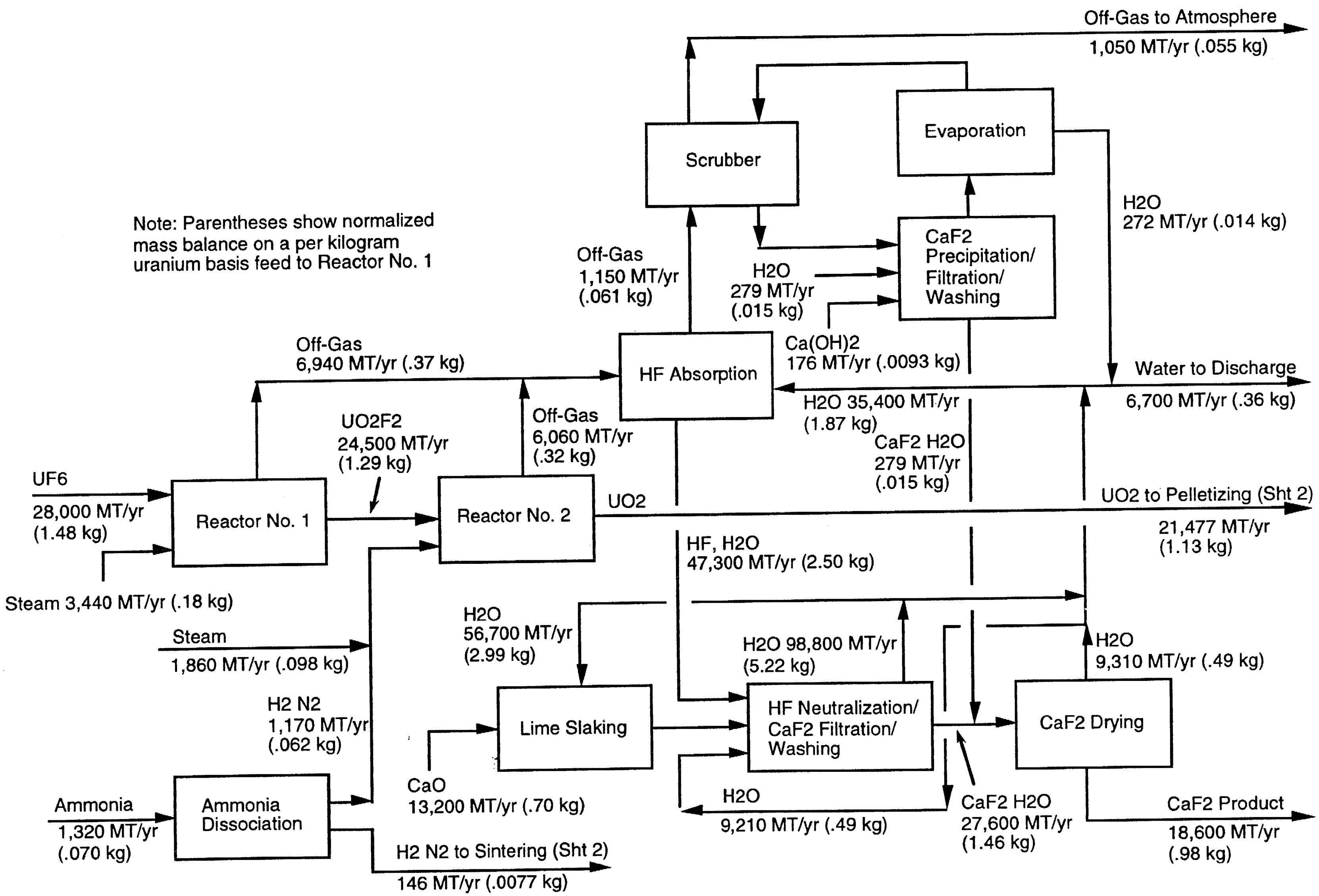
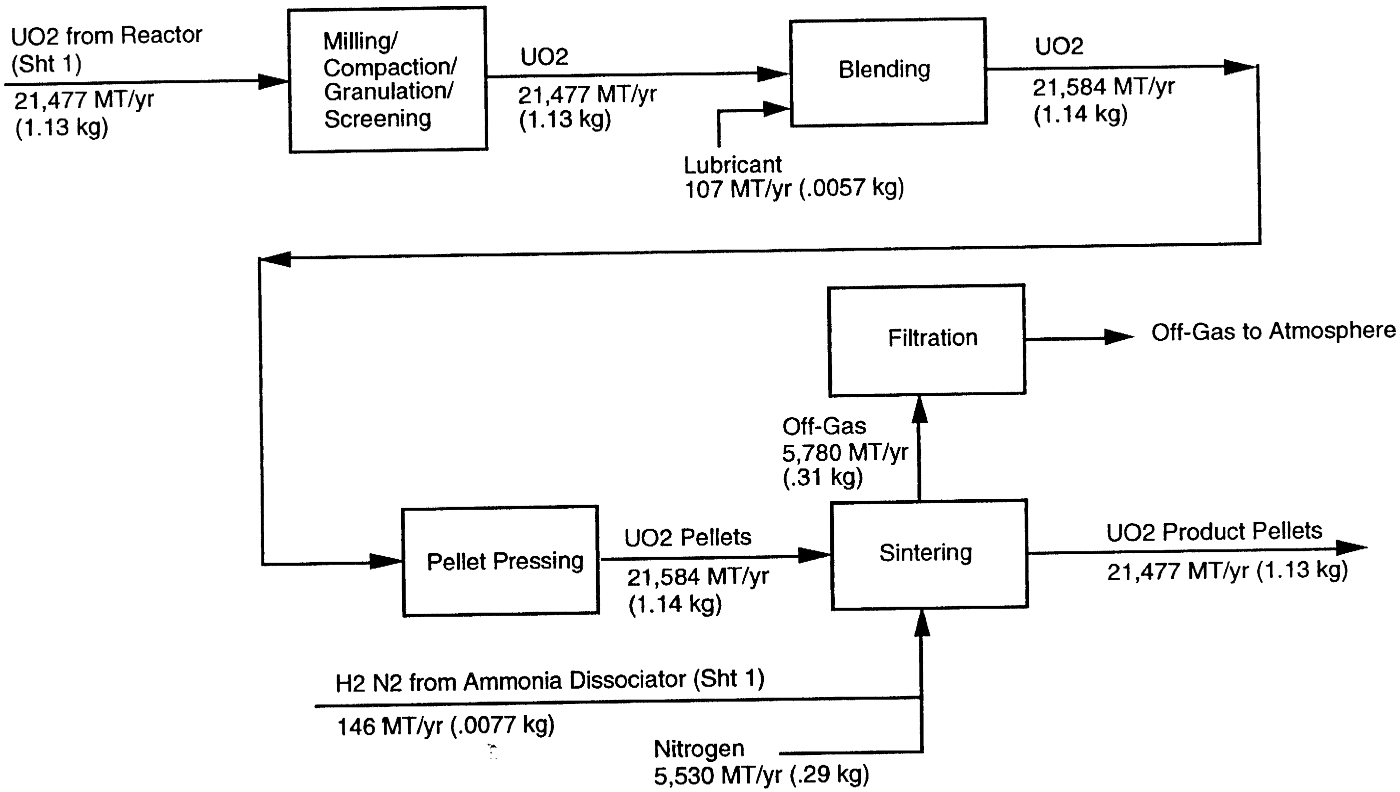


Figure 4-1 Ceramic UO2 / HF Neutralization Block Flow Diagram - Sheet 1



Notes:
1. Parentheses show normalized mass balance on a per kilogram uranium basis feed to Reactor No. 1.
2. Process operations shown in this figure are located primarily in gloveboxes or ventilated enclosures.

Figure 4-2 Ceramic UO2 / HF Neutralization Block Flow Diagram - Sheet 2

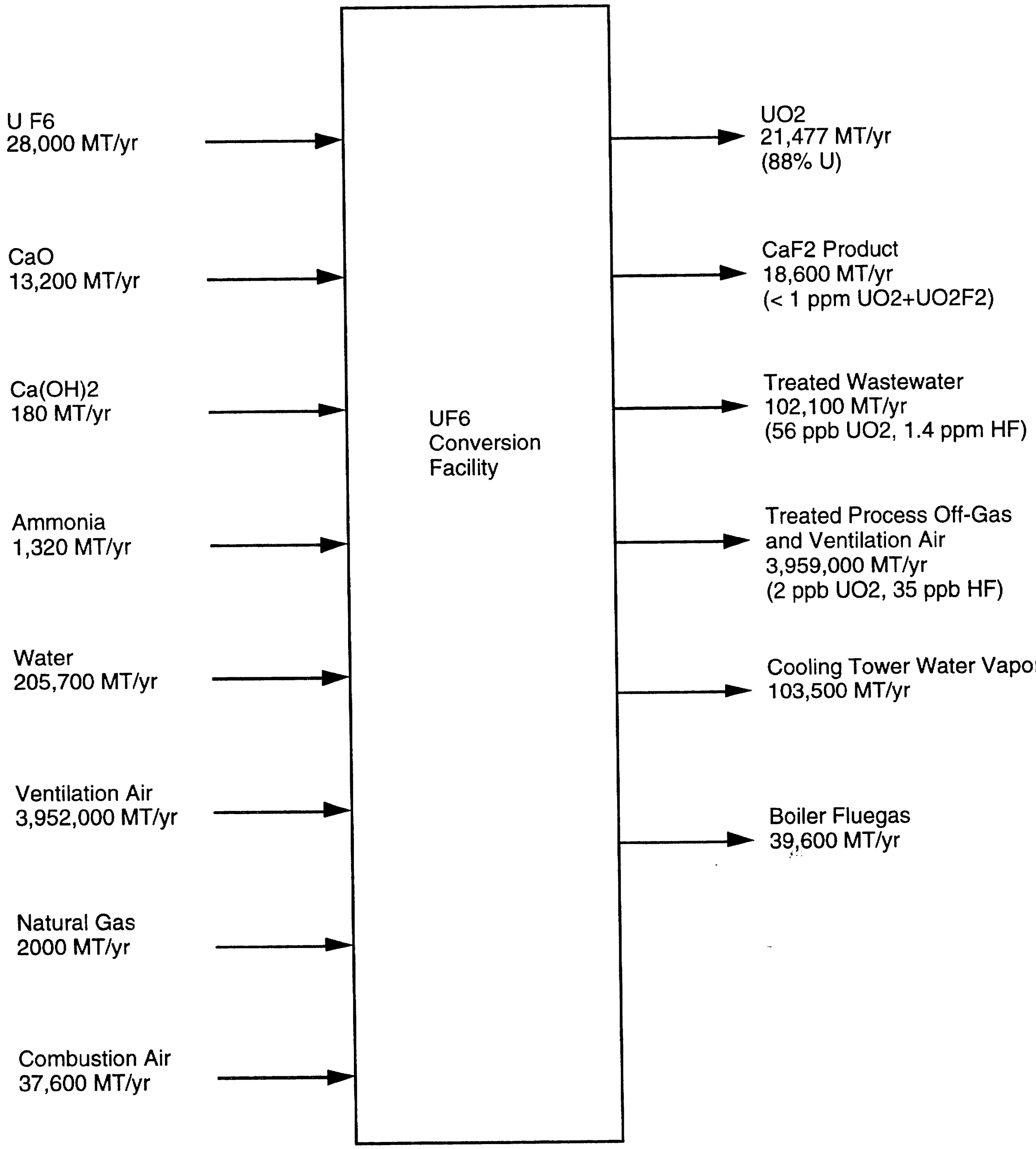


Figure 4-3 Ceramic UO2 / HF Neutralization Input/Output Diagram

4.1 UF_6 CONVERSION REACTIONS

Reactor No. 1 converts UF_6 feed into UO_2F_2 and HF by hydrolysis in a fluidized bed. The chemical reaction is $UF_6 + 2H_2O \text{ ---> } UO_2F_2 + 4HF$. This system is shown in Figure 4-4.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in steam-heated autoclaves and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is heated and vaporized (sublimed) at 140°F. Gaseous UF_6 flows out of the cylinder and is fed by a compressor into a fluidized bed reactor or spray tower containing UO_2F_2 particles. Eleven UF_6 cylinders feed simultaneously to provide the required feed rate of 8,800 lb/hr. Steam acts as the fluidizing gas. Steam reacts with the UF_6 to form solid UO_2F_2 and gaseous HF. The reaction is exothermic, and a cooling water jacket is provided to maintain the reactor at about 500°F.

The solid UO_2F_2 flows from this reactor to Reactor No. 2. The HF-water vapor flows through a cyclone and sintered metal filter to remove UO_2F_2 particulates, which are discharged back into the reactor. The HF-water vapor flows to the HF absorption column. After cooling, the empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

Reactor No. 2 converts UO_2F_2 into UO_2 and HF in a rotary kiln. The overall chemical reaction is $UO_2F_2 + H_2 \text{ ---> } UO_2 + 2HF$. This system is shown in Figure 4-5.

Solid UO_2F_2 from Reactor No. 1 flows into the rotary kiln, where it reacts with hydrogen and steam to form solid UO_2 and gaseous HF. The reaction is endothermic, and the kiln is electrically-heated to maintain the temperature at about 1,200°F. Solid UO_2 is discharged from the reactor, cooled, and conveyed to the granulation area. There is also a drum loading station to provide interim storage of UO_2 in drums as necessary.

The HF and water vapor flow through a cyclone and sintered metal filter to remove UO_2 particulates, which are discharged back into the reactor. The off-gas vapor flows to the HF absorption column.

Hydrogen is provided from a packaged ammonia dissociator unit. The chemical reaction is $2NH_3 \text{ ---> } N_2 + 3H_2$. Liquid ammonia is vaporized and fed to the dissociator, which decomposes the ammonia at 1,600°F in a catalyst bed. The hydrogen/nitrogen mixture is fed to Reactor No. 2.

Preliminary major equipment descriptions for the conversion process include 14 autoclaves and UF_6 compressors, two 3 ft-6 in diameter by 10 ft high Monel fluidized bed reactors, two 6 ft by 30 ft long Inconel rotary kilns, two 12 in by 10 ft long screw conveyor/coolers, and a drum loading station.

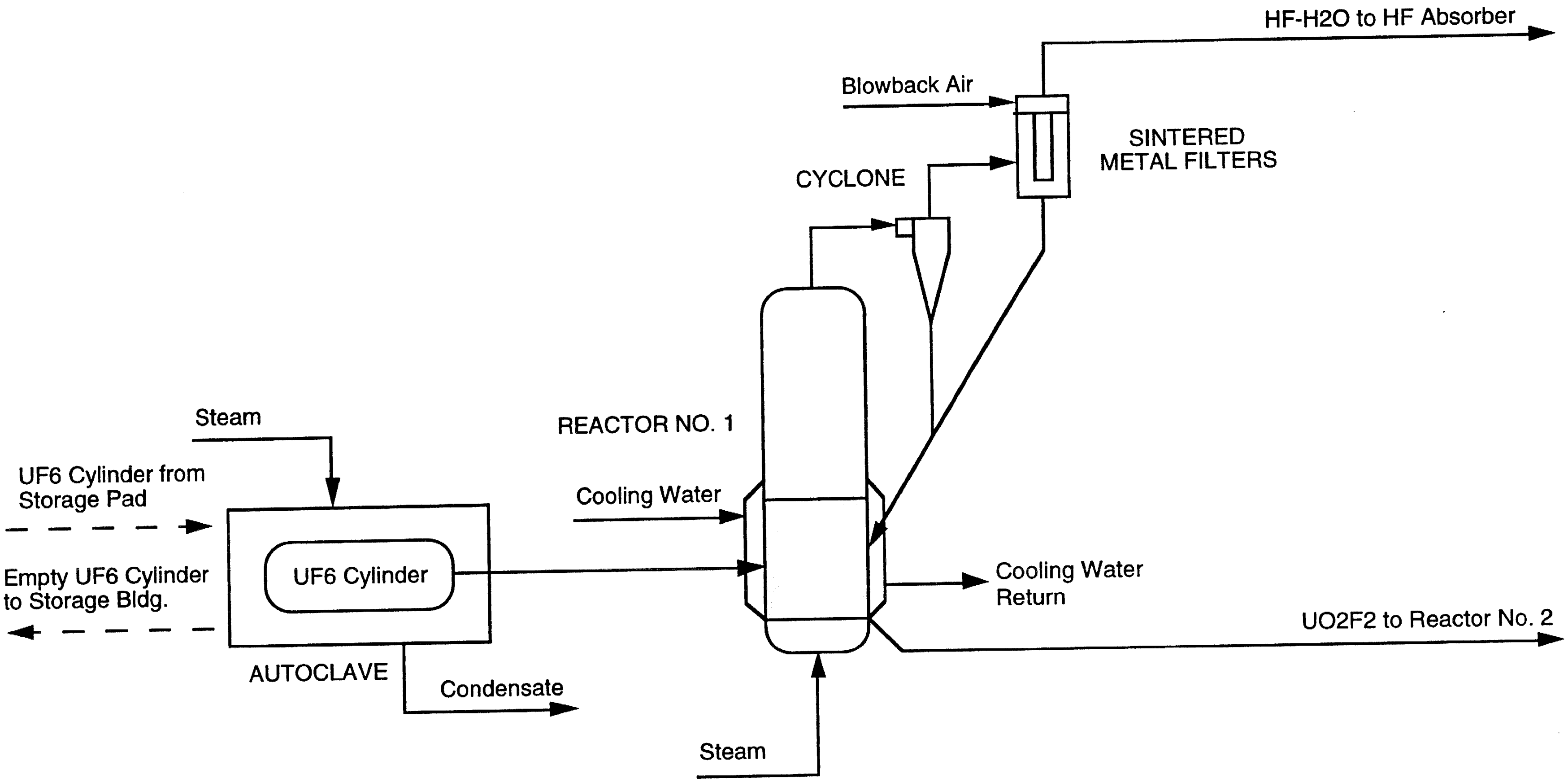


Figure 4-4 Reactor No. 1 Process Flow Diagram

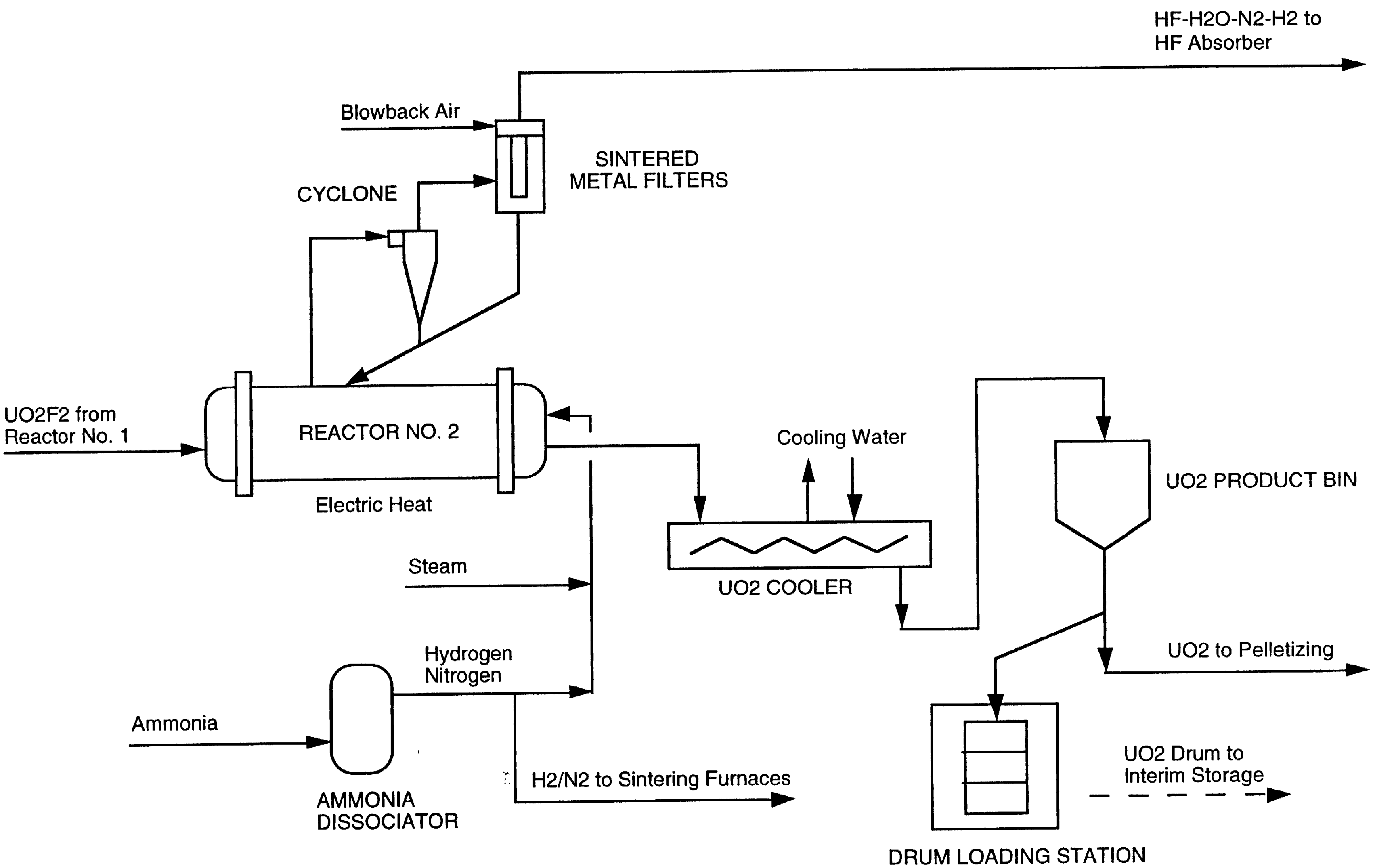


Figure 4-5 Reactor No. 2 Process Flow Diagram

4.2 UO_2 GRANULATION

The UO_2 powder is processed to form free-flowing granules that enable precise and reproducible feeding of the pellet presses. This system is shown in Figure 4-6.

The raw UO_2 powder is fed to a hammer mill to eliminate any lumps or agglomerates. The milled powder is fed to a roller compactor, which compresses the powder to about 40% of theoretical density. The compacted powder sheets are then size-reduced in a granulator.

The UO_2 granules are then screened, with oversize particles recycled to the granulator and undersize particles recycled to the compactor. The product granules, with a particle size between -20 and +60 mesh, are blended with a dry lubricant in a double-cone mixer or ribbon mixer to produce granules containing 0.5 wt% Sterotex lubricant (powdered hydrogenated cottonseed oil by Capital City Products). The granules are conveyed to the pelletizing area. There is also a drum loading station to provide interim storage of UO_2 granules in drums as necessary.

Major process equipment includes a hammer mill, roller compactor, granulator, a vibrating screen separator, two 15 ft^3 double-cone blenders, a drum loading station, and a dust collection system.

4.3 UO_2 PELLETIZING AND SINTERING

The granulated UO_2 is pressed to form pellets, which are sintered at high temperature to increase their density. This system is shown in Figure 4-6.

The UO_2 granules are fed to an automatic, high-speed, rotary powder compacting press operating at 20,000 to 60,000 psi. Cylindrical pellets about 1 in diameter by 1 in long with a density of about 50% of theoretical are produced. These "green" (unsintered) pellets are automatically loaded into molybdenum boats (trays), which are conveyed to the sintering area.

The sintering furnace is a continuous, tunnel kiln with separate zones for heatup, soak (sinter) and cooldown. The furnace atmosphere is 6% hydrogen and 94% nitrogen to provide a reducing environment. Boats containing pellets are placed on carts which enter the furnace through a double-door airlock. The airlock has a nitrogen purge to keep air out of the furnace and a flame curtain to destroy any hydrogen that leaks out of the furnace. The carts slowly move through the kiln. Total cycle time in the furnace is about 8 hours, which includes a 3 hour heatup, 3 hour soak at 1,700°C, and 2 hour cooldown. If later development work shows a lower sintering temperature is feasible, the furnace design and materials of construction would be simpler and less costly.

Off-gas from the furnace is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. Hydrogen is provided from the ammonia dissociator and nitrogen is provided from a membrane separation unit or cryogenic tank.

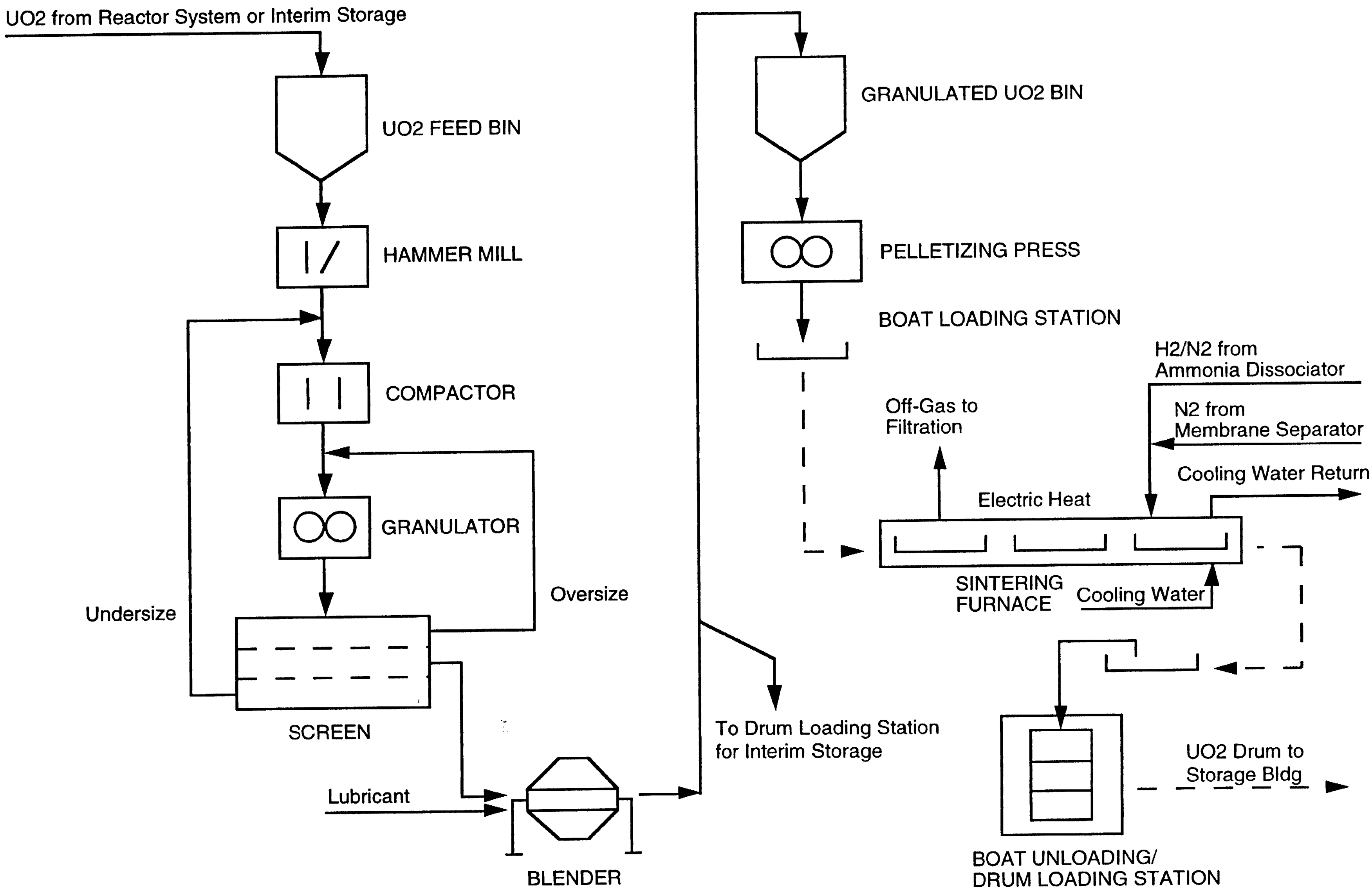


Figure 4-6 UO2 Pelletizing/Sintering Process Flow Diagram

The sintered pellets have a density of about 9.8 g/cc (90% of theoretical), and are about 0.82 in diameter by 0.82 in long. The boats and carts exit the furnace through a second airlock, and the sintered pellets are removed from the boats and loaded into 30 gallon drums in a drum filling station. The drum is sealed, cleaned and transported to the storage building.

Major process equipment includes two 365 pellets/min rotary powder compacting presses, three 6 ft wide by 6 ft high by 70 ft long 400 kw sintering furnaces, an off-gas treatment system, a dust collection system, a drum loading station, and conveyors for the pellet boats.

4.4 HF ABSORPTION

The hot off-gas from the reactors, containing HF, water vapor, nitrogen and hydrogen, flows to a series of two absorption columns for HF recovery. The system is shown in Figure 4-7.

The vapor enters the first column, where it is contacted with aqueous HF solution. The HF and water condense, which increases the solution temperature by the heat of condensation and heat of solution. The liquid drains to the bottom of the column, where it mixes with liquid from the second absorber column. The resulting 20% HF solution is pumped through a heat exchanger for cooling and is recirculated to the top of the absorber column. A portion of the circulating liquid is continuously withdrawn and discharged to the HF neutralization system.

The vapor leaving the first column flows to the second column for additional HF removal. Fresh water is added to the second column to make up for the liquid that was discharged to the first column.

Major process equipment for the HF absorption process includes a 3 ft-6 in diameter by 20 ft high Monel absorption column, a 2 ft-6 in diameter by 10 ft long 1050 ft^2 Monel cooler, a 2 ft diameter by 19 ft high Monel absorption column, a 1 ft-6 in diameter by 7 ft long 250 ft^2 Monel cooler, and associated circulation pumps.

4.5 HF SCRUBBING SYSTEM

Off-gas from HF absorption is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The system is shown in Figure 4-8.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \dashrightarrow KF + H_2O$. The treated off-gas is filtered, mixed with ventilation exhaust air to dilute the hydrogen to a safe concentration, and discharged to atmosphere. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2KF + Ca(OH)_2 \dashrightarrow CaF_2 + 2KOH$. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out

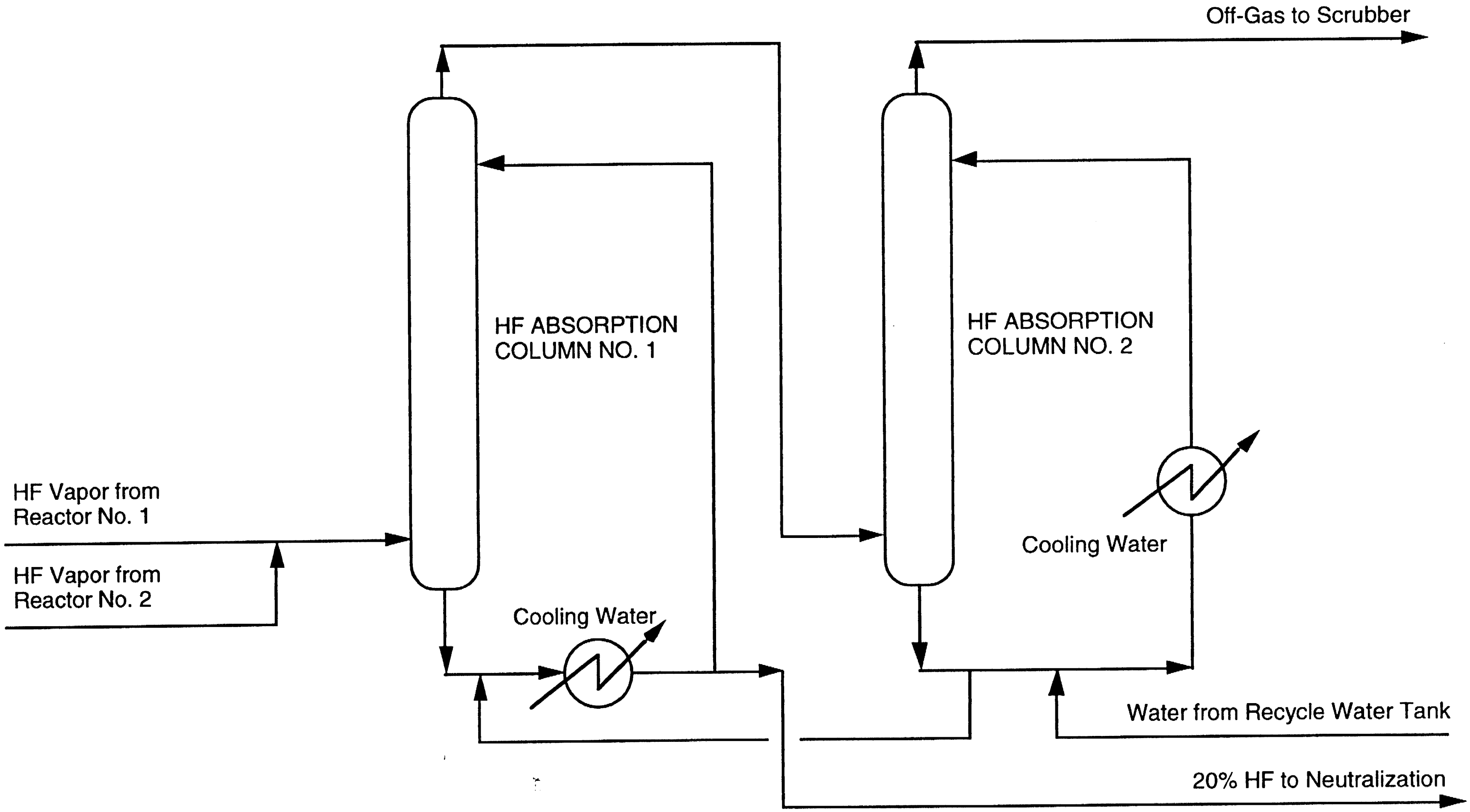


Figure 4-7 HF Absorption Process Flow Diagram

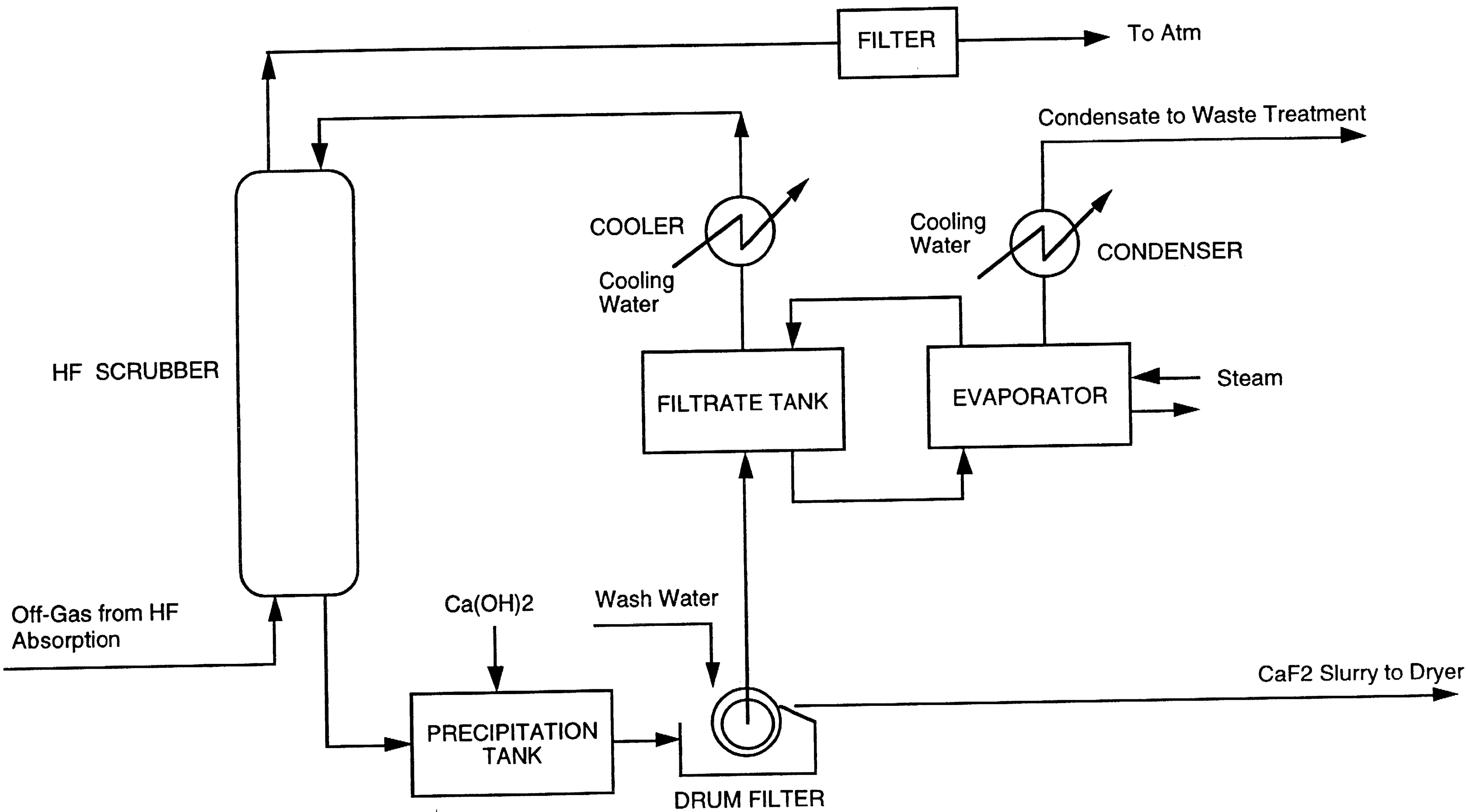


Figure 4-8 HF Scrubber Process Flow Diagram

of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter or a pressure filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities, and transferred to the CaF_2 dryer in the HF neutralization system.

The KOH and wash water filtrate are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The filtrate is then cooled and pumped back to the scrubber as scrub solution.

Major equipment includes a 1 ft diameter by 10 ft high Monel HF scrubber with plastic packing, 4 ft diameter by 6 ft high 550 gallon Monel precipitation and filtrate tanks, a 6 ft diameter by 4 ft long Monel rotary drum filter, a 1 ft-6 in diameter by 4 ft high Monel evaporator/condenser unit, and associated tanks and pumps.

4.6 HF NEUTRALIZATION SYSTEM

The 20% HF solution from absorption is neutralized with slaked lime to form CaF_2. The system is shown in Figure 4-9.

Pebble lime (CaO) is mixed with water in a vertical stirred mill to form a 25 wt% $Ca(OH)_2$ slaked lime slurry. The exothermic chemical reaction is $CaO + H_2O \dashrightarrow Ca(OH)_2$. The slurry is collected in a feed tank with cooling coils, which cools the hot slurry to near ambient temperature.

The HF solution is mixed with the slaked lime in a continuous neutralization tank. The chemical reaction is $2HF + Ca(OH)_2 \dashrightarrow CaF_2 + 2H_2O$. The reaction is exothermic and cooling coils are provided. The slurry then flows to a second neutralization tank for final pH adjustment.

The neutralized slurry, containing about 16 wt% solids, is filtered in a rotary drum vacuum filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities, and dried in a steam-heated rotary tube dryer. After cooling, the CaF_2 is packaged in drums and sent to the storage building. The filtrate and condensate are collected and reused in HF absorption and lime slaking. Excess water is sent to the industrial waste treatment facility.

Major equipment includes a two 9 ft diameter by 10 ft high 4,500 gal Monel HF neutralization tanks (one tank with cooling coils), a 9 ft diameter by 10 ft high 4,500 gal steel filtrate tank, a 3 ft diameter by 4 ft long steel rotary drum filter, an 11 ft diameter by 12 ft high 8,500 gallon recycle water tank, a 6 ft diameter by 35 ft long rotary steam tube dryer, and associated pumps, conveyors and bins.

4.7 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart,

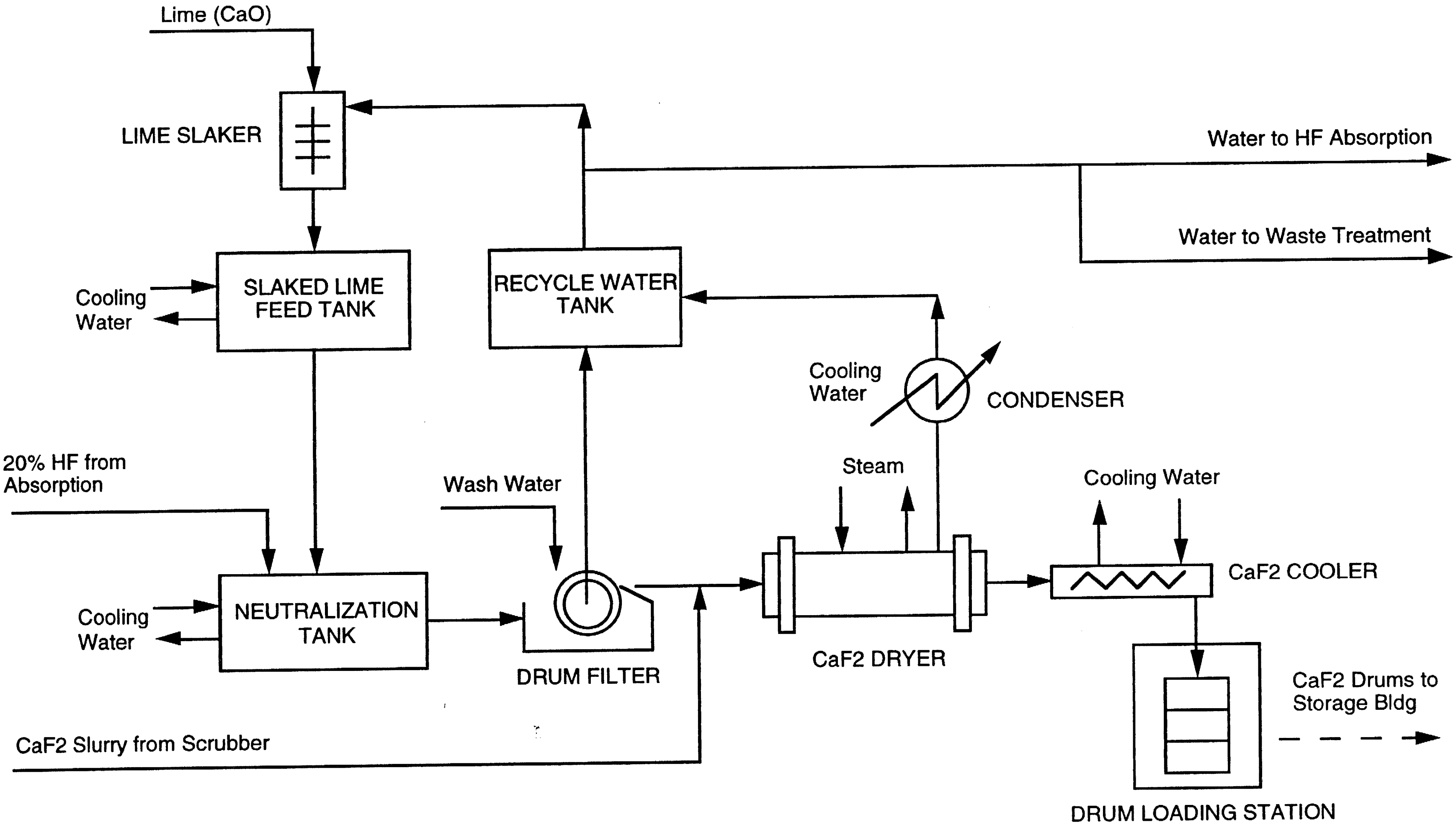


Figure 4-9 HF Neutralization Process Flow Diagram

which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

4. 8 WASTE MANAGEMENT

The primary wastes produced by the process are empty UF_6 cylinders. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing, packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820. 2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g., size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	24 GWh	3.2 MW
Liquid Fuel	7,000 gals	NA
Natural Gas[2]	99×10^6 scf	NA
Raw Water	55×10^6 gals	NA

1 Peak demand is the maximum rate expected during any hour.
2 Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance. This balance is based on the greenfield generic midwestern U. S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

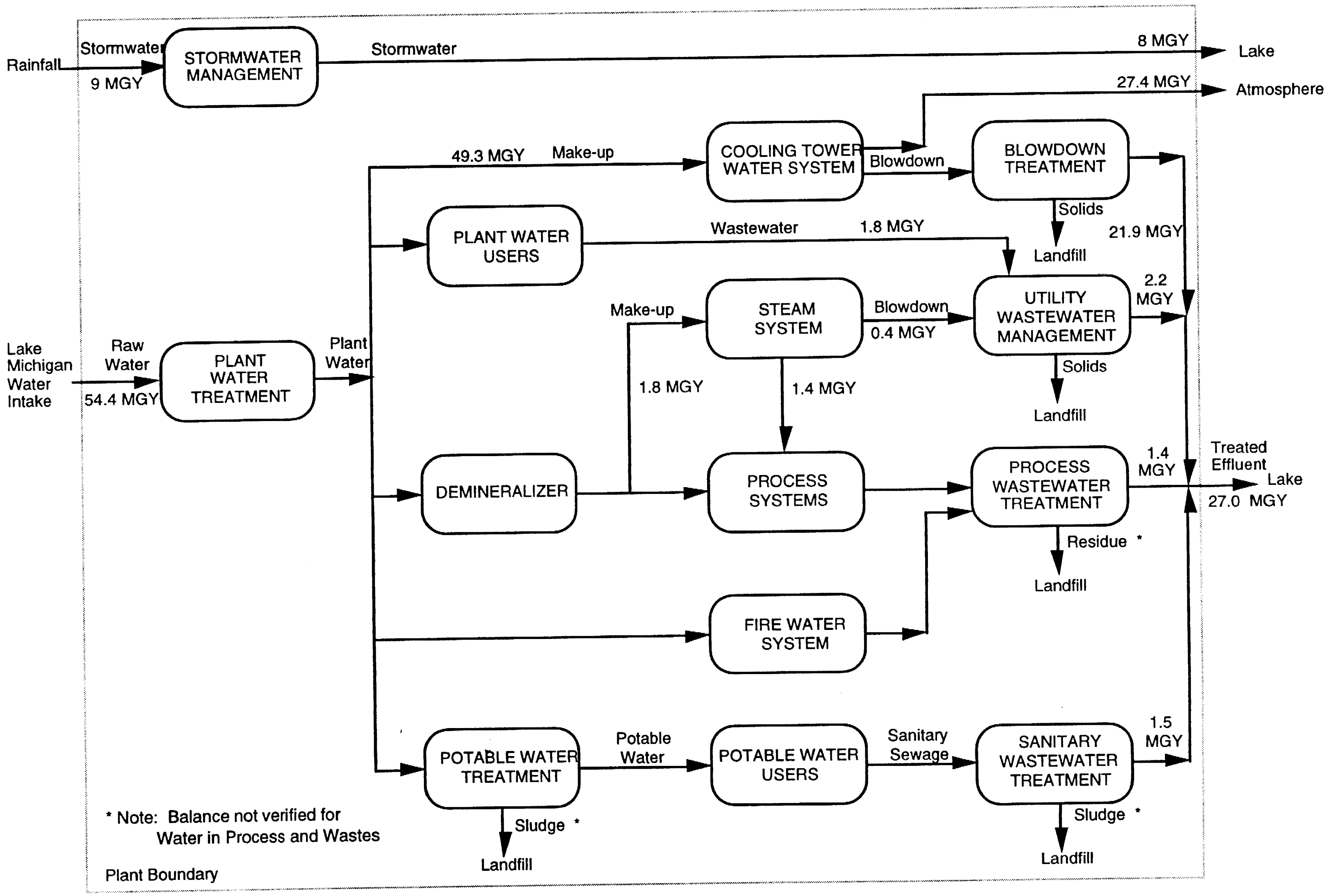


Figure 5-1 Preliminary Water Balance Ceramic UO2 / HF Neutralization

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	Quantity (lb/yr)
Solid	
Pelletizing Lubricant (Sterotex or equal)	236,000
Calcium Oxide (Quicklime)	29,000,000
Calcium Hydroxide (Hydrated Lime)	390,000
Detergent	600
Liquid	
Ammonia (99.95% min. NH_3)	2,900,000
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	13,600
Sodium Hydroxide (50% NaOH)	10,700
Sodium Hypochlorite	5,200
Copolymers	9,100
Phosphates	910
Phosphonates	910
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (radioactive and hazardous) Waste Containers (55 gallon drums & 4x2x7 ft boxes - see also Table 9-1)	641 drums 31 boxes

1 Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6). The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14 ton DOT approved carbon steel containers.

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5-3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	35,000 MWh	1.5 MW
Water	10×10^6 gal	700 gal
Solids		NA
Concrete	19,000 yd^3	
Steel (carbon or mild)	8,000 tons	
Electrical raceway	25,000 yd	
Electrical wire and cable	60,000 yd	
Piping	40,000 yd	
Steel decking	25,000 yd^2	
Steel siding	13,000 yd^2	
Built-up roof	19,600 yd^2	
Interior partitions	1,500 yd^2	
Lumber	5,400 yd^3	
HVAC ductwork	150 tons	
Asphalt paving	270 tons	
Liquids		
Fuel[2]	1.6×10^6 gals	
Gases		
Industrial Gases (propane)	4,400 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel, etc.) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 30 tons of Monel and 10 tons of Inconel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 Employment Needs During Operation

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	8
Professionals	8
Technicians	34
Office and Clerical	22
Craft Workers (Maintenance)	11
Operators / Line Supervision	107/17
Security	26
TOTAL EMPLOYEES (for all on-site facilities)	233

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 Employees at Risk of Radiological Exposure

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF, the operator will wear acid-resistant protective gear including a respirator.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4 [1]
Process Building	52	28	28	28
UO_2 Storage Building	3	1	1	1
CaF_2 Storage Building	2	1	1	1
Cylinder Storage Pad & Building	7	3	3	3
Utilities/Services/Admin Areas	40	10	10	10
TOTAL EMPLOYEES	104	43	43	43

[1] The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	170	290	510	250
Construction Management and Support Staff	30	60	90	50
TOTAL EMPLOYEES	200	350	600	300

1 Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	Principal Release Point	Annual Emissions (lb)
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	60/60
Nitrogen Dioxide	Boiler Stack / Grade	8,000/470
Hydrocarbons	Boiler Stack / Grade	170/410
Carbon Monoxide	Boiler Stack / Grade	4,000/2,700
Particulate Matter PM-10	Boiler Stack / Grade	300/92
OTHER POLLUTANTS		
HF	Process Bldg. Stack	300
UO_2	Process Bldg. Stack	12
Copolymers	Cooling Tower	1,800
Phosphonates	Cooling Tower	180
Phosphates	Cooling Tower	180
Calcium	Cooling Tower	3,200
Magnesium	Cooling Tower	800
Sodium and Potassium	Cooling Tower	330
Chloride	Cooling Tower	600
Dissolved Solids	Cooling Tower	17,700

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	Principal Release Point	Release Rate (Ci/yr)[1]
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	2×10^{-3}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	2×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (compacted plastic, paper, cloth)	248,000	115	28 lb UO2	425 55-gal drums
Metal, surface contaminated	Failed equipment	73,000	45	82 lb UO2	166 55-gal drums
Noncombustible, compactible solid	HEPA filters	13,000	64	2,500 lb UO2	31 4x2x7 ft boxes (3/4" plywood)
Other	LabPack (chemicals plus absorbent)	3,500	2.2	4 lb UO2	8 55-gal drums
Hazardous Waste					
Organic liquids	Solvents, oil, paint	4,500	3 (600 gal)	See description	11 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	8,100	5	8 lb HF 8 lb NaOH	19 55-gal drums
Combustible debris	Wipes, etc.	540	1	1 lb HF 1 lb NaOH	4 55-gal drums
Other	Fluorescent bulbs (compacted)	970	0.6	Mercury (trace)	2 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb UO2 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb UO2 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	270	0.5	0.1 lb UO2 0.1 lb Acetone	2 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	1.5×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	580	25.5×10^6
Recyclable Wastes	230	-

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 WASTES AND EMISSIONS GENERATED DURING CONSTRUCTION

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2
Nitrogen Dioxide	30
Hydrocarbons	8
Carbon Monoxide	200
Particulate Matter PM-10	50

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the facility since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	60 yd^3
Hazardous Liquids	25,000 gals
Nonhazardous Solids	
Concrete	130 yd^3
Steel	40 tons
Other	1,000 yd^3
Nonhazardous Liquids	
Sanitary	3.5×10^6 gals
Other	1.5×10^6 gals

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 Bounding Accidents

The DUF_6 Conversion Facility buildings include areas with hazard categories of chemically high hazard (HH) for buildings containing DUF_6 and HF and radiologically moderate hazard (HC2) for buildings containing UO_2. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgement and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario,
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques,
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following systems, structures and components (SSC's) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of gaseous HF and liquid NH_3 because their rupture could release HF or NH_3 with unacceptable consequences.
- Vessels containing significant inventories of UF_6 at elevated temperatures because their rupture could release HF or UF_6 (UO_2F_2) with unacceptable consequences.
- The Process Building and UO_2 Building structures because they house large gaseous HF and uranium inventories or UF_6 at elevated temperatures, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	9.8 lb UO_2
Tornado	Extremely Unlikely	3.7 lb UO_2
Flood	Incredible	No Release
HF System Leak	Anticipated	10 lb HF
UO_2 Drum Spill	Anticipated	3.7×10^{-5} lb UO_2
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	19 lb HF
Hydrogen Explosion	Extremely Unlikely	0.25 lb UO_2 7 lb HF
Ammonia Release	Unlikely	255 lb NH_3

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	197,000 lb UO_2	5×10^{-5} (a)	1	30 min
Tornado	1,470 lb UO_2	2.5×10^{-3} (b)	1	30 sec
Flood	No Release	NA	NA	NA
HF System Leak	25 lb HF	1	.4 (c)	15 min
UO_2 Drum Spill	735 lb UO_2	5×10^{-5} (a)	1×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	19 lb HF	1	1	2 min
Hydrogen Explosion	5,000 lb UO_2 7 lb HF	.05 (d) 1	1×10^{-3} 1	30 min
Ammonia Release	255 lb NH_3	1	1	1 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).
2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).
3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

b. Respirable airborne fraction is assumed to be 50 times greater than that for free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

c. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

d. Based on deflagration of large volume of flammable mixture above powder in DOE-HDBK-0013-93, p. 4-5. Fraction airborne is 1. Fraction in respirable range is .05, based on the assumption that 5% of the powder is 10 microns or smaller.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234, Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium, hydrofluoric acid and ammonia are the primary hazardous materials handled in this facility. Uranium and ammonia are toxic and hydrofluoric acid is both toxic and corrosive.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where high inventory of HF or UF_6 at elevated temperatures is present. Therefore, it would be incredible if these structures failed in the event of the DBE.

The UO_2 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 2,680 drums each containing 1,470 lb of UO_2. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum cover is lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Assuming a conservative average fall height of 8 ft, approximately 0.005% of the pellets are fractured into respirable particles which are assumed to subsequently exhibit powder-like behavior and could be expected to become airborne. Thus, approximately 9.8 lb of UO_2 is released to the environment. The release point is at grade.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

Selected areas of the Process Building are performance category PC-4 for structures for chemically high hazard facilities. These building areas are designed to resist the DBT for high hazard facilities. The DBTs defined for these structures would not result in a significant release from these structures. The UO_2 Storage Building is a category PC-3 structure for moderate hazard facilities. The DBT defined for this structure would withstand the DBT and not result in a significant release. However, in the extremely unlikely event of a DBT exceeding the PC-3 defined DBT or failure of PC-3 SSCs, a tornado wind-driven missile could impact a UO_2 storage drum and release the 1,470 lb inventory of the drum. It is assumed that, due to the high wind conditions, all of the pellets become airborne and some fraction of these are pulverized into respirable fragments. This fraction is estimated to be fifty times greater than the pulverizing fraction associated with a drum spill, or 0.25%. Therefore, approximately 3.7 lb of respirable UO_2 is released during this extremely unlikely event. However, the particles will be highly dispersed due to tornado wind conditions.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF System Leak

Gaseous HF is produced from the conversion reactions. The HF is absorbed in a series of two columns to form 20% HF / 80% water solution. After absorption, the HF hazard is diminished because the vapor pressure of 20% HF is low at room temperature. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the off-gas line from the reactors to the absorbers leaks 5% of its flowing contents for 10 minutes, thus releasing 25 lb of HF into the process building. After the leak is detected by air monitoring instruments, the reactor feed is halted to stop the leak. It is assumed that the 40% of the HF vapor (10 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 UO_2 Drum Spill

Solid UO_2 is produced and packaged in drums in the process building. The drums are transported and stored in the UO_2 Storage Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the storage building floor. A drum contains 1,470 lb of UO_2. It is assumed that 50% of the UO_2 is released from the drum and falls to the floor. The pulverizing fraction for this scenario is 0.005%, meaning that this proportion of the pellets are fractured into respirable particles which become airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne UO_2. Thus 3.7×10^{-5} lb of UO_2 is discharged through the UO_2 Building exhaust to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.4 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

8.1.3.5 Loss of Cooling Water

Pressure relief valves are provided to protect the reactors, vessels and equipment. Loss of cooling water to the absorption column coolers would cause the absorber liquid to boil and the relief valve to open.

It is postulated that cooling water is lost and hot off-gas continues to flow into the column for 1 minute, vaporizing 19 lb of HF and 75 lb of water. High temperature and pressure alarms and interlocks would shut down the feed input to the columns to stop the release. About 19 lb of HF would be discharged through the relief valve and released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.6 Hydrogen Explosion

Hydrogen is fed to Reactor No. 2 as a reagent, to react with UO_2F_2. There are two reactors in parallel, and each reactor receives about 33 lb/hr of hydrogen.

Hydrogen is generated by ammonia dissociation and is fed to the reactor as a 75% hydrogen 25% nitrogen mixture. Steam is also fed to the reactor. The reactor vapor space normally contains excess unreacted hydrogen, steam, HF and nitrogen. There is normally no air in the reactor.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the reactor. The reactor off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the reactor, air to leak into the reactor, and an ignition source to be present. This might occur if the reactor was not purged to remove air during startup and the reactor vent was blocked. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the reactor vessel.

The reactor is assumed to contain about 10,000 lb of UO_2 during normal operation (3 hour residence time). It is assumed that 50% of the material is released into the room, of which 100% becomes airborne and 5% is in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the material. Thus, 0.25 lb of UO_2 is discharged through the Process Building exhaust stack. The reactor also contains 7 lb of HF that is released through the stack. This accident is judged to be extremely unlikely.

8.1.3.7 Sintering Furnace Explosion

A 6% hydrogen / 94% nitrogen gas mixture is fed to the sintering furnaces. There is normally no air in the furnaces. Each furnace receives about 2.7 lb/hr of hydrogen. The furnaces contain uranium pellets, which are much less dispersable than powder. The consequences of a furnace hydrogen explosion will be bounded by the reactor explosion described previously.

8.1.3.8 Ammonia Release

Ammonia is stored as a liquid in two 25,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so it will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia," Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is considered unlikely.

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

9. 0 Transportation

9. 1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, UO_2 product in 30 gallon drums from the Process Building to the UO_2 Storage Building, and low level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of UO_2 to the plant boundary. Hazardous waste materials such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, laboratory wastes, etc. requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary for shipment to off-site hazardous waste treatment, storage and disposal facilities.

9. 2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product and waste materials is shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include sodium hydroxide (NaOH), hydrochloric acid (HCl), and ammonia (NH_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium dioxide, low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

The UO_2 product is packaged in 30 gallon steel drums that are 29 inches high by 18.2 inches outside diameter. The empty drum weighs 50 lbs and has a wall thickness of 0.053 inches (16 gage). Each drum contains 1,470 lbs of UO_2.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4
Transported Materials				
Type	UF_6	HCl	NaOH	NH_3
Physical Form	Solid	Liquid	Liquid	Liquid
Chemical Composition / Temperature, Pressure	UF_6 / ambient	HCl / ambient	NaOH / ambient	NH_3 / 100°F, 197 psig (max.)
Packaging				
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	Rail Car 11,000 gal
Certified by	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	105S-300-W
Container Weight (lb)	2,600	50	50	TBD
Material Weight (lb)	27,000	540	660	52,000
Chemical Content (%)	100% UF_6	37% HCl	50% NaOH	100% NH_3
Shipments				
Average Volume (ft^3)/Year	323,000	184	118	82,300
Packages/Year	2,322	25	16	56
Packages/Life of Project	46,440	400	320	1120
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	13	8	1
Shipments/Year	2,322 (truck) or 49 (rail)	2	2	56
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	40	1120
Form of Transport/Routing				
Form of Transportation	Truck/Rail	Truck	Truck	Rail
Destination - Facility Type	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (cont'd)

Type of Data	Output Material #1	Output Material #2	Output Material #3	Output Material #4	Output Material #5
Transported Materials					
Type	Uranium Dioxide	Low-Level Rad Waste	Hazardous Waste	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid	Solid & Liquid	Solid	Solid
Chemical Composition / Temperature, Pressure	UO_2 / ambient	See Table 7-3	See Table 7-3	See Table 7-3	UF_6 / ambient
Packaging					
Type	30 Gallon Drum	55 Gallon Drum / Box	55 Gallon Drum	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	TBD	Varies	Varies	Varies	48G
Container Weight (lb)	50	50/300	50	50	2,600
Material Weight (lb)	1,470	See Table 7-3	See Table 7-3	See Table 7-3	22
Chemical Content (%)	100% UO_2	See Table 7-3	See Table 7-3	See Table 7-3	100% UF_6 (Note 1)
Shipments					
Average Volume (ft^3)/Year	129,000	6,200	265	44	323,000
Packages/Year	32,150	599/31	36	6	2,322
Packages/Life of Project	642,900	11,980/620	720	120	46,440
Packages/Shipment	24 (truck) or 76 (railcar), 4 cars/train	40/11	18	6	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	1,340 (truck) or 106 (rail)	15/3	2	1	387 (truck) or 49 (rail)
Shipments/Life of Project	26,800 (truck) or 2,120 (rail)	300/60	40	20	7,740 (truck) or 980 (rail)
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Truck/Rail
Destination - Facility Type	TBD	LLW Disposal Site	Hazardous Waste Treatment	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

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11.0 Glossary

List of Acronyms

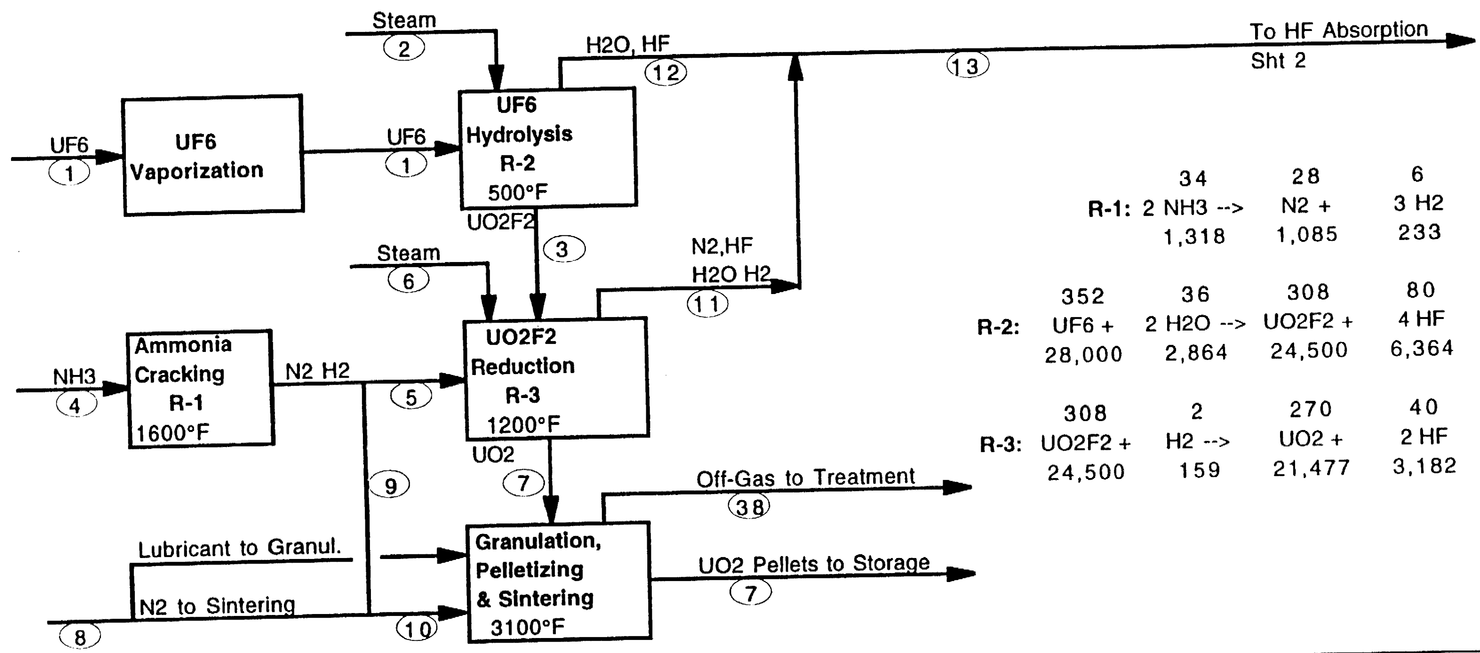
ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt ($1x10^6$ kW) hour(s)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MgF_2	magnesium fluoride
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

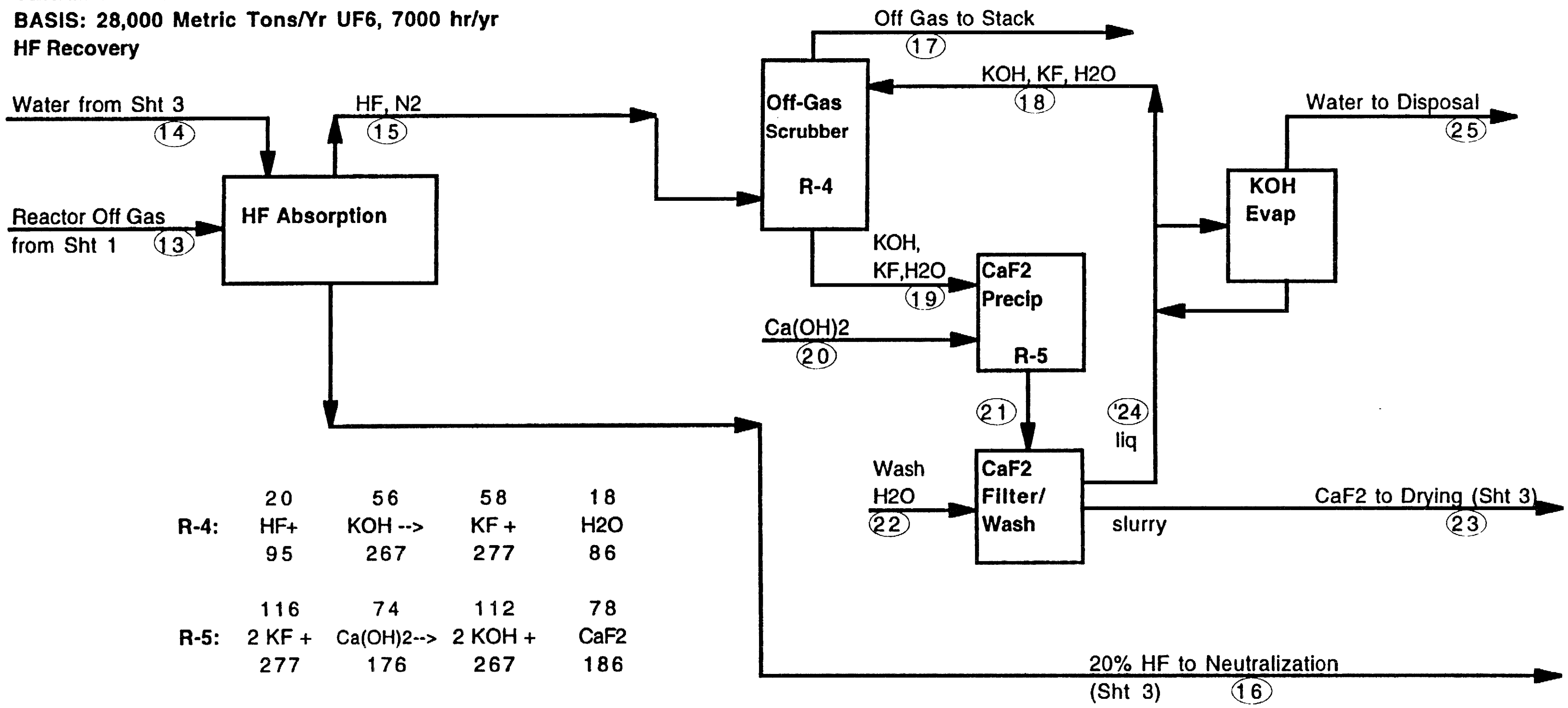
CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions



	34	28	6	
R-1:	2 NH3 -->	N2 +	3 H2	
	1,318	1,085	233	
	352	36	308	80
R-2: UF6 +		2 H2O -->	UO2F2 +	4 HF
	28,000	2,864	24,500	6,364
	308	2	270	40
R-3: UO2F2 +		H2 -->	UO2 +	2 HF
	24,500	159	21,477	3,182

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13
UF6	352	28,000												
UO2F2	308			24,500										
UO2	270							21,477						
U3O8	842													
HF	20											3,182	6,364	9,545
H2O	18		3,436				1,861					1,861	573	2,434
NH3	17				1,318									
H2	2					207				25.8	25.8	48		48
N2	28					965			5,533	120	5,653	965		965
O2	32													
Lubricant									107					
Total MT/yr		28,000	3,436	24,500	1,318	1,172	1,861	21,477	5,640	146	5,679	6,056	6,936	12,992
kg/kg U		1.48	0.18	1.29	0.070	0.062	0.10	1.13	0.30	0.008	0.30	0.32	0.37	0.69

CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery

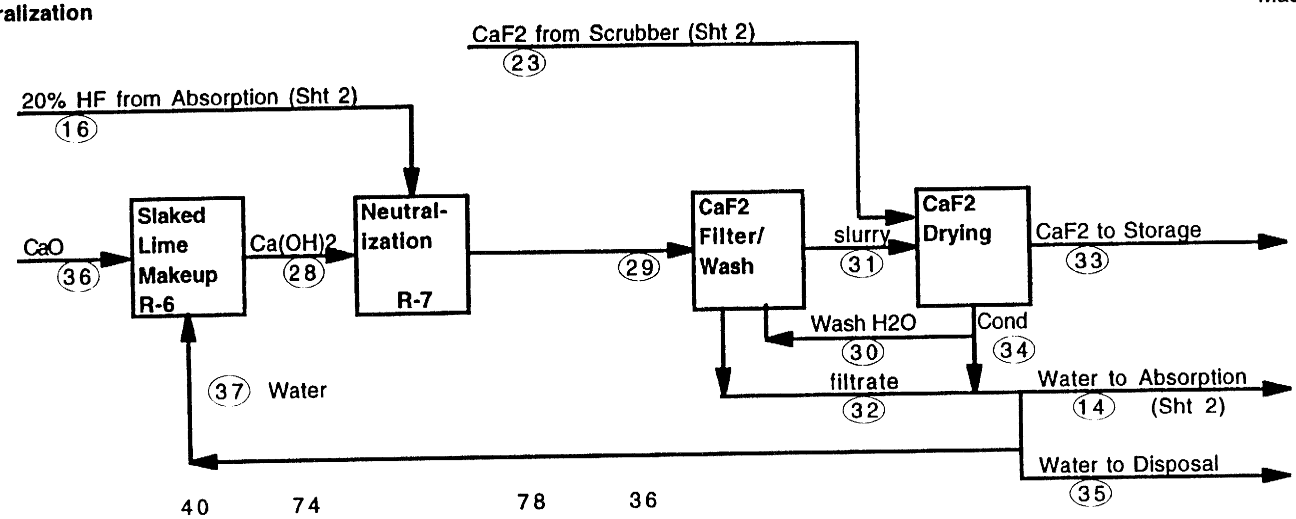


R-4:	20	56	58	18
	HF+	KOH -->	KF +	H2O
	95	267	277	86
R-5:	116	74	112	78
	2 KF +	Ca(OH)2-->	2 KOH +	CaF2
	277	176	267	186

	Mol Wt	14	15	16	17	18	19	20	21	22	23	24	25	26
Ca(OH)2	74							176	0					
CaF2	78								186		186			
KOH	56					334	67		334			334		
KF	58					28	304		28			28		
HF	20		95.5	9,450	0.10									
H2O	18	35,406	40	37,800	40	12,489	12,575		12,575	279	93	12,761	272	
H2	2		48		48									
N2	28		965		965									
O2	32													
Total MT/yr		35,406	1,149	47,250	1,053	12,850	12,946	176	13,122	279	279	13,122	272	0
kg/kg U		1.87	0.061	2.50	0.056	0.68	0.68	0.0093	0.69	0.015	0.015	0.69	0.014	0.00

CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Neutralization

Overall Balance
Mass In 53,941
Mass Out 53,941



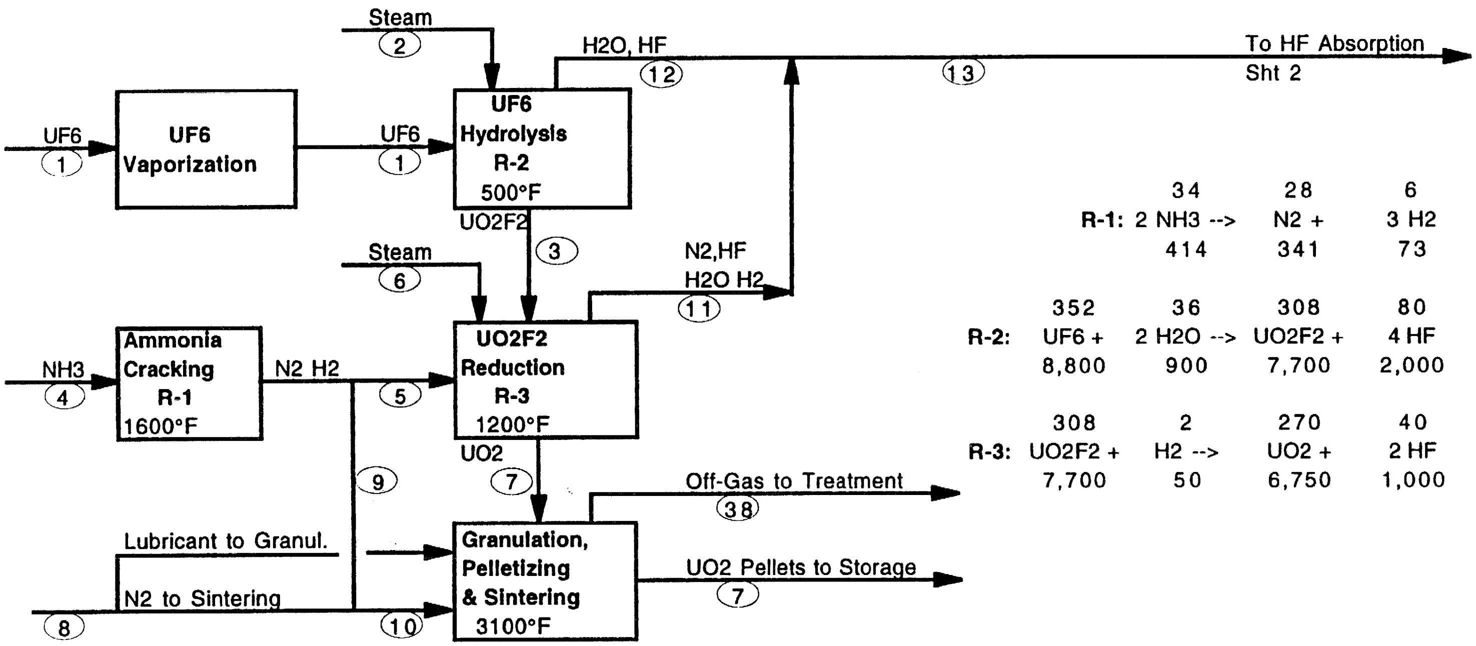
	40	74		78	36
R-7:	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
	9,450	17,483		18,428	8,505

	56	18		74
R-6:	CaO +	H2O	--->	Ca(OH)2
	13,230	4,253		17,483

	Mol Wt	27	28	29	30	31	32	33	34	35	36	37	38
Ca(OH)2	74		17,483	0									
CaF2	78			18,428		18,428		18,613					
KOH	56												
KF	58												
HF	20			0									
H2O	18		52,448	98,753	9,214	9,214	98,753		93	6,739		56,700	
CaO	56										13,230		
H2	2												26
N2	28												5,653
O2	32												
Lubricant													107
Total MT/yr		0	69,930	117,180	9,214	27,641	98,753	18,613	93	6,739	13,230	56,700	5,786
kg/kg U		0.00	3.69	6.19	0.49	1.46	5.22	0.98	0.0049	0.36	0.70	2.99	0.31

Sheet 3

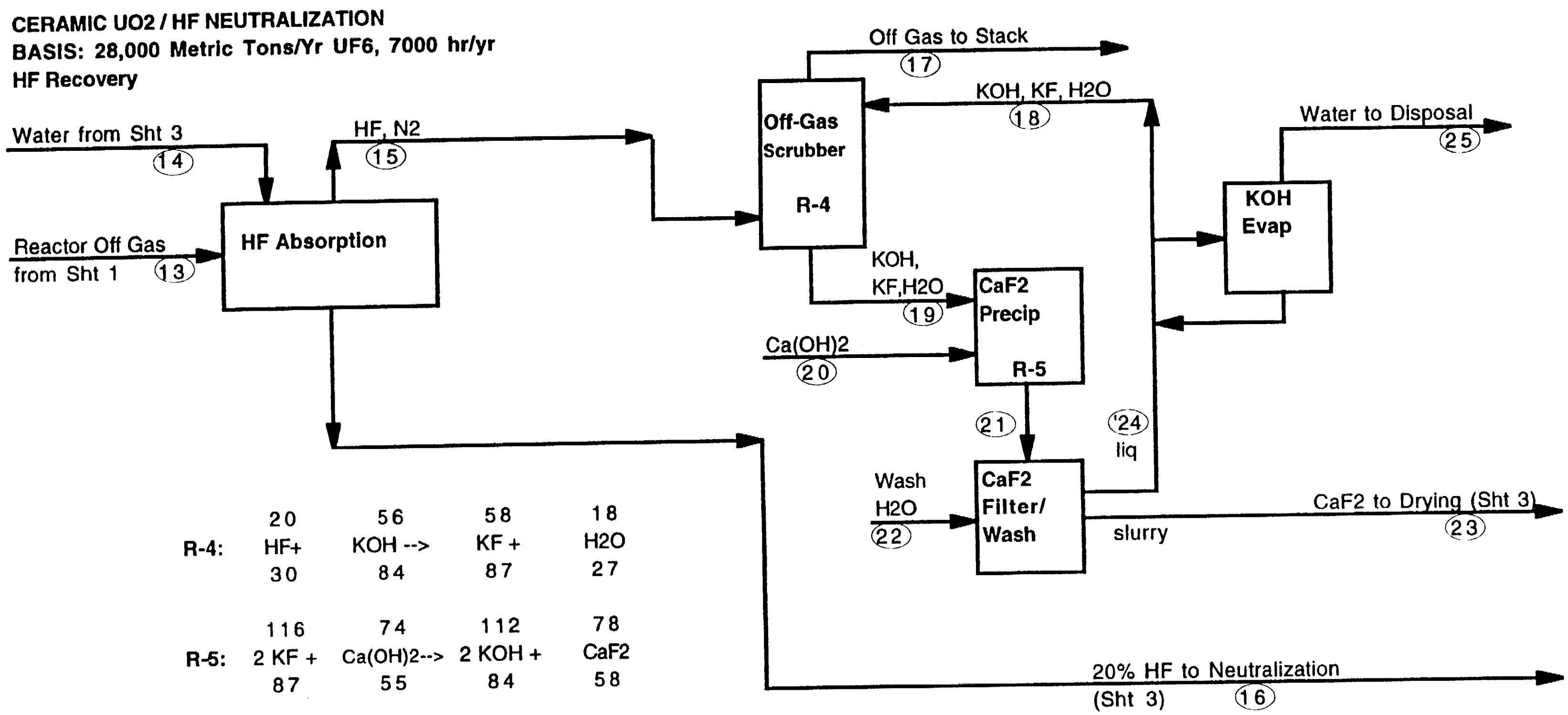
CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions



	34	28	6	
R-1:	2 NH3 -->	N2 +	3 H2	
	414	341	73	
	352	36	308	80
R-2: UF6 +	2 H2O -->	UO2F2 +	4 HF	
	8,800	900	7,700	2,000
	308	2	270	40
R-3: UO2F2 +	H2 -->	UO2 +	2 HF	
	7,700	50	6,750	1,000

	Mol Wt	1	2	3	4	5	6	7	8	9	10	11	12	13
UF6	352	8,800												
UO2F2	308			7,700										
UO2	270							6,750						
U3O8	842													
HF	20											1,000	2,000	3,000
H2O	18		1,080				585					585	180	765
NH3	17				414									
H2	2					65				8.1	8.1	15		15
N2	28					303			1,739	38	1,777	303		303
O2	32													
Lubricant									34					
Total lb/hr		8,800	1,080	7,700	414	368	585	6,750	1,773	46	1,785	1,903	2,180	4,083
kg/kg U		1.48	0.18	1.29	0.070	0.062	0.10	1.13	0.30	0.008	0.30	0.32	0.37	0.69

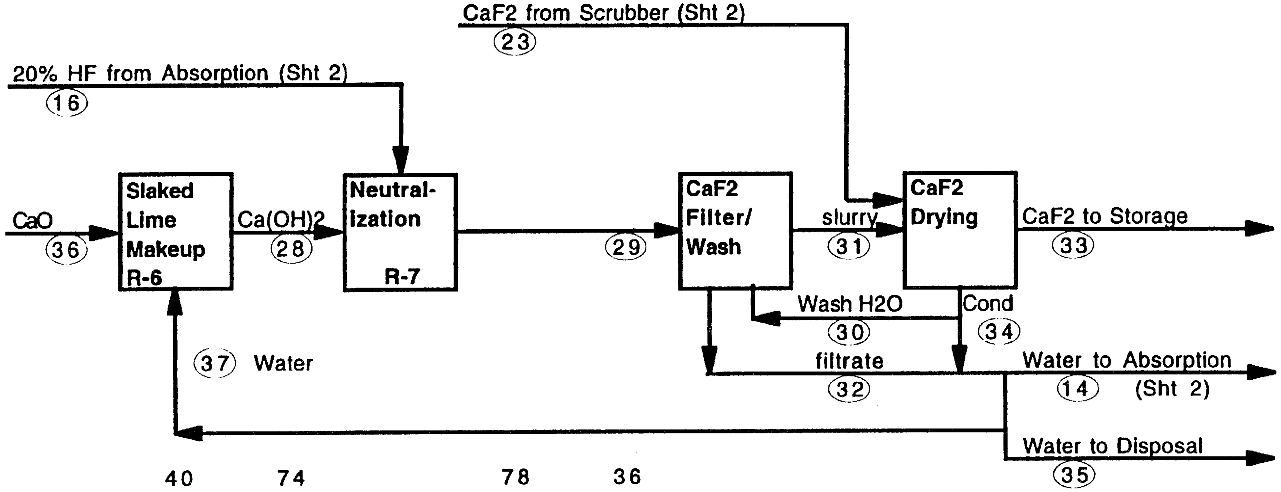
CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery



	Mol Wt	14	15	16	17	18	19	20	21	22	23	24	25	26
Ca(OH)2	74							55	0					
CaF2	78								58		58			
KOH	56					105	21		105			105		
KF	58					9	96		9			9		
HF	20		30.0	2,970	0.03									
H2O	18	11,128	13	11,880	13	3,925	3,952		3,952	88	29	4,010	85	
H2	2		15		15									
N2	28		303		303									
O2	32													
Total lb/hr		11,128	361	14,850	331	4,039	4,069	55	4,124	88	88	4,124	85	0
kg/kg U		1.87	0.061	2.50	0.056	0.68	0.68	0.0093	0.69	0.015	0.015	0.69	0.014	0.00

CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Neutralization

Overall Balance
Mass In 16,953
Mass Out 16,953



	40	74		78	36
R-7:	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
	2,970	5,495		5,792	2,673
	56	18		74	
R-6:	CaO +	H2O	--->	Ca(OH)2	
	4,158	1,337		5,495	

	Mol Wt	27	28	29	30	31	32	33	34	35	36	37	38
Ca(OH)2	74		5,495	0									
CaF2	78			5,792		5,792		5,850					
KOH	56												
KF	58												
HF	20			0									
H2O	18		16,484	31,037	2,896	2,896	31,037		29	2,118		17,820	
CaO	56										4,158		
H2	2												8
N2	28												1,777
O2	32												
Lubricant													34
Total lb/hr		0	21,978	36,828	2,896	8,687	31,037	5,850	29	2,118	4,158	17,820	1,818
kg/kg U		0.00	3.69	6.19	0.49	1.46	5.22	0.98	0.0049	0.36	0.70	2.99	0.31

Appendix B

Equipment List

MAJOR EQUIPMENT LIST
Ceramic UO_2 / HF Neutralization

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
UF6 Autoclave (14)	6'Dx18'L, carbon steel, steam-heated	Proc. Bldg
UF6 Compressor (14)	800 lb/hr UF6, 15 psig discharge	Proc. Bldg
Reactor No. 1 (2)	3'6"Dx10'H, fluidized bed, cooling jacket, Monel	Proc. Bldg
Screw Conveyor (2)	6"Dx10'L, 40 cfh, Monel	Proc. Bldg
Reactor No. 2 (2)	6'Dx30'L rotary kiln, 66 kw, Inconel	Proc. Bldg
Reactor Off-Gas System	Cyclone, sintered metal filter	Proc. Bldg
UO2 Product Cooler (2)	12"Dx10'L, screw conveyor with cooling water, steel, 33 cfh	Proc. Bldg
UO2 Bucket Elevator No. 1 (2)	20'H, 33 cfh	Proc. Bldg
UO2 Product Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
UO2 Drum Filling Station	4.5 drums/hr, glovebox	Proc. Bldg
UO2 Dust Collector	baghouse	Proc. Bldg
HF Absorber Column No. 1	3.5'Dx20'H, plastic packing, Monel shell	Proc. Bldg
Absorber No. 1 Pump	125 gpm, Monel	
Absorber No. 1 Cooler	2'6"Dx10'L, 1050 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Absorber Column No. 2	2'Dx19'H, plastic packing, Monel shell	Proc. Bldg
Absorber No. 2 Pump	35 gpm, Monel	Proc. Bldg
Absorber No. 2 Cooler	1'6"Dx7'L, 250 sq ft, Monel tubes, steel shell	Proc. Bldg
HF Neutralization Tank No. 1	9'Dx10'H, 4500 gal, Monel, 1300 sq ft cooling coil	Proc. Bldg
HF Neutralization Tank No. 2	9'Dx10'H, 4500 gal, Monel, no coils	Proc. Bldg
Drum Filter	3'Dx4'L, 40 sq ft, steel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	9'Dx10'H, 4500 gal, steel	Proc. Bldg
Filtrate Transfer Pump	70 gpm, cast iron	Proc. Bldg
Recycle Water Tank	11'Dx12'H, 8500 gal, steel	Proc. Bldg
Recycle Water Transfer Pump	70 gpm, cast iron	Proc. Bldg
CaF2 Rotary Dryer	6'Dx35'L, 1800 sq ft steam tubes, 10 hp, steel	Proc. Bldg
CaF2 Dryer Condenser	1'6"Dx4'L, 75 sq ft, bronze tubes, steel shell	Proc. Bldg
CaF2 Dryer Condensate Tank	4'Dx4'H, 400 gal, steel	Proc. Bldg
CaF2 Solids Cooler	12"Dx8'L screw conveyor with cooling water, steel, 60 cfh	Proc. Bldg
CaF2 Bucket Elevator	20'H, 60 cfh, steel	Proc. Bldg
CaF2 Product Bin	4'Dx11'H, 120 cf, steel	Proc. Bldg
CaF2 Drum Filling Station	7.3 drums/hr, glovebox	Proc. Bldg
CaF2 Dust Collector	baghouse	Proc. Bldg
Off-Gas Scrubber	1'Dx10'H, plastic packing, Monel shell	Proc. Bldg
Off-Gas Heater	1 kw electric heater	Proc. Bldg
Off-Gas HEPA Filter (2)	24"x24"x12"	Proc. Bldg
Off-Gas Exhauster (2)	100 scfm	Proc. Bldg

MAJOR EQUIPMENT LIST
Ceramic UO_2 / HF Neutralization

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
PROCESS		
Lime Feed Bin	4'Dx6'H, 60 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 0.8 cfh, steel	Proc. Bldg
Precipitation Tank	4'Dx6'H, 550 gal, Monel	Proc. Bldg
Drum Filter	6'Dx4'L, 75 sq ft, Monel	Proc. Bldg
Vacuum Pump	100 cfm	Proc. Bldg
Filtrate Tank	4'Dx6'H, 550 gal, Monel	Proc. Bldg
Scrub Solution Cooler	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Scrub Solution Pump	8 gpm, Monel	Proc. Bldg
Evaporator	1'6"Dx4'L, 50 sq ft, Monel	Proc. Bldg
Condenser	1'6"Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	3'Dx3'H, 100 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
Feed Hopper	4'Dx7'H, 70 cf, steel	Proc. Bldg
UO2 Powder Mill	hammer mill, 33 cfh	Proc. Bldg
UO2 Compactor	33 cfh feed	Proc. Bldg
UO2 Granulator	20 cfh	Proc. Bldg
Vibrating Screen Separator	4'Dx5'H, stainless steel	Proc. Bldg
UO2 Blender (2)	Double-cone tumbler, 13 cf working capacity	Proc. Bldg
Lubricant Feed Tank	3'Dx3'H, 100 gal, steel	Proc. Bldg
Granulated UO2 Bin	4'Dx7'H, 70 cf, steel	Proc. Bldg
Pellet Press (2)	365 pellets/min	Proc. Bldg
Boat Loading Station (3)	33 1'x1' boats/hr, 3'x3'x30'L glovebox	Proc. Bldg
Sintering Furnace (3)	6'Wx6'Hx70'L, 400 kw, water jacketed	Proc. Bldg
Furnace Off-Gas Filters		
Boat Unload/Drum Load Station	4.6 drums/hr, glovebox	Proc. Bldg
Lime Silo (2)	12'Dx58'H, 6000 cf, steel	Yard
Lime Pneumatic Conveyor	16 tons/hr	Yard / Proc. Bldg
Lime Feed Bin	7'Dx17'H, 600 cf, steel	Proc. Bldg
Lime Feeder	weigh belt feeder, 70 cfh, steel	Proc. Bldg
Lime Slaker	5'Dx23'H, 20 hp, steel, 2.1 tons lime/hr	Proc. Bldg
Slaked Lime Transfer Pump	40 gpm, cast iron	Proc. Bldg
Slaked Lime Feed Tank	9'Dx11'H, 5000 gal, steel, 500 sq ft cooling coil	Proc. Bldg
Slaked Lime Feed Pump	40 gpm, cast iron	Proc. Bldg
Ammonia Storage Tank (2)	9'Dx53'L, 25,000 gal, steel, 250 psig design	Yard
Ammonia Dissociator (3)	6000 cfh H2+N2, 90 kw	Proc. Bldg
Nitrogen Generator	380 scfm, membrane separator	Proc. Bldg
Air Compressor	800 cfm, 150 psi, 230 bhp	Proc. Bldg
Nitrogen Receiver (2)	4'Dx13'H, 1200 gal, 150 psig design, steel	Proc. Bldg

MAJOR EQUIPMENT LIST
Ceramic UO_2 / HF Neutralization

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Process Material Handling Systems	DUF_6 cylinder handling:	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated carbon steel storage racks for 400 14-ton DUF_6 cylinders	Proc. Bldg
	Two(2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195storage racks each for cylinders	Proc. Bldg/ Storage Areas
	UO_2 drum interim handling:	
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg
	UO_2 pellet drum handling:	
	-3 flatbed trucks	Yard
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg/ UO_2 Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg/ UO_2 Bldg
	Grouted waste & CaF_2 handling:	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ CaF_2 Bldg
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF_2 traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based liquid processing distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, UO_2 drum handling, waste grouting / LLW packaging and CaF_2 drum handling areas	Proc. Bldg

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / HF Neutralization

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Sampling / Analytical Systems	-6 local sampling glove boxes equipped with laboratory liquid / powder sampling hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste concentrator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and U Prod drums	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and UO_2 tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard

MAJOR EQUIPMENT LIST (Continued)
Ceramic UO_2 / HF Neutralization

EQUIPMENT NAME / QTY	EQUIPMENT DESCRIPTION	LOCATION
SUPPORT SYSTEMS		
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	 Yard/Buildings Buildings Buildings
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 20,000 lb/hr, 50 psig gas fired Air compressors - 2@ 300 cfm 150 psig Breathing air compressors- 2 @ 100 cfm Air Dryers - desiccant, minus 40°F dew point Demineralized water system - 5000 gpd Sanitary water treatment system - 4100 gpd Industrial wastewater treatment system - 80,000 gpd Electrical substation - 3200 kW Emergency generators - 2 @ 500kW Uninteruptible Power Supply - 100 kVA Cooling Tower - 31 MM Btu/hr, 3100 gpm	Util. Bldg Util. Bldg Util. Bldg Util. Bldg Util. Bldg Sanitary Treatment area Wastewater Treatment area Substation Substation Proc. Bldg Yard
HVAC SYSTEMS		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 2-3000 cfm, 7 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 2-80,000 cfm, 200 HP exhaust fans, 2-80,000 cfm 100 HP supply air units	UO_2 Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, 2-10,000 cfm, 15 HP supply air units	Grout Areas CaF_2 Areas Waste Process'g Control Room Support Areas
HVAC Chillers	3-360 ton chillers	Proc. Bldg
Circulating Pumps	3-600 gpm, 20 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

CERAMIC UO2 / HF NEUTRALIZATION - OPERATIONAL ACTIVITIES

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4 +1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25"	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	24	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	24	6	Steel	1/4"	3483.0
UO2F2 reactor surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
UO2 reactor surveillance	1	0.50	1752	7	6	Inconel	1.5"	876.0
UO2 drum loading (powder)	1	0.50	715	9,10	6	Steel	0.06"	357.5
Transfer UO2 drums to interim storage	2	0.50	715	10,11	3	Steel	0.06"	715.0
Transfer UO2 drums to pelletizing	2	0.50	715	10,11	3	Steel	0.06"	715.0
UO2 interim storage surveillance	1	0.50	2190	10,12,14	3	Steel	0.06"	1095.0
UO2 pelletizing surveillance	2	7000.00	continuous	19,20	6	Steel	1/4"	14000.0
UO2 sintering surveillance	2	7000.00	continuous	21	6	Steel	1/4"	14000.0
Transfer UO2 pellets to interim storage	2	0.50	6400	12,11	3	Steel	0.06"	6400.0
Transfer UO2 pellets to storage building	2	0.50	6400	12,11	3	Steel	0.06"	6400.0
Load UO2 pellets for shipment offsite	1	1.00	1600	13,15	3	Steel	0.06"	1600.0
UO2 Storage Building surveillance	1	0.50	2190	15	3	Steel	0.06"	1095.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS
HF absorption surveillance	1	0.50	1752	6,7	20	Monel,Inconel	3/4",1.5"	876.0
Off-gas Scrubbing / Process Liq. Treatment surveillance	1	0.50	1752	8,9	40	Steel	1/4"	876.0
HF Neutralization / CaF2 Processing surveillance	1	0.50	1752	6,7	60	Monel,Inconel	3/4",1.5"	876.0
Transfer CaF2 drums to interim storage	2	0.50	7300	6,7,16	100	Monel,Inconel	3/4",1.5"	7300.0
Transfer CaF2 drums to storage area	2	0.50	7300	8,9,16	80	Steel	1/4"	7300.0
Load CaF2 drums for shipment offsite	1	1.00	1275	15,17	30	Steel	0.06"	1275.0
CaF2 interim storage surveillance	1	0.25	2190	6,7	100	Monel,Inconel	3/4",1.5"	547.5
CaF2 storage building surveillance	1	0.50	2190	4,15	30	Steel	1/4",0.06"	1095.0
LLW processing, packaging, and shipping	2	8.00	1100	23	3	Steel	0.06"	17600.0
Process control room operations	8	8.00	1100	20, 21	30	Steel	1/4"	70400.0
Laboratory operations (including pellet testing)	5	8.00	1100	20	30	Steel	1/4"	44000.0
HP	2	8.00	1100	21	30	Steel	1/4"	17600.0
Management / Professionals	16	8.00	250	20	30	Steel	1/4"	32000.0
Accountability	3	2.00	1100	3,4,15	3	Steel	1/4",0.06"	6600.0
Industrial and sanitary waste treatment	4	8.00	1100	2,5	50	Steel	1/4"	35200.0
Utilities operations	4	8.00	1100	6,7	120	Monel,Inconel	3/4",1.5"	35200.0
Administration	22	8.00	250	2,5	100	Steel	1/4"	44000.0
Guardhouse / Process Bldg.	5	8.00	1100	2,5	100	Steel	1/4"	44000.0
Maintenance								15056.0
								460024.6

1) A single full UF6 cylinder.

2) A single empty UF6 cylinder.

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 18)	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS

3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; There are 2 reactors.
7) UO2 reactor; There are 2 reactors.
8) Compactor feed bin; There are 2 bins.
9) Drum fill bin.
10) Drum of UO2 powder.
11) Each transfer consists of 5 UO2 drums.
12) Drum of UO2 pellets.
13) There are 20 drums UO2 pellets per shipment.
14) Assume up to 1 weeks production in interim storage = 690 drums
15) There are up to 2673 UO2 drums in the storage building.
16) Each transfer consists of 7 CaF2 drums
17) There are 40 CaF2 drums per shipment
18) 2322 UF6 cylinders per year

    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    35683 UO2 powder drums/yr equivalent
    assume 2% of production is sent to interim storage in drums = .02* 35683 = 715
    32000 UO2 pellet drums/yr /5 drums per transfer = 6400 transfers
    32000 UO2 pellet drums/yr /20 drums per shipment = 1600 shipments
    51000 CaF2 drums/yr / 7 drums per transfer = 7300 transfers per year
    51000 CaF2 drums/yr / 40 drums per shipment = 1275 transfers per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year

19) Cumulative inventory UO2 Feed Bin through Granulated UO2 Bin.
20) Cumulative UO2 inventory Pellet Press and Boat Loading Station.
21) Sintering Furnace inventory.
22) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.
23) Batch of LLW
24) A single 3 mo. old empty UF6 cylinder

CERAMIC UO2 / HF NEUTRALIZATION - MAINTENANCE ACTIVITIES

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4" + 1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4" + 1/4"	1456
UO2F2 Reactor (Reactor No. 1) (2)	2	26	2	6	3	Monel	3/4"	104
UO2F2 screw conveyor (2)	2	108	2	6	3	Monel	3/4"	432
UO2F2 sintered metal filter (2)	2	4	2	23	1			16
UO2 reactor (Reactor No. 2) (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 product cooler (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 sintered metal filter (2)	2	4	2	23	1			16
UO2 bucket elevator No. 1 (2)	2	108	2	7	3	Inconel	1.5"	432
UO2 dust collector (baghouse) (1)	2	4	1	23	1			8
UO2 powder mill (1)	2	52	1	19	2	Steel	1/4"	104
UO2 compactor (1)	2	52	1	19	2	Steel	1/4"	104
UO2 granulator (1)	2	52	1	19	2	Steel	1/4"	104
Vibrating screen separator (1)	2	52	1	19	2	Steel	1/4"	104
UO2 blender (1)	2	52	1	19	2	Steel	1/4"	104
Pellet press (1)	2	108	1	20	2	Steel	1/4"	216
Boat loading station (3)	2	26	3	20	2	Steel	1/4"	156
Sintering furnace (3)	2	26	3	21	2	Steel	1/4"	156
Sintering furnace off-gas filters	2	4	3	23	1			24
Boat unload / drum load station (1)	2	26	1	21	2	Steel	1/4"	52
HF absorber column (2)	2	26	2	6,7	20	Monel, Inconel	3/4", 1.5"	104
HF absorber cooler (2)	2	26	2	6,7	20	Monel, Inconel	3/4", 1.5"	104
HF absorber pumps (2)	2	52	2	6,7	20	Monel, Inconel	3/4", 1.5"	208
CaF2 drum filter (1)	2	26	1	6,7	40	Monel, Inconel	3/4", 1.5"	52
Vacuum pump (1)	2	52	1	6,7	40	Monel, Inconel	3/4", 1.5"	104
Filtrate transfer pump (1)	2	52	1	6,7	40	Monel, Inconel	3/4", 1.5"	104
Recycle water transfer pump (1)	2	52	1	6,7	40	Monel, Inconel	3/4", 1.5"	104
CaF2 dryer condenser (1)	2	26	1	6,7	60	Monel, Inconel	3/4", 1.5"	52

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR
CaF2 rotary dryer (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
CaF2 solids cooler (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
CaF2 bucket elevator (1)	2	104	1	6,7	60	Monel, Inconel	3/4", 1.5"	208
CaF2 dust collector (baghouse) (1)	2	4	1	6,7	60	Monel, Inconel	3/4", 1.5"	8
Off-gas scrubber (1)	2	26	1	8,9	20	Steel	1/4"	52
Off-gas heater (1)	2	26	1	8,9	20	Steel	1/4"	52
Off-gas HEPA filters (2)	2	4	2	8,9	20	Steel	1/4"	16
Off-gas exhausters (2)	2	26	2	8,9	20	Steel	1/4"	104
Lime feeder (1)	2	104	1	6,7	60	Monel, Inconel	3/4", 1.5"	208
Drum filter (1)	2	26	1	6,7	60	Monel, Inconel	3/4", 1.5"	52
Vacuum pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
Scrub solution cooler (1)	2	26	1	6,7	60	Monel, Inconel	3/4", 1.5"	52
Scrub solution pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
Evaporator (1)	2	26	1	6,7	60	Monel, Inconel	3/4", 1.5"	52
Condenser (1)	2	26	1	6,7	60	Monel, Inconel	3/4", 1.5"	52
Condensate pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
Lime feeder (1)	2	104	1	6,7	60	Monel, Inconel	3/4", 1.5"	208
Lime slaker (1)	2	104	1	6,7	60	Monel, Inconel	3/4", 1.5"	208
Slaked lime transfer pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
Slaked lime feed pump (1)	2	52	1	6,7	60	Monel, Inconel	3/4", 1.5"	104
Ammonia dissociator (3)	2	26	3	6,7	250	Monel, Inconel	3/4", 1.5"	156
Nitrogen generator	2	26	1	6,7	250	Monel, Inconel	3/4", 1.5"	52
Air compressor (1)	2	52	1	6,7	250	Monel, Inconel	3/4", 1.5"	104
Boiler, Water Systems, and other Utilities	2	52	3	6,7	250	Monel, Inconel	3/4", 1.5"	312
HVAC equipment	2	520	1	19	30	Steel	1/4"	1040
Waste water treatment equipment	1	2190	1	2,5	50	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	6,7	120	Monel, Inconel	3/4", 1.5"	2190
Admin building	1	1000	1	2,5	50	Steel	1/4"	1000
								15056

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 18)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 22)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder.
2) A single empty UF6 cylinder.
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 195 empty UF6 cylinders in the storage area.
6) UO2F2 reactor; There are 2 reactors.
7) UO2 reactor; There are 2 reactors.
8) Compactor feed bin; There are 2 bins.
9) Drum fill bin.
10) Drum of UO2 powder.
11) Each transfer consists of 5 UO2 drums.
12) Drum of UO2 pellets.
13) There are 20 drums UO2 pellets per shipment.
14) Assume up to 1 weeks production in interim storage = 690 drums
15) There are up to 2763 UO2 drums in the storage building.
16) Each transfer consists of 7 CaF2 drums
17) There are 40 CaF2 drums per shipment
18) Average of 2 hours per week on conveyor systems
    Average of 1 hour per week on active components (pumps, compressors, compactor, granulator, slacker) - includes instrumentation
    Average of 1/2 hour per week on passive components (autoclaves, coolers, scrubbers, condensers) - includes instrumentation
    10 hours per week on HJVAC components
    6 hours per day of waste water treatment components
    6 hours per day on sanitary waste treatment components
    1000 hours per year on the administration building
19) Cumulative inventory UO2 Feed Bin through Granulated UO2 Bin.
20) Cumulative UO2 inventory Pellet Press and Boat Loading Station.
21) Sintering Furnace inventory.
22) Materials do not include walls between operating areas.
23) Loaded filter/bag.

Draft Engineering Analysis Report for the Long-Term Management of Depleted Uranium Hexafluoride - Rev. 2

Section 6.8

UO_2: Gelation / Ceramic UO_2 Facility

Draft Engineering Analysis Report
Depleted Uranium Hexafluoride Management Program

Section 6.8
UO2: Gelation / Ceramic UO2 Facility

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Preface

This report provides the EIS data input for the conversion of DUF_6 into uranium dioxide (UO_2) microspheres and byproduct anhydrous hydrogen fluoride (AHF). Due to its chemical stability and high density, UO_2 is a principal option for either use, long term storage, or disposal. Fluorine recovery as saleable AHF improves process economics by adding revenue in place of the expense of disposing of it as a waste.

Defluorination of UF_6 to U_3O_8 is achieved through a steam hydrolysis/ pyrohydrolysis route, which is generically the same as the existing industrial (Cogema) process practiced in France. Upgrading of the aqueous HF to AHF is accomplished by conventional distillation. Conversion of U_3O_8 to UO_2 is based on internal gelation flowsheet conditions developed at Oak Ridge National Laboratory. Specific process aspects for the U_3O_8 production flowsheet were based on the Sequoyah Fuels patent.

There are a number of significant technical uncertainties with respect to the gelation flowsheet. Among these is the lack of an obvious method to recover and recycle the major process reagents, namely urea and hexamethylenetetramine (HMTA). In the absence of an identified recovery process, the effluent stream containing these reagents was assumed to be discarded as a sanitary waste. This represents a major system deficiency from the standpoint of waste generation and process reagent cost.

It was beyond the scope of this effort to carry out a comprehensive examination of recovery methods. A practical recovery and recycle process would significantly improve the economics and viability of gelation. Also, the possibility exists that the urea and HMTA could be recycled as a mixed solution, rather than as separate solutions. This would eliminate one separation step, but this approach still requires the development and testing of a recovery process.

Process Summary

Depleted uranium hexafluoride (UF_6) is processed to produce uranium dioxide (UO_2) and byproduct anhydrous hydrogen fluoride (AHF). A dry process (steam hydrolysis/steam pyrolysis) is used for conversion of UF_6 to U_3O_8. The U_3O_8 is dissolved in nitric acid, and converted to UO_2 spheres by an internal gelation process. The gelation process was based on flowsheet conditions developed at Oak Ridge National Laboratory for a nuclear fuel fabrication development program.

The UF_6 is converted to U_3O_8 in two steps. The UF_6 is vaporized using steam heated autoclaves and fed to a reactor, where it is mixed with a recycled HF-steam mixture. Solid uranyl fluoride (UO_2F_2) is produced and it flows to a second reactor, where it is mixed with superheated steam to produce U_3O_8. Conversion of UO_2F_2 to U_3O_8 enables essentially complete recovery of fluorine as saleable AHF. The oxide is discharged from the reactor, cooled, and conveyed to dissolution.

Vapor containing HF and water vapor flows to the HF distillation column. Distillation of the stream produces AHF that can be sold commercially. The HF azeotrope (distillation column bottoms) is vaporized and recycled to the first reactor. Uncondensed off-gas from the distillation process flows to an alkaline scrubber system for HF removal.

The U_3O_8 is dissolved in nitric acid to form an acid deficient uranyl nitrate solution (ADUN). The dissolver off-gas is treated for NO_x removal by absorption and catalytic reduction. The HNO_3 recovered by the absorber is recycled to the dissolver. The ADUN is mixed with urea, denitrited, cooled, and mixed with cold HMTA solution to form a feed broth.

The broth is fed to gelation columns through nozzles that break up the feed stream into small droplets. The droplets form UO_3 gel spheres as they sink in gelation columns filled with hot trichloroethylene (TCE). Gelation columns are provided for producing 1200μ and 300μ diameter spheres. The spheres are filtered and dried to separate the TCE, which is recycled to the columns.

The UO_3 spheres are washed with an ammonia solution to remove HMTA, urea and reaction byproducts. No recycle of the HMTA/urea waste stream is provided because no feasible recycle process was identified during this study.

The spheres are dried and sintered in a hydrogen atmosphere to form ceramic UO_2 spheres. A stripping column recovers ammonia from the wash solution and dryer condensate, and recycles the ammonia solution to washing. The dry, sintered UO_2 spheres are blended in a 70 wt% 1200μ, 30 wt% 300μ mixture that increases the bulk density to 9 g/cc. The mixture is packaged in 30-gallon drums for shipment.

1.0 DUF_6 Conversion Facility - Missions, Assumptions, and Design Basis

1.1 MISSIONS

The Depleted Uranium Hexafluoride (DUF_6) Gelation / Ceramic UO_2 Conversion Facility converts depleted UF_6 into uranium dioxide (UO_2) for use, long-term storage, or disposal.

1.2 ASSUMPTIONS AND DESIGN BASIS

1.2.1 Assumptions

The following assumptions are made in this report:

- The facility will receive the DUF_6 feed in 14 ton cylinders by truck or rail car. They are unloaded onto trucks and placed in storage by on-site cranes. Outdoor storage for one months supply of full cylinders is provided. Incoming cylinders are assumed to be approved for transportation and arrive on-site in an undamaged, clean condition.
- For this study, it is assumed that the outgoing empty DUF_6 cylinders are shipped off-site to a cylinder refurbishment or waste treatment facility. Indoor storage of three month's supply of empty cylinders is provided.
- DUF_6 feed to the facility is assumed to be chemically pure, and the assumed average isotopic composition is: 0.001% U-234, 0.25% U-235, and 99.75% U-238. The corresponding specific activity (alpha) is 4×10^{-7} Ci/g DU. In the UF_6 filled cylinder, the short-lived daughter products of U-238, Th-234 and Pa-234, are in the same equilibrium with the U-238. Therefore, these beta emitters each have the same activity as U-238 (3.3×10^{-7} Ci/g).
- No recycle of the gelation chemicals hexamethylenetetramine (HMTA) and urea is assumed. The scope of this study did not include a detailed analysis of possible recycle methods of these chemicals. Further research is required to identify a feasible and economic method of recycle. Since both the feed makeup and waste streams produced by this process are large, the process would be greatly improved if recycle could be employed. It has been further assumed that this waste is non-hazardous sanitary waste and is loaded into 15-ton capacity, 8 ft wide by 22 ft long by 4 ft high bulk containers. Outdoor storage of one week's production is provided.
- Operations will be continuous for 24 hours/day, 7 days/week, 52 weeks/year.

- Annual operating time is assumed to be 7000 hours based on a plant availability factor of 0.8.
- The hydrofluoric acid (HF) produced in the process is stored in tanks and loaded into railcars or tank trucks for shipment off-site. Indoor on-site storage of one month's production is provided.
- To obtain the desired bulk density of 9 g/cc, the UO_2 product contains 70 wt% 1200μ (micron) diameter spheres and 30 wt% 300μ spheres.
- UO_2 product is packaged in 30 gallon drums. Since the weight of UO_2 in a full drum exceeds the maximum weight limitations for a standard drum, it is assumed that specially engineered drums are used for UO_2. Indoor on-site storage space for 1 month's production is provided.
- Grouted waste and CaF_2 are packaged in 55 gallon drums. Indoor storage of one month's production is provided.
- The medium chosen for gelation in this report was trichloroethylene (TCE) because it provides process advantages such as smaller gelation columns. It is recognized that the use of TCE is now discouraged by regulators because it is toxic and a suspected carcinogen. However, this facility will be designed to limit occupational exposure and environmental releases to below acceptable levels. Using a different gelation medium such as silicone oil is not expected to significantly affect the environmental impacts of the gelation facility.
- On-site storage of one month's supply of urea, hexamethylene-tetramine (HMTA), urea, nitric acid, calcium hydroxide (lime), ammonia and cement feed material is provided.
- The radiological hazard associated with the outgoing empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.
- The facility is assumed to be constructed and operated at a generic greenfield site. This site is currently assumed to be the EPRI Standard Hypothetical East/West Central Site as defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

1.2.2 Design Basis

The general design basis document used in designing the facility is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes, and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, is used as a guide to develop preliminary hazards classifications and related design features of the facilities containing radioactive or hazardous materials.

Design codes and standards applicable to "special facilities", as defined in DOE Order 6430.1A, and facilities with moderate or low hazard classifications per DOE-STD-1027-92 include the following:

- Process Building
- HF Storage Building
- UO_2 Storage Building
- Outgoing, Empty Cylinder Storage Building

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in general use in the facility, including the following:

- CaF_2 Storage Building
- Administration Building
- Sludge Loading Building
- Utilities Building
- Warehouse
- Maintenance Shop Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Facility Cooling Tower.

A more detailed listing of compliance standards is presented in Section 1.2.5.

1.2.3 Facility Capacity/Capability

The facility is designed to process 28,000 metric tons of depleted UF_6 annually. The DUF_6 inventory of 560,000 metric tons would be converted within a 20-year processing period. The facility will operate 24 hours/day, seven days a week, 292 days/year for an 80% plant availability during operations.

1.2.4 Facility Operating Basis

A preliminary schedule to deploy, operate, and decontaminate and decommission a representative depleted UF6 conversion facility is illustrated in Figure 1-1. The schedule is assumed to be generic to conversion (including empty cylinder treatment) and manufacturing (shielding) facilities within the program. Differentiation of schedule durations assuming DOE or privatized facility options have not been addressed at this time.

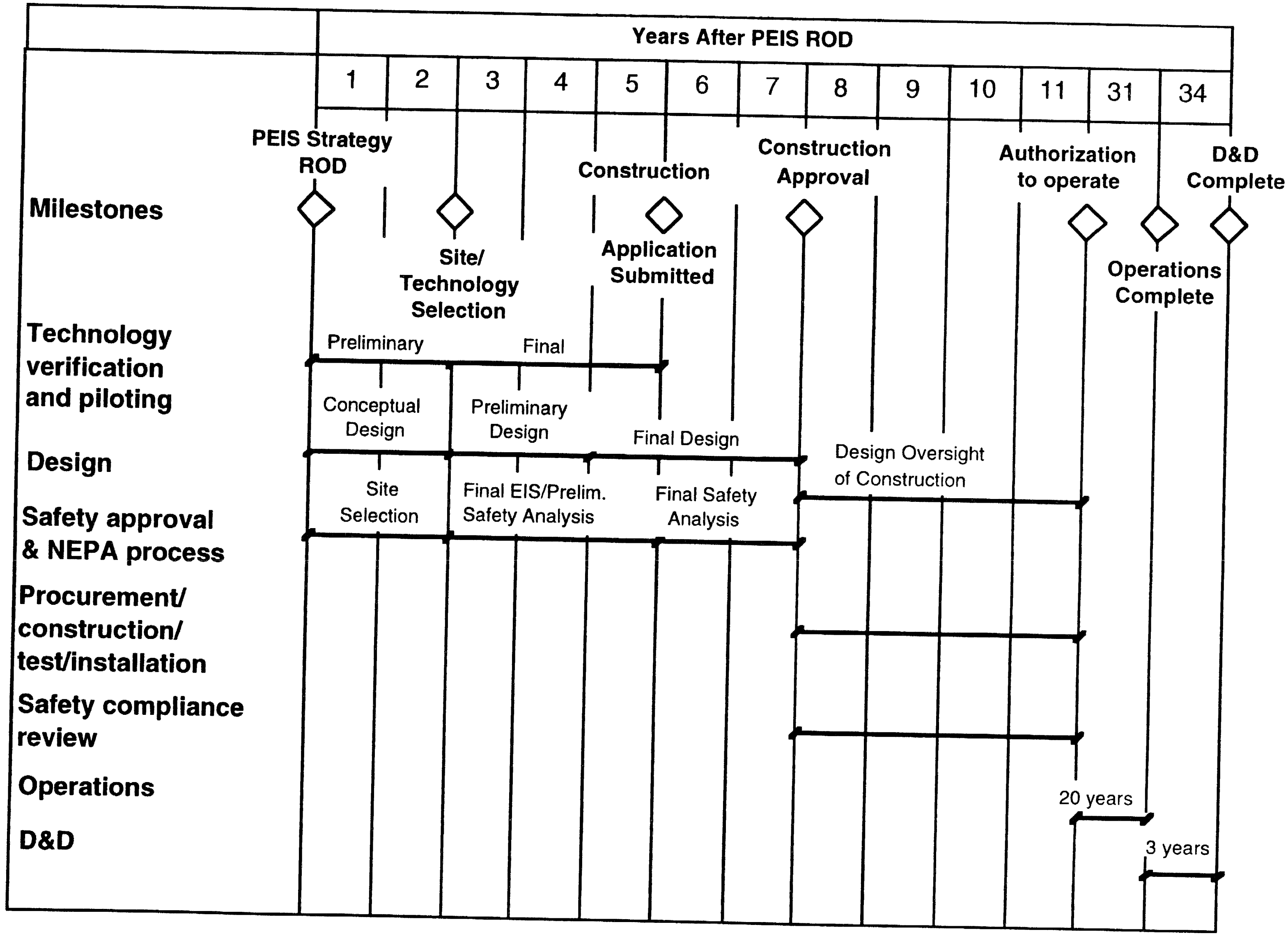


Figure 1-1 Preliminary Project Schedule

Technology verification and piloting are allocated for 3 years following preliminary assessments. Design activities include both preliminary and final designs, while safety approval/NEPA processes include documentation approval. Site preparation, facility construction, procurement of process equipment, and testing/installation are assumed to require 4 years. Plant start-up occurs about 11 years after the PEIS Record of Decision (ROD). Operations are complete in 20 years, followed by about a three year period for decontamination and decommissioning.

1.2.5 Compliance

The major applicable compliance documents for design of the facility are as follows:

1.2.5.1 Basic Rules, Regulations, Codes, and Guidelines

Basic references concerning the content and procedures for issuance of an EIS can be found in the Council on Environmental Quality Regulation 40 CFR 1502, *Environmental Impact Statement*, 10 CFR 1021, *National Environmental Policy Act Implementing Procedures (for DOE)*, and DOE Orders 5400.1, *General Environmental Protection Program* and 5440.1E, *National Environmental Policy Act Compliance Program.*

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, and guidelines, as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities," Sections 1318, "Uranium Enrichment Facilities"; 1322, "Uranium Conversion and Recovery Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable Nuclear Regulatory Commission (NRC) regulatory guides referenced in DOE Order 6430.1A will be used where appropriate.

1.2.5.2 Environmental, Safety, and Health

Environmental, safety, and health requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards*, DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act.* Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection.*

1.2.5.3 Buffer Zones

The need for buffer zones surrounding the facility will be determined by the site-specific environmental impact studies, which will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements;* the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series; and Section 1300-9 of DOE Order 6430.1A, "Effluent Control and Monitoring."

1.2.5.4 Decontamination and Decommissioning

Design requirements for decontamination and decommissioning (D&D) of the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1322-7 "D&D of Uranium Conversion and Recovery Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.5 Toxicological/Radiological Exposure

Exposures to hazardous effluents (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on *Radiation Protection of the Public and the Environment* in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring (of Special Facilities)."

1.2.5.6 Waste Management

Waste management systems provided for the facility will be in accordance with the requirements of DOE Order 6430.1A, Section 1300-8, "Waste Management (for special facilities)"; Section 1322-6, "Effluent Control and Monitoring (of Uranium Conversion and Recovery Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)." Specific DOE design and operating requirements for radioactive wastes, including low level waste (LLW) appear in DOE Order 5820.2A, *Radioactive Waste Management*. Nonradioactive, hazardous waste requirements appear in DOE 5480.1B and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution prevention program - including waste minimization, source reduction, and recycling of solid, liquid, and air emissions - will be implemented in accordance with DOE Orders 5400.1, *General Environmental Protection Program*; and 5820.2A, *Environmental Compliance Issue Coordination*.

1.2.5.7 Materials Accountability and Plant Security

The basic compliance documents for materials accountability and security requirements for the facility design are DOE Order 6430.1A, *General Design*

Criteria, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Section 2.2.3 of this report.

1.2.6 Uncertainties

Uncertainties associated with the process include the following:

- The process has not been demonstrated on a throughput scale assumed for this study (28,000 MT/yr UF_6). All ORNL work was at laboratory scale. Primary concern is direct scale-up of the conversion reactors and gelation columns.
- The gelation process produces a large waste sludge stream containing hexamethylenetetramine (HMTA), urea, ammonium nitrate and formaldehyde. This report assumes that this waste is non-hazardous and can be disposed as sanitary waste. This assumption is based on expected polymerization of formaldehyde and minimum solubility of uranium in the gel washing step to form a non-hazardous solid. These assumptions require laboratory testing for confirmation.
- The large waste sludge stream produced is a major deficiency. Research is required to develop a process to recover and recycle the HMTA and urea from the waste sludge stream. This would substantially reduce the waste stream quantity, and eliminate the cost of these chemicals as process feeds. A cursory review found no obvious method to accomplish the recovery. This report assumes no recovery or recycle.
- Sintering furnaces combining high temperature, special gas atmosphere and high capacity are required. Furnaces with one or two of these features are common, but a furnace incorporating all of these will require some engineering and development. However it is believed the furnace design is technically feasible.
- The optimum material of construction for reactor system process equipment and components exposed to fluorides has not been determined. For this study, Inconel and Monel have been assumed.
- The ultimate use or disposal form of the UO_2 product has not been finalized. Also, the viability of shipment of UO_2 spheres in 30 gallon drums has not been determined.
- The relative hazards and economics of on-site storage of large quantities of hydrofluoric acid (HF) in tanks versus on-site storage of HF in rail tank cars has not been fully assessed.
- Due to the pre-conceptual nature of the facility design, design details of process and support system equipment and components as well as facility building and site construction quantities have not been fully defined. With the exception of the major process equipment, current equipment, system, and facility descriptions are based primarily on engineering judgment and comparisons with historical data from similar facilities.

- Building area hazards categorizations are based on preliminary analyses as defined in DOE-STD-1027-92 and require additional analyses before final hazards categories can be defined.
- The radiological hazard associated with the outgoing, empty cylinders has not been finalized. Preliminary estimates have indicated possible dose rates in the range of 1 Rem/hr at the lower surface of the cylinders due to retention of a heel of radioactive daughter products in the cylinder after emptying. It has been assumed that a period of approximately three months of on-site storage is required to allow these daughter products to decay to acceptable levels for shipment off-site.

2.0 DUF_6 Conversion Facility Description

2.1 GENERAL FACILITY DESCRIPTION

2.1.1 Functional Description

The process presented in this report consists of conversion of depleted uranium hexafluoride (DUF_6) to uranium oxide (U_3O_8) and anhydrous hydrogen fluoride (AHF) by defluorination with steam, and conversion of U_3O_8 to sintered UO_2 spheres by a gelation process. An overall facility material flow diagram is shown in Figure 2-1.

DUF_6 is received in DOT-approved cylinders and is converted within the Process Building in a series of two reactors, oxide dissolution vessels, gelation columns and washing, drying, calcining and sintering equipment to produce solid UO_2 product. The UO_2 spheres are packaged in 30 gallon drums. The product uranium dioxide is stored on-site until it is transported to another site for subsequent disposition; long term storage, use or disposal. Hydrofluoric acid (HF) produced by the process is stored on-site and is assumed to be sold. Non-hazardous byproduct calcium fluoride is shipped offsite.

2.1.2 Plot Plan

A three-dimensional rendering of the facility is shown in Figure 2-2, Plot Plan.

The plot plan shows the major structures on the site, as follows:

- Process Building
- HF Storage Building
- UO_2 Storage Building
- CaF_2 Storage Building
- Outgoing, Empty Cylinder Storage Building
- Incoming cylinder and organic sludge waste storage pads
- Miscellaneous support buildings, including the Administration Building, Sludge Loading Building, Utilities Building, Maintenance Shop, Industrial Waste and Sanitary Waste Treatment Buildings, and Warehouse
- Facility cooling tower
- Process Building exhaust and boiler stacks
- Perimeter fencing enclosing the entire site.

Note: The size, number, and arrangement of facility buildings is pre-conceptual and can change significantly as the design progresses. This plot

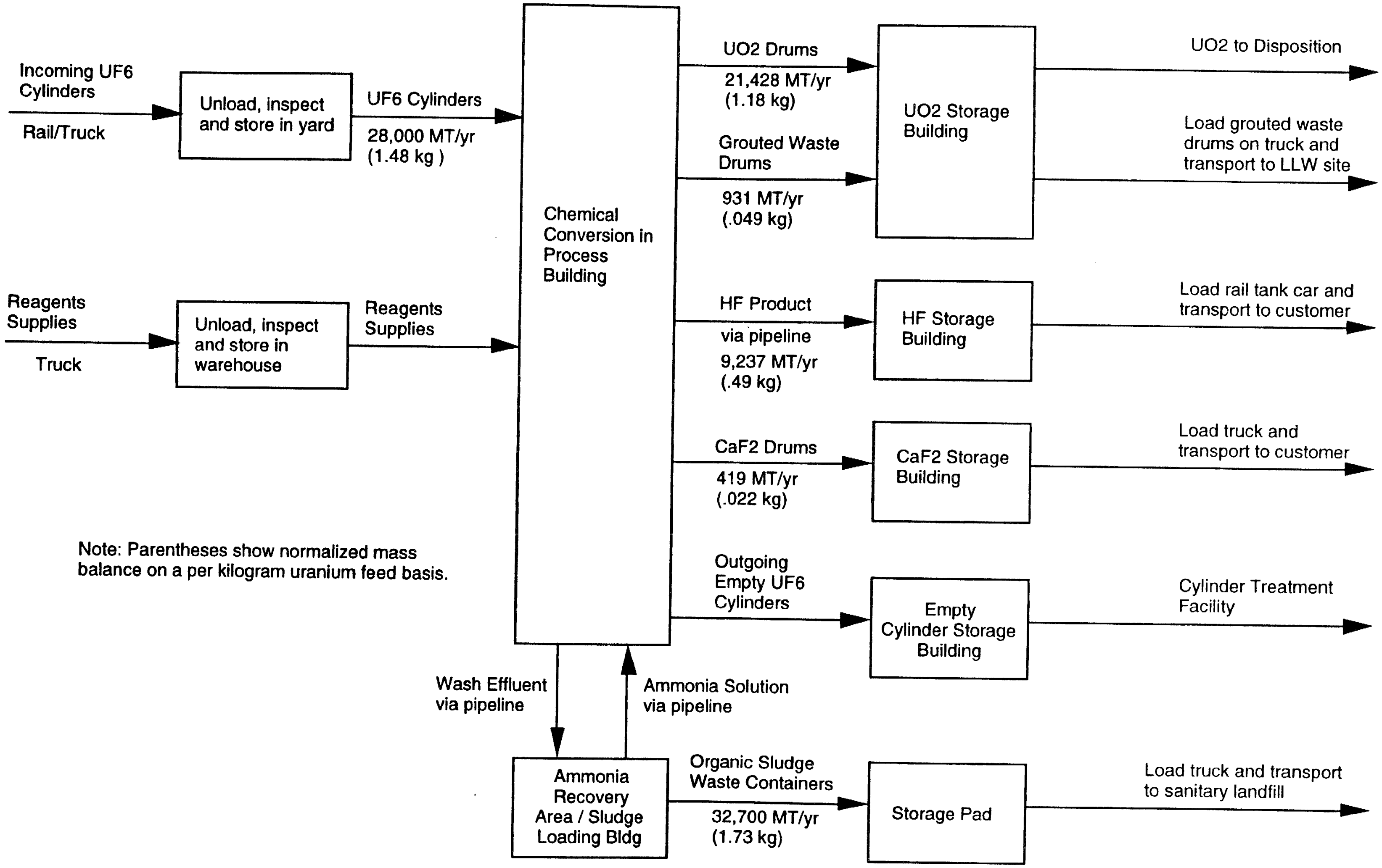


Figure 2-1 Facility Material Flow Diagram

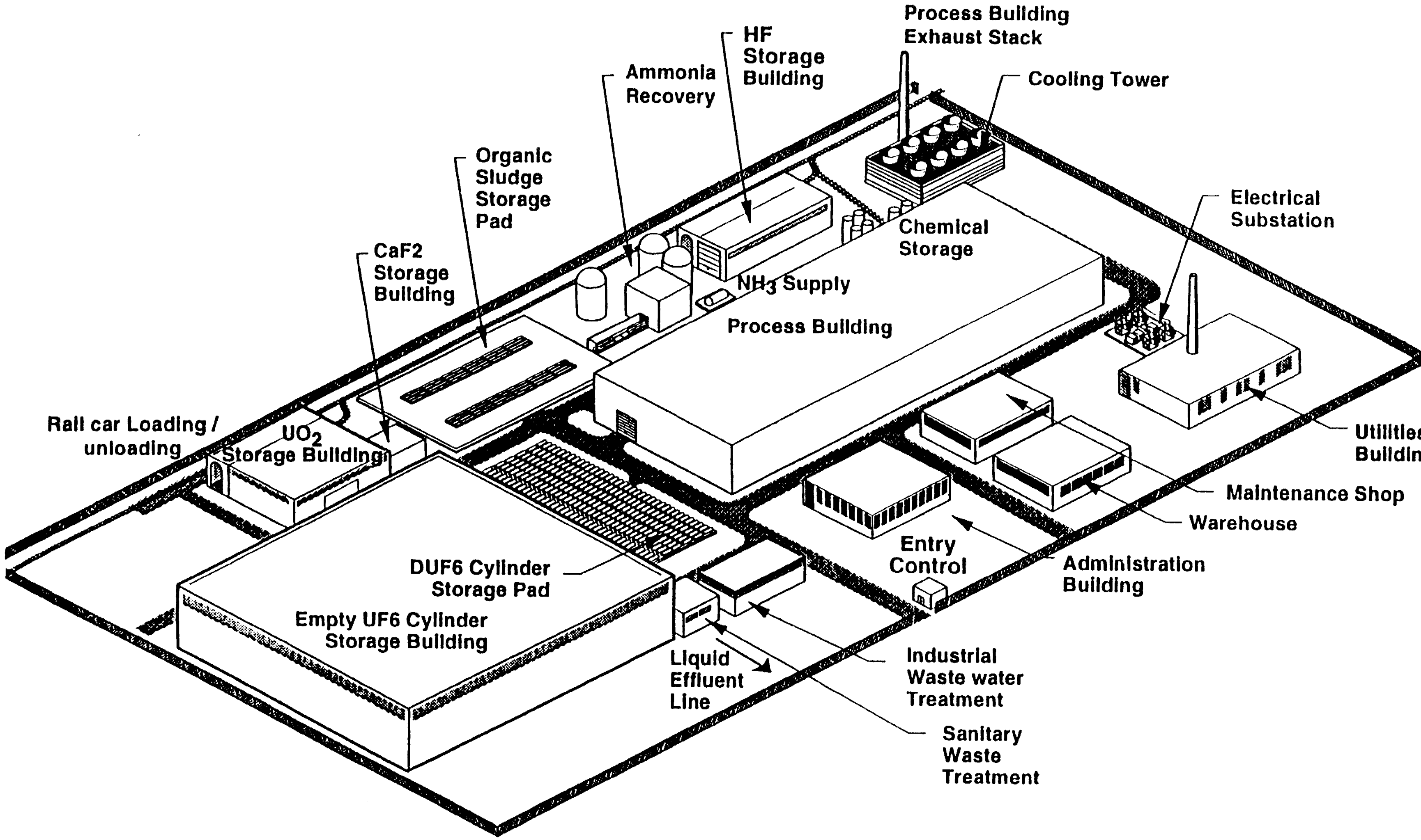


Figure 2-2 Plot Plan
Gelation / Ceramic UO_2 Facility

plan conveys general layout information only and is based on the assumption of a generic, greenfield site.

2.1.3 Building Descriptions

Table 2-1 summarizes the facilities building data.

Table 2-1, Facility Building Data

Building Name	Foot-print (ft^2)	No. of Levels	Contains Depleted Uranium	Contains Hazardous Materials	Prelim. Hazards Classification (Rad/Chem)*	Construction Type
Process Building	101,000	2	Yes	Yes	HC2 / HH	Reinforced Concrete
HF Storage Building	10,500	1	No	Yes	NA/HH	Reinforced Concrete
UO_2 Storage Bldg	11,250	1	Yes	Yes	HC2 / MH	Metal Frame
CaF_2 Storage Bldg	1,800	1	No	No	General	Metal Frame
Outgoing Empty Cylinder Storage Building	112,200	1	Yes	Yes	HC3 / MH	Metal Frame
Utilities Building	22,500	1	No	Yes	General	Metal Frame
Administration Building	10,000	1	No	No	General	Metal Frame
Maintenance Shop	8,000	1	No	Yes	General	Metal Frame
Warehouse	9,000	1	No	Yes	General	Metal Frame
Industrial Waste Building	6,000	1	No	Yes	General	Metal Frame
Sanitary Waste Bldg	2,400	1	No	No	General	Metal Frame
Sludge Loading Bldg	1,260	1	No	No	General	Metal Frame
Cooling Tower	15,000	---	---	---	---	---

* HC2 = Hazard Category 2 (moderate radiological hazard)
HC3 = Hazard Category 3 (low radiological hazard)
HH = High Hazard (high chemical hazard)
MH = Moderate Hazard (moderate chemical hazard)

2.1.3.1 Process Building

The Process Building equipment layout and section are shown in Figures 2-3 and 2-4. The building is a two-story reinforced concrete structure classified radiologically as a category HC2 moderate hazard facility and chemically as a category HH high hazard facility where significant quantities of UF_6 and HF are present. These hazards classifications are preliminary as currently defined by DOE-STD-1027-92 and UCRL-15910. The first floor contains the feed receiving and product shipping areas, the processing and process support system areas, maintenance and chemical storage areas, personnel entry control, change rooms, offices and health physics areas and an analytical laboratory and facility control room. The second floor primarily contains mechanical support systems such as the heating, ventilating and air conditioning systems and emergency electric power systems. HVAC system design is described in Section 2.2.5.

2.1.3.2 HF Storage Building

Due to the presence of a large inventory of HF, the HF Storage Building is classified as a nonradiological, chemically high hazard (HH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is a one-story reinforced concrete structure providing space for tanks that store one month's production of HF. The facility is provided with a rail car loading bay and space for the required storage tanks. An air refrigeration system is provided to maintain temperatures in the building in the range of 45 to 55°F to limit vaporization of HF in the event of a spill. Also, a water spray system and floors surrounded by dikes are provided to mitigate the effects of an HF spill.

2.1.3.3 UO_2 Storage Building

The UO_2 Storage Building is a one-story metal frame structure classified as a radiologically moderate hazard (HC2) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for one month's production of UO_2 and grouted waste. A zone 2 HVAC system with filtered exhaust air is provided (See also Section 2.2.5).

2.1.3.4 Outgoing, Empty Cylinder Storage Building

The Outgoing, Empty Cylinder Storage Building is a one-story, metal frame structure classified as a radiologically low hazard (HC3) and chemically moderate hazard (MH) facility as defined by DOE-STD-1027-92 and UCRL-15910. The building is primarily a warehouse which provides space for three months storage of old, empty, cylinders during radiological "cooling". Since the building is a restricted area with very limited personnel access, the only utilities provided are roof ventilators and lighting.

2.1.3.5 Miscellaneous Support Buildings and Facilities

In addition to the process facilities described in the sections above, the Gelation / Ceramic UO_2 Facility includes the following facilities and systems shown on Site Map Fig. 3-1 or in the support system equipment list in Appendix B.

A metal frame CaF_2 Storage Building for storage of one month's production of CaF_2.

A metal frame Sludge Loading Building for housing organic sludge waste loading operations.

A metal frame general use Utilities Building housing raw water treatment systems, water storage tanks, fire-water pumps, central chilled water cooling and steam heating boiler systems.

A metal frame or masonry Administration Building to house the facility support personnel.

A metal framed general use Maintenance Shops Building for housing clean maintenance and repair shops.

An 150 MM BTU/hr multiple cell, wood construction, induced draft, crossflow type cooling tower and a 15,000 gpm cooling tower water circulation system to provide cooling for both the process and HVAC systems.

A Warehouse provides storage space for materials, spare parts, and other supplies.

An Industrial Waste Treatment Building for the receipt, treatment and disposal of noncontaminated chemical, liquid and solid wastes other than liquid wastes disposed of through the sanitary waste system. Utility wastewater discharges, including cooling tower and boiler blowdown and cold chemical area liquid effluents will be treated and discharged in this facility to assure that wastewater discharges meet applicable environmental standards.

A Sanitary Waste Treatment Building with a capacity of approximately 6,400 gpd.

Compressed air systems including plant air, instrument air and breathing air. A single set of two redundant 500 cfm reciprocating air compressors provide compressed air to both systems. The plant air system is provided through a receiver set at 100 psig. Instrument air is dried in dessicant type air dryers to a dew point of -40 °F and is supplied to a piping distribution system from a separate air receiver set at 100 psig. A separate breathing air compressor and receiver provide air to breathing air manifold stations in areas with potential for radiological or hazardous chemical contamination.

An 11,000 cfh hydrogen supply system consisting of two 25,000 gal steel ammonia storage tanks and one ammonia dissociator to supply hydrogen to the UO_2 sphere sintering furnaces.

Four HMTA silos, two urea silos, one lime silo and one cement silo are located in the yard. Two nitric acid storage tanks and one liquid nitrogen storage tank are provided.

Building heating, ventilating and air conditioning (HVAC) systems use a central chilled water system for building cooling. Three 50% capacity, 625 ton centrifugal water chillers, and three 1000 gpm circulating pumps are provided.

A steel stack serving the Process Building HVAC exhaust systems is provided. The steam plant boiler vents through a dedicated steel stack. (See Table 2-3 for stack dimensions).

All cooling water systems are connected to the cooling tower system described above.

A central steam plant is provided in the Utilities Building to produce steam for process uses and for building heating by the HVAC systems. The plant produces 190,000 lb/hr of 50 psig steam which is distributed around the site by outside overhead piping.

Raw water treatment and demineralized water systems are provided. Raw water treatment consists of water softening, filtration and chlorination. The demineralized water is used in the process and for steam boiler feedwater (See also Figure 5-1). A tempered water system to control temperatures in U_3O_8 dissolution and ADUN denitriting vessels is also provided

The site receives electric power at 13.8 kV from the utility grid system and distributes it on site at the required voltages. The Electrical Substation has a design capacity of 13,000 kW and includes the primary switching and voltage transformer facilities for the site. The electrical system also includes two, redundant, 1000 kW emergency power diesel generators, housed in a seismic and tornado-resistant structure, to ensure the operation of all safety systems during a power outage. Uninterruptible power supply (UPS) systems are provided for the control system to ensure continued operation of safety equipment and systems during a power outage.

Yard lighting is provided to allow 24-hour operations. Specific areas which require special lighting for nightime operation include the UF_6 cylinder storage pad areas, the railcar spur area, the utility area and the site entry control area.

Site security fencing as shown on Site Map, Figure 3-1, consists of galvanized steel fabric fencing with barbed wire or barbed tape coil topping, per DOE Order 6430.1A, Section 0283.

2.2 DESIGN SAFETY

The facility is designed with features to prevent, control and mitigate the consequences of potential accidents. The facility design uses a defense-in-depth approach to protect workers, the public and the environment from a release of radioactive or hazardous materials.

The facility design includes systems, structures, and components that serve as:

- Barriers to contain uncontrolled hazardous material or energy release.
- Preventive systems to protect those barriers.
- Systems to mitigate uncontrolled hazardous material or energy release upon barrier failure.
- Systems that monitor released material.

Table 2-2 summarizes the significant mitigating design safety features provided for plant facilities. Section 8.1 describes these features in more detail for bounding accident scenarios.

Table 2-2, Mitigating Safety Design Features

Building Name	HVAC Zoning	Exhaust Filtration	Structural Design	Other
Process Building	Zone 1 - High Hazard Areas Zone 2 - Moderate Hazard Areas	Zone 1- Single HEPA Filters Zone 2-Single HEPA Filters	PC-4 for High Hazard Areas (Design for DBE & DBT) PC-3 for Moderate Hazard Areas PC-2 or 1 for Low Hazard Areas	Water Spray System for UF_6 Reactor and HF Distillation Areas
UO_2 Storage Building	Zone 2 - Moderate Hazard Building	Single HEPA Filters	PC-3 for DBE & DBT	
HF Storage Building	Zone 1 - High Chemical Hazard	Conventional	PC-4 for High Hazard Areas	Automatic water spray and shutdown of HVAC system upon HF leak
Outgoing, Empty Cylinder Storage Building	NA	NA	PC-2 for Low Hazard Areas	Restricted Access
NH_3 Storage Tanks	NA (Located Outdoors)	NA	Per ANSI Std. K61.1, Section 5.2	Vehicle Barriers, Diked Area, Emergency Equip., etc. per ANSI Std. K61.1
Overall Site	NA	NA	NA	Site Environmental Monitoring / Alarm System

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the facility design and are treated as design basis events:

- Earthquake
- Tornado
- Flooding

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the generic site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures and components (SSC's) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake

The design basis earthquake (DBE) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. All safety class systems, structures, and components (SSCs) will be designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.2 Tornadoes

The design basis tornado (DBT) for the plant facilities will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.1.3 Floods

The design basis flood (DBF) for the plant will be chosen in accordance with DOE-STD-1020-94 and UCRL-15910. Buildings housing hazardous materials will be designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

2.2.2 Fire Protection

The requirements for fire protection for the facility are contained in DOE 6430.1A, General Design Criteria; DOE 5480.4, Environmental, Safety and Health Protection Standards; and DOE 5480.7, Fire Protection.

The facility fire protection systems design will incorporate an "improved risk" level of fire protection as defined in DOE 5480. 7. This criteria requires that the facility be subdivided into fire zones and be protected by fire suppression systems based on the maximum estimated fire loss in each area. Fire protection systems and features are designed to limit this loss as specified in DOE 6430.1A. A fire protection design analysis and a life safety design analysis will be performed in accordance with DOE 6430.1A and 5480.7 to determine fire zoning requirements and fire protection systems required for the facility. Redundant fire protection systems are required to limit the maximum possible fire loss and to prevent the release of toxic or hazardous material. All fire protection systems are designed in accordance with National Fire Protection Association (NFPA) Codes. The following fire protection systems and features are provided:

- All buildings are subdivided by fire rated barriers to limit the maximum possible fire loss and to protect life by providing fire rated escape routes for operating personnel.
- Automatic fire sprinkler systems are used throughout the facilities.
- Fire detection and alarm systems are provided in all buildings.
- A site-wide fire water supply system with a looped distribution main and fire hydrants for building exterior fire protection is provided.

2.2.3 Materials Accountability and Plant Security Protection

Measures will be provided for depleted uranium materials accountability (per DOE Order 5633.3) and to protect the plant radiological and hazardous materials from unauthorized access and removal, including depleted uranium material accounting and reporting procedures, facility fencing, guard posts, and security surveillance and alarm systems.

2.2.4 Confinement and Containment

The design of facilities housing radioactive uranium and hazardous chemicals includes a system of multiple confinement barriers to minimize releases of radioactive and hazardous materials to the environment.

The primary confinement system consists of the uranium and HF containers, process vessels, piping, gloveboxes, and the facility ventilation systems. Gloveboxes are provided where uranium powders or hazardous chemicals pose a potential for release (i.e., UO_2 calcining and drum loading operations, UF_6 sampling stations, etc.).

The secondary confinement system consists of the structures that surround the primary confinement system and the facility ventilation system.

The final hazards classification, performance categories, and zone designation of these systems and associated design details will be determined during later design phases in accordance with DOE-STD-1020-94 and UCRL-15910.

2.2.5 Ventilation Systems

The HVAC systems will utilize a combination of dividing the buildings into zones according to level of hazard, space pressure control and filtration of building air to isolate areas of potential radiological and hazardous chemical contamination.

The buildings will be divided into three ventilation zones according to potential for uranium contamination: zone 1 for areas of high potential contamination hazard, zone 2 for areas of moderate to low potential for contamination, and zone 3 for general areas with no potential for contamination. All areas of the building will also be classified as having high, moderate or low potential for hazardous chemical contamination.

Zone 1 areas of the Process Building will utilize autoclaves for confinement of DUF_6 if a cylinder is breeched or a leak develops during the transfer, once-through ventilation systems to prevent recirculation of contaminants, single filtration for building exhaust air through HEPA filters to prevent the release of radioactive particulate, and pressure control to assure air flow from areas of low hazard to areas of higher hazard.

Zone 2 areas include rooms containing gloveboxes, and other uranium processing areas. The ventilation system for these rooms utilize once-through air flow to prevent recirculation of contaminants, single filtration of exhaust air through HEPA filters and pressure control to assure air flow from areas of low hazard to areas of high hazard. The UO_2 Storage Building will also be treated as a zone 2 area.

The remainder of the Process Building will be zone 3, including grouting areas, CaF_2 areas, waste processing areas, chemical feed storage and preparation rooms, and support system areas. These rooms will be maintained at a positive pressure with respect to the rest of the building, but slightly negative with respect to the outside. The HVAC for the Process Building is based on six air changes per hour and once-through ventilation. The ventilation systems for certain small areas (personnel change rooms and offices) will use conventional recirculating air conditioning systems sized based on cooling and heating loads.

The UF_6 reactor, HF distillation and off-gas scrubbing areas of the Process Building and the HF Storage Building have high chemical hazard potential and will be served by separate once-through air conditioning systems. HF monitors in these areas will automatically shut down the ventilation system and isolate the room or building area in the event of a HF leak.

2.2.6 Effluent Release Points

Facility effluent release points include both liquid and gaseous releases to the environment. Due to the generic nature of the site, a single hypothetical liquid release point has been shown on the Site Map, Figure 3-1. This figure also shows the effluent air release point ventilation and boiler stacks. A small flare mounted at the top of the Building Exhaust Stack burns hydrogen gas purged from sphere sintering. There are no pollutants from the flare. Table 2-3 summarizes the facility effluent air release points.

Table 2-3 Facility Air Release Points

Stack	Height (ft)	Diameter (in)	Temperature (°F)	Flow Velocity (ft/sec)
Bldg. Exhaust	100	144	80	60
Boiler	100	80	500	60

3.0 Site Map and Land Use Requirements

3.1 Site Map

The facility site map is shown in Figure 3-1. The site is surrounded by a facility fence with a single entry control point for normal access of personnel and vehicles. A rail spur is provided for shipment of DUF_6 cylinders and chemical feeds to the facility and UO_2, HF, waste sludge, grout, and CaF_2 from the facility. Air emission points are shown from the Process Building ventilation exhaust stack and the facility boiler stack. The site liquid effluent discharge point is shown for the assumed generic greenfield site. The location of these site discharge points will require adjustment during later site-specific EIS studies. Though not always shown in the figures, buildings have truck bays and access roads as needed.

3.2 Land Area Requirements During Operation

As shown in Figure 3-1, the total land area required during operations is approximately 888,000 ft^2 or about 20.4 acres.

3.3 Land Area Requirements During Construction

Figure 3-2 shows the site map during construction. Land area requirements during construction are approximately 30.6 acres. Construction areas required in addition to the site structures and facilities include:

- A construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for control of surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuels.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

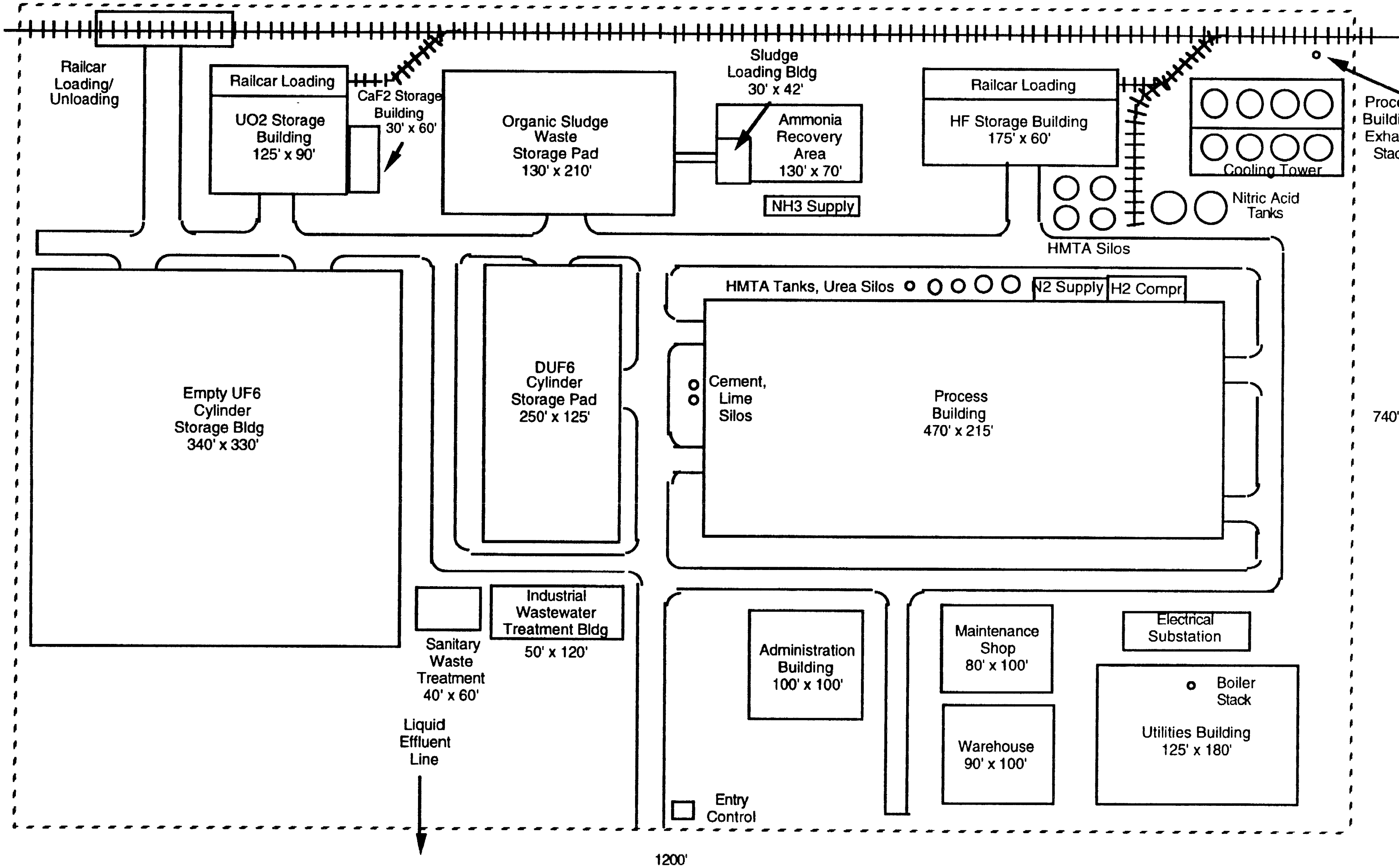


Figure 3-1 Site Map
Gelation / Ceramic UO2

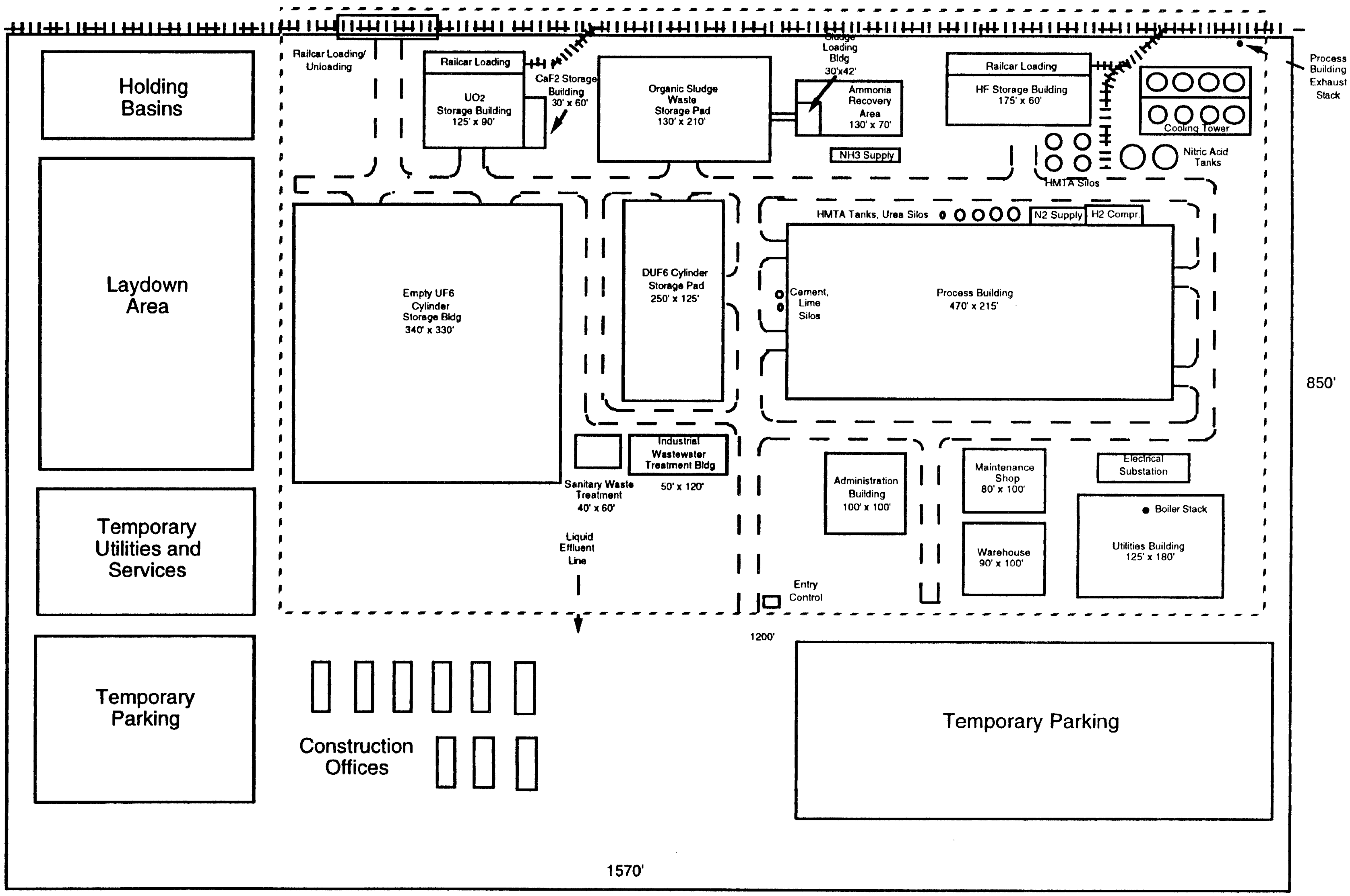


Figure 3-2 Site Map During Construction
Gelation / Ceramic UO2

4.0 Process Descriptions

Depleted uranium hexafluoride (UF_6) is processed to produce uranium dioxide (UO_2), calcium fluoride (CaF_2) and anhydrous hydrofluoric acid (HF). The CaF_2 and HF are of sufficient purity to be sold commercially. Impurities (primarily uranium byproducts) from the process are grouted and disposed of as low level waste. The process is summarized in Figures 4-1 and 4-2. Process flow diagrams, Figures 4-3 to 4-20, are found at the end of Section 4. The material balances are given in Appendix A. The process equipment is listed in Appendix B.

The UF_6 is first converted to U_3O_8 in a two-step process. The UF_6 is vaporized using steam heated autoclaves and fed to Reactor No. 1, where it is mixed with 45% HF-water vapor. Solid UO_2F_2 is produced and flows to Reactor No. 2. Vapor containing HF and water flows to the HF distillation column. In the second reactor, the UO_2F_2 is mixed with steam to produce solid U_3O_8. Vapor containing HF, water and oxygen flows to the HF distillation column. The U_3O_8 is discharged from the reactor, cooled, and transferred to U_3O_8 dissolution.

The HF distillation column receives feed from Reactors No. 1 and 2. The column purifies the HF to produce anhydrous HF. The HF product is pumped to storage tanks and loaded into railroad tank cars for delivery to customers. The distillation column bottoms stream is collected, vaporized and recycled to Reactor No. 1. Uncondensed off-gas from the distillation column flows to the scrubber system.

The HF in the off-gas is removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) to regenerate the potassium hydroxide and to remove the fluoride by precipitating calcium fluoride. The solid CaF_2 is separated by filtering, washed with water, dried and packaged in drums. The potassium hydroxide filtrate is evaporated to remove excess water and is reused as scrub solution.

To prevent the buildup of uranium and other impurities in the HF distillation column bottoms stream that is recycled to Reactor No. 1, a small purge stream is continuously withdrawn. This purge stream is neutralized with hydrated lime, and mixed with cement and water to form a grout. The solid waste grout is packaged in drums and disposed as low level waste.

The U_3O_8 is dissolved in nitric acid to form an acid deficient uranyl nitrate solution (ADUN). The dissolver off-gas is treated by water absorption and catalytic reduction with ammonia injection to reduce the nitrogen oxide concentration for discharge to atmosphere. The water absorber effluent containing recovered nitric acid is recycled to dissolution. The ADUN is mixed with urea and agitated to reduce the concentration of nitrites.

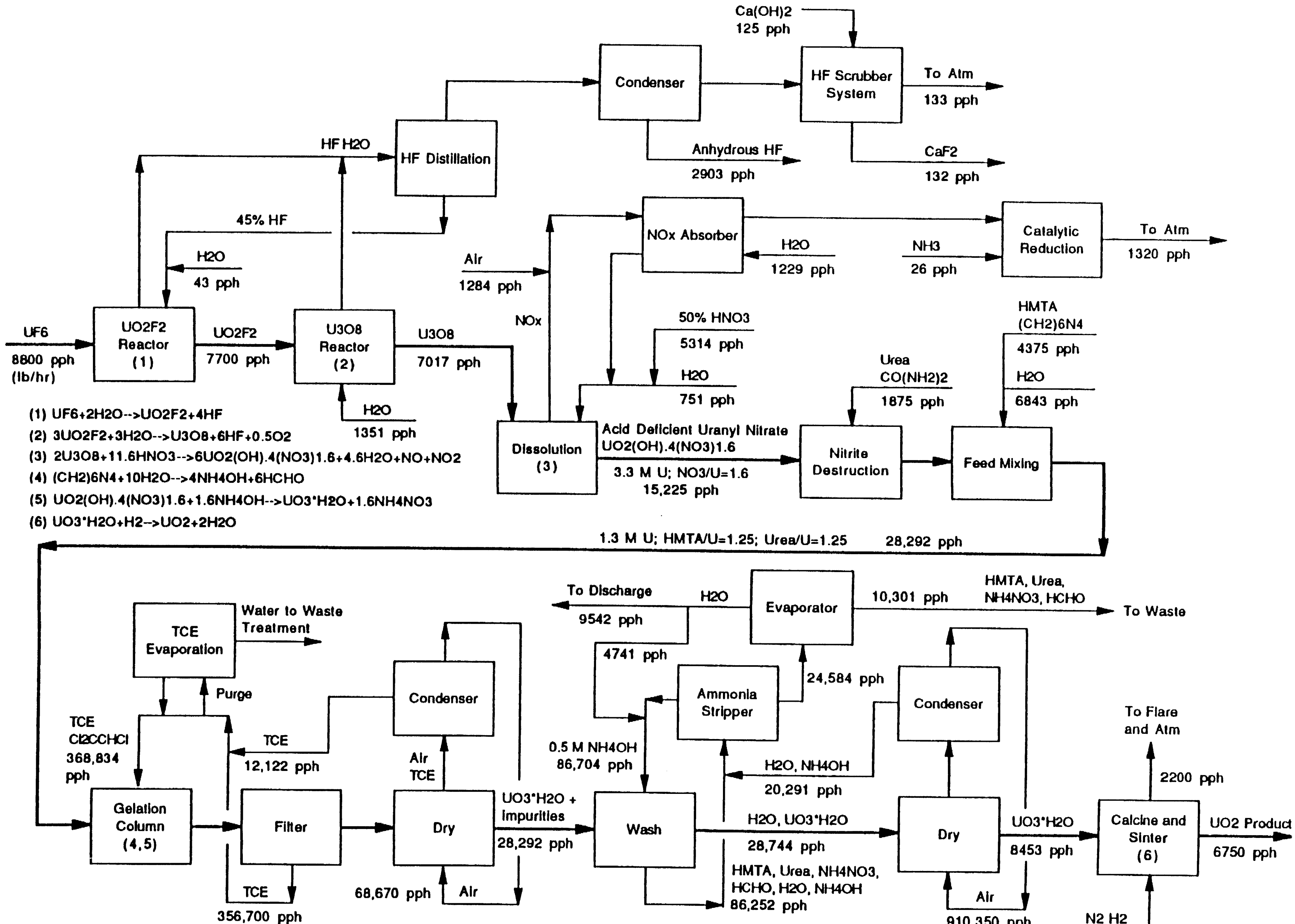


Figure 4-1 Ceramic UO2 by Gelation Block Flow Diagram

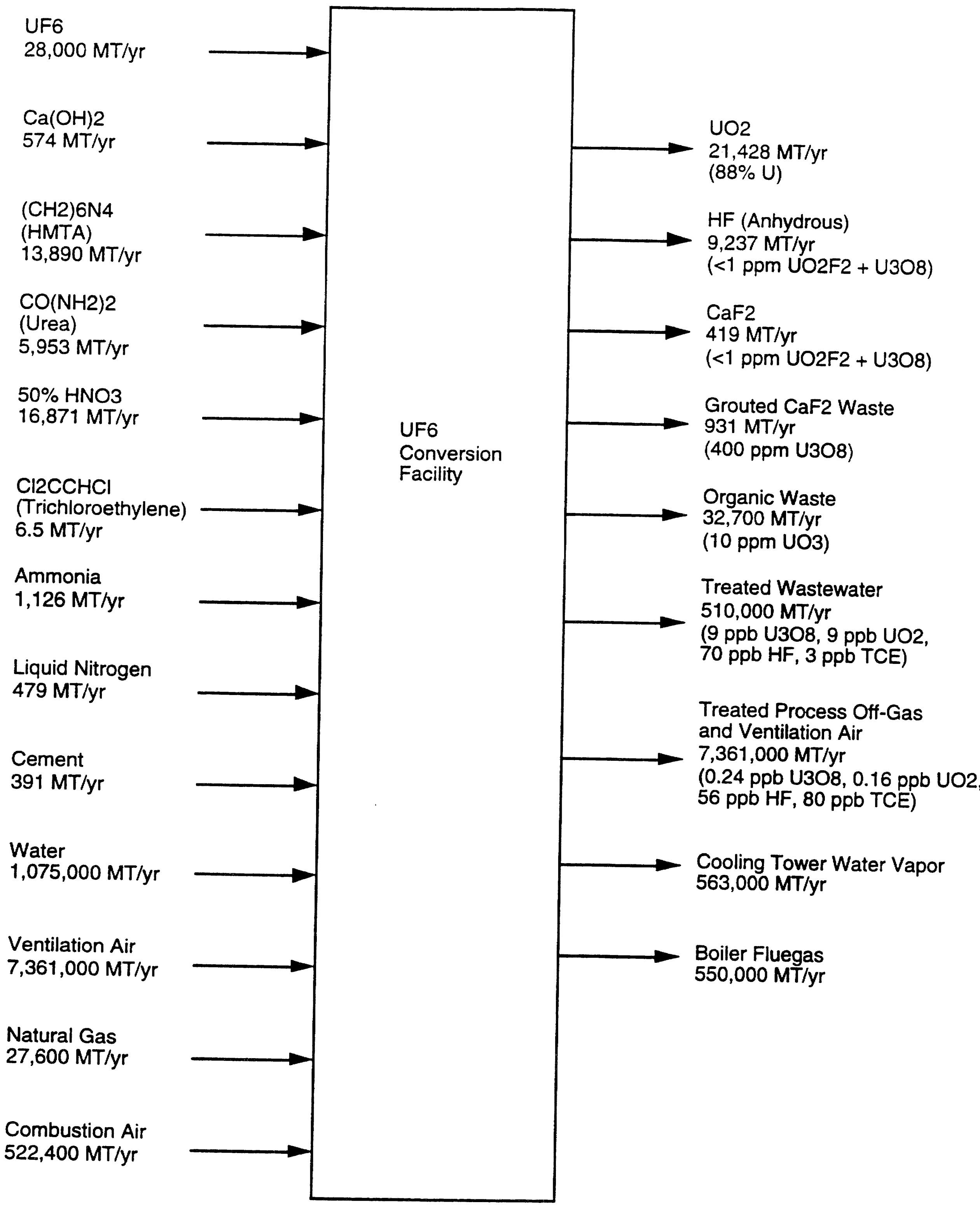


Figure 4-2 Ceramic UO2 by Gelation Input/Output Diagram

The denitrited ADUN is cooled and mixed with cold hexamethylene-tetramine (HMTA) solution to form a feed broth. The broth is fed to gelation columns through nozzles which break up the feed stream into small droplets. The droplets form UO_3 gel spheres as they sink in gelation columns filled with hot trichloroethylene (TCE). Gelation columns are provided for producing 1200 and 300μ diameter spheres. The spheres are filtered and dried to separate the TCE, which is recycled to the columns.

The spheres are washed with an ammonia solution and dried. An ammonia stripper recovers ammonia from the wash solution and dryer exhaust gas condensate, and recycles the ammonia solution to washing. The stripper bottoms is evaporated to produce a sludge containing urea, HMTA, ammonium nitrate and formaldehyde. The sludge is loaded into bulk containers and disposed as sanitary waste.

The dried spheres are heated to drive off the remaining water, reduced in a hydrogen atmosphere to form UO_2, and sintered to form ceramic UO_2 spheres. The sintered UO_2 spheres are blended in a 70 wt% 1200μ, 30 wt% 300μ mixture to increase the bulk density to 9 g/cc, and the mixture is packaged in drums for shipment.

The facility has two reactor trains of UF_6 defluorination to U_3O_8 process equipment. Critical equipment such as a blowers or filters have spares installed in parallel. There are two lines of equipment for U_3O_8 dissolution, and multiple lines of equipment for gelation, washing, drying and sintering. Specific aspects of the conversion of UF_6 to U_3O_8 are based on a process patented by Sequoyah Fuels Corporation. Specific aspects of the conversion of U_3O_8 to UO_2 are based on flowsheet conditions developed at Oak Ridge National Laboratory.

4.1 CONVERSION OF UF_6 TO U_3O_8

Reactor No. 1 converts UF_6 feed into UO_2F_2 and HF by hydrolysis in a fluidized bed. The chemical reaction is $UF_6 + 2\,H_2O \longrightarrow UO_2F_2 + 4\,HF$. This system is shown in Figure 4-3.

Depleted UF_6 is received primarily in 14-ton cylinders. The cylinders are inspected and stored in the yard. Cylinders are transported into the Process Building, where they are placed in a steam-heated autoclave and hooked up to the reactor feed line. As necessary, the contents of a cylinder are sampled and analyzed. The solid UF_6 is vaporized by heating, and gaseous UF_6 is fed by compressor into a fluidized bed reactor containing UO_2F_2 particles. Eleven cylinders simultaneously feed the required UF_6 feed rate of 8,800 lb/hr. The bottoms stream from HF distillation and makeup water are vaporized in a steam-heated exchanger. This 45% HF-water vapor enters the bottom of the reactor and acts as the fluidizing gas. Water vapor reacts with the UF_6 to form solid UO_2F_2 and gaseous HF. The reaction is exothermic, and cooling water is provided to maintain the reactor at about 550°F. A small heater is provided for reactor start-up.

The solid UO_2F_2 flows from this reactor to Reactor No. 2. The HF-water vapor flows through a cyclone and sintered metal filter to remove UO_2F_2 particulates, which are discharged back into the reactor. The HF-water vapor flows to the HF distillation column. A small purge stream is discharged from the vaporizer to prevent buildup of uranium and impurities. This stream is sent to the waste grouting system. After cooling, the empty UF_6 cylinders are removed and transported to the Empty Cylinder Storage Building.

Reactor No. 2 converts UO_2F_2 into U_3O_8 and HF in a rotary kiln. The chemical reaction is $3\ UO_2F_2 + 3\ H_2O \rightarrow U_3O_8 + 6\ HF + 0.5\ O_2$. This system is shown in Figure 4-4.

Solid UO_2F_2 from Reactor No. 1 flows into the rotary kiln, where it reacts with steam to form solid U_3O_8 and gaseous HF and O_2. The reaction is endothermic, and the kiln is indirectly heated with natural gas to maintain the temperature at about 900°F. The solid U_3O_8 is discharged from the reactor, cooled and conveyed to U_3O_8 Dissolution (Section 4.5).

The HF, oxygen and water vapor flow through a cyclone and sintered metal filter to remove U_3O_8 particulates, which are discharged back into the reactor. The off-gas vapor flows to the HF distillation column.

4.2 HF Distillation

The hot off-gas and vapor from the reactors flow to a distillation column for HF purification and recovery. The system is shown in Figure 4-5.

The vapor is first quenched with distillation column bottoms to cool the superheated vapor to its saturation temperature. The saturated vapor is fed to the column, which produces an anhydrous HF overhead product at 67°F containing about 200 ppm water, and a 45 wt% HF bottoms stream at 230°F that is recycled to Reactor No. 1.

The overhead product is condensed in a chilled water condenser at 40°F, collected and sampled. Upon satisfactory analysis, the HF is pumped through an underground pipeline to storage tanks in the HF storage building. The HF is then loaded into railroad tank cars or tank trucks for shipment to customers.

The noncondensible gases, primarily oxygen, pass through a -20°F refrigerated condenser to recover additional HF. The gases then flow to the HF scrubbing system.

4.3 HF Scrubbing System

Off-gas from HF Distillation is treated in a scrubber to reduce atmospheric releases of HF to acceptable levels. The HF is recovered and converted to solid CaF_2 product for sale. The system is shown is Figure 4-6.

The off-gas enters a packed column, where it is contacted with a potassium hydroxide (KOH) scrub solution. The HF is removed by the reaction $HF + KOH \rightarrow KF + H_2O$. The spent scrub solution is collected in a precipitation tank, where hydrated lime is added to remove the fluoride and regenerate the KOH by the reaction $2\ KF + Ca(OH)_2 \longrightarrow CaF_2 + 2\ KOH$. A minimum level of KF is maintained in the scrub solution by adding less than the stoichiometric quantity of lime. This ensures all the lime reacts, which keeps solid lime out of the CaF_2 product and the packed bed scrubber.

The scrub solution slurry is filtered in a rotary drum vacuum filter to remove the solid CaF_2 precipitate. The CaF_2 is washed with water to remove impurities and dried in a steam-heated rotary dryer. After cooling, the CaF_2 is packaged in drums and sent to the warehouse for storage. The KOH filtrate and spent wash water are collected, and a side stream is withdrawn and evaporated to remove the water formed by the scrubber chemical reaction and the water added for CaF_2 washing. The scrub solution is then cooled and pumped back to the scrubber.

4.4 WASTE GROUTING

The blowdown stream from the vaporizer to Reactor No. 1 is converted into a solid grout for disposal. The blowdown stream, containing HF, water, uranium and impurities, is neutralized with hydrated lime. The main reaction is $2\ HF + Ca(OH)_2 \longrightarrow CaF_2 + 2\ H_2O$. The slurry is then mixed with cement and water in a drum to form a grout. After solidification, the waste drums are transported to the warehouse for storage, and then sent to a low level waste disposal site. The composition of the grout is 42% cement, 38% H_2O, 20% CaF_2, and 0.04% U_3O_8. The system is shown in Figure 4-7.

4.5 U_3O_8 DISSOLUTION AND OFF GAS TREATMENT

Process flow diagrams for U_3O_8 dissolution and off-gas treatment are shown on Figures 4-8 and 4-9.

U_3O_8 from the Product Bin (Section 4.1) is transferred to the U_3O_8 Storage Bins. Dissolution is carried out at 60°C in two parallel lines operating on staggered 6 hour batch cycles. U_3O_8 is weighed into the dissolver, followed by a predetermined quantity of cold nitric acid. Per the following dissolution equation, the acid is added in a slightly deficient stoichiometric quantity.

$$2\ U_3O_8 + 11.6\ HNO_3 \longrightarrow 6\ UO_2(OH)_{0.4}(NO_3)_{1.6} + NO + NO_2 + 4.6\ H_2O$$

Some nitrite is formed in the dissolver by the following reaction.

$$H_2O + NO_2 + NO \longrightarrow 2\ HNO_2$$

Dissolution is initiated and the rate is controlled by heating, then cooling as needed to remove reaction heat, with a tempered water jacket on the dissolver vessel. Since the U_3O_8 is produced from vaporized UF_6, there should be few insoluble impurities, and dissolution should be rapid and complete. However, to allow for any possible insoluble U_3O_8, a filter is placed in the effluent line from the dissolver. Part of the acid charge is used to backwash any such material back into the dissolver to give it longer exposure to dissolution in the next batch. Dissolver off-gas passes through a reflux condenser, and then to NOx absorption.

The acid deficient uranyl nitrate (ADUN) from the dissolver goes to denitriting tanks, where a 24 hour treatment with urea destroys the nitrite content. Four denitriting tanks are required. The nitrite is detrimental because it would react with urea during gelation and cause gel spheres to crack. Excess urea is added to complex the uranium, which controls the rate of reaction during gelation. The denitriting reaction is as follows:

$$2\ HNO_2 + CO(NH_2)_2 \dashrightarrow CO_2 + 2\ N_2 + 3\ H_2O$$

Air for oxidation of NOx is added to the dissolver off-gas stream, and the mixture fed to the NOx Absorber for NOx removal and HNO_3 recovery. The following are the overall reactions taking place in the absorber.

$$2\ NO + O_2 \dashrightarrow 2\ NO_2$$
$$3\ NO_2 + H_2O \dashrightarrow 2\ HNO_3 + NO$$

These reactions generate heat that is removed by cooling water coils on the absorber trays, and by recirculating cooled absorber bottoms over the bottom trays.

Complete removal of NOx by aqueous absorption is not economical at near atmospheric pressure. However, environmental regulations can be met by adding an abatement step on the absorber overhead using ammonia over a zeolite catalyst. This step has been included. Temperature rise in the catalytic reactor is controlled by recycling cooled treated off-gas through the reactor. The following reactions take place:

$$6\ NO + 4\ NH_3 \dashrightarrow 5\ N_2 + 6\ H_2O$$
$$6\ NO_2 + 8\ NH_3 \dashrightarrow 7\ N_2 + 12\ H_2O$$
$$3\ O_2 + 4\ NH_3 \dashrightarrow 2\ N_2 + 6\ H_2O$$

Treated off-gas is filtered and discharged to the atmosphere.

4.6 GELATION COLUMN FEED

ADUN solution and HMTA solution are mixed to form a feed broth, which is fed to the Gelation Columns. The makeup and feed system is shown on Figure 4-10.

ADUN solution is transferred from the Denitriting Tanks to Storage Tanks. The ADUN is cooled to 0°C and fed by metering pump to an inline mixer. A 3*M* HMTA solution is prepared by dissolving HMTA solids with cold water in an agitated tank. The HMTA solution is cooled to 0°C and fed to the inline mixer, where it mixes with the ADUN solution. There are two metering pumps, one inline mixer and one feed line for each gelation column. The solutions are cooled to prevent gelation from occurring in the feed system and to control the reaction rate in the gelation column.

4.7 GELATION SYSTEM

Feed broth is fed to the gelation columns, where UO_3 gel spheres form in hot trichloroethylene (TCE or Cl_2CCHCl). The gel spheres are filtered and dried with air to remove the TCE. The TCE is collected and recycled to the Gelation Column. The dry spheres are transferred to washing. Two gel sphere sizes are produced, 1200 micron and 300 micron. The gelation system is shown on Figures 4-11 and 4-12.

To produce high quality gel spheres, the feed broth composition must be controlled within a relatively narrow range. The feed broth is 1.3*M* uranium with molar ratios of $NO_3/U = 1.6$, urea/U = 1.25 and HMTA/U = 1.25. The 0°C feed broth is fed to a gelation column through a feed pipe assembly with multiple orifices. The assembly is vibrated to shear off droplets, which fall into the gelation column filled with TCE at 60°C. The feed droplets are converted to gel spheres as they settle in the column, which requires about 6 ft of column height and takes about 30 seconds. As the droplets settle, they are heated by the TCE, which causes the HMTA to decompose to ammonium hydroxide and formaldehyde. The chemical reaction is:

$$(CH_2)_6N_4 + 10\ H_2O \text{---}> 4\ NH_4OH + 6\ HCHO$$

The ammonium hydroxide then reacts with the ADUN to form a hydrated UO_3 complex. A simplified chemical reaction, used for the mass balance, is:

$$UO_2(OH)_{.4}(NO_3)_{1.6} + 1.6\ NH_4OH \text{---}> UO_3{*}H_2O + 1.6\ NH_4NO_3$$

Hot TCE is fed to the column to provide heat and to compensate for the TCE exiting the column with the gel spheres.

The gel spheres settle at the bottom of the column, where they are aged for 20 minutes to allow the gelation reaction to go to completion. The aged spheres along with TCE are continuously discharged from the column to a screen filter, which separates TCE from the gel spheres. The wet spheres are fed to a continuous dryer, where the TCE is evaporated with hot air. The dry spheres are collected and conveyed to the washing system.

The dryer exhaust air is cooled in two condensers in series to remove the TCE. The first condenser operates at 0°C, and the second at -29°C (-20°F). The air is then heated to 80°C and returned to the dryer. The TCE from filtration and condensation is collected, heated and returned to the Gelation Column.

A small stream of air is purged from the dryer air system to prevent buildup of impurities. This purge air stream is sent to carbon adsorption. As necessary, TCE is sent to the evaporation system to remove impurities.

A small amount of surfactant (Span 80, a sorbitan monooleate ester from Atlas Powder Co.) is added to the gelation columns to prevent the spheres from sticking to the column and to each other. Surfactant is continuously added to the 300μ columns. The 1200μ columns only require periodic addition of surfactant. Separate gelation systems are provided for producing 1200μ spheres and 300μ spheres. Based on the required throughput, four parallel systems are provided for 1200μ spheres and six systems are provided for 300μ spheres.

4.8 TCE EVAPORATION

TCE from gelation is purified by evaporation and purge air from drying is treated for release. These systems are shown on Figure 4-13.

TCE is continuously recycled in the gelation system. Over time, impurities and TCE degradation products can build up. As needed, the TCE is purified by sending it to a forced-circulation evaporator. The TCE is vaporized, condensed and drained to a decanter, where the TCE is separated from aqueous impurities. The clean TCE is returned to gelation. A small amount of fresh TCE is added to make up for losses. High boiling heel in the evaporator is periodically discharged into drums and is disposed of as mixed waste.

The aqueous stream, primarily water, is fed to an air stripping column, which removes residual TCE. The water effluent is sent to disposal. The air containing TCE vapor is treated in a carbon adsorption column to remove the TCE and the air is released to atmosphere. Purge air from the gel sphere dryers is also fed to the carbon adsorbers. When the carbon adsorber is saturated, the carbon is regenerated by feeding steam into the adsorber. The steam vaporizes the TCE, and the gasous mixture is condensed and drains to the decanter.

4.9 SPHERE WASHING AND DRYING

Gel sphere washing and drying is shown on Figures 4-14 through 4-17. The wash effluent treatment process is shown on Figure 4-18.

The 1200 and 300 micron spheres from gelation are washed and dried separately, but in identical equipment, and by identical processes. Four parallel trains are required for 1200 micron spheres, and two trains for 300 micron spheres. Wash and drying equipment was selected to minimize physical damage to the spheres such as deformation, fracture, or abrasion. Such damage could defeat the objective of a high bulk density gained by combining these two specified sphere sizes and amounts. The washing is necessary to remove byproducts such as ammonium nitrate, which would cause the spheres to crack during sintering.

Spheres are washed countercurrently by a 0.5 *M* ammonia solution. Three volumes of solution are contacted with one volume of spheres in a slightly sloped rotating pipe containing an internal helix that advances the spheres countercurrently against the flow of wash solution. The wash is assumed to remove 99.9% of the impurities on the spheres.

Continuous drying is accomplished on a screen that carries the spheres through three drying zones, countercurrently contacting a flow of heated air passing downward through the screen. Moisture is removed from the spheres by adiabatic cooling of the air from 200 to 136°F. The air is assumed to reach a relative humidity of 70% in drying the spheres to a moisture content of 10%. The humid air is cooled to condense the water and ammonia removed from the spheres, reheated, and recirculated in a closed loop.

Wash water and condensates are collected and steam stripped to recover and recycle ammonia. Stripper bottoms are sent to an evaporator, concentrated to about 95% solids and 5% water, loaded into bulk containers, and sent to sanitary waste storage. The composition of this sludge is approximately 31% ammonium nitrate, 29% HMTA, 18% urea, 17% formaldehyde (assumed to be polymerized), and 5% water. The properties of this sludge concentrate are not known, but it would probably foul the heat transfer surfaces of most heat exchange equipment. For this reason, wiped film evaporators were specified for the application.

The properties of this waste stream even at higher water concentrations could create processing problems. Formaldehyde is known to polymerize even in the gaseous state. The material balance assumes it to polymerize when heated in the ammonia stripper. The solubility of the polymer, and its behavior on heat transfer surfaces is speculative. Formaldehyde also forms polymers with urea whose properties in this environment have not been studied. One favorable effect of formaldehyde polymerization might be to decrease the toxicity of the waste.

A method to minimize the large sludge waste stream and to recycle the HMTA and urea was considered, but was not implemented in this report because further research and confirmation is required. A reference (J. F. Walker, *Formaldehyde*, 1964, p. 235) describes the reaction of formaldehyde with caustic in ammonium salt solutions to form HMTA. The reaction is:

$$6\ HCHO + 4\ NH_4NO_3 + 4\ NaOH \longrightarrow (CH_2)_6N_4 + 4\ NaNO_3 + 10\ H_2O$$

This suggests treating the waste stream with excess caustic, which consumes the formaldehyde and ammonium nitrate, and produces HMTA and sodium nitrate. The solubilities of $NaNO_3$, HMTA and urea in cold water are similar (70-100 parts/100 parts water), so crystallization would not separate them. The $NaNO_3$ and excess NaOH could perhaps be removed by a separation process such as reverse osmosis. Then a HMTA/urea mixture could be crystallized from the solution by evaporation. The HMTA and urea would be recycled to the gelation process as a mixed solution. Some fresh urea (or other reagent) must be added to denitrite the ADUN prior to

HMTA/urea addition. The amount of fresh urea required would be much less than the recycled urea.

4.10 SPHERE SINTERING AND BLENDING

Gel sphere sintering and blending operations are shown on Figures 4-19 and 4-20.

The 1200 and 300 micron spheres from Washing and Drying are sintered separately, in identical equipment and by identical processes. Eight parallel trains are required for 1200 micron spheres, and three trains for 300 micron spheres. As in other process steps, equipment was selected to minimize deformation, fracture, and abrasion of the spheres.

The spheres are loaded into large boats formed from firebrick to withstand the high temperatures required. The boats are mounted on mobile platforms that move sequentially through the following stations:

(1) Load boat.
(2) Heat to 450°C in 3 hours in 4% H_2. Soak for 1 hour.
(3) Heat to 1600°C in 3 hours in 75% H_2. Soak for 4 hours.
(4) Purge with 100% N_2 and cool under forced N_2 circulation for 3 hours.
(5) Unload boat and move to loading position in adjacent train. Adjacent trains are oriented in opposite directions to facilitate recycling of boats.

Steps 2, 3, and 4 are conducted in electrically heated, firebrick lined chambers accessed and egressed through movable refractory partitions. The mobile platforms supporting the boats form a seal between the three high temperature chambers and the suspension system carrying the platform and boat. This seal is purged with a small flow of 100% N_2 to prevent air inleakage to the chambers.

All gas streams to the various chambers are purged to a flare to assure combustion of the vented hydrogen. For safety the flare has a continuous pilot flame fueled with natural gas.

Cooled spheres are transferred to surge bins, from which the spheres are weighed into double cone blenders in a 70/30 weight ratio of 1200 to 300 micron material. After thorough blending, the mixture is loaded by weight into 30 gallon drums and shipped to storage.

The 75 vol% H_2 is produced by catalytic cracking of anhydrous ammonia by the following chemical equation.

$$2\ NH_3 \longrightarrow N_2 + 3\ H_2$$

The 4% H_2 (safe gas) is produced by batchwise blending of 75% hydrogen with 100% N_2 in a gasholder, from which it is compressed to a surge drum for distribution.

Nitrogen is purchased as the cryogenic liquid, vaporized, and compressed to a surge drum for distribution.

4.11 WASTE MANAGEMENT

The primary wastes produced by the process are organic sludge, empty UF_6 cylinders and vaporizer blowdown liquid. For this study, it is assumed that the empty DUF_6 cylinders are shipped off-site for treatment, disposal, or reuse without on-site treatment. The treatment of blowdown wastes and sludge was described in Sections 4.4 and 4.9.

Radioactive or hazardous material liquid waste includes decontamination liquids, laboratory liquid wastes, contaminated cleaning solutions, lubricants, paints, etc. Radioactive or hazardous material-contaminated solid waste from the process includes failed process equipment, failed or plugged sintered metal filters, dust collector filter bags, and HEPA filters. Other contaminated solid waste includes laboratory waste, wipes, rags, operator clothing packaging materials, etc.

The waste management operations are in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act.

Low level radioactive waste will be shipped to an off-site disposal facility. Mixed and hazardous waste will be shipped off-site for final treatment and disposal. Waste processing/packaging systems have been provided for minimal pretreatment prior to shipment (e.g. size reduction, compaction, grouting).

Liquid and gaseous effluents are treated as necessary to meet effluent standards and discharge permit limits. A decontamination waste treatment system and an industrial waste treatment system are provided. Domestic sanitary waste is treated in an onsite treatment facility. Nonhazardous solid waste is sent to a sanitary waste landfill.

4.12 UF_6 CYLINDER HANDLING SYSTEMS

Incoming, filled DUF_6 cylinders will be off-loaded from either rail cars or flatbed trucks by a yard crane. The crane will place the cylinder on a cart, which is towed to the storage area. The crane will then lift the cylinder off the cart and place it into a storage position. When a cylinder is to be transported to the Process Building, the yard crane will again load the cylinder on a cart, which is towed into the Process Building. Once the cylinders are in the autoclave area of the Process Building, the cylinders will be handled by an overhead bridge crane.

Because of the potential radiation exposure to workers, the outgoing, empty cylinders will be removed from the autoclaves by the use of remote handling equipment to disconnect the cylinders from the autoclaves and attach it to the overhead crane. The crane will remove the cylinders and position them for pick-up by a shielded straddle carrier. The shielded straddle carrier will transport the cylinders to the Outgoing, Empty Cylinder Storage Building.

In the course of normal operations, the only personnel that will enter the Outgoing, Empty Cylinder Storage Building will be the straddle carrier operators, who will be in an enclosed and ventilated operator's cab. After the daughter products have decayed to acceptable levels, the straddle carrier will retrieve the cylinders from the storage building and transport them to the crane facility for shipment. The yard crane will load all cylinders for shipment off-site.

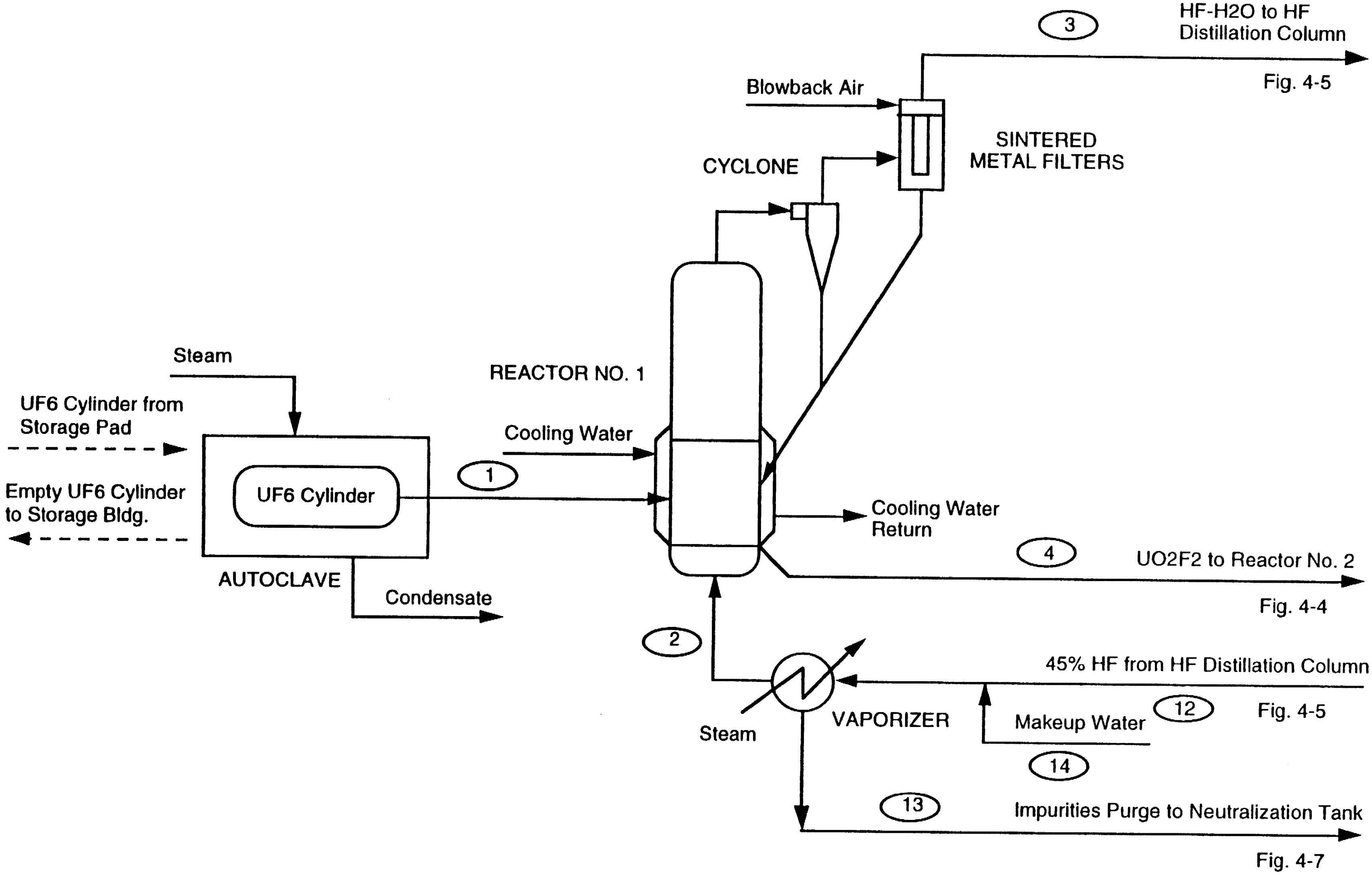


Figure 4-3 Reactor No. 1 Process Flow Diagram

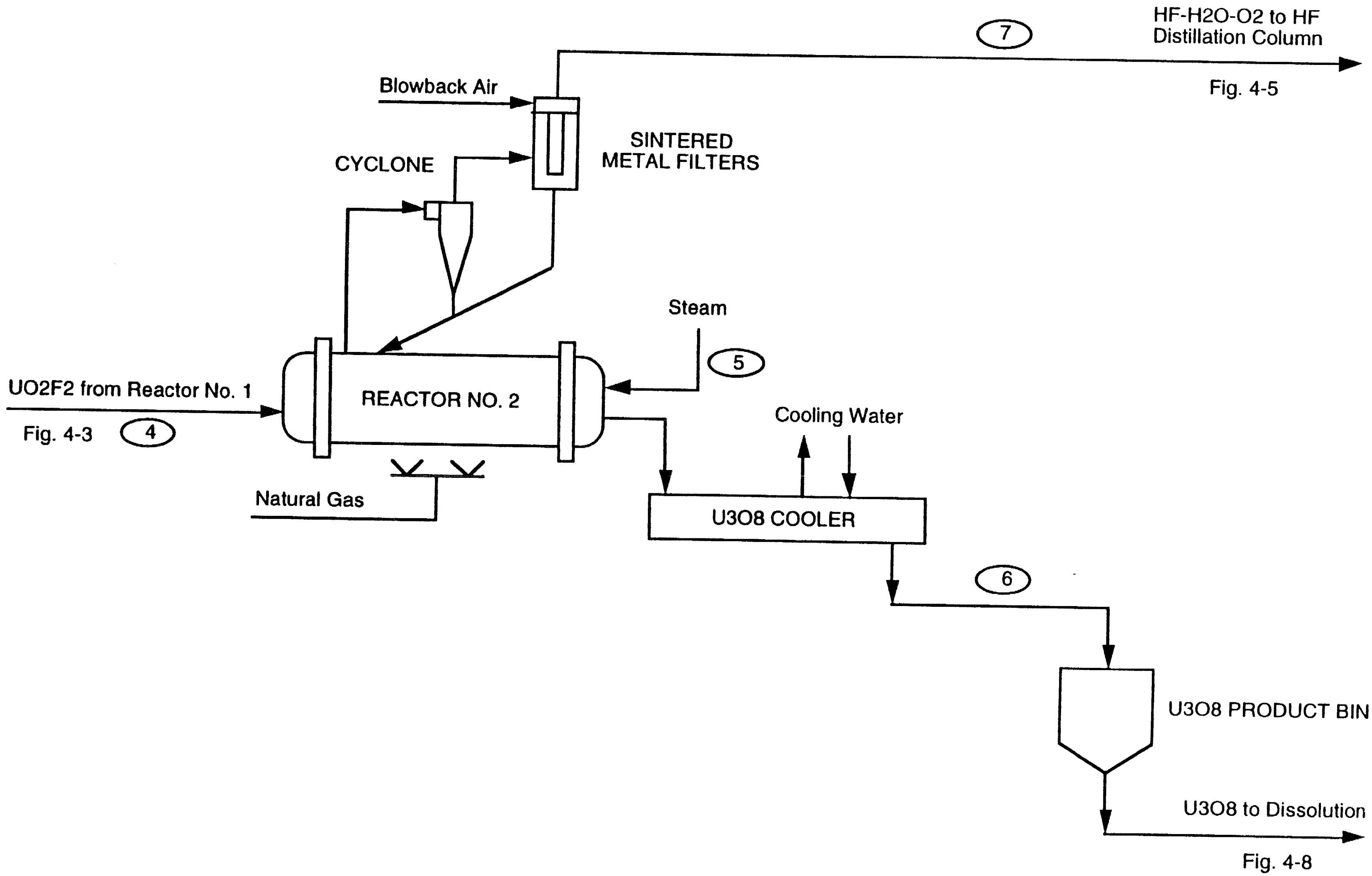


Figure 4-4 Reactor No. 2 Process Flow Diagram

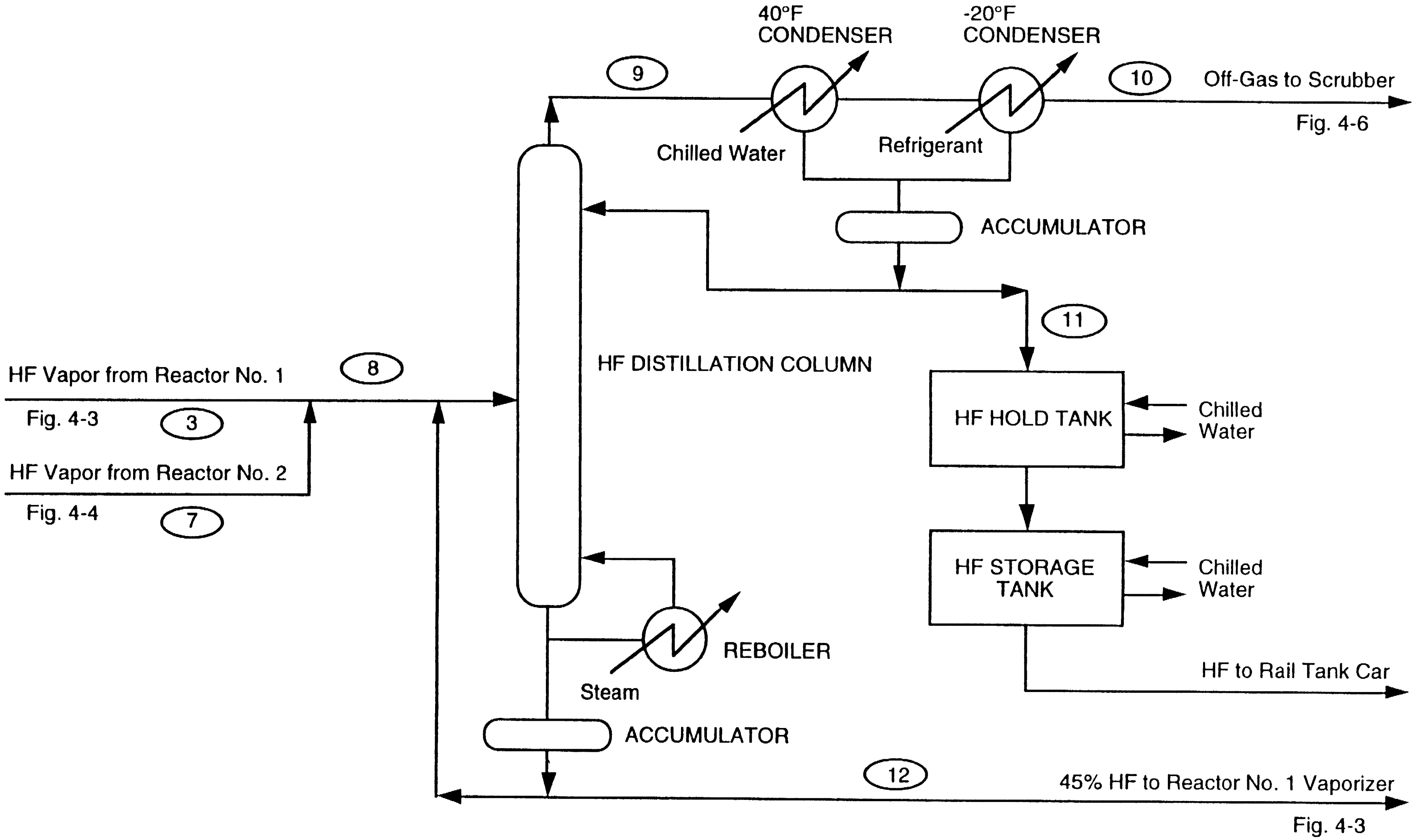


Figure 4-5 HF Distillation Process Flow Diagram

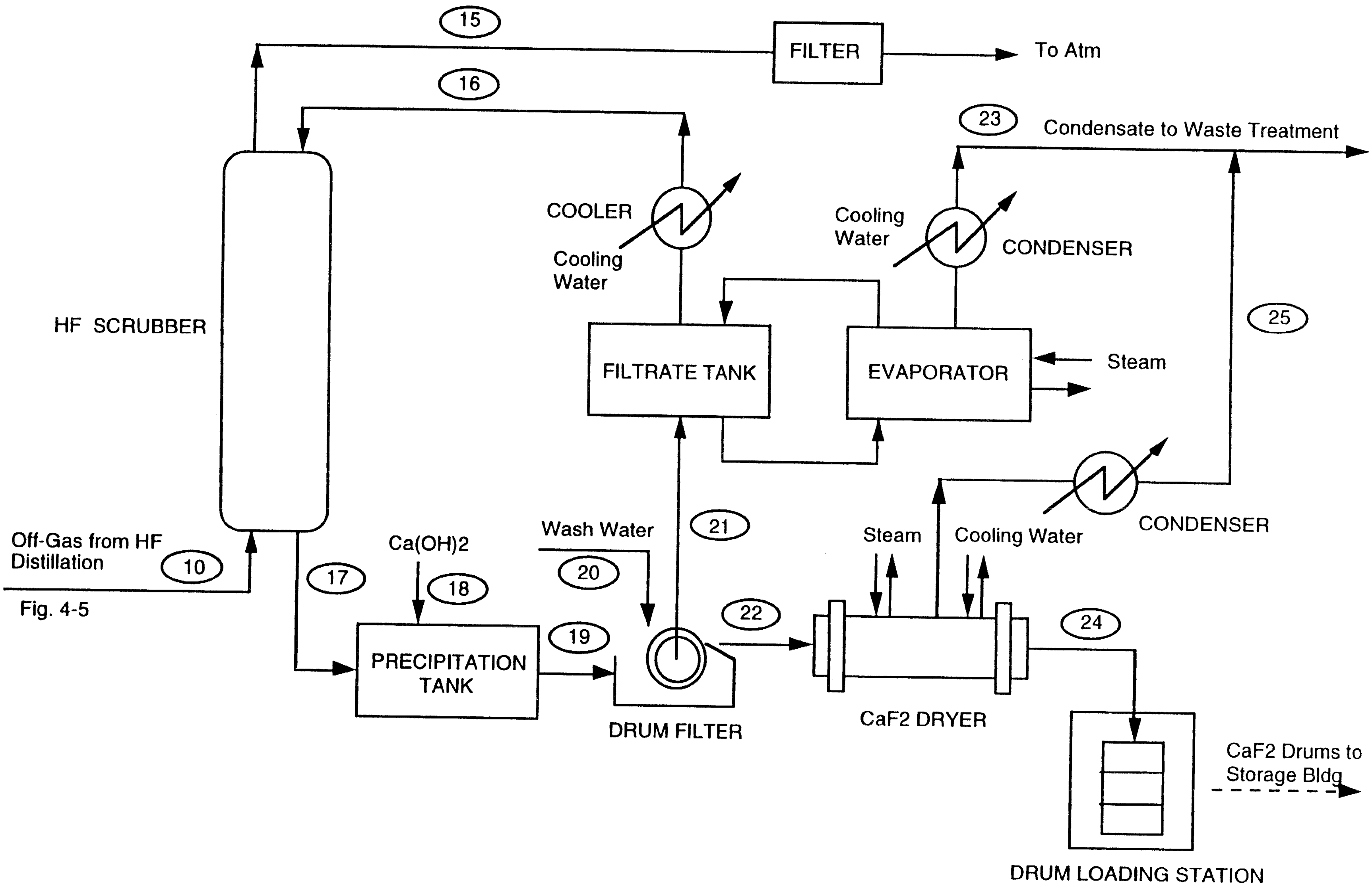


Figure 4-6 HF Scrubber Process Flow Diagram

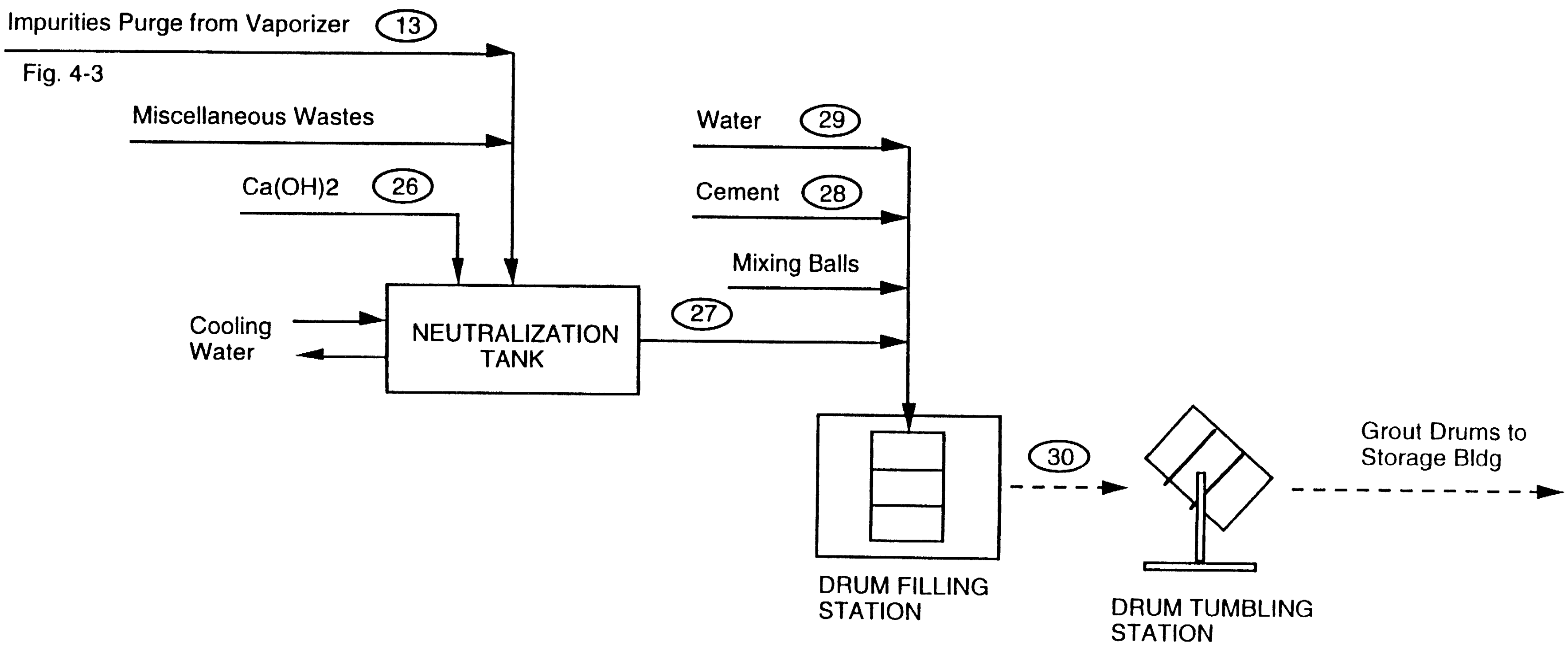
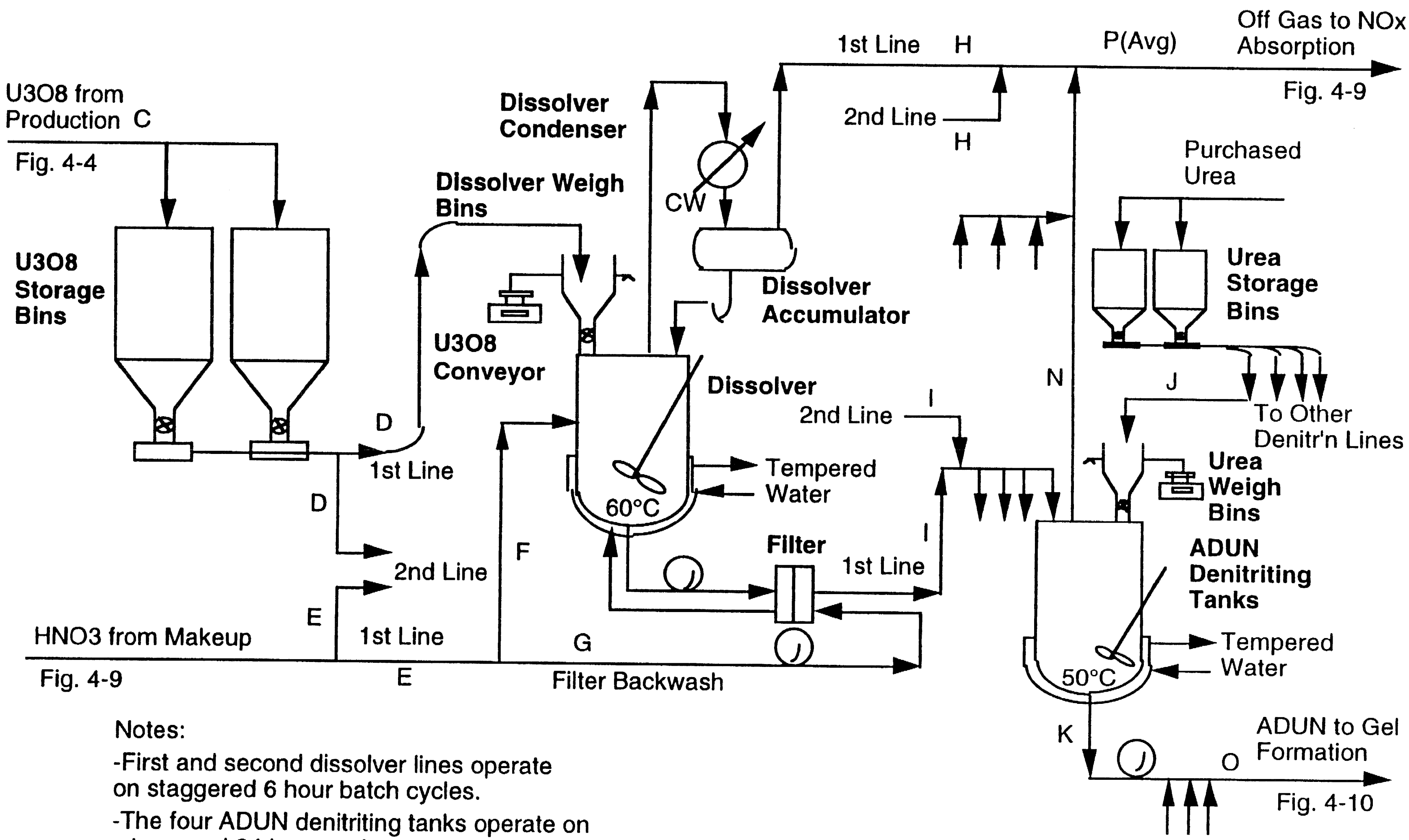


Figure 4-7 Waste Grouting Process Flow Diagram



Notes:

-First and second dissolver lines operate on staggered 6 hour batch cycles.

-The four ADUN denitriting tanks operate on staggered 24 hour cycles.

Figure 4-8 U3O8 Dissolution Process Flow Diagram

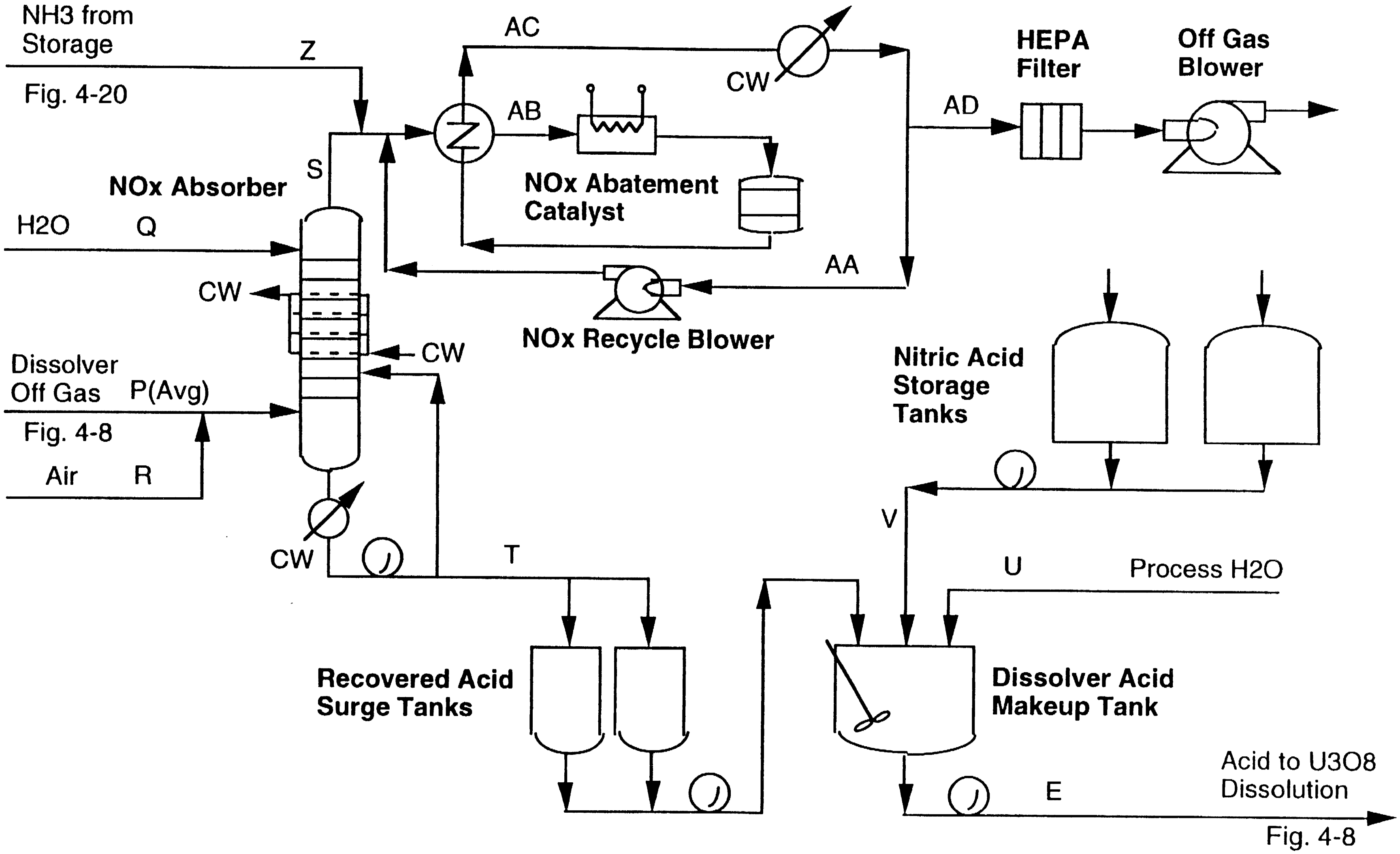


Figure 4-9 Dissolver Off-Gas Treatment Process Flow Diagram

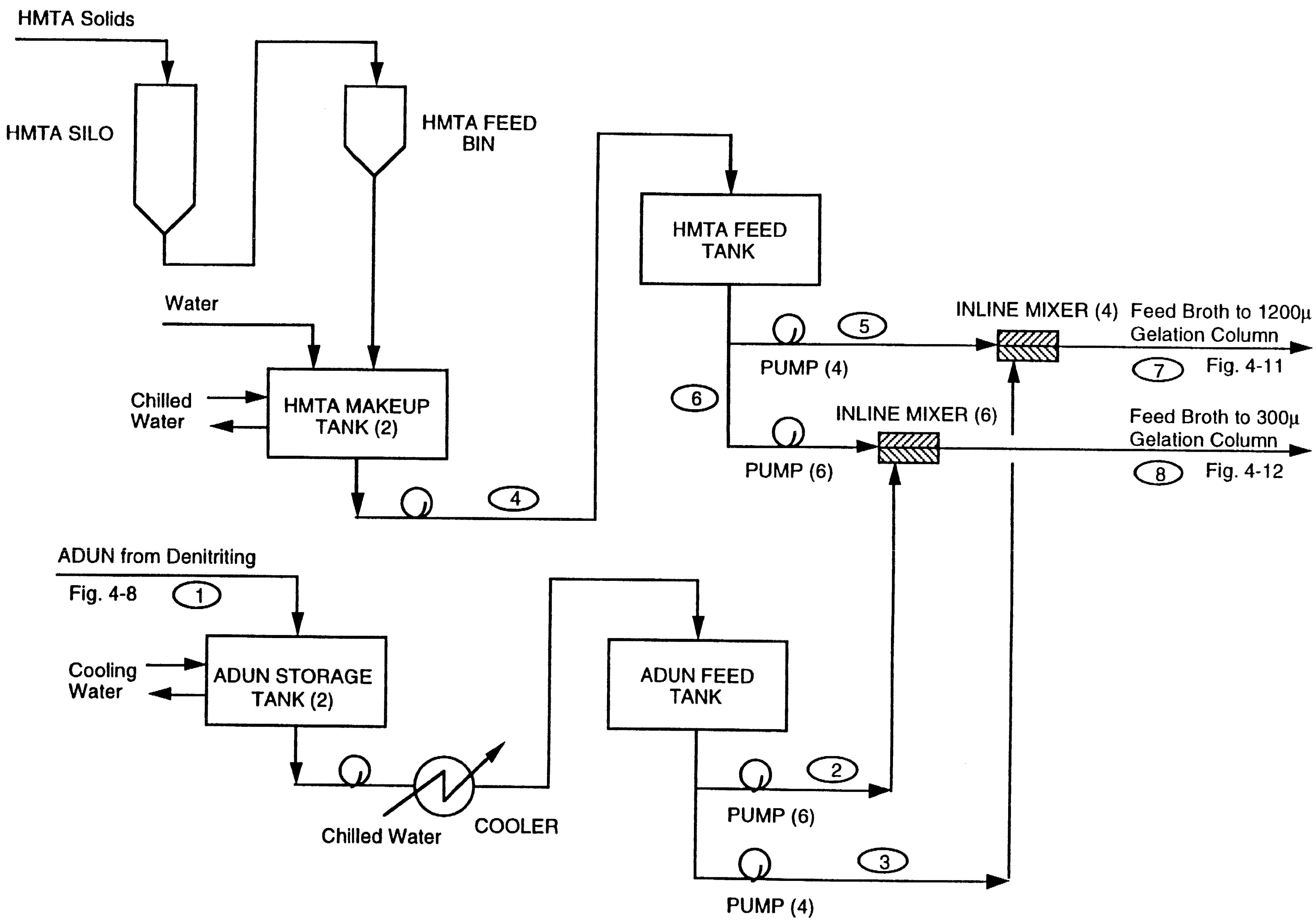


Figure 4-10 Gelation Column Feed Process Flow Diagram

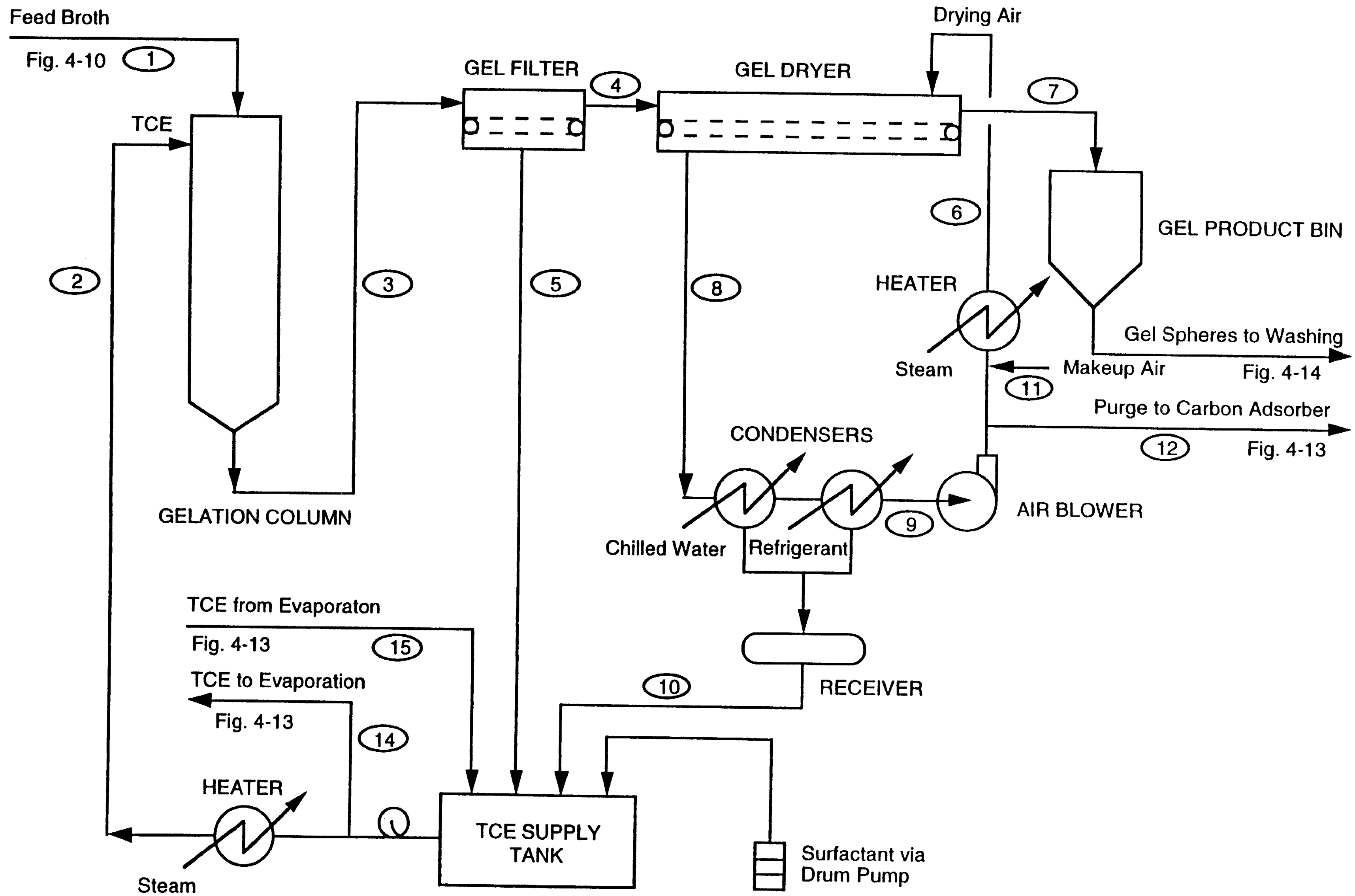


Figure 4-11 1200μ Sphere Gelation Process Flow Diagram

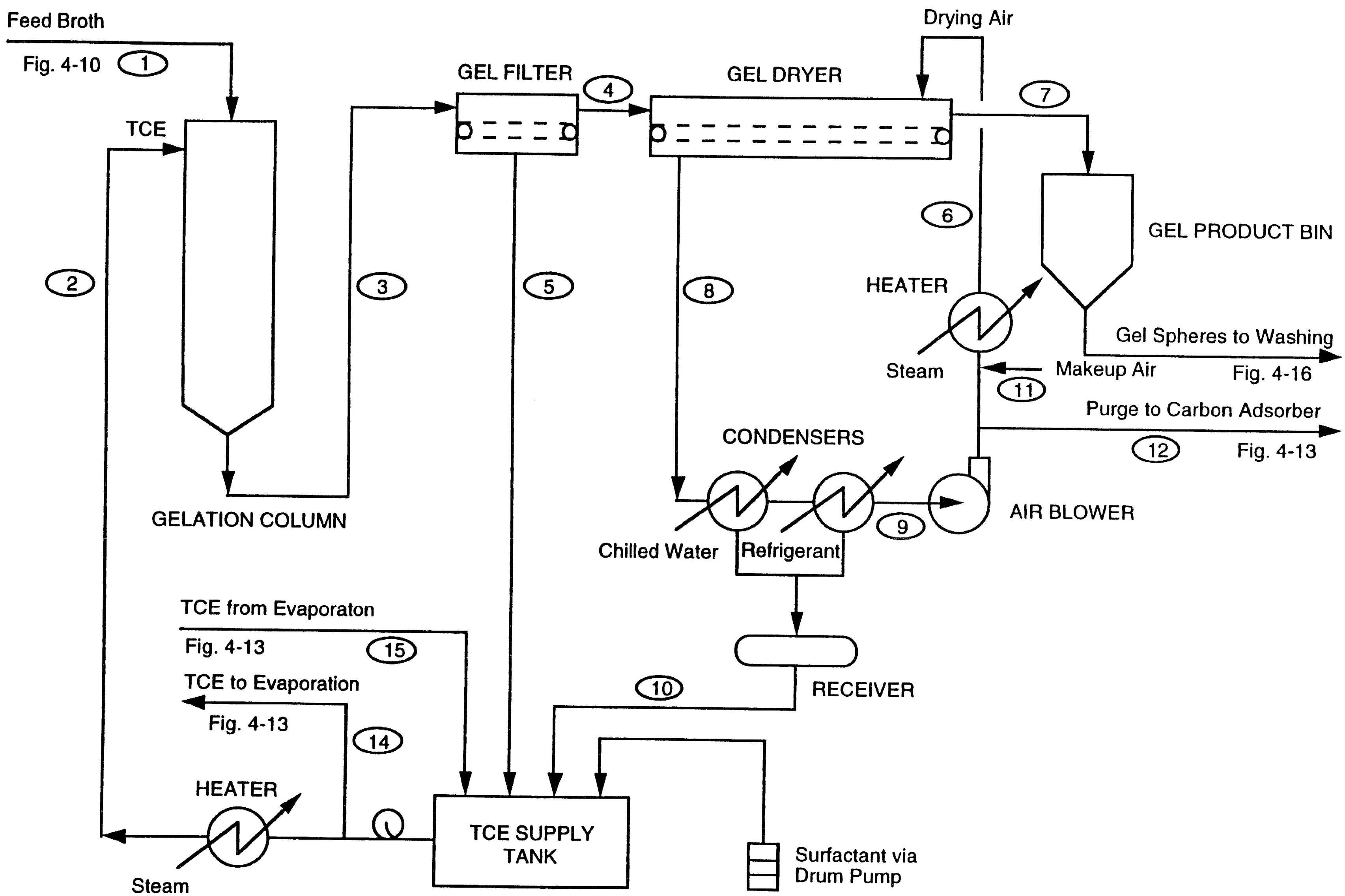


Figure 4-12 300μ Sphere Gelation Process Flow Diagram

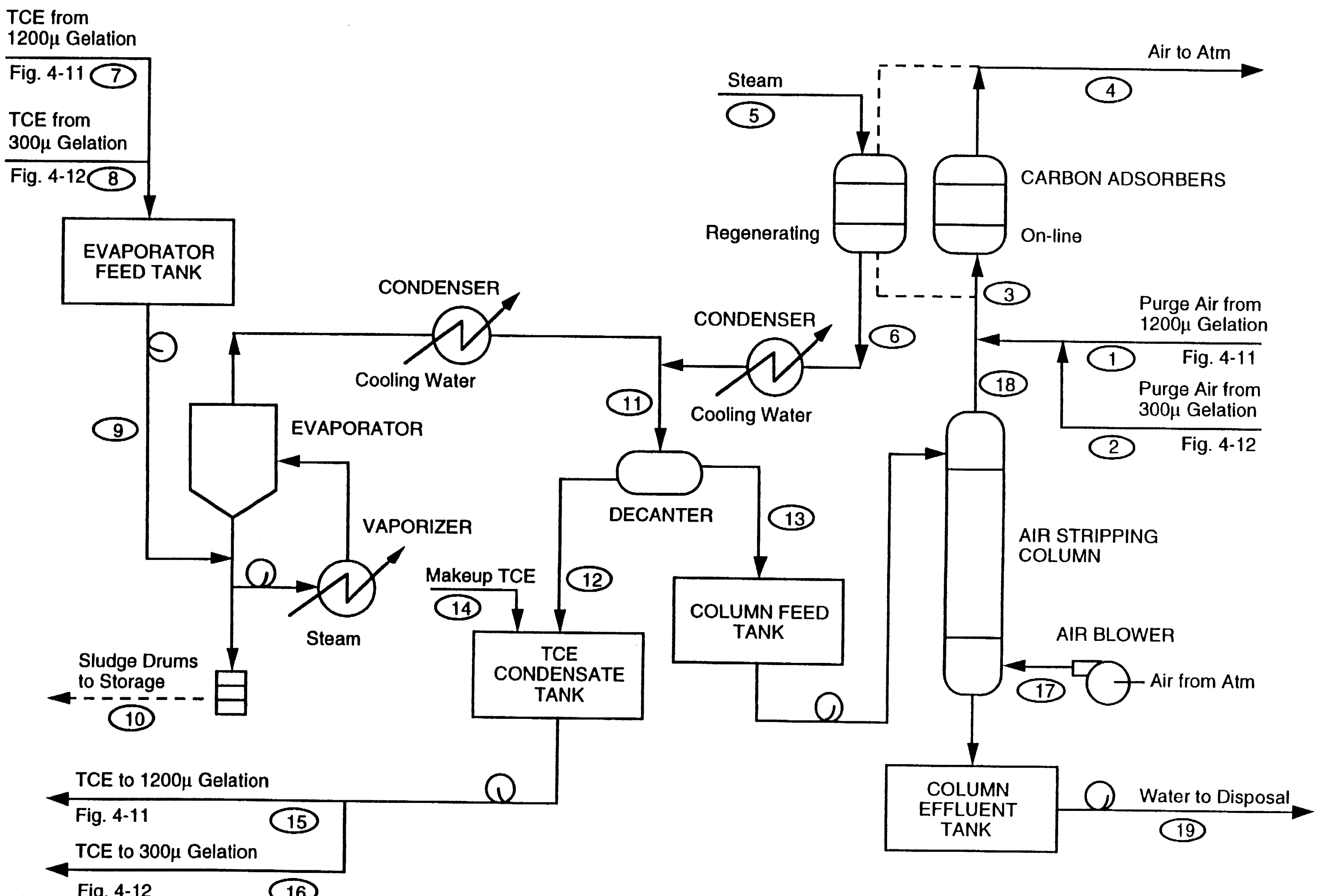


Figure 4-13 TCE Evaporation Process Flow Diagram

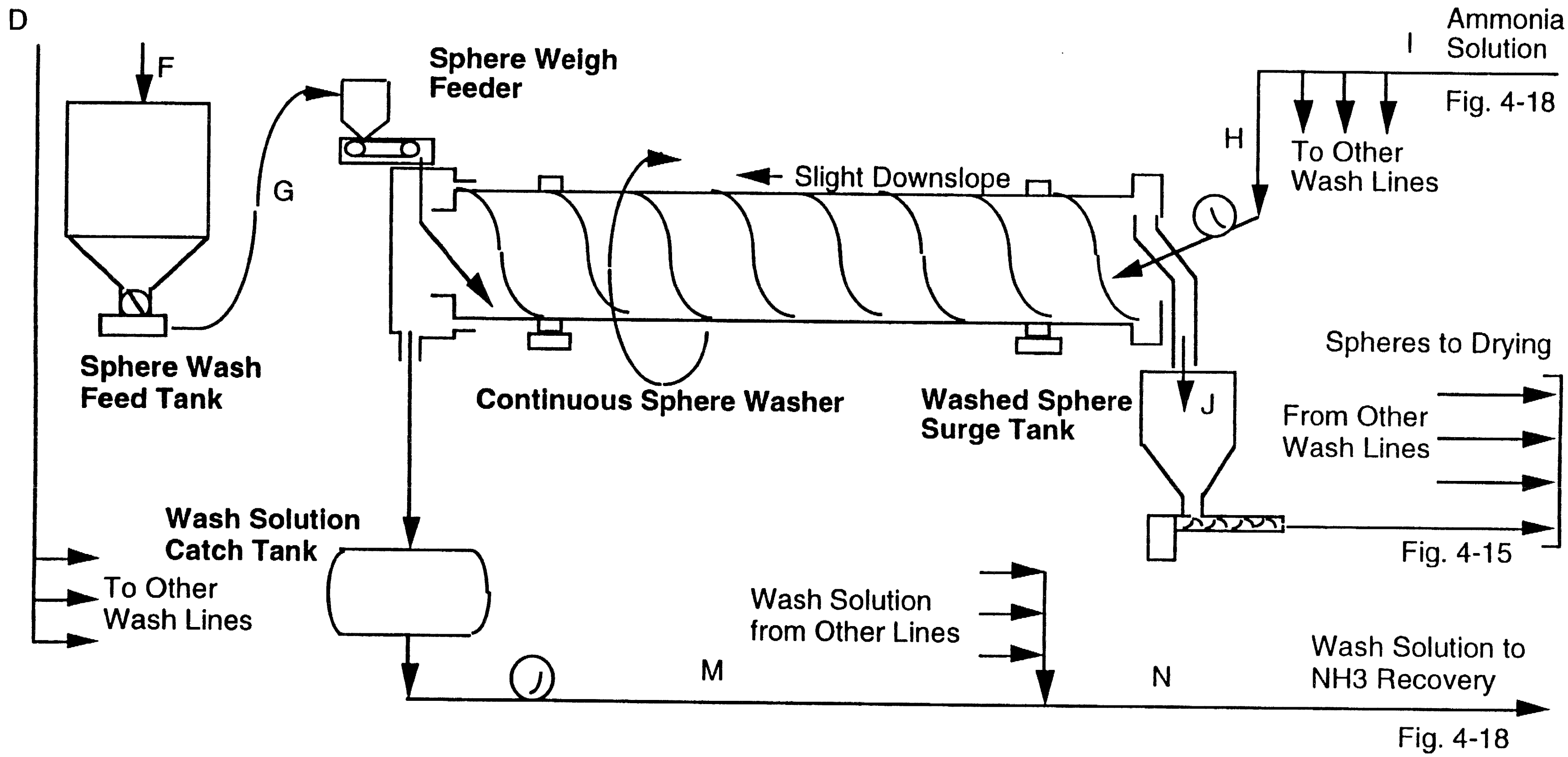


Figure 4-14 1200μ Gel Sphere Washing Process Flow Diagram

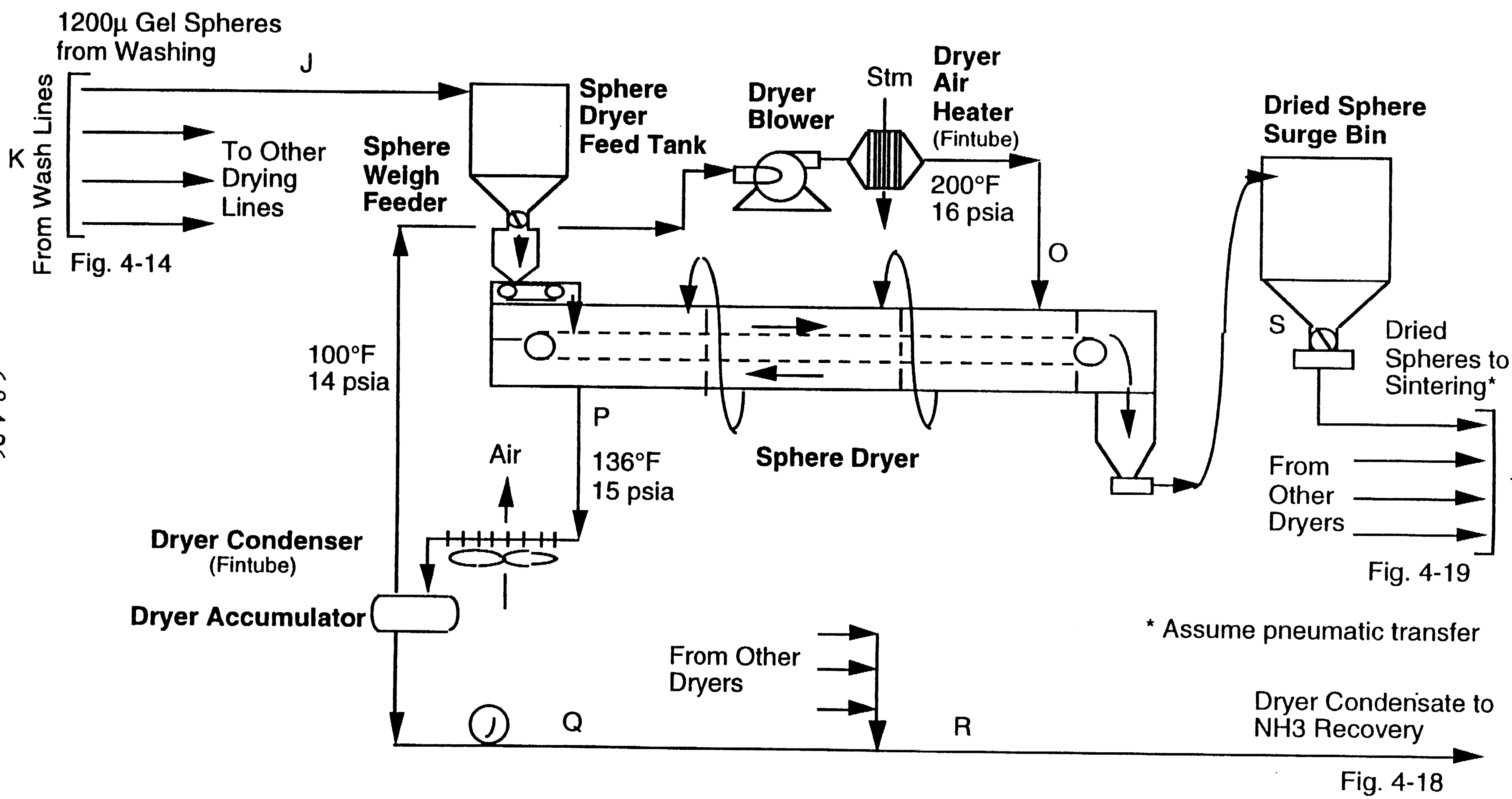


Figure 4-15 1200μ Gel Sphere Drying Process Flow Diagram

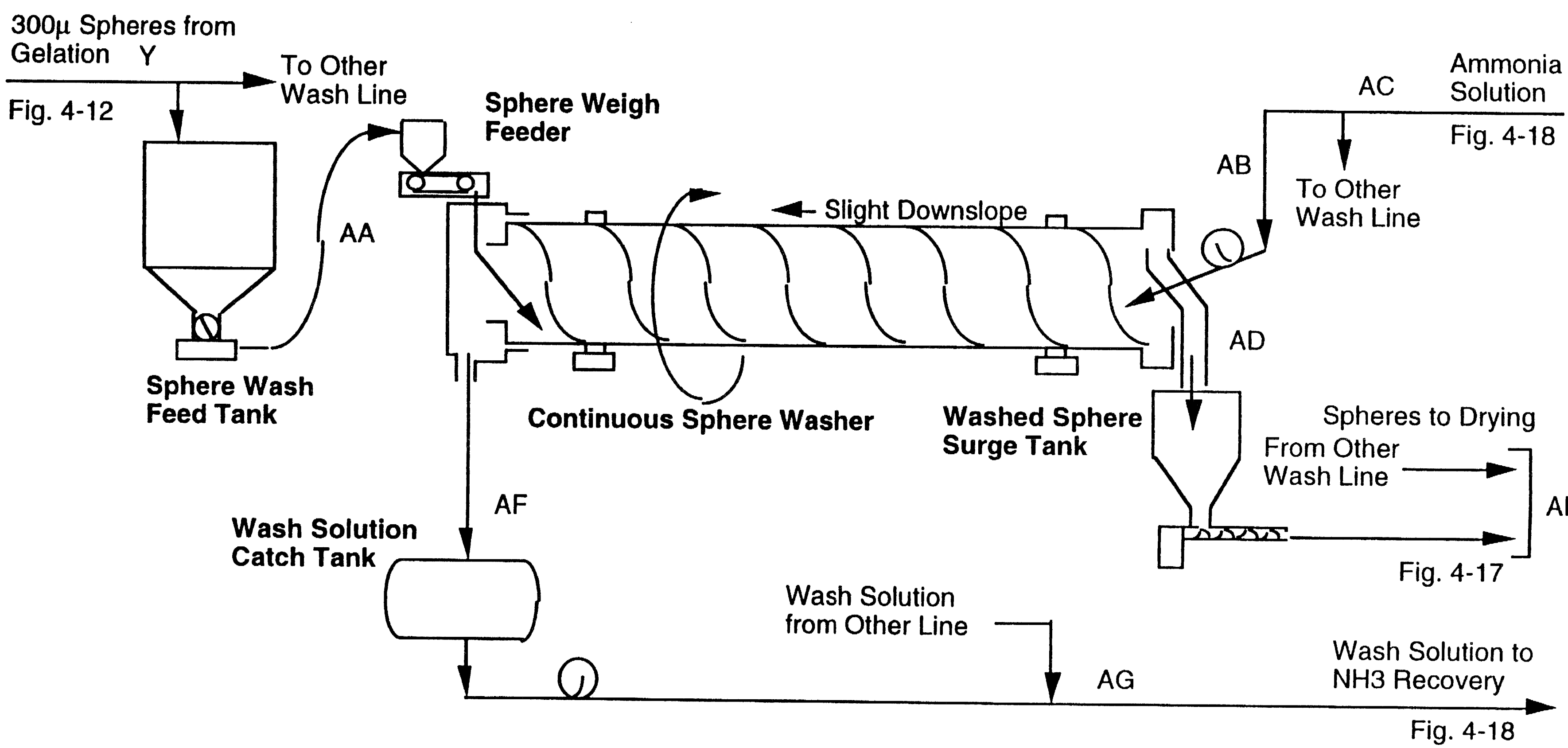


Figure 4-16 300μ Gel Sphere Washing Process Flow Diagram

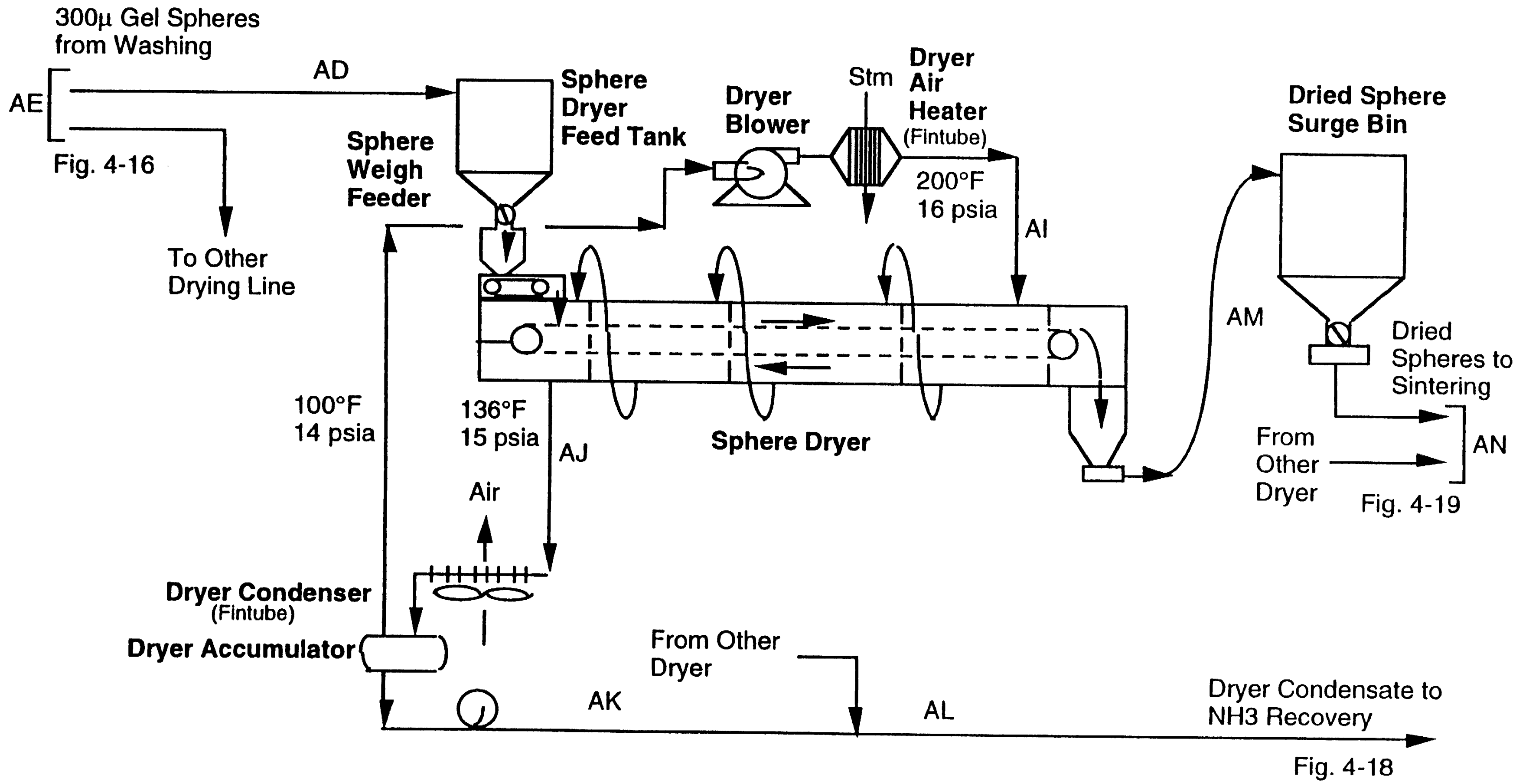


Figure 4-17 300µ Gel Sphere Drying Process Flow Diagram

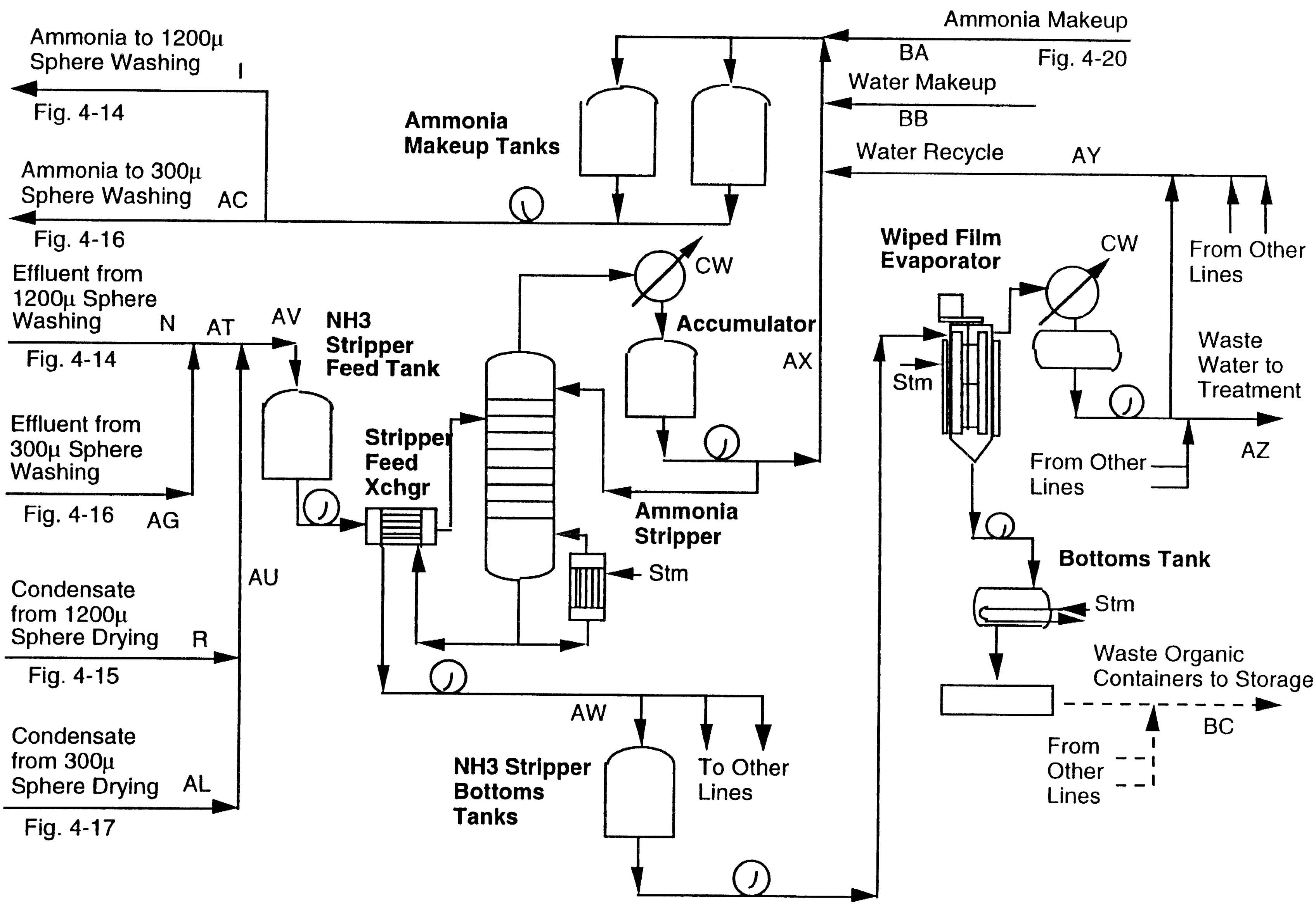


Figure 4-18 Wash Effluent Treatment Process Flow Diagram

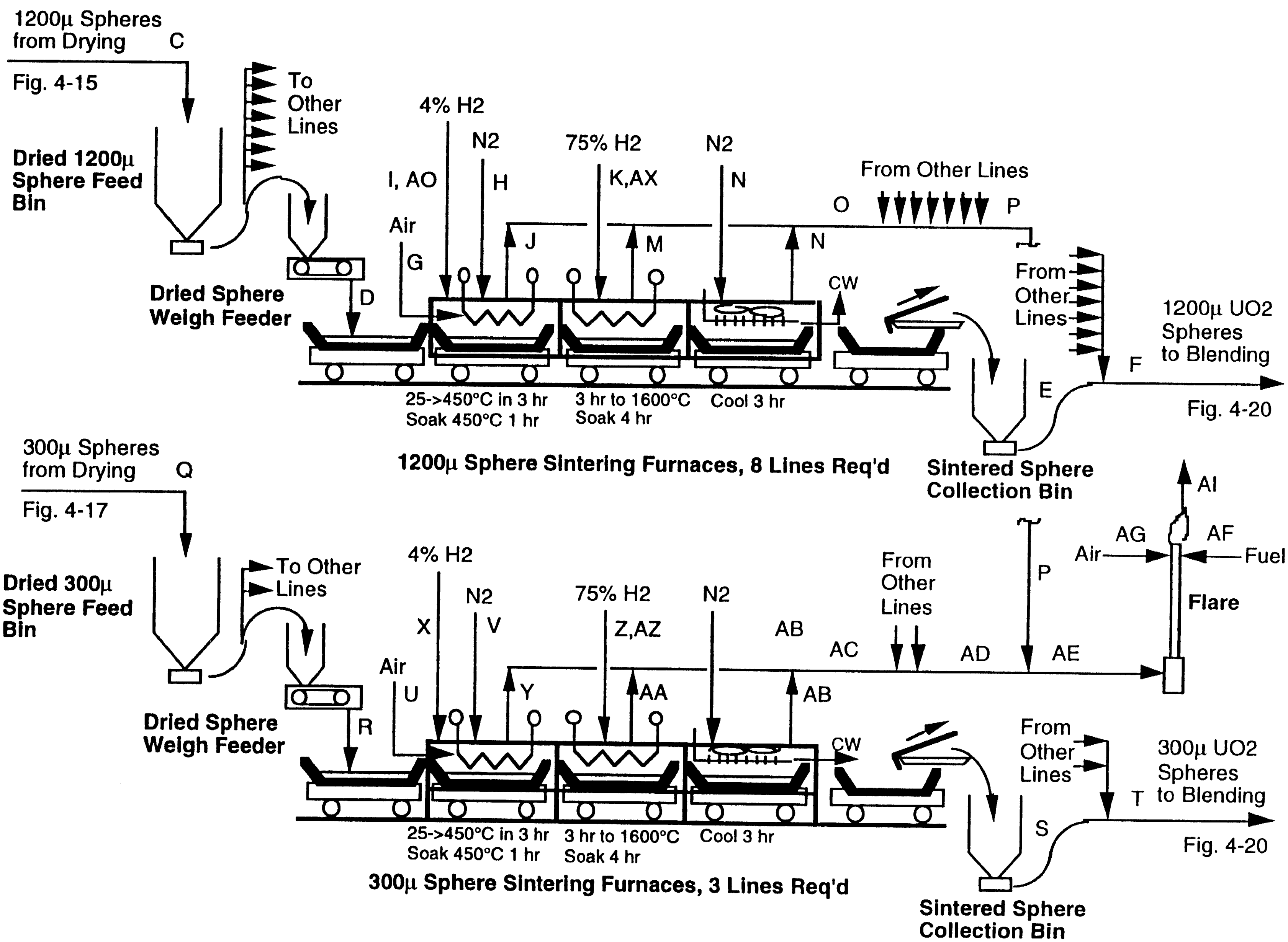


Figure 4-19 Sphere Sintering Process Flow Diagram

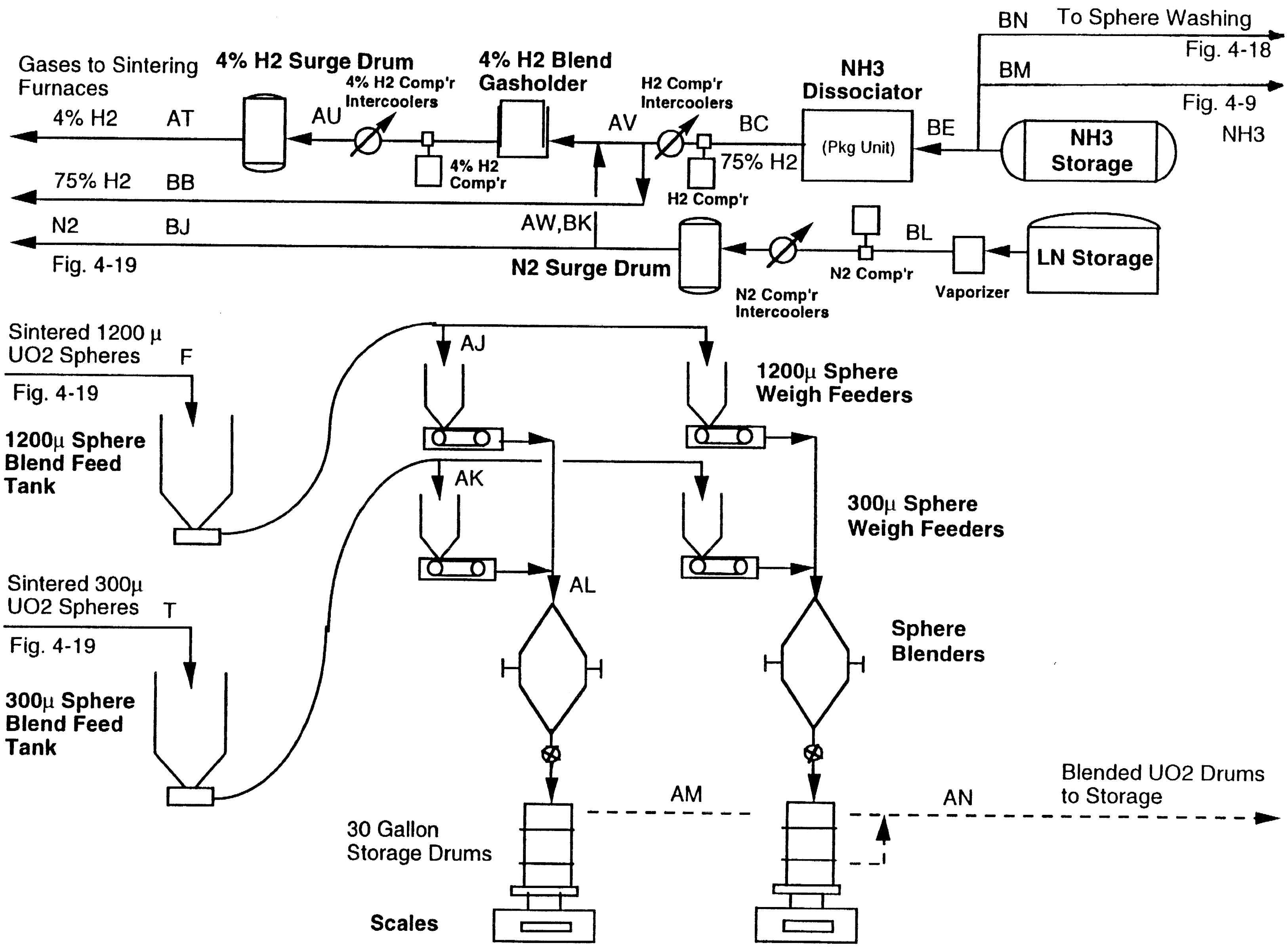


Figure 4-20 UO2 Sphere Blending Process Flow Diagram

5.0 Resource Needs

5.1 MATERIALS/RESOURCES CONSUMED DURING OPERATION

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1, including electricity, fuel, and water usage. This is followed by Table 5-2 showing consumable chemical and process material annual usage. An assumed average or normal throughput is the basis for the data.

Table 5-1, Utilities Consumed During Operation

Utilities	Annual Average Consumption	Peak Demand[1]
Electricity	94 GWh	13 MW
Liquid Fuel	10,000 gals	NA
Natural Gas[2]	1,373 x 10^6 scf	NA
Raw Water	285 x 10^6 gals	NA

[1] Peak demand is the maximum rate expected during any hour.
[2] Standard cubic feet measured at 14.7 psia and 60 °F.

5.1.2 Water Balance

Figure 5-1 is a preliminary conceptual water balance. This balance is based on the greenfield generic midwestern U. S. (Kenosha, WI) site as described in Appendix F of the DOE Cost Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3.

5.1.3 Chemicals and Materials Consumed

Table 5-2 shows annual chemicals and materials consumed during normal operations. In addition to chemicals required for process and support systems, estimated quantities of waste containers are included.

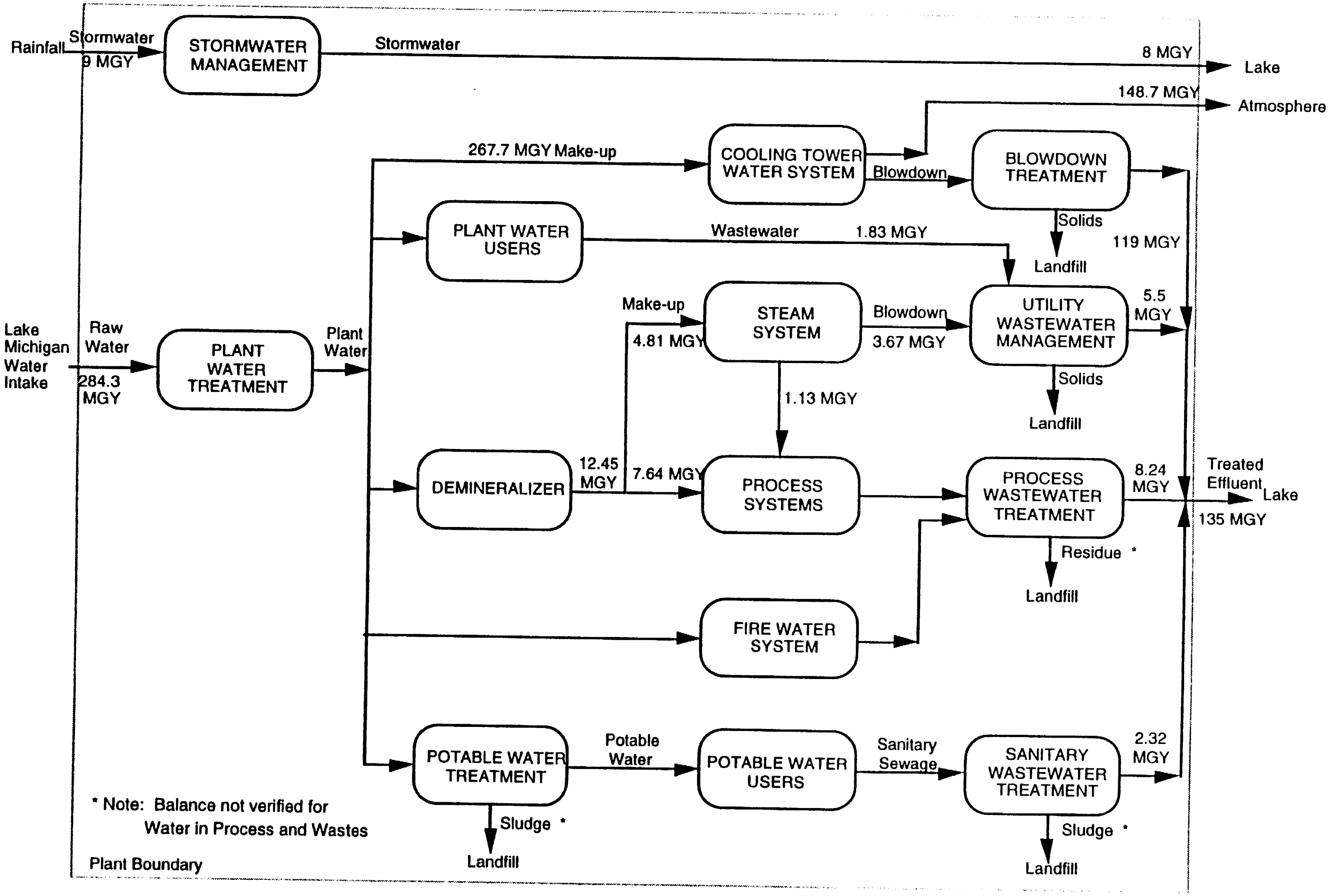


Figure 5-1 Preliminary Water Balance
Ceramic UO2 by Gelation Process

Table 5-2, Materials Consumed Annually During Normal Operation

Chemical	**Quantity (lb/yr)**
Solid	
Hexamethylenetetramine (HMTA)	30,625,000
Urea	13,125,000
Calcium Hydroxide (Hydrated Lime)	1,266,000
Cement	862,000
Detergent	600
Liquid	
Nitric Acid (50% HNO3)	37,200,000
Ammonia (99.95% NH3)	2,483,000
Nitrogen	1,056,000
Surfactant (Span 80)	39,000
Trichloroethylene	14,200
Water Treatment Chemicals	
Hydrochloric Acid (37% HCl)	91,000
Sodium Hydroxide (50% NaOH)	72,000
Sodium Hypochlorite	26,000
Copolymers	50,000
Phosphates	5,000
Phosphonates	5,000
Gaseous	NA
Containers[1]	**Quantity (containers/yr)**
Contaminated (low-level radioactive, mixed and hazardous) Waste Containers (55 gallon drums & 56 ft^3 boxes - see also Table 9-1)	3,254 drums 58 boxes

[1]Containers listed include only those that are expected to be sent to ultimate disposal and not reused.

5.1.4 Radiological Materials Required

The only radiological material input to the site is depleted uranium fluoride (DUF_6). The annual consumption is 28,000 MT of DUF_6 as a solid shipped in 14 ton DOT approved carbon steel containers

5.2 MATERIALS/RESOURCES CONSUMED DURING CONSTRUCTION

Table 5-3 provides an estimate of construction materials consumed during construction.

Table 5-3, Materials/Resources Consumed During Construction

Material/Resources	Total Consumption	Peak Demand[1] (if applicable)
Utilities		
Electricity	50,000 MWh	3.0 MW
Water	15×10^6 gal	900 gal
Solids		NA
Concrete	30,000 yd^3	
Steel (carbon or mild)	15,000 tons	
Electrical raceway	35,000 yd	
Electrical wire and cable	80,000 yd	
Piping	60,000 yd	
Steel decking	35,000 yd^2	
Steel siding	15,000 yd^2	
Built-up roof	20,000 yd^2	
Interior partitions	2,000 yd^2	
Lumber	7,000 yd^3	
HVAC ductwork	250 tons	
Special Coatings	4000 yd^2	
Asphalt paving	350 tons	
Liquids		
Fuel[2]	2.5×10^6 gals	
Gases		
Industrial Gases (propane)	6,000 gal	

1 Peak demand is the maximum rate expected during any hour.
2 Fuel is 50% gasoline and 50% diesel fuel.

The process equipment will be purchased from equipment vendors. The total quantities of commonly used construction material (e.g., steel, etc.) for equipment will be minor compared to the quantities given in Table 5-3. The primary specialty material used for equipment fabrication is approximately 30 tons of Monel and 10 tons of Inconel.

6.0 Employment Needs

This section provides preliminary estimates of the employment needs of the facility during both operation and construction. Note that employment shown is for all on-site facilities.

6.1 EMPLOYMENT NEEDS DURING OPERATION

Table 6-1 provides labor category descriptions and the estimated numbers of employees required to operate the facility.

Table 6-1, On-Site Employment During Operation

Labor Category	Number of Employees
Officials and Managers	12
Professionals	12
Technicians	44
Office and Clerical	34
Craft Workers (Maintenance)	20
Operators	180
Line Supervisors	25
Security	35
TOTAL EMPLOYEES (for all on-site facilities)	362

Table 6-2 gives the estimated location of facility employees during normal operations.

6.2 EMPLOYEES AT RISK OF RADIOLOGICAL EXPOSURE

Appendix C provides rough estimates of worker activities and associated radiation sources and distances.

Workers do not use respiratory or breathing equipment during normal operation. Respirators or supplied air masks may be used during certain decontamination or maintenance operations. For activities in which workers come in contact with HF (e.g., connecting the tank car loading hose), the operator will wear acid-resistant protective gear including a respirator. For activities where they may be exposed to high TCE concentrations, operators will wear respirators with an organic filtering cartridge.

6.3 EMPLOYMENT NEEDS DURING CONSTRUCTION

Table 6-3 provides an estimate of the employment buildup by year during construction.

Table 6-2, Number and Location of Employees During Operation

Facility	Shift 1	Shift 2	Shift 3	Shift 4 [1]
Process Building	75	50	50	50
HF Storage Building	2	1	1	1
UO_2 Storage Building	3	1	1	1
CaF_2 Storage Building	1	1	1	1
Ammonia Recovery Area	2	1	1	1
Sludge Storage Pad	2	2	2	2
Cylinder Storage Pad & Building	7	3	3	3
Utilities/Services/Admin Areas	48	15	15	15
TOTAL EMPLOYEES	140	74	74	74

[1] The 4th shift allows coverage for 7 days per week operations.

Table 6-3, Number of Construction Employees Needed by Year[1]

Employees	Year 1	Year 2	Year 3	Year 4
Total Craft Workers	200	400	700	300
Construction Management and Support Staff	60	75	120	70
TOTAL EMPLOYEES	260	475	820	370

[1] Numbers shown are for the peak of the year. Average for the year is 60% of the peak.

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological and hazardous emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering estimates due to the pre-conceptual nature of the design.

7.1 WASTES AND EMISSIONS DURING OPERATION

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the facility are shown in Tables 7-3 and 7-4. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce.

7.1.2.1 Low-Level Wastes

Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.2 Mixed Low-Level Wastes

Mixed low-level (radioactive and hazardous) waste is packaged and shipped to a waste management facility for temporary storage, pending final treatment and disposal. It is expected that administrative procedures will minimize the generation of mixed wastes.

Table 7-1, Annual Air Emissions During Operation

Pollutants	**Principal Release Point**	**Annual Emissions (lb)**
CRITERIA POLLUTANTS		**Boiler/Other[1]**
Sulfur Dioxide	Boiler Stack / Grade	820/80
Nitrogen Dioxide	Boiler Stack / Grade	111,000/720
Hydrocarbons	Boiler Stack / Grade	2,300/690
Carbon Monoxide	Boiler Stack / Grade	55,000/3,700
Particulate Matter PM-10	Boiler Stack / Grade	4,100/140
OTHER POLLUTANTS		
HF	Process Bldg. Stack	900
U_3O_8	Process Bldg. Stack	3.9
UO_2	Process Bldg. Stack	2.5
Trichloroethylene	Process Bldg. Stack	1,300
Copolymers	Cooling Tower	9,900
Phosphonates	Cooling Tower	1000
Phosphates	Cooling Tower	1000
Calcium	Cooling Tower	17,500
Magnesium	Cooling Tower	4,500
Sodium and Potassium	Cooling Tower	1,800
Chloride	Cooling Tower	3,200
Dissolved Solids	Cooling Tower	96,000

1 Other sources are diesel generator and vehicles

Table 7-2, Annual Radiological Emissions During Operation

Radiological Isotope	**Principal Release Point**	**Release Rate (Ci/yr)[1]**
Depleted Uranium in Gaseous Effluent	Process Bldg. Stack	1.0×10^{-3}
Depleted Uranium in Liquid Effluent Stream	Effluent Outfall	3.0×10^{-3}

1 Based on an assumed activity of 4×10^{-7} Ci/g of depleted uranium - see Section 1.2.1 for isotopic composition

Table 7-3, Annual Radioactive and Hazardous Waste Generated During Operation

Type	Description [1]	Weight (lb)	Volume (cu yd)	Contents	Quantity Packages
Low Level Waste					
Combustible solid	Gloves, wipes, rags, clothing, etc. (plastic, paper, cloth)	384,000	178	32 lb U3O8 13 lb UO2	658 55-gal drums
Metal, surface contaminated	Failed equipment	97,000	60	80 lb U3O8 33 lb UO2	222 55-gal drums
Noncombustible compactible solid	HEPA filters	22,000	120	776 lb U3O8 497 lb UO2	58 4x2x7 ft boxes (3/4" plywood)
Noncombustible noncompactible solid	Grouted waste See Sect. 4.4	2,053,000	609	821 lb U3O8	2,236 55-gal drums
Other	LabPack (chemicals plus absorbent)	4,400	2.7	5 lb U3O8	10 55-gal drums
Hazardous Waste					
Organics liquids	Solvents, oil, paint	6,000	4 (800 gal)	See description	15 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	24,000	15	24 lb TCE	56 55-gal drums
Combustible debris	Wipes, etc.	1,600	3	2 lb TCE	11 55-gal drums
Other	Fluorescent bulbs (compacted)	1,600	1	Mercury (trace)	4 55-gal drums
Mixed Low Level Waste					
Labpacks	Chemicals plus absorbent	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Inorganic process debris	Failed equipment (metal, glass)	810	0.5	1 lb U3O8 1 lb Acetone	2 55-gal drums
Combustible debris	Wipes, etc.	2,700	5	0.3 lb UO3 3 lb TCE	18 55-gal drums
Organic liquids	Trichloroethylene See Sect. 4.8	13,000	5.5 (1100 gal)	100 lb UO3 12,900 lb TCE	20 55-gal drums

1 All wastes are in solid form unless noted otherwise.

Table 7-4, Annual Nonhazardous Waste Generated During Operation

Category	Solid (yd^3)	Liquid (gals)
Nonhazardous (Sanitary) Wastes	-	2.3×10^6
Nonhazardous (Other) Wastes (Liquid quantity based on cooling tower blowdown, industrial wastewater, process water - see Figure 5-1, Water Balance)	40,000 (1)	135×10^6
Recyclable Wastes	360	-

(1) Includes 39,000 yd^3 of organic sludge waste.

7.1.2.3 Hazardous Wastes

Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

7.1.2.4 Nonhazardous Wastes

Nonhazardous sanitary liquid wastes generated in the facility are transferred to an onsite sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.1.2.5 Recyclable Wastes

Recyclable wastes includes paper, aluminum, etc. generated by the facility. These wastes are generally assumed to be collected on-site for pickup by off-site recycling organizations.

7.2 WASTES AND EMISSIONS GENERATED DURING CONSTRUCTION

This section presents the significant gaseous emissions and wastes generated during construction.

7.2.1 Emissions

Estimated emissions from construction activities during the peak construction year are shown in Table 7-5. The emissions shown are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption.

Table 7-5, Air Emissions During the Peak Construction Year

Criteria Pollutants	Quantity (tons)
Sulfur Dioxide	2.8
Nitrogen Dioxide	46
Hydrocarbons	13
Carbon Monoxide	316
Particulate Matter PM-10	60

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-6. The waste generation quantities are based on factors from historic data, construction area size, and the projected construction labor force.

7.2.2.1 Radioactive Wastes

There are no radioactive wastes generated during construction of the facility since it has been assumed that the facility will be located on a greenfield site.

7.2.2.2 Hazardous Wastes

Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facilities off-site for treatment and disposal in accordance with latest EPA RCRA guidelines.

Table 7-6, Total Wastes Generated During Construction

Waste Category	Quantity
Hazardous Solids	100 yd^3
Hazardous Liquids	35,000 gals
Nonhazardous Solids	
Concrete	200 yd^3
Steel	60 tons
Other	1,500 yd^3
Nonhazardous Liquids	
Sanitary	4.5×10^6 gals
Other	2.0×10^6 gals

7.2.2.3 Nonhazardous Wastes

Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to offsite facilities for treatment and disposal.

8.0 Accident Analysis

8.1 BOUNDING ACCIDENTS

The facility includes areas with hazard categories of chemically high hazard (HH) for buildings containing HF and radiologically moderate hazard (HC2) for buildings containing DUF_6 and UO_2 product. These preliminary hazard categories have been developed as defined in DOE-STD-1027-92. Corresponding preliminary performance categories as defined in DOE-STD-1021-93 have been developed for selected structures, systems and components (SSCs). These categories were assigned based on engineering judgment and further analysis should be performed as the design evolves. A detailed safety analysis and risk assessment under DOE Order 5480.23 will be required. Preliminary radiological and non-radiological hazardous accident scenarios that bound and represent potential accidents for the facility are summarized in Table 8-1 and described in the following sections. The description of each accident includes the following elements:

- A description of the accident scenario
- An estimate of the frequency of the scenario (as defined in Table 8-2) based on engineering judgment (because the design of the facility is not advanced sufficiently to justify use of rigorous risk analysis techniques)
- An estimate of the effective amount of material at risk in the accident based on the equipment sizes (see Table 8-3),
- An estimate of the fraction of effective material at risk that becomes airborne in respirable form (see Table 8-3), and
- An estimate of the fraction of material airborne in respirable form released to the atmosphere, taking into account the integrity of the containment system (see Table 8-3).

Based on the postulated accidents and on DOE and NRC guidance, the following structures, systems, and components (SSCs) are assumed to be performance category PC-3 or PC-4 as defined in DOE-STD-1021-93:

- Vessels containing significant quantities of liquid HF or NH_3 because their rupture could release HF or NH_3 with unacceptable consequences.
- Vessels containing significant inventories of gaseous HF or UF_6 because their rupture could release HF or UF_6 (UO_2F_2) with unacceptable consequences.
- The Process Building, HF Storage Building and UO_2 Storage Building structures because they house large HF and uranium inventories or gaseous UF_6, and building collapse could result in significant releases.

Table 8-1, Bounding Postulated Accident Summary

Accident	Frequency	Respirable Airborne Material Released to Environment
Earthquake	Extremely Unlikely	9.8 lb UO_2
Tornado	Extremely Unlikely	5.6 lb UO_2
Flood	Incredible	No Release
HF System Leak	Anticipated	216 lb HF
HF Pipeline Rupture	Unlikely	500 lb HF to Soil
HF Storage Tank Overflow	Unlikely	45 lb HF
UO_2 Drum Spill	Anticipated	5.6×10^{-5} lb UO_2
Loss of Offsite Electrical Power	Anticipated	No Release
Loss of Cooling Water	Anticipated	22 lb HF
Hydrogen Explosion	Extremely Unlikely	0.017 lb UO_2
Ammonia Release	Unlikely	255 lb NH_3
Trichloroethylene Vapor Leak	Anticipated	20 lb TCE
Trichloroethylene Spill	Anticipated	120 lb TCE
Ammonia Stripper Overpressure	Anticipated	15 lb NH_3

Table 8-2, Accident Frequency Categories

Frequency Category	Accident Frequency Range (accidents/yr)
Anticipated Accidents	$1/yr > frequency \geq 10^{-2}/yr$
Unlikely Accidents	$10^{-2}/yr > frequency \geq 10^{-4}/yr$
Extremely Unlikely Accidents	$10^{-4}/yr > frequency \geq 10^{-6}/yr$
Incredible Events	$10^{-6}/yr > frequency$

Table 8-3, Accident Source Terms and Parameters

Accident	Effective Material at Risk (1)	Respirable Airborne Fraction (2)	Fraction of Respirable Airborne Material Released to Environment (3)	Release Duration
Earthquake	197,000 lb UO_2	5×10^{-5} (a)	1	30 min
Tornado	2,250 lb UO_2	2.5×10^{-3} (b)	1	30 sec
Flood	No Release	NA	NA	NA
HF System Leak	540 lb HF	1	.4 (c)	15 min
HF Pipeline Rupture	500 lb HF	(d)	(d)	10 min
HF Storage Tank Overflow	830 lb HF	.22 (e)	.25 (f)	15 min
UO_2 Drum Spill	1,125 lb UO_2	5×10^{-5} (a)	1×10^{-3}	30 min
Loss of Offsite Electrical Power	No Release	NA	NA	NA
Loss of Cooling Water	22 lb HF	1	1	2 min
Hydrogen Explosion	6,500 lb UO_2	2.5×10^{-3} (b)	1×10^{-3}	30 min
Ammonia Release	255 lb NH_3	1	1	1 min
TCE Vapor Leak	20 lb TCE	1	1	1 hr
TCE Spill	1,220 lb TCE	0.1 (g)	1	2 hr
Ammonia Stripper Overpressure	15 lb NH_3	1	1	1 min

Notes for Table 8-3 Accident Source Terms and Parameters

1. Effective Material at Risk, represents (inventory at risk) x (damage factor).
2. Respirable Airborne Fraction, represents (fraction airborne) x (fraction in respirable range).

3. Fraction of Respirable Airborne Material Released to Environment, represents building leak factor.

a. Based on free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

b. Respirable airborne fraction is assumed to be 50 times greater than that for free-fall spill/crush of brittle solids in DOE-HDBK-0013-93, p. 4-4.

c. Based on 6 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

d. Assume 100% of the HF drains into the ground at a point 3 ft below grade during a 10 minute period. The contaminated soil is removed after 48 hrs.

e. Airborne release fraction is .22 based on 0.06 lb/min-sq ft evaporation rate, 200 sq ft spill area and 15 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*, American Industrial Hygiene Association Journal, November 1974. Fraction in respirable range is 1.

f. Based on 3 air changes/hr, .33 mixing efficiency and 15 minute duration before HVAC system is shut down.

g. Airborne release fraction is .1 based on 0.01 lb/min-sq ft evaporation rate, 200 sq ft spill area and 60 minute duration, using method in D. G. Gray, *Solvent Evaporation Rates*. Fraction in respirable range is 1.

8.1.1 Hazardous Material and Radiological Accidents

Due to the low fissile material content of depleted uranium (typically 0.25% U-235), a criticality accident is considered to be incredible and is not considered.

The depleted uranium will contain trace quantities of daughter products (primarily Th-234, Pa-234) from U-238 radioactive decay. The trace products tend to plate out in the UF_6 cylinders and only a small fraction of them enter the UF_6 conversion process. However, the daughter products build up with time and approach their equilibrium value in about two months.

Empty UF_6 cylinders are expected to have a fairly high radiation rate on contact. Special handling equipment and procedures will be employed to reduce radiation exposure to workers. The radiation rate drops as the daughter products decay (24 day half-life). The filled cylinders have a much lower radiation rate due to self-shielding by the solid UF_6, and special handling is not required.

Uranium, hydrofluoric acid, trichloroethylene and ammonia are the primary hazardous materials handled in this facility. Uranium and ammonia are toxic and hydrofluoric acid is both toxic and corrosive. Trichloroethylene is toxic and is a suspected carcinogen.

8.1.2 Natural Phenomena

8.1.2.1 Earthquake

The design basis earthquake (DBE) will be chosen in accordance with DOE-STD-1020-94 and DOE-STD-1021-93 (derived from UCRL-15910) for the appropriate hazard safety classification. Systems, structures, and components (SSCs) are designed to withstand the DBE defined by the hazard classification performance category exceedance probability. Earthquakes exceeding the magnitude of the DBE or causing failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Earthquakes of sufficient magnitude to cause the failure of performance category PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

The HF Storage Building and selected areas of the Process Building are designed for the performance category PC-4 DBE for chemically high hazard structures in areas where high inventory of HF or UF_6 at elevated temperatures is present. Therefore, it would be incredible that these structures fail in the event of the DBE.

The UO_2 Storage Building is designed for the performance category PC-3 DBE for radiologically moderate hazard structures. The appropriate DBE as defined by DOE-1020-94 for this facility would not result in damage such that confinement of hazardous materials is compromised. The building contains up to 1,753 drums each containing 2,250 lb of UO_2. In the extremely unlikely event of an earthquake exceeding the DBE or failure of PC-3 SSCs, it is postulated that 10% of the drums are damaged and the drum cover is lost. It is also assumed that the building containment is breached due to earthquake damage, the ventilation system is not operable and that 50% of the drum contents are released and fall to the floor. Assuming a conservative average fall height of 8 ft, approximately 0.005% of the spheres are fractured into respirable particles which are assumed to subsequently exhibit powder-like behavior and could be expected to become airborne. Thus, approximately 9.8 lb of UO_2 is released to the environment. The release point is at grade.

8.1.2.2 Design Basis Tornado

The design basis tornado (DBT) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard classification. Systems, structures, and components (SSCs) are designed to withstand the appropriate DBT and DBT-generated tornado missiles for each hazard category. Tornadoes exceeding the magnitude of the DBT for PC-3 category facilities and failure of PC-3 SSCs are extremely unlikely accidents as defined in DOE-STD-3009-94. Tornadoes of sufficient energy to cause the failure of PC-4 SSCs are considered incredible events as defined in DOE-STD-3009-94.

The HF Storage Building and selected areas of the Process Building are performance category PC-4 for structures for chemically high hazard facilities.

These building areas are designed to resist the DBT for high hazard facilities. The DBTs defined for these structures would not result in a significant release.

The UO_2 Storage Building is a category PC-3 structure for moderate hazard facilities. This structure would withstand the DBT and would not enable a significant release. However, in the extremely unlikely event of a DBT exceeding the PC-3 defined DBT or failure of PC-3 SSCs, a tornado wind-driven missile could impact a UO_2 storage drum and release the 2,250 lb inventory of the drum. It is assumed that, due to the high wind conditions, all of the spheres become airborne and some fraction of these are pulverized into respirable fragments. This fraction is estimated to be fifty times greater than the pulverizing fraction associated with a drum spill as described above or 0.25%. Therefore, approximately 5.6 lb of respirable UO_2 is released during this extremely unlikely event. However, the particles will be highly dispersed due to tornado wind conditions.

A tornado wind-driven missile could impact the UF_6 storage pad and damage some of the cylinders. There is no significant release because the UF6 is a solid at ambient temperature.

8.1.2.3 Design Basis Flood

The design basis flood (DBF) will be chosen in accordance with DOE-STD-1020-94 (UCRL-15910) for each SSC at the appropriate hazard category. Systems, structures, and components (SSCs) are designed to withstand the DBF for the appropriate hazard classification performance category. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3009-94. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3009-94.

Depending on the facility location and elevation, flooding may or may not be credible. For this study, it is assumed that the facility site precludes severe flooding.

8.1.3 Other Postulated Events

8.1.3.1 UF_6 Cylinder Yard Accidents

Accidents involving the temporary storage and handling of depleted UF_6 cylinders are found in Section 7.0, Supplemental Accident Analyses, of the Draft Engineering Analysis Report.

8.1.3.2 HF Distillation System Leak

Gaseous HF is produced from the conversion reactions. The HF is separated in a distillation column to form anhydrous (~100%) HF and 49 wt%

HF in water. The boiling point of anhydrous HF is 67°F and that of 49 wt% HF is 233°F. Possible accidents are vessel, pump or pipe leakage.

It is postulated that the distillation column overhead vapor line carrying anhydrous HF leaks 5% of its flowing contents for 10 minutes, thus releasing 540 lb of HF into the Process Building. After the leak is detected by air monitoring instruments, the distillation column operation and reactor feed are halted to stop the leak. It is assumed that 40% of the HF vapor (216 lb) is released to atmosphere before the HVAC system is shut down to stop further releases. The release point is the Process Building exhaust stack. The building water spray system is then activated to absorb HF vapor remaining in the area. This accident is judged to be anticipated.

8.1.3.3 HF Pipeline Rupture

Anhydrous HF is pumped from the Process Building to the HF Storage Building through an underground pipeline. The pipe is double-walled to contain possible leakage and has a leak detection alarm. It is postulated that an earthquake ruptures the pipeline and its outer pipe. Assuming it takes 5 minutes to stop the HF pump, the pipeline is 200 ft of 1" pipe, and the pump runs at 10 gpm, it is estimated that approximately 60 gallons (500 lb) of anhydrous HF is released into the ground in a ten minute period. The contaminated soil is removed after 48 hours. This accident has been judged to be unlikely.

8.1.3.4 HF Storage Tank Overflow

Anhydrous HF is stored in six 38,000-gallon tanks in the HF Storage Building. Each tank contains about 282,000 lb of HF. The tanks and building are cooled to about 50°F to minimize the HF that vaporizes if a spill should occur. The tanks are performance category PC-4, have high level alarms and interlocks that stop the transfer pump, and are diked to contain spillage. The building has HF air monitoring instruments and a water spray system that can be activated to absorb HF.

It is postulated that during filling, a storage tank overflows at 10 gpm for 10 minutes and releases 100 gallons (830 lb) of HF. The HF spills onto the floor and drains to a covered sump. The HF evaporates at a rate of 12 lb/min for 15 minutes, based on an evaporation rate of 0.06 lb/min-sq ft and a spill area of 200 sq ft. The building HVAC system discharges 25% of the HF vapor (45 lb) to atmosphere in a 15 minute period, based on 3 air changes/hr and a mixing factor of 0.33. The building HVAC system is then shut down to stop further releases to atmosphere and the building water spray system is activated to absorb HF vapor remaining in the building. The release point is the Process Building exhaust stack. This accident has been judged to be unlikely.

8.1.3.5 UO_2 Drum Spill

Solid UO_2 is produced and packaged in drums in the process building. The drums are transported and stored in the UO_2 Storage Building. It is postulated that a drum on an 8 ft high storage rack is damaged by a forklift and spills its contents onto the storage building floor. A drum contains 2,250 lb of UO_2. It is assumed that 50% of the UO_2 is released from the drum and fall to the floor. The pulverizing fraction for this scenario is 0.005% meaning that this proportion of the spheres are fractured into respirable particles which become airborne. The building HVAC system has HEPA filters which remove 99.9% of the airborne UO_2. Thus 5.6×10^{-5} lb of UO_2 is discharged through the UO_2 Building exhaust to atmosphere. It is assumed that the spill on the floor is cleaned up within 2 hours so resuspension of solids is not significant. This accident has been judged to be anticipated.

8.1.3.6 Loss of Off-Site Electrical Power

An uninterruptible power supply and backup diesel generator provide electrical power to perform a safe shutdown if off-site power is lost. This accident has been judged to be anticipated and does not result in a release to the environment.

8.1.3.7 Loss of Cooling Water

The HF distillation column and conversion reactors operate at pressures up to 15 psig. Pressure relief valves are provided to protect vessels and equipment. Loss of cooling water to the distillation column condenser would cause the pressure in the column to rise and the relief valve to open. The relief valve outlet is piped to a bed of limestone to neutralize the HF vapor (or a water quench tank to absorb the vapor) before discharging to atmosphere.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 1,100 lb of HF. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. Assuming that the limestone bed has a 98% removal efficiency for HF, about 22 lb of HF would be released to atmosphere through the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.8 Hydrogen Explosion

A 4% hydrogen/96% nitrogen gas mixture and a 75% hydrogen/25% nitrogen gas mixture are fed to eleven UO_2 sintering furnaces. There is normally no air in the furnaces. The furnace vapor space normally contains nitrogen, hydrogen, steam and a little ammonia.

Detailed startup, operational, and shutdown procedures are provided to ensure safe operation of the furnaces. The furnace off-gas line is equipped with instrumentation to detect oxygen and to detect combustible gas concentrations. Alarms and interlocks are provided to stop the hydrogen flow should an unsafe condition be detected.

It is postulated that a series of malfunctions causes a large amount of hydrogen to accumulate in the furnace, air to leak into the furnace, and an ignition source to be present. This might occur if the furnace was not purged to remove air during startup. The hydrogen ignites and it is assumed that the explosion is powerful enough to rupture the furnace.

A furnace is assumed to contain about 13,000 lb of UO_2 during normal operation. It is assumed that 50% of the material is released into the room, of which 0.25% is pulverized and becomes airborne in the respirable size range. The ventilation system has HEPA filters that remove 99.9% of the material. Thus 0.017 lb of UO_2 is discharged through the Process Building exhaust stack. This accident is judged to be extremely unlikely.

8.1.3.9 Ammonia Release

Ammonia is stored as a liquid in two 25,000 gallon pressure vessels located outdoors in the yard. The ammonia pressure increases as the ambient temperature increases. Tank pressure would be 93 psig if the tank contents are at 60°F, and 166 psig at 90°F. Ammonia is toxic but is not considered flammable.

A leak in an ammonia system can be readily detected by odor. Ammonia vapor or gas is lighter than air, so small leaks will tend to rise and dissipate. Ammonia is highly soluble in water and water sprays are effective in absorbing ammonia vapor. The ammonia tank outlets are equipped with an excess flow valve, which would close and stop the ammonia flow in the event the outlet piping was cleanly broken off.

It is postulated that the ammonia supply truck fill line for an ammonia storage tank is momentarily disconnected during fill operations The release is detected by an operator who is required to be present to monitor the unloading operations per ANSI Standard K61.1, "Safety Requirements for the Storage and Handling of Anhydrous Ammonia", Section 5.10.

Assuming a flow of 50 gpm for one minute, 255 lb of ammonia is released to atmosphere at grade. This accident is judged to be unlikely.

Catastrophic failure of an ammonia tank is considered incredible since the fabrication and installation of the tank will follow ANSI Standard K61.1, which requires ASME Code fabrication and appropriate vehicle barriers and diked areas around the tanks to protect them from vehicle damage and contain leakage. Also, vegetation and other flammable materials will be excluded from the immediate storage tank area.

8.1.3.10 Trichloroethylene Vapor Leak

Trichloroethylene (TCE) is vaporized by hot air in the gel sphere dryers. It is postulated that a dryer exhaust line from a 1200μ gel sphere dryer leaks 5% of its flowing contents for 10 minutes. The gas, whose composition is 17% TCE 83% air, results in a 20 lb release of TCE into the Process Building. After the leak is detected by air monitoring instruments, the dryer air blower is shut down stop the leak. It is assumed that all the TCE is removed by the HVAC system and released to atmosphere over a 60 minute period. The release point is the Process Building exhaust stack. This accident is judged to be anticipated.

8.1.3.11 Trichloroethylene Spill

Trichloroethylene is present in tanks, columns and piping in the sphere gelation system in the Process Building. The area is diked to contain spillage. The diked area drains to a covered sump with a high level alarm.

It is postulated that during operation 100 gallons (1,220 lb) of TCE spills onto the floor, of which 90% (1,100 lb) drains into a sump. Based on an evaporation rate of 0.01 lb/min-sq ft and a wetted floor area of 200 sq ft, the TCE evaporates at a rate of 2 lb/min. The TCE on the floor (120 lb) evaporates in 1 hr. The TCE in the sump (1,100 lb) is transferred to a closed vessel. The building HVAC system discharges the evaporated TCE vapor (120 lb) to atmosphere over a 2 hr period. The release point is the Process Building exhaust stack. This accident has been judged to be anticipated.

8.1.3.12 Ammonia Stripper Overpressure

The ammonia stripping column operates above atmospheric pressure. Pressure relief valves are provided to protect the column and equipment. Loss of cooling water to the stripping column condenser would cause the pressure in the column to rise and the relief valve to open.

It is postulated that cooling water is lost and 100% of the overhead vapor flows through the relief valve for 1 minute, releasing 15 lb of ammonia and 1,350 lb of steam. High temperature and pressure alarms and interlocks would shut down the heat input to the column to stop the release. The release point is the Ammonia Recovery Area in the yard. This accident has been judged to be anticipated.

9.0 Transportation

9.1 INTRASITE TRANSPORTATION

Intrasite transport of radioactive materials will be limited to transport by truck of incoming 14-ton DUF_6 feed containers to the Process Building, UO_2 product in 30 gallon drums from the Process Building to the UO_2 Storage Building, and low level radioactive waste materials in DOE-approved storage and shipping containers (i.e., 55-gal drums, plywood boxes, etc.) from the waste treatment area of the Process Building to the plant boundary.

Intrasite transport of hazardous materials will consist primarily of rail car or truck transport of UO_2 to the plant boundary. Hazardous waste materials such as hazardous waste cleaning solutions, spent lubricants, contaminated clothing, rags and wipes, laboratory wastes, etc., requiring special treatment before disposal will be packaged on-site for truck transport primarily from the Process Building to the plant boundary for shipment to off-site hazardous waste treatment, storage and disposal facilities.

9.2 INTERSITE TRANSPORTATION

Intersite transportation data for offsite shipment of radioactive and hazardous feed, product and waste materials is shown in Table 9-1.

9.2.1 Input Material Streams

Hazardous materials shipped to the site include nitric acid (HNO_3), sodium hydroxide (NaOH), hydrochloric acid (HCl), trichloroethylene (TCE), and ammonia (NH_3). Depleted uranium hexafluoride (DUF_6) is the only radioactive material shipped to the site. Table 9-1 provides data on these input material streams.

9.2.2 Output Material Streams

Output uranium dioxide, hydrofluoric acid (HF), and low-level radioactive wastes, and hazardous wastes are shipped from the facility to offsite locations. Table 9-1 provides data on these output material streams.

The UO_2 product is packaged in 30 gallon steel drums that are 29 inches high by 18.2 inches outside diameter. The empty drum weighs 90 lbs and has a wall thickness of 0.095 inches. Each drum contains 2,250 lbs of UO_2.

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data

Type of Data	Input Material #1	Input Material #2	Input Material #3	Input Material #4	Input Material #5
Transported Materials					
Type	UF_6	TCE	HCl	NaOH	HNO_3
Physical Form	Solid	Liquid	Liquid	Liquid	Liquid
Chemical Composition / Temperature,Pressure	UF_6 / ambient	Cl_2CCHCl/ ambient	HCl / ambient	NaOH / ambient	HNO_3 / ambient
Packaging					
Type	14 MT Cylinder	55 Gallon Drum	55 Gallon Drum	55 Gallon Drum	Rail Car 11,000 gal
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	48G	TBD	TBD	TBD	TBD
Container Weight (lb)	2,600	50	50	50	TBD
Material Weight (lb)	27,000	645	540	700	107,000
Chemical Content (%)	100% UF_6	100% TCE	37% HCl	50% NaOH	50% HNO_3
Shipments					
Average Volume (ft^3)/Year	323,000	162	1,230	765	459,000
Packages/Year	2,322	22	167	104	348
Packages/Life ofProject	46,440	440	3,340	2,080	6,960
Packages/Shipment	1 (truck) or 4 (railcar), 12 cars/train	11	42	26	12 cars / train
Shipments/Year	2,322 (truck) or 49 (rail)	2	4	4	29
Shipments/Life of Project	46,440 (truck) or 980 (rail)	40	80	80	580
Form of Transport/Routing					
Form of Transportation	Truck/Rail	Truck	Truck	Truck	Rail
Destination - Facility Type	NA	NA	NA	NA	NA

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Input Material #6	Output Material #1	Output Material #2	Output Material #3	Output Material #4
Transported Materials					
Type	NH_3	Uranium dioxide	Hydrofluoric Acid	Low-Level Rad Waste	Hazardous Waste
Physical Form	Liquid	Solid	Liquid	Solid	Solid & Liquid
Chemical Composition / Temperature, Pressure	NH_3 / 100°F, 197 psig (max.)	UO_2 / ambient	HF / ambient	See Table 7-3	See Table 7-3
Packaging					
Type	Rail Car 11,000 gal	30 Gallon Drum	Rail Tankcar 11,000 gal.	55 Gallon Drum / Box	55 Gallon Drum
Certified by	DOT	DOT	DOT	DOT	DOT
Identifier	105S-300-W	TBD	105A-300-W	Varies	Varies
Container Weight (lb)	TBD	90	TBD	50/300	50
Material Weight (lb)	52,000	2,250	84,000	See Table 7-3	See Table 7-3
Chemical Content (%)	100% NH_3	100% UO_2	100% HF	See Table 7-3	See Table 7-3
Shipments					
Average Volume (ft^3)/Year	66,000	85,000	358,000	26,200	630
Packages/Year	48	21,000	243	3,126/58	86
Packages/Life of Project	960	420,000	4,860	62,520/1,160	1,720
Packages/Shipment	1	16 (truck) or 48 (railcar), 4 cars/train	12 railcars / train	40/10	43
Shipments/Year	48	1,313 (truck) or 110 (rail)	20	78/6	2
Shipments/Life of Project	960	26,260 (truck) or 2,200 (rail)	400	1,560/120	40
Form of Transport/Routing					
Form of Transportation	Rail	Truck/Rail	Rail	Truck	Truck
Destination - Facility Type	NA	TBD	TBD	LLW Disposal Site	Hazardous Waste Treatment

Table 9-1, Intersite Radioactive/Hazardous Material Transportation Data (continued)

Type of Data	Output Material #5	Output Material #6
Transported Materials		
Type	Mixed Waste	Empty UF_6 Cylinders
Physical Form	Solid	Solid
Chemical Composition / Temperature, Pressure	See Table 7-3	UF_6 / ambient
Packaging		
Type	55 Gallon Drum	14 MT Cylinder
Certified by	DOT	DOT
Identifier	Varies	48G
Container Weight (lb)	50	2,600
Material Weight (lb)	See Table 7-3	22
Chemical Content (%)	See Table 7-3	100% UF_6 (Note 1)
Shipments		
Average Volume (ft^3)/Year	310	323,000
Packages/Year	42	2,322
Packages/Life of Project	840	46,440
Packages/Shipment	21	6 (truck) or 12 (railcar) 4 cars/train
Shipments/Year	2	387 (truck) or 49 (rail)
Shipments/Life of Project	40	7,740 (truck) or 980 (rail)
Form of Transport/Routing		
Form of Transportation	Truck	Truck/Rail
Destination - Facility Type	Mixed Waste Treatment	Cylinder Treatment Facility

1. Also contains 0.16 Ci Pa-234 + 0.16 Ci Th-234.

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11.0 Glossary

List of Acronyms

ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
DUF_6	depleted uranium hexafluoride
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ft/sec	feet per second
g	gram(s)
gal	gallon(s)
gpd	gallon(s) per day
gpm	gallon(s) per minute
GWh	gigawatt ($1x10^6$ kW) hour(s)
HEPA	high-efficiency particulate air
HF	hydrofluoric acid (hydrogen fluoride)
HMTA	hexamethylenetetramine
HVAC	heating, ventilating, and air conditioning
kV	kilovolt
kW	kilowatt
lb	pound
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
MT	metric ton (1000 kg)
MWh	megawatt hour(s)
nCi	nano curies
NFPA	National Fire Protection Association
NO_x	nitrogen oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PDEIS	preliminary draft environmental impact statement
psia	pounds per square inch absolute
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

ROD	record of decision
scf	standard cubic feet
SSC	structures, systems, and components
TBD	to be determined
TCE	trichloroethylene
TRU	transuranic waste
UCRL	University of California Radiation Laboratory
UF_6	uranium hexafluoride
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
yd	yard(s)
yd^2	square yard(s)
yd^3	cubic yard(s)

Appendix A

Material Balance

UO2 by Gelation Process
U3O8 Preparation (Figures 4-3 to 4-7)
28,000 MT/Yr UF6
7000 hr/yr

		UF6 Feed	HF-Steam to Reactor No. 1	Reactor No.1 Off-Gas	UO2F2	Steam to Reactor No. 2	U3O8	Reactor No. 2 Off-Gas	Distillation Column Feed	Distillation Column Overhead*	Condenser Off-Gas
Component	Mol Wt	1	2	3	4	5	6	7	8	9	10
UF6	352	8,800									
UO2F2	308				7,700						
U3O8	842						7,017				
HF	20		1,841	3,841				1,000	4,841	2,970	68
H2O	18		2,250	1,350		1,351		901	2,251	0.6	0
O2	32							133	133	133	133
KOH	56										
KF	58										
Total lb/hr		8,800	4,091	5,191	7,700	1,351	7,017	2,034	7,225	3,104	201
kg/kg U		1.48	0.69	0.87	1.29	0.23	1.18	0.34	1.21	0.52	0.034

*Stream 9 flowrate does not include reflux flow.

UO2F2 Production

352	36	308	80
UF6 +	2 H2O -->	UO2F2 +	4 HF
8,800	900	7,700	2,000

U3O8 Production

924	54	842	120	16
3 UO2F2 +	3 H2O -->	U3O8 +	6 HF +	0.5 O2
7,700	450	7,017	1,000	133

UO2 by Gelation Process
U3O8 Preparation (Figures 4-3 to 4-7)
28,000 MT/Yr UF6
7000 hr/yr

		HF Product	Distillation Column Bottoms	Impurities Purge	Makeup Water	Scrubber Exhaust	Scrub Solution	Scrub Solution	Hydrated Lime	Scrub Solution Slurry	Wash Water
Component	Mol Wt	11	12	13	14	15	16	17	18	19	20
Cement											
KOH	56						236	47		236	
KF	58						20	215		20	
Ca(OH)2	74								125		
CaF2	78									132	
HF	20	2,902	1,871	30		0.07					
H2O	18	0.6	2,250	43	43	0	3,349	3,409		3,409	197
O2	32					133					
Total lb/hr		2,903	4,121	73	43	133	3,605	3,672	125	3,797	197
kg/kg U		0.49	0.69	0.012	0.0073	0.022	0.61	0.62	0.021	0.64	0.033

Off-Gas Scrubbing

20	56	58	18
HF +	KOH -->	KF +	H2O
68	189	196	61

Scrub Solution Regeneration

116	74	78	112
2 KF +	Ca(OH)2-->	CaF2 +	2 KOH
196	125	132	189

UO2 by Gelation Process
U3O8 Preparation (Figures 4-3 to 4-7)
28,000 MT/Yr UF6
7000 hr/yr

		Filtrate	CaF2 Slurry	Conden-sate	CaF2	Dryer Conden-sate	Hydrated Lime	Neutralized Slurry	Cement	Water	Grouted Waste
Component	Mol Wt	21	22	23	24	25	26	27	28	29	30
Cement									123		123
KOH	56	236									
KF	58	20									
Ca(OH)2	74						56				
CaF2	78		132		132			59			59
HF	20										0
H2O	18	3,541	66	192		66		70		41	111
O2	32										
Total lb/hr		3,797	197	192	132	66	56	129	123	41	293
kg/kg U		0.64	0.033	0.032	0.022	0.011	0.0093	0.022	0.021	0.0069	0.049

Neutralization of Blowdown

40	74	78	36
2 HF +	Ca(OH)2-->	CaF2 +	2 H2O
30	56	59	27

U3O8 Dissolution Material Balance

	A	B	C	D	E	F	G	H	I	J	K
1	**DUF6 to DUO2 by Gelation**			**(Ref Figure 4-8)**							
2	**28,000 MT/Yr UF6**										
3	**U3O8 Dissolution**			* See note.							
4			**U3O8 from**	*** U3O8 to**	**Tot HNO3 to**	**HNO3 to**	**HNO3 to**	**Dissolver**	*See Note	*See Note	**Denitrited**
5	**Component**	**Mol Wt**	**Production**	**Dissolution**	**Dissolution**	**Dissolver**	**Filter Bkwsh**	**Off Gas**	***Dissolver**	***Urea to**	**ADUN**
6	U3O8	842	3,182.3	9,546.9					**Product**	**ADUN Tank**	**to Gelation**
7	UO2(OH)0.4(NO3)1.6	376							12,789.7		25,579.45
8	CH4N2O(urea)	60								5,102.3	5,075.84
9	HNO3	63			4,143.1	3,728.7	414.3				
10	HNO2	47							20.71		
11	H2O	18			7,452.2	6,707.0	745.2	14.20	7,903.5		15,827.40
12	NO	30						163.47			
13	NO2	46						250.65			
14	N2	28									
15	CO2	44									
16	Total, Kg/Hr		3,182.3								
17	Kg/Batch			**9,546.9**	**11,595.3**	**10,435.7**	**1,159.5**	**428.31**	**20,713.9**	5,102.3	46,482.69
18	Kg/L		4.39	4.39	1.21	1.21	1.21		2.01	0.87	2.07
19	L/Batch			2,177	9,582.9	8,624.6	958.3		10,307.6		22,460
20	L/Hr										
21	Batch Freq'y, Hr			**3**	**3**	**3**	**3**	**3**	**3**	**6**	**6**
22	Molarity, U								3.30		3.03
23	Mol Ratio, NO3/U								1.60		1.60
24	Molarity, NO3				6.86	6.86	6.86		5.28		4.85
25	**Avg Lb/Hr**		**7017**								
26	**Lb/Batch**			**21,051**	**25,568**	**23,011**	**2,557**	**944**	**45,674**	**11,251**	**102,494**
27	GPM										
28	Gallons/Batch				2,531.8	2,278.6	253.2		2,723.3		5,933.98
29	Cubic Ft		25.64	34.88							
30	Temperature, °C				30	30	30	40	60		
31	MT/Yr									5,953	
32			1684	730.8	2256		30	46	82.8		
33	**Dissolution Reactions:**		2 U3O8 +	11.6 HNO3 ->	6UO2(OH)0.4(NO3)1.6 +		NO +	NO2 +	4.6 H2O		
34			9546.94	4143.05	12789.72		170.08	260.78	469.41		
35											
36			46	30	18	94					
37			NO2 +	NO +	H2O-->	2 HNO2					
38			10.14	6.61	3.97	20.71					
39											
40											
41	Bulk U3O8,Kg/L=	4.39									
42	Density, Kg/L,	ADUN =	rho(H2O)+0.2659(M U) + 0.0282(M NO3)								
43											

U3O8 Dissolution Material Balance

	L	M	N	O	P	Q	R	S	T	U	V
1	**DUF6 to DUO2 by Gelation**		**(Ref Figures 4-8&9)**								
2	**28,000 MT/Yr UF6**										
3	**U3O8 Dissolution**			**Total Avg**	*See note						**Purchased**
4			**ADUN Surge**	**ADUN to**	***Avg Feed to**	**Process H2O**	**Air to NOx**	**NOx Abs**	**NOx Abs**	**Dilution**	**HNO3 to**
5	**Component**	**Mol Wt**	**Tank Off Gas**	**Gelation**	**NOx Absorber**	**to Absorber**	**Absorber**	**O'head, 30°C**	**Bottoms**	**H2O**	**Acid Makeup**
6	UO2(OH)0.4(NO3)1.6	376		4,263.2							
7	CH4N2O	60		846.0							
8	HNO3	63							175.92		3,615.30
9	H2O	18	3.30	2,634.5	5.28	557.48	5.77	15.65	527.75	2,253.65	3,615.30
10	NO	30			54.49			20.71			
11	NO2	46			83.55			6.90			
12	N2	28	24.68		4.11		455.45	459.56			
13	O2	32					121.07	80.71			
14	CO2	44	19.39		3.23			3.23			
15	NH3	17									
16	Total, Kg/Hr			7,743.7	150.66	557.48	582.28	586.76	703.67		
17	Kg/Batch		**47.37**							2,253.65	7,230.61
18	Kg/L			2.07		0.983			1.13		1.30
19	L/Batch			3,741.7							5,562.00
20	L/Hr					567.12			622.72		5,562.00
21	Batch Freq'y, Hr		**6**							3	3
22	Molarity, NO3			3.03					4.48		10.32
23	**Avg Lb/Hr**			**17,075**	**332.21**	**1229.25**	**1283.93**	**1293.81**	**1551.59**	**751.22**	**5,314.49**
24	**Lb/Batch**		**104.45**							2,253.65	15,943.48
25	GPM			16.5		2.50			2.75		
26	ACFM							298			
27	MT/7000 Hr										0.50
28	**NOx Abs Reactions:**										16,871
29	Delta Hf	86.4	0	-136.6	-196.80	Delta Hrx, Kcal/g mole NO		-36.65			
30	MW	120	96	36	252		BTU/Hr	-163,775			
31		4 NO +	3 O2 +	2 H2O -->	4 HNO3						
32	Avg Kg/Hr	33.78	27.03	10.13	70.94						
33											
34	Delta Hf	31.84	0	-136.6	-196.80	Delta Hrx, Kcal/g mole NO2		-23.01			
35	MW	184	32	36	252		BTU/Hr	-152,144			
36		4 NO2 +	O2 +	2 H2O -->	4 HNO3	Tot Abs Cooling, BTU/Hr		-315,919			
37	Avg Kg/Hr	76.65	13.33	15.00	104.97						
38											
39	**Nitrite Decomp'n Reaction:**										
40	MW	94	60	44	56	54					
41		2 HNO2 +	CH4N2O -->	CO2 +	2 N2 +	3 H2O					
42	Kg/Batch	41.43	26.44	19.39	24.68	23.80					
43	Plt Avg Kg/Hr	10.36	6.61	4.85	6.17	5.95					

U3O8 Dissolution Material Balance

	W	X	Y	Z	AA	AB	AC	AD	AE	AF
1	DUF6 to DUO2 by Gelation		(Ref Figure 4-9)							
2	28,000 MT/Yr UF6					* See note				
3	U3O8 Dissolution				Abatement	NOx Abate'te	NOx Abate'te			
4			Acid Batch	NH3 to NOx	Reactor	Cat Inlet	Cat. Outlet*	Net Effl't		
5	Component	Mol Wt	to Dissol'n	Abatement	Recycle	(Say 572°F)	(Say 752°F)	to Atm		
6	UO2(OH)0.4(NO3)1.6	376								
7	CH4N2O	60								
8	HNO3	63	4,143.05							
9	H2O	18	7,452.20		123.15	138.80	157.51	34.36		
10	NO	30			< 5 ppm	20.71	< 5 ppm	< 5 ppm		
11	NO2	46			< 5 ppm	6.90	< 5 ppm	< 5 ppm		
12	N2	28			1723.96	2183.52	2204.99	481.03		
13	O2	32			286.42	367.14	366.35	79.92		
14	CO2	44			11.58	14.81	14.81	3.23		
15	NH3	17		11.78	0.00	11.78	0.00	0.00		
16	Avg Tot Kg/Hr			11.78	2145.12	2731.88	2743.66	598.54		
17	Kg/Batch		11,595.26							
18	Kg/L		1.21							
19	Liters/Batch		9,582.86							
20	Avg Liters/Hr		9,582.86							
21	Batch Freq, Hr		3.00							
22	Molarity, NO3		6.86							
23	**Avg Lb/Hr**		**8,522.51**	**25.98**	**4,730**	**6,024**	**6,050**	**1,320**		
24	Lb/Batch		25,567.54							
25	Kg Moles/Hr			0.693	77.63	98.34	99.29	21.66		
26	ACFM					2,667	3,249	334		
27	WF HNO3		0.36							
28										
29						Appx. recy. ratio req to limit temp rise to 180F° (100C°)=				3.58
30	**Reactions:**	Delta Hf	0	-43.84	0	-346.8	Delta Hrx, Kcal/g mole NH3		-75.74	
31		mw	96	68	56	108		BTU/Hr	-9,921	
32			3 O2 +	4 NH3 -->	2 N2 +	6 H2O				
33		Kg/Hr	0.79	0.56	0.46	0.89				
34										
35		Delta Hf	129.6	-43.84	0	-346.8	Delta Hrx, Kcal/g mole NO		-72.09	
36		mw	180	68	140	108		BTU/Hr	-197,452	
37			6 NO +	4 NH3 -->	5 N2 +	6 H2O				
38		Kg/Hr	20.71	7.82	16.10	12.42				
39										
40		Delta Hf	47.76	-87.68	0	-693.6	Delta Hrx, Kcal/g mole NO2		-108.95	
41		mw	276	136	196	216		BTU/Hr	-64,867	
42			6 NO2 +	8 NH3 -->	7 N2 +	12 H2O		Total BTU/Hr	-272,240	
43		Kg/Hr	6.90	3.40	4.90	5.40		AppxTempRise,°F	825	w/o recycle

U3O8 Dissolution Material Balance

Cell: AB2
Note: Assumes 5% x's NH3 reacts to N2 + H2O with O2. Available literature not conclusive on what happens to excess NH3, but some evidence that it disappears.

Cell: D4
Note: Material balance is based on two dissolver trains operating on 6 hour staggered batch cycles. One batch of U3O8 is fed to a dissolver every 3 hours.

Cell: I4
Note: HNO2 concentration estimated at about 1000 ppm. Ref. ORNL/TM-6850.

Cell: J4
Note: Urea to U ratio = 1.25. Stir for 24 hours at 50°C. Treat 2 dissolver batches per urea treatment batch. This is equivalent to 4 urea treatment (denitrite) batches per day.

Cell: P4
Note: Material balance shows sum of average dissolver plus denitriting off gas rates. Actual rates will have peaks and troughs, magnitudes TBD.

Gelation Feed

UO2 by Gelation Process
Gelation Column Feed (Figure 4-10)
28,000 MT/Yr UF6
7000 hr/yr

Component	Mol Wt	3 M U ADUN 1	ADUN to 1200μ Gelation 2	ADUN to 300μ Gelation 3	3 M HMTA 4	HMTA to 1200μ Gelation 5	HMTA to 300μ Gelation 6	Feed Broth to 1200μ Gelation 7	Feed Broth to 300μ Gelation 8
UO2(OH).4(NO3)1.6	376	9,400	6,580	2,820				6,580	2,820
UO3*H2O	304							0	0
(CH2)6N4	140				4,375	3,063	1,313	3,063	1,313
CO(NH2)2	60	1,865	1,306	560				1,306	560
H2O	18	5,809	4,066	1,743	6,843	4,790	2,053	8,856	3,796
NH4NO3	80								
HCHO	30								
Cl2CCHCl	131								
Air	29								
Total lb/hr		17,074	11,952	5,122	11,218	7,853	3,365	19,804	8,488
kg/kg U		2.87	2.01	0.86	1.89	1.32	0.57	3.33	1.43

Gelation 1200

UO2 by Gelation Process
1200μ Gelation (Fig. 4-11)
28,000 MT/Yr UF6
7000 hr/yr

		Feed Broth to Column	TCE to Column	Spheres from Column	Spheres from Filter	TCE Filtrate	Air to Drying	Dry Spheres	Air to Condenser	Air from Condenser
Component	Mol Wt	1	2	3	4	5	6	7	8	9
UO2(OH).4(NO3)1.6	376	6,580								
UO3*H2O	304			5,320	5,320			5,320		
(CH2)6N4	140	3,063		2,083	2,083			2,083		
CO(NH2)2	60	1,306		1,306	1,306			1,306		
H2O	18	8,856	52	7,648	7,598	50		7,596		
NH4NO3	80			2,240	2,240			2,240		
HCHO	30			1,260	1,260			1,260		
Cl2CCHCl	131		258,128	258,128	8,488	249,640	938		9,426	943
Air	29						47,131		47,131	47,131
Total lb/hr		19,804	258,180	277,984	28,294	249,690	48,069	19,804	56,557	48,074
kg/kg U		3.33	43.39	46.72	4.76	41.96	8.08	3.33	9.51	8.08

Gelation

376	56		304	128
UO2(OH).4(NO3)1.6	+ 1.6 NH4OH --->		UO3*H2O	+ 1.6 NH4NO3
6,580	980		5,320	2,240

HMTA Decomposition

140	180		140	180
(CH2)6N4	+ 10 H2O	--->	4 NH4OH	+ 6 HCHO
980	1,260		980	1,260

UO2 by Gelation Process
1200μ Gelation (Fig. 4-11)
28,000 MT/Yr UF6
7000 hr/yr

Component	Mol Wt	TCE Condensate 10	Makeup Air 11	Air Bleed 12	TCE Filtrate +Condnte 13	TCE to Evaporation 14	TCE from Evaporation 15
UO2(OH).4(NO3)1.6	376						
UO3*H2O	304						
(CH2)6N4	140						
CO(NH2)2	60						
H2O	18	2			52		
NH4NO3	80						
HCHO	30						
Cl2CCHCl	131	8,484		4.7	258,123	1,291	1,295
Air	29		236	236			
Total lb/hr		8,485	236	240	258,175	1,291	1,295
kg/kg U		1.43	0.040	0.040	43.39	0.22	0.22

UO2 by Gelation Process
300μ Gelation (Fig. 4-12)
28,000 MT/Yr UF6
7000 hr/yr

Component	Mol Wt	Feed Broth to Column 1	TCE to Column 2	Spheres from Column 3	Spheres from Filter 4	TCE Filtrate 5	Air to Drying 6	Dry Spheres 7	Air to Condenser 8	Air from Condenser 9
UO2(OH).4(NO3)1.6	376	2,820								
UO3*H2O	304			2,280	2,280			2,280		
(CH2)6N4	140	1,313		893	893			893		
CO(NH2)2	60	560		560	560			560		
H2O	18	3,796	22	3,278	3,256	21		3,256		
NH4NO3	80			960	960			960		
HCHO	30			540	540			540		
Cl2CCHCl	131		110,626	110,626	3,638	106,988	402		4,040	404
Air	29						20,199		20,199	20,199
Surfactant (Span 80)			5.8							
Total lb/hr		8,488	110,654	119,136	12,126	107,010	20,601	8,488	24,239	20,603
kg/kg U		1.43	18.60	20.02	2.04	17.98	3.46	1.43	4.07	3.46

Span 80 is sorbitan monooleate ester

Gelation

376	56		304	128
UO2(OH).4(NO3)1.6	+ 1.6 NH4OH	--->	UO3*H2O	+ 1.6 NH4NO3
2,820	420		2,280	960

HMTA Decomposition

140	180		140	180
(CH2)6N4	+ 10 H2O	--->	4 NH4OH	+ 6 HCHO
420	540		420	540

UO2 by Gelation Process
300μ Gelation (Fig. 4-12)
28,000 MT/Yr UF6
7000 hr/yr

		TCE Condensate	Makeup Air	Air Bleed	TCE Filtrate +Condnte	TCE to Evaporation	TCE from Evaporation
Component	Mol Wt	10	11	12	13	14	15
UO2(OH).4(NO3)1.6	376						
UO3*H2O	304						
(CH2)6N4	140						
CO(NH2)2	60						
H2O	18	0.73			22		
NH4NO3	80						
HCHO	30						
Cl2CCHCl	131	3,636		2.02	110,624	553	555
Air	29		101	101			
Surfactant (Span 80)							
Total lb/hr		3,637	101	103	110,646	553	555
kg/kg U		0.61	0.017	0.017	18.60	0.093	0.093

Span 80 is sorbitan monooleate ester

UO2 by Gelation Process
TCE Evaporation (Fig. 4-13)
28,000 MT/Yr UF6
7000 hr/yr

		Air from 1200μ Gelation	Air from 300μ Gelation	Air to Carbon Adsorber	Air to Atm	Steam to Carbon Adsorber	Conden-sate from Adsorber	TCE from 1200μ Gelation	TCE from 300μ Gelation	TCE to Evaporator	Sludge from Evaporator
Component	Mol Wt	1	2	3	4	5	6	7	8	9	10
UO2(OH).4(NO3)1.6	376										
UO3*H2O	304										
(CH2)6N4	140										
CO(NH2)2	60										
H2O	18					20	20				
NH4NO3	80										
HCHO	30										
Cl2CCHCl	131	4.7	2.0	6.8	0.068		6.7	1,291	553	1,844	
Air	29	236	101	338	338						
											1.84
Total lb/hr		240	103	345	338	20	27	1,291	553	1,844	1.84
kg/kg U		0.040	0.017	0.058	0.057	0.0034	0.0045	0.22	0.093	0.31	0.00031

UO2 by Gelation Process
TCE Evaporation (Fig. 4-13)
28,000 MT/Yr UF6
7000 hr/yr

Component	Mol Wt	Liquid to Decanter 11	Organic from Decanter 12	Aqueous from Decanter 13	Makeup TCE 14	TCE to 1200μ Gelation 15	TCE to 300μ Gelation 16	Air to Stripper 17	Air from Stripper 18	Water from Stripper 19
UO2(OH).4(NO3)1.6	376									
UO3*H2O	304									
(CH2)6N4	140									
CO(NH2)2	60									
H2O	18	20	0.37	19.7		0.26	0.11			19.7
NH4NO3	80									
HCHO	30									
Cl2CCHCl	131	1,849	1,849	0.040	1.9	1,295	555		0.039	0.00040
Air	29							1.2	1.2	
Total lb/hr		1,869	1,849	20	1.9	1,296	555	1.2	1.2	20
kg/kg U		0.31	0.31	0.0033	0.00032	0.22	0.093	0.00020	0.00021	0.0033

Gel Washing and Drying Material Balance

	A	B	C	D	E	F	G	H	I	J	K
1	**DUF6 to DUO2 by Gelation**		**(Ref Figure 4-14)**			**1200 micron Sphere Washing**					
2	**28,000 MT/YR UF6**										
3	**1200 micron Sphere Wash & Dry**					**Batch to One**	**Feed to One**	**NH3 to One**		**Washed**	**Washed**
4			**Total Feed**	**1200 micron**	**300 micron**	**1200 micron**	**of Four**	**of Four**	**NH3 to All**	**Spheres frm**	**Spheres frm**
5	**Component**	**MW**	**frm Gelation**	**Feed**	**Feed**	**Washer Fd Tk**	**Washers**	**Washers**	**Four Washers**	**One Washer**	**4 Washers**
6	UO3•H2O	304	7,600	5,320	2,280	**31,920**	1,330			1,330	5320
7	(CH2)6N4, HMTA	140	2,975	2,083	893	**12,495**	521			0.52	2.08
8	CO(NH2)2, Urea	60	1,865	1,306	560	**7,833**	326			0.33	1.31
9	NH4NO3	80	3200	2,240	960	**13,440**	560			0.56	2.24
10	HCHO	30	1,800	1,260	540	**7,560**	315			0.32	1.26
11	(HCHO)x	30x				**0**					0
12	NH4OH	35				**0**		267	1,068	77	309
13	H2O	18	10,852	7,596	3,256	**45,578**	1,899	14,906	59,625	3,621	14,484
14	O2	32									
15	N2	28									
16	NH3	17									
17											
18	Total Lb/Hr		28,292	19,804	8,488		4,951	15,173	60,693	5,030	20,121
19	Lb/Batch					**118,826**					
20	Bulk Density, Kg/L		0.975	0.975	0.975	**0.975**	0.975	0.996	0.996	0.989	0.989
21	GPM		58.06	40.64	17.42		10.16	30.48	121.92	10.16	40.64
22	Gal/Batch					**14,631**					
23	Batch Frequency, Hr					**6**					
24	Batches/Day/Line					**1**					
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

Gel Washing and Drying Material Balance

	L	M	N	O	P	Q	R	S	T	U	V
1	**DUF6 to DUO2 by Gelation**		**(Ref Fig 4-14&15)**		**1200 micron Sphere Drying**						
2	**28,000 MT/YR UF6**										
3	**1200 micron Sphere Wash & Dry**										
4		**NH3Washfrm**	**WashfrmAll**	**Air to**	**Avg Air frm**	**One Drier**	**Cond'te frm**	**Dried**	**Avg Dried**		
5	**Component**	**1 Washer**	**4 WashLines**	**One Drier**	**One Drier**	**Condensate**	**Four Driers**	**Gel Spheres**	**Gel Spheres**		
6	UO3•H2O	0	0					**per Drier**	**Four Driers**		
7	(CH2)6N4, HMTA	520	2,080					1,330	5,320		
8	CO(NH2)2, Urea	326	1,304					0.52	2.08		
9	NH4NO3	559	2,238					0.33	1.31		
10	HCHO	315	1,259		0.32	0.32	1.26	0.56	2.24		
11	(HCHO)x		0								
12	NH4OH	190	759			77	309				
13	H2O	13,184	52,737	6,568	10,081	3,473	13,893	148	591.11		
14	O2			35,589	35,589						
15	N2			117,154	117,154						
16	NH3				38						
17											
18	Total Lb/Hr	15,094	60,377	159,311	162,862	3,551	14,204	1,479	5916.74		
19	Lb/Batch										
20	Bulk Density, Kg/L	1.020	1.020			1.00	1.00	1.50	1.50		
21	GPM	29.61	118.43			7.10	28.42	1.97	7.89		
22	Gal/Batch										
23	Batch Frequency, Hr										
24	Batches/Day/Line										
25	Lb/Moles/Hr			5,668	5,866						
26	ACFM			43,068	41,806						
27	**Drier conditions,**										
28	**one of four driers**										
29	**Inlet Air**										
30	Temp., °F	220									
31	Hum., LbH2O/Lb air	0.043									
32	**Outlet Air**			**Chemical Reactions:**							
33	Temp., °F	126		35	17	18					
34	% Rel Humidity	70		NH4OH <-->	NH3 +	H2O					
35	Lb H2O/Lb air	0.066		77.34	37.57	39.78					
36	H2O removed/Lb air	0.023									
37	H2O removed,Lb/Hr	3,513									
38	Lb/Hr dry air req'd	152,743									
39	O2	35,589									
40	N2	117,154									

Gel Washing and Drying Material Balance

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-16)		300 micron Sphere Washing					
2	28,000 MT/YR UF6										
3	300 micron Sphere Wash & Dry			Batch to One	Feed to One	NH3 to One					
4			300 micron	300 micron	of Two	of Two		Washed	Washed		
5	Component	MW	Feed	Washer Fd Tk	Washers	Washers	Total NH3 to Two Washers	Spheres frm One Washer	Spheres frm TwoWashers	NH3 Wash frm One Washer	Wash from 2 Washers
6	UO3•H2O	304	2,280	27,360	1,140			1,140	2280	0	0
7	(CH2)6N4, HMTA	60	893	10,710	446			0.45	0.89	446	892
8	CO(NH2)2, Urea	60	560	6,714	280			0.28	0.56	279	559
9	NH4NO3	80	960	11,520	480			0.48	0.96	480	959
10	HCHO	30	540	6,480	270			0.27	0.54	270	539
11	(HCHO)x	30x	0	0					0		0
12	NH4OH	35	0	0		229	458	66	133	163	325
13	H2O	18	3,256	39,067	1,628	12,777	25,553	3,104	6,208	11,301	22,601
14	O2	32	0								
15	N2	28	0								
16	NH3	17	0								
17			0								
18	Total Lb/Hr		8,488		4,244	13,006	26,011	4,312	8,623	12,938	25,876
19	Lb/Batch		0	101,851							
20	Bulk Density, Kg/L		0.975	0.975	0.975	0.996	0.996	0.989	0.989	1.020	1.020
21	GPM		17.42		8.71	26.13	52.25	8.71	17.42	25.38	50.76
22	Gal/Batch			12,541							
23	Batch Frequency, Hr			12							
24	Batches/Day/Line			1							
25	Lb/Moles/Hr										
26	ACFM										
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

Gel Washing and Drying Material Balance

	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
1	**DUF6 to DUO2 by Gelation**			**300 micron Sphere Drying**							
2	**28,000 MT/YR UF6**		**(Ref Fig 4-17)**								
3	**300 micron Sphere Wash & Dry**			**Drier**	**Drier**	**Dried**	**Dried**				
4		**Air to**	**Avg Airfrm**	**Condensate**	**Condensate**	**Gel Spheres**	**Gel Spheres**				
5	**Component**	**One Drier**	**One Drier**	**per Drier**	**Two Driers**	**per Drier**	**Two Driers**				
6	UO3•H2O					1,140	2,280				
7	(CH2)6N4, HMTA					0.45	0.89				
8	CO(NH2)2, Urea					0.28	0.56				
9	NH4NO3					0.48	0.96				
10	HCHO		0.27	0.27	0.54						
11	(HCHO)x										
12	NH4OH			66	133						
13	H2O	5,630	8,641	2,977	5,954	127	253				
14	O2	30,505	30,505								
15	N2	100,418	100,418								
16	NH3		32								
17											
18	Total Lb/Hr	136,553	139,596	3,044	6,087	1,268	2,536				
19	Lb/Batch										
20	Bulk Density, Kg/L			1.00	1.00	1.50	1.50				
21	GPM			6.09	12.18	1.69	3.38				
22	Gal/Batch										
23	Batch Frequency, Hr										
24	Batches/Day/Line										
25	Lb/Moles/Hr	4,859	5,028								
26	ACFM	36,915	35,834								
27	**Drier conditions,**										
28	**one of four driers**										
29	**Inlet Air**										
30	Temp., °F	220									
31	Hum., LbH2O/Lb air	0.043									
32	**Outlet Air**										
33	Temp., °F	126									
34	% Rel Humidity	70									
35	Lb H2O/Lb air	0.066									
36	H2O removed/Lb air	0.023									
37	H2O removed,Lb/Hr	3,011									
38	Lb/Hr dry air req'd	130,923									
39	O2	30,505									
40	N2	100,418									

Gel Washing and Drying Material Balance

	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-18)							
2	28,000 MT/YR UF6										
3	Ammonia Recovery										
4		Total Wash	TotalCond'te	Total NH3	Stripper	Stripper	Recycle	Waste Water	Ammonia	Water	Waste Organic
5	Component	Solution	Solution	StripperFeed	Bottoms	Overhead	Water	to Treatment	Makeup	Makeup	to Storage
6	UO3•H2O	0.11		0.11	0.11						0.11
7	(CH2)6N4, HMTA	2,972		2,972	2,972	0					2,972
8	CO(NH2)2, Urea	1,863		1,863	1,863	0					1,863
9	NH4NO3	3,197		3,197	3,197	0					3,197
10	HCHO	1,798	1.80	1,800	0	0					0.00
11	(HCHO)x	0	0.00	0	1,800	0					1,800
12	NH4OH	1,084	441.97	1,526	1.53	1,524.47	0.50	1.01	0.50		0.02
13	H2O	75,338	19,847.56	95,186	14,750	80,435	4,742.67	9,538.47		2.93	469.08
14	O2										
15	N2										
16	NH3										
17											
18	Total Lb/Hr	86,252	20,291.32	106,544	24,584	81,960	4,743.18	9,539.48	0.50	2.93	10,301.06
19	Lb/Batch										
20	Bulk Density, Kg/L	1.02	1.00	1.016	1.13	0.993	1.00	1.00	0.62	1.00	1.10
21	GPM	169.19	40.60	209.79	43.53	165.14					18.74
22	Gal/Batch										
23	Batch Frequency, Hr										
24	Batches/Day/Line										
25	Lb/Moles/Hr			5,483.93	923.74	4,512.19					
26	ACFM										
27	Mole Fraction H2O			0.964	0.887	0.990					0.200
28											
29	MT/7000 Hr								1.59		32,702
30	ppm U	1.00									8.37
31											
32											
33											
34								17.00	18.00	35.00	
35								NH3 +	H2O -->	NH4OH	
36								0.50	0.53	1.03	
37											
38											
39											
40											

Gel Washing and Drying Material Balance

Cell: S3
Note: Ref. ORNL/TM-6850 page 58. Dried material is about 15% volatiles (mostly H_2O) and 85% UO_3.

Cell: H5
Note: Assume 3 vol NH_3 sol'n per vol gel account counter- current operation. Gel residence time in wash appx 70 minutes. NH_3 conc. 0.5 molar, or 1.76 wt %. Ref. ORNL/TM-6850.

Cell: AB5
Note: Assume 3 vol NH_3 sol'n per vol gel account counter- current operation. Gel residence time in wash appx 70 minutes. NH_3 conc. 0.5 molar, or 1.76 wt %. Ref. ORNL/TM-6850.

Cell: C20
Note: Assume particulate density of 1.50, with void factor of 0.35.

Cell: S20
Note: Density estimated from Table 4, ORNL/ TM-6850.

Cell: AM20
Note: Density estimated from Table 4, ORNL/ TM-6850.

Sintering and Blending Material Balance

	A	B	C	D	E	F	G	H	I	J	K
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-19)							
2	28,000 MT/YR UF6					1200 MICRON SPHERES					
3	Sintering and Blending						Air Inleak	N2 Purge	4% H2 to	*To Flare	75% H2 to
4			Avg Total	Dried Spheres	Sint'd Sphres	Sint'd Sphres	to 450°C	to 450°C	450°C	from 450°C	1600°C
5	Component	MW	Dried Spheres	One Line	One Line	Eight Lines	Compart't	Compart't	Compart't	Compart't	Compart't
6	UO3•H2O	304	5,320.00	4,655.00							
7	UO2	270			4,134.38	4,725.00					
8	(CH2)6N4, HMTA	140	2.08	1.82							
9	CO(NH2)2, Urea	60	1.31	1.15							
10	NH4NO3	80	2.24	1.96							
11	CH4	16									
12	H2O	18	591.11	517.22						515.18	
13	NH3	17								1.38	
14	H2	2							0.09	0.37	36.75
15	N2	28					2.86	32.56	31.26	66.67	171.50
16	O2	32					0.87			0.87	
17	N2O	44								0.9702	
18	CO2									3.85	
19	Total Avg Lb/Hr		5,916.74			4,725.00					
20	Total Lb/Batch			5,177.15	4,134.38		3.73	32.56	31.35	589.29	208.25
21	Density, Kg/L		1.014	1.014	6.54	6.54					
22	Batch Freq., Hr			7	7		7	7	7	7	7
23	Batch Duratioin, Hr				21						
24	Cu ft @ 70°F, 1 atm		93.51	81.82	10.13	11.58	50	450	450	12,154	9,482
25	Chemical Reactions/Batch/1200 micron Line:										
26			304.00	2	270	36					
27	1600°C Compartment-		UO3•H2O +	H2 -->	UO2 +	2 H2O				*See note	
28			4,655.00	30.63	4,134.38	551.25					
29											
30			140	216	68	24	264				
31	1600°C+450°C Compart's-		(CH2)6N4 +	12 H2O -->	4 NH3 +	12 H2 +	6 CO2				
32			1.82	2.81	0.88	0.312	3.432				
33											
34			60	18	44	34					
35	1600°C+450°C Compart's-		CO(NH2)2 +	H2O -->	CO2 +	2 NH3					
36			1.15	0.34	0.84	0.65		Potential parasitic nitriding reactions:			
37								2 UO2 +	N2 -/-/->	2 UN +	2 O2
38			80.00	44.00	36.00			2 UO2 +	3 N2 -/-/->	2 U2N3 +	2 O2
39	1600°C+450°C Compart's-		NH4NO3 -->	N2O+	2 H2O			Both reactions show positive free energy change, therefore			
40			1.96	1.08	0.88			will be considered negligible.			

Sintering and Blending Material Balance

	L	M	N	O	P	Q	R	S	T	U	V
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-19)							
2	28,000 MT/YR UF6							300 MICRON SPHERES			
3	Sintering and Blending			1200 micron							
4		ToFlare frm	N2 Purge to	Tot 1 Line	Tot8Lines	Avg Total	DriedSphrs	Sint'd Sphres	Sint'd Sphres	Air Inleak	N2 Purge
5	Component	1600°C C't	Cool Comp't	to Flare	toFlare,Avg	DriedSphrs	One Line	One Line	Three Lines	to 450°C Compart't	to 450°C Compart't
6	UO3•H2O					2,280.00	5,320.00				
7	UO2						0.00	4,725.00	2,025.00		
8	(CH2)6N4, HMTA					0.89	2.08				
9	CO(NH2)2, Urea					0.56	1.31				
10	NH4NO3					0.96	2.24				
11	CH4										
12	H2O	551.02		1,066.20	1,218.52	253.00	590.33				
13	NH3	0.15		1.53	1.75						
14	H2	6.16		6.53	7.46						
15	N2	171.50	32.56	270.73	309.41					2.86	32.56
16	O2			0.87	0.99					0.87	
17	N2O	0.11		1.08	1.23						
18	CO2	0.43		4.27	4.88						
19	Total Avg Lb/Hr				1,544.24	2,535.41			2,025.00		
20	Total Lb/Batch	729.37	32.56	1,351.21			5,915.96	4,725.00		3.73	32.56
21	Density, Kg/L					1.014	1.014	6.54	6.54		
22	Batch Freq., Hr	7	7				7	7		7	7
23	Batch Duratioin, Hr							21			
24	Cu ft @ 70°F, 1 atm	15,417	450	28,021	32,024	40.07	93.50	11.58	4.94	50	450
25	Chemical Reactions/Batch/300 micron Line:										
26			304	2	270	36					
27	1600°C Compartment-		UO3•H2O +	H2 -->	UO2 +	2 H2O					
28			5,320.00	35.00	4,725.00	630.00					
29											
30			140	216	68	24	264				
31	1600°C+450°C Comp't'ts-		(CH2)6N4 +	12 H2O -->	4 NH3 +	12 H2 +	6 CO2				
32			2.08	3.20	1.01	0.356	3.916				
33											
34			60	18	44	34					
35	1600°C+450°C Compart'ts-		CO(NH2)2 +	H2O -->	CO2 +	2 NH3					
36			1.31	0.39	0.96	0.74					
37											
38			80.00	44.00	36.00						
39	1600°C+450°C Compart'ts-		NH4NO3 -->	N2O+	2 H2O						
40			2.24	1.23	1.01						

Sintering and Blending Material Balance

	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-19)							
2	28,000 MT/YR UF6				300Micron						
3	Sint'ng&Blending	4% H2 to	*To Flare								
4		450°C	from 450°C	75% H2 to	ToFlare frm	N2 Purge to	Tot 1 Line	Average	Average		Average Air
5	Component	Compart't	Compart't	1600°C C't	1600°C C't	Cool Comp't	to Flare	Tot 3 Lines to Flare	1200 + 300 Lines to Flare	Avg Pilot Fuel toFlare	to Flare at 30% x's
6	UO3•H2O										
7	UO2										
8	(CH2)6N4, HMTA										
9	CO(NH2)2, Urea										
10	NH4NO3										
11	CH4									17.76	
12	H2O		588.00		629.74		1,217.75	521.89	1,740.41		8.90
13	NH3		1.57		0.17		1.75	0.75	2.50		
14	H2	0.09	0.41	42.00	7.04		7.45	3.19	10.66		
15	N2	31.26	66.67	196.00	196.00	32.56	295.23	126.53	435.93		682.58
16	O2		0.87				0.87	0.37	1.36		207.77
17	N2O		1.1088		0.12		1.23	0.53	1.76		
18	CO2		4.39		0.49		4.87	2.09	6.97		
19	Total Avg Lb/Hr							655.35	2,199.59	17.76	899.25
20	Total Lb/Batch	31.35	663.03	238.00	833.56	32.56	1,529.15				
21	Density, Kg/L										
22	Batch Freq., Hr	7	7	7	7	7	7				
23	Batch Duratioin, Hr										
24	Cu ft @ 70°F, 1 atm	450	13,738	10,836	17,619	450	31,807	13,632	45,656	430	11,318
25											
26			*See note								
27				Flare Combustion Reactions Assumed:							
28	Appx flare fuel req'd:				16	64	44	36			
29	Say avg sp ht, Btu/Lb Mole/°F=		9.00		CH4 +	2 O2-->	CO2 +	2 H2O			
30	Btu/Hr to heat gas to 500°F=		318,530		17.76	71.05	48.85	39.96			
31	CH4 low HV, Btu/Lb=		21,520								
32	CH4 req'd, Lb/Hr=		17.76		4	32	36				
33					2 H2 +	O2-->	2 H2O				
34					10.66	85.24	95.90				
35											
36					34.00	48.00	28.00	54.00			
37					2 NH3+	1.5 O2 -->	N2 +	3 H2O			
38					2.50	3.53	2.06	3.97			
39											
40											

Sintering and Blending Material Balance

	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR
1	DUF6 to DUO2 by Gelation		(Ref Fig 4-19 and 4-20)								
2	28,000 MT/YR UF6			One Blender							
3	Sint'ng&Blending		1200 micron	300 micron	1200+300	Mix from	Average	Average	Average 4%	Average	Average 4%
4		Avg Flare	to W. Feeder	to W. Feeder	micron to	One Blender	Mix from	4% H2 to	H2 to Eight	4% H2 to	H2 to Three
5	Component	Off Gas	(10 Drums)	(10 Drums)	Blender10Dm	Per Drum	Two Blenders	One 1200 Line	1200 Lines	One 300 Line	300 Lines
6	UO3•H2O										
7	UO2		15,743.70	6,747.30	22,491.00	2,249.10	6,750.00				
8	(CH2)6N4, HMTA										
9	CO(NH2)2, Urea										
10	NH4NO3										
11	CH4										
12	H2O	1,889.15									
13	NH3	0.00									
14	H2	0						0.01	0.11	0.01	0.04
15	N2	1,120.57						4.47	35.72	4.47	13.40
16	O2	49.31									
17	N2O	1.76									
18	CO2	55.82									
19	Total Avg Lb/Hr	3,116.61					6,750.00	4.48	35.83	4.48	13.44
20	Total Lb/Batch		15,743.70	6,747.30	22,491.00	2,249.10					
21	Density, Kg/L		6.54	6.54	6.54	9.00	9.00				
22	Avg. Batch Freq., Hr		6.66	6.66	6.66	0.67					
23	Cu ft @ 70°F, 1 atm	57,207	38.58	16.53	55.11		12.02	64.29	514.29	64.29	192.86
24	Drums/Hr					1.50	3.00				
25	Drums/Day					36.01	72.03				
26	Drums/30 Days					1,080	2,161				
27	Contents of 30 gallon drum:										
28	Fill to 30 gallons										
29	Est'd Mixed Kg/L	9.00									
30	Lb UO2/Drum	2,249.10									
31	Lb 1200 m./Drum	1,574.37									
32	Lb 300 m./Drum	674.73									
33											
34											
35											
36											
37											
38											
39											
40											

Sintering and Blending Material Balance

	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC
1	DUF6 to DUO2 by Gelation		(Ref Fig 4-20)								
2	28,000 MT/YR UF6										
3	Sint'ng&Blending	Average 4%	Batch	Batch	Batch	Average	Average 75%	Average	Average 75%	Average 75%	Total Avg
4		H2 to All 11	4% H2 to	75% H2 to	100% N2 to	75% H2 to	H2 to Eight	75% H2 to	H2 to Three	H2 to All 11	75% H2
5	Component	Plant Lines	Surge Drum	Blend Drum	Blend Drum	One 1200 Line	1200 Lines	One 300 Line	300 Lines	Plant Lines	Production
6	UO3•H2O										
7	UO2										
8	(CH2)6N4, HMTA										
9	CO(NH2)2, Urea										
10	NH4NO3										
11	CH4										
12	H2O										
13	NH3										
14	H2	0.15	0.29	0.29		5.25	42.00	5.25	15.75	57.75	57.90
15	N2	49.12	98.23	1.36	96.87	24.50	196.00	24.50	73.50	269.50	270.18
16	O2										
17	N2O										
18	CO2										
19	Total Avg Lb/Hr	49.26				29.75	238.00	29.75	89.25	327.25	328.08
20	Total Lb/Batch		98.52	1.66	96.87						
21	Density, Kg/L										
22	Batch Freq., Hr		2.00	2.00	2.00						
23	Cu ft @ 70°F, 1 atm	707.14	1,414.29	75.43	1,338.86	1,354.50	10,836.00	1,354.50	4,063.50	14,899.50	14,937.21
24											
25											
26											
27											
28											
29											
30											
31											
32											
33											
34											
35											
36											
37											
38											
39											
40											

Sintering and Blending Material Balance

	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM
1	DUF6 to DUO2 by Gelation			(Ref Fig 4-20)						
2	28,000 MT/YR UF6									
3	Sint'ng&Blending		Average N2	Average N2	Average N2	Average N2		Average N2		
4		Total Avg	to One	to Eight	to One	toThree	Total Avg N2	to 4% H2	Total Avg	NH3 to U3O8
5	Component	NH3 Feed	1200 Line	1200 Lines	300 Line	300 Lines	to Purging	Blending	N2 Feed	Diss'n Off Gas
6	UO3•H2O									
7	UO2									
8	(CH2)6N4, HMTA									
9	CO(NH2)2, Urea									
10	NH4NO3									
11	CH4									
12	H2O									
13	NH3	328.08								
14	H2									25.98
15	N2		9.30	74.42	9.30	27.91	102.33	48.43	150.76	
16	O2									
17	N2O									
18	CO2									
19	Total Avg Lb/Hr	328.08	9.30	74.42	9.30	27.91	102.33	48.43	150.76	25.98
20	Total Lb/Batch									
21	Density, Kg/L									
22	Batch Freq., Hr									
23	Cu ft @ 70°F, 1 atm		128.57	1,028.57	128.57	385.71	1,414.29	669.43	2,083.71	
24	MT/7000 Hr	1,042								
25									479	
26										
27										
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										

Sintering and Blending Material Balance

Cell: J3
Note: Assumes all free H2O and 90% of HMTA, urea, and NH4NO3 decompositions take place in 450°C compartment.

Cell: Y3
Note: Assumes all free H2O and 90% of HMTA, urea, and NH4NO3 decompositions take place in 450°C compartment.

Appendix B

Equipment List

CERAMIC UO2/GELATION: PROCESS SYSTEMS

Equipment Name (Quantity)	Equipment Description	Location
U3O8 Production (Fig. 4-3 & 4-4)		
UF6 Autoclaves (14)	6'Dx18'L, carbon steel, steam-heated	Proc Bldg
UF6 Compressors (14)	800 lb/hr UF6, 15 psig discharge press.	Proc Bldg
Reactor No. 1 (2)	3'6"Dx10'H fluidized bed, cooling jacket, Monel	Proc Bldg
Reactor Off-Gas Equipment	Cyclone, sintered metal filters, Monel	Proc Bldg
Vaporizer (2)	2'Dx6'L, 150 sq ft, Monel tubes, steel shell	Proc Bldg
Screw Conveyor (2)	Monel, 6"Dx10'L, 40 cfh	Proc Bldg
Reactor No. 2 (2)	6'Dx30'L rotary kiln, nat. gas heating, Inconel	Proc Bldg
U3O8 Product Cooler (2)	12"Dx8'L, screw conveyor with cooling water, steel, 40 cfh	Proc Bldg
U3O8 Bucket Elevator No. 1 (2)	20'H, 40 cfh	Proc Bldg
U3O8 Product Bin (2)	5'Dx11'H, 160 cf, steel	Proc Bldg
U3O8 Conveyor (2)	40 cfh, 6"Dx30'L	Proc Bldg
U3O8 Dust Collector	baghouse	Proc Bldg
HF Distillation (Fig. 4-5)		
HF Distillation Column	4'6"Dx24'H, Monel	Proc Bldg
Reboiler	2'Dx6'H, 150 sq ft, Monel tubes, steel shell	Proc Bldg
40°F Condenser	4'Dx12'L, 3500 sq ft, Monel tubes, steel shell	Proc Bldg
-20°F Condenser	2'Dx6'L, 150 sq ft, Monel tubes, steel shell	Proc Bldg
Reflux Accumulator	4'Dx8'L, Monel	Proc Bldg
Reflux Pump	135 gpm, Monel	Proc Bldg
Bottoms Accumulator	3'Dx4'L, Monel	Proc Bldg
Bottoms Pump	10 gpm, Monel	Proc Bldg
HF Hold Tanks (2)	6'Dx14'L, 3000 gal, cooling coils, steel	Proc Bldg
HF Transfer Pump	10 gpm, bronze	Proc Bldg
HF Storage Tanks (6)	12'Dx45'L, 38,000 gal, cooling coils, steel	HF Bldg
HF Loading Pump	25 gpm, bronze	HF Bldg
HF Scrubber (Fig. 4-6)		
HF Scrubber	1'Dx10'H, plastic packing, Monel shell	Proc Bldg
Off-Gas Heater	1 kw electric heater	Proc Bldg
Off-Gas HEPA Filters (2)	24"x24"x12"	Proc Bldg
Off-Gas Exhausters (2)	100 scfm	Proc Bldg
Lime Feed Bin	3'Dx7'H, 40 cf, steel	Proc Bldg
Lime Feeder	weigh belt feeder, 132 lb/hr	Proc Bldg
Precipitation Tank	4'Dx5'H, 450 gal, Monel	Proc Bldg
Drum Filter	2'Dx6'L, 40 sq ft, Monel	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
Vacuum Pump	100 scfm	Proc Bldg
Filtrate Tank	4'Dx5'H, 450 gal, Monel	Proc Bldg
Scrub Solution Cooler	2'Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc Bldg
Scrub Solution Pump	8 gpm, Monel	Proc Bldg
Evaporator	2'Dx4'L, 50 sq ft, Monel	Proc Bldg
Condenser	2'Dx4'L, 50 sq ft, Monel tubes, steel shell	Proc Bldg
Evaporator Condensate Tanks (2)	5'Dx5'H, 750 gal, steel	Proc Bldg
Condensate Pump	10 gpm, cast iron	Proc Bldg
CaF2 Screw Conveyor	6"Dx10'L, steel	Proc Bldg
CaF2 Rotary Dryer	1'6"Dx5'L, steel	Proc Bldg
CaF2 Drum Filling Station	0.2 drum /hr glovebox	Proc Bldg
CaF2 Dust Collector	baghouse	Proc Bldg
<u>Waste Grouting (Fig. 4-7)</u>		
Neutralization Tank (2)	5'Dx5'H, 750 gal, cooling jacket, Monel	Proc Bldg
Lime Feed Bin	3'6"Dx7'H, 50 cf, steel	Proc Bldg
Lime Feeder	weigh belt feeder, 2000 lb/hr	Proc Bldg
Neutralized Waste Feed Pump	5 gpm, 316 ss	Proc Bldg
Cement Feed Bin	4'Dx10'H, 90 cf, steel	Proc Bldg
Cement Feeder	6"Dx6'L screw feeder, steel	Proc Bldg
Grout Mixing/Drum Tumbling Station		Proc Bldg
<u>Misc. Chemicals & Chillers</u>		
Cement Silo	7'Dx23'H, 700 cf, steel	Yard
Cement Pneumatic Conveyor	4 tons / hr	Yard
Lime Silo	8'Dx31'H, 1400 cf, steel	Yard
Lime Pneumatic Conveyor	2 tons / hr	Yard
30°F Chiller	9.3×10^6 BTU/hr, 650 bhp	Proc Bldg
-30°F Chiller	1.5×10^6 BTU/hr, 230 bhp	Proc Bldg
20°F Chiller	3.1×10^6 BTU/hr, 160 bhp	Proc Bldg
<u>U3O8 Dissolution (Fig. 4-8)</u>		
U3O8 Storage Bin (2)	12'Dx20' + 60° cone bottom, cs	Proc Bldg
Conveyors, U3O8 Stg Bins to Dissr Weigh Bins	Hapman or equal, 6"D, cs, 150'	Proc Bldg
Dissolver Weigh Bin (2)	3'Dx6'+60° cone bottom, scale, cs	Proc Bldg
Dissolver (2)	7'-6"Dx10'H w/mixer, tempered water jacket, 304L ss	Proc Bldg
Dissolver Condenser (2)	80,000 Btu/hr, 55 sq ft, 1'Dx4', 304L ss	Proc Bldg
Dissolver Accumulator (2)	1'-6"Dx3', 304L ss	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
Dissolver Bottoms Pump (4)	150 gpm, 50' head, 304L ss	Proc Bldg
Dissolver Filter (2)	Plate & Frame, 2'x2'x5', 304L ss	Proc Bldg
Dissolver Backwash Pump (2)	50 gpm, 50' head, 304L ss	Proc Bldg
ADUN Denitriting Tank (4)	10'Dx12'H w/mixer, tempered water jacket, 304L ss	Proc Bldg
Urea Weigh Bin (4)	6'Dx8'+60° cone bottom, scale, cs	Proc Bldg
Urea Storage Bin (2)	15'Dx30'+60° cone bottom, cs	Yard
Conveyor, Urea Storage Bins to Weigh Bins	Hapman or equal, 6"D, cs, 250'	Yard/Proc Bldg
ADUN Pump to Gelation (6)	200 gpm, 100' head, 304L ss	Proc Bldg
<u>Dissolver Off-Gas Treatment (Fig. 4-9)</u>		
NOx Absorber	2'-6"Dx40'H, 20 trays,CW coils on 16 trays, 50,000 Btu/hr total, 304L ss	Proc Bldg
NOx Absorber Bottoms Cooler	270,000 Btu/hr, 75 sq ft, 1'-3"Dx3', 304L ss	Proc Bldg
NOx Absorber Bottoms Pump (2)	35 gpm, 50' head, 304L ss	Proc Bldg
NOx Abatement Heat Exchanger	680,000 Btu/hr, 350 sq ft, 2'Dx8', 304L ss	Proc Bldg
NOx Abatement Trim Heater	68,000 Btu/hr, 20 KW, 1'Dx3', 304L ss	Proc Bldg
NOx Abatement Cooler	300,000 Btu/hr, 300 sq ft, 2'Dx8',	Proc Bldg
NOx Abatement Catalyst Bed	25 cu ft zeolite cat., 4'Dx4', 304L ss	Proc Bldg
NOx Recycle Blower (2)	1600 ACFM, 20 bhp, lcs	Proc Bldg
HEPA Filter (2 banks)	Two 24"x24" in series, each bank	Proc Bldg
Off Gas Blower (2)	350 ACFM, 3 bhp, cs	Proc Bldg
Recovered Acid Surge Tank (2)	7'Dx10'H, API type, 304L ss	Proc Bldg
Recovered Acid Transfer Pump (2)	50 gpm, 100' head, 304L ss	Proc Bldg
Dissolver Acid Makeup Tank (1)	7'Dx10'H, API type, 304L ss	Proc Bldg
Dissolver Acid Transfer Pump (2)	200 gpm, 100' head, 304L ss	Proc Bldg
Nitric Acid Storage Tank (2)	30'Dx40'H, API type, 304L ss	Yard
Nitric Acid Transfer Pump (2)	200 gpm, 100' head, 304Lss	Yard
<u>Gelation Column Feed (Fig. 4-10)</u>		
HMTA Silo (4)	20'Dx60'H, 16,000 cf, steel	Yard
HMTA Pneumatic Conveyor	4.5 tons/hr	Yard
HMTA Feed Bin	8'Dx21'H, 850 cf, steel	Yard
HMTA Solids Feeder	2.5 tons/hr	Yard
HMTA Make-up Tank (2)	12'Dx13'H, 10,000 gal, steel, cooling jacket	Yard
HMTA Transfer Pump	163 gpm, 5 hp, steel	Yard
HMTA Feed Tank	12'Dx13'H, 10,000 gal, steel, insulated	Proc Bldg
ADUN Storage Tank (2)	12'Dx16'H, 13,000 gal, 304L ss, cooling jacket	Proc Bldg
ADUN Cooler	15"Dx8'L, 200 sq ft, 304L ss	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
ADUN Transfer Pump	16 gpm, 316 ss	Proc Bldg
ADUN Feed Tank	6'Dx6'H, 1200 gal, 304L ss, insulated	Proc Bldg
1200μ HMTA Feed Pump (4)	3.6 gpm, steel	Proc Bldg
1200μ ADUN Feed Pump (4)	2.8 gpm, 316 ss	Proc Bldg
1200μ ADUN-HMTA Inline Mixer (4)	6.4 gpm, 316 ss	Proc Bldg
300μ HMTA Feed Pump (6)	1.0 gpm, steel	Proc Bldg
300μ ADUN Feed Pump (6)	0.8 gpm, 316 ss	Proc Bldg
300μ ADUN-HMTA Inline Mixer (6)	1.8 gpm, 316 ss	Proc Bldg
<u>1200μ Sphere Gelation (Fig. 4-11)</u>		
Gelation Column (4)	3'Dx15'H, vibrating assembly with 567 feed orifices, 316 ss	Proc Bldg
Gel Filter (4)	2'Wx10'L, 20 sq ft horizontal screen, 316 ss	Proc Bldg
Gel Dryer (4)	3'Wx45'L, moving horizontal screen, 316 ss	Proc Bldg
Dryer Air Blower (4)	2700 cfm, 2 psi, 42 bhp, 316 ss	Proc Bldg
Dryer Air Heater (4)	16"Dx8'L, 120 sq ft, 316 ss fin tubes	Proc Bldg
Dryer 32°F Condenser (4)	2'Dx12'L, 350 sq ft, 316 ss fin tubes	Proc Bldg
Dryer -20°F Condenser (4)	2'Dx12'L, 350 sq ft, 316 ss fin tubes	Proc Bldg
Condensate Receiver (4)	3'Dx3'L, 150 gal, 316 ss	Proc Bldg
Gel Product Bin (4)	6'Dx10'H, 230 cf, steel	Proc Bldg
TCE Supply Tank (4)	7'Dx9'H, 2500 gal, 316 ss	Proc Bldg
TCE Feed Pump (4)	88 gpm, 316 ss	Proc Bldg
TCE Heater (4)	1'Dx4'L, 50 sq ft, 316 ss	Proc Bldg
<u>300μ Sphere Gelation (Fig. 4-12)</u>		
Gelation Column (6)	3'Dx11'H, vibrating assembly with 608 feed orifices, 316 ss	Proc Bldg
Gel Filter (6)	1'Wx6'L, 20 sq ft horizontal screen, 316 ss	Proc Bldg
Gel Dryer (6)	3'Wx25'L, moving horizontal screen, 316 ss	Proc Bldg
Dryer Air Blower (6)	750 cfm, 2 psi, 12 bhp, 316 ss	Proc Bldg
Dryer Air Heater (6)	1'Dx8'L, 60 sq ft, 316 ss fin tubes	Proc Bldg
Dryer 32°F Condenser (6)	16"Dx8'L, 100 sq ft, 316 ss fin tubes	Proc Bldg
Dryer -20°F Condenser (6)	16"Dx8'L, 120 sq ft, 316 ss fin tubes	Proc Bldg
Condensate Receiver (6)	2'Dx3'L, 70 gal, 316 ss	Proc Bldg
Gel Product Bin (6)	4'Dx7'H, 70 cf, steel	Proc Bldg
TCE Supply Tank (6)	5'Dx7'H, 1000 gal, 316 ss	Proc Bldg
TCE Feed Pump (6)	25 gpm, 316 ss	Proc Bldg
TCE Heater (6)	8"Dx3'L, 20 sq ft, 316 ss	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
TCE Evaporation (Fig. 4-13)		
Evaporator Feed Tank	7'Dx9'H, 2500 gal, 316 ss	Proc Bldg
Evaporator Feed Pump	2.5 gpm, 316 ss	Proc Bldg
Evaporator Body	3'Dx5'H, 250 gal, Monel	Proc Bldg
Vaporizer	1'Dx4'H, 50 sq ft heating coil, Monel tubes	Proc Bldg
Circulation Pump	100 gpm, Monel	Proc Bldg
Condenser	1'Dx4'L, 50 sq ft, Monel tubes	Proc Bldg
Decanter	2'Dx3'L, 50 gal, 316 ss	Proc Bldg
TCE Condensate Tank	7'Dx9'H, 2500 gal, 316 ss	Proc Bldg
TCE Transfer Pump	100 gpm, 316 ss	Proc Bldg
Column Feed Tank	4'Dx5'H, 450 gal, 316 ss	Proc Bldg
Column Feed Pump	15 gpm, 316 ss	Proc Bldg
Stripping Air Blower	80 cfm	Proc Bldg
Stripping Column	1'Dx15'H, packed column, 316 ss shell	Proc Bldg
Column Effluent Tank	4'Dx5'H, 450 gal, steel	Proc Bldg
Effluent Transfer Pump	25 gpm	Proc Bldg
Carbon Adsorber (2)	2'Dx5'H, 335 lb activated carbon	Proc Bldg
Regeneration Condenser	8"Dx3'L, 20 sq ft	Proc Bldg
Gel Sphere Washing (Fig. 4-14 & 4-16)		
1200μ Sphere Conveyor, Product Bin to Feed Tanks	10"D Hapman or equal, 350'	Proc Bldg
300μ Sphere Conveyor, Product Bin to Feed Tanks	8"D Hapman or equal, 100'	Proc Bldg
Sphere Wash Feed Tanks (6)	12'Dx18' w/60° cone bottom, cs	Proc Bldg
Conveyor, Wash Feed Tank to Weigh Feeders (6)	6"D Hapman or equal, 60' each	Proc Bldg
Sphere Weigh Feeder (6)	3'Dx5' w/60° cone bottom, cs	Proc Bldg
Sphere Washer (6)	5'Dx40'L w/12" internal helix, 6'x6'x2' end boxes, est. 22,000 lb, 20 bhp drive, carbon steel	Proc Bldg
Wash Solution Catch Tank (6)	7'Dx12', cs,	Proc Bldg
Wash Solution Transfer Pump (12)	40 gpm, 50' hd, cs	Proc Bldg
Wash Solution Feed Pump (12)	40 gpm, 50' hd, cs	Proc Bldg
Washed Sphere Surge Tank (6)	5'Dx10' w/60° cone bottom, cs	Proc Bldg
Washed Sphere Transfer Pump (12)	12 gpm, Progressive Cavity (Moyno or equal), cs	Proc Bldg
Gel Sphere Drying (Fig. 4-15 & 4-17)		
Sphere Dryer Feed Tank (6)	6'Dx12' w/60° cone bottom, cs	Proc Bldg
Sphere Dryer Weigh Feeder (6)	3'Dx55 w/60° cone bottom, cs	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
Sphere Dryer (6)	14' wide x 36' long x 6' high, w/ 12' x 30' of sphere-loaded travelling screen.Estimated total weight 40,000 lb, 10 bhp drive, cs.	Proc Bldg
Dryer Blower (6)	43,000 ACFM, 2.0 psi, 500 bhp, cs	Proc Bldg
Dryer Heater (6)	2.7 x 10^6 Btu/hr, 160 bare sq ft, airfin, 6'x4'x1' plus 45° cone plenum in/out, cs/Al	Proc Bldg
Dryer Condenser (6)	1.8x10^6 Btu/hr, 4000 bare sq ft, airfin, 20'x20'x1'-3", cs/Al, 40 bhp	Yard
Dryer Accumulator (6)	4'Dx10', cs	Proc Bldg
Sphere Conveyor, Dryer to Surge Bin (6)	Hapman type, 3"Dx60'	Proc Bldg
Dried Sphere Surge Bin (6)	4'Dx5' plus 60° cone bottom, cs	Proc Bldg
<u>Wash Effluent Treatment (Fig. 4-18)</u>		
NH3 Stripper Feed Tank	20'Dx25'H, API type, cs	Yard
NH3 Stripper Feed Pump (2)	210 gpm, 50' head, cs	Yard
NH3 Stripper	14'Dx37'H, 10 trays, cs	Yard
NH3 Stripper Feed Exchanger	2.5x10^6 Btu/hr, 400 sq ft, 2.5'Dx6'L, cs	Yard
NH3 Stripper Condenser	96x10^6 Btu/hr, 6500 sq ft, 5'Dx16'L, cs	Yard
NH3 Stripper Reboiler	106x10^6 Btu/hr, 5000 sq ft, 5'Dx15'H, cs	Yard
Stripper Accumulator	12'Dx14' API Tk, cs	Yard
Stripper Overhead Pump (2)	200 gpm, 100' head, cs	Yard
Stripper Bottoms Tank (2)	10'Dx12'H API Tk, cs	Yard
Stripper Bottoms Pump (2)		Yard
Wiped Film Evaporator (3)	4.7x10^6 Btu/hr, 400 sq ft, 6'-0"Dx50'H, cs, 150 bhp, Kontro or equal	Yard
Wiped Film Evap Feed Pump (5)	30 gpm, 100' head, cs	Yard
Wiped Film Evap Bottoms Tank (3)	4'-6"Dx15' w/steam coil, cs	Yard
Wiped Film Evap Bottoms Pump (6)	10 gpm, 50' head, cs	Yard
Wiped Film Evap Condenser (3)	5.7x10^6 Btu/hr, 400 sq ft, 2'-0"Dx6', cs	Yard
Wiped Film Evap Condensate Pump (6)	15 gpm, 100' head, cs	Yard
Ammonia Makeup Tank (2)	25'Dx25'H, API Tk, cs	Yard
<u>Sphere Sintering (Fig. 4-19)</u>		
1200μ Sphere Conveyor, Surge Bins to Feed Bins	Hapman type, 6"D, 300'	Proc Bldg
300μ Sphere Conveyor, Surge Bins to Feed Bins	Hapman type, 4"D, 150'	Proc Bldg
Dried 1200μ Sphere Feed Bin	15'x12' + 60° cone bottom, cs	Proc Bldg

Equipment Name (Quantity)	Equipment Description	Location
Dried 300μ Sphere Feed Bin	12'x10' + 60° cone bottom, cs	Proc Bldg
Sphere Conveyor, Feed Bins to Weigh Feeders (6)	Hapman type, 3"D, 60'	Proc Bldg
Dried Sphere Weigh Feeders (11)	5'x5' + 60° cone bottom, cs	Proc Bldg
Mobile Sintering Boats (50)	7'Wx11'Lx3'-6" H, Steel supported firebrick on wheels, 12,000 lb ea.	Proc Bldg
Sintering Furnace (11)	10'Wx30'Lx6'H w/compartments, firebrick lined A. 450°C (842°F) 250KW B. 1600°C (2912°F) 600KW C. Cooling, 6.5×10^6 Btu over 3 hr, fintube, 50 sq ft bare, 3 bhp fan	Proc Bldg
Sintered Sphere Collection Bins (11)	2'Dx4' + 60° cone bottom, cs	Proc Bldg
UO2 Sphere Blending (Fig. 4-20)		
1200μ Sphere Conveyor, Collection Bin to Blend Feed Tank	Hapman type, 6"D, 500'	Proc Bldg
300μ Sphere Conveyor, Collection Bin to Blend Feed Tank	Hapman type, 4"D, 150'	Proc Bldg
1200μ Sphere Blend Feed Tank	7'Dx7' + 60° cone, cs	Proc Bldg
300μ Sphere Blend Feed Tank	5'Dx6' + 60° cone, cs	Proc Bldg
1200μ Sphere Conveyor, Tk /Feeder	Hapman type, 4"D, 50'	Proc Bldg
300μ Sphere Conveyor, Tk/Feeder	Hapman type, 4"D, 50'	Proc Bldg
1200μ Sphere Weigh Feeder (2)	3'Dx4' + 60° cone, cs	Proc Bldg
300μ Sphere Weigh Feeder (2)	2'-6"Dx2'-6" + 60° cone, cs	Proc Bldg
Sphere Blenders (2)	5'Dx3' + two 60° cone ends, cs	Proc Bldg
Drum Scales (2)	3000 lb capacity	Proc Bldg
Sintering Gas Supply (Fig. 4-20)		
Anhydrous NH3 Storage Tank (2)	9'Dx53'L, 25,000 gal, 250 psig, cs	Yard
Ammonia Dissociator	11,000 cfh of H2, 20 KW, 10'Lx7'Wx14'H	Yard
75% H2 Compressor (2)	250 ACFM suction, 30 bhp, 2 stage, cs	Yard
75% H2 Compressor Intercooler (2)	77,000 Btu/hr, 60 sq ft, 1'Dx4', cs	Yard
4% H2 Blend Gasholder	20'Dx20', cs	Yard
4% H2 Blend Compressor (2)	100 ACFM suction, 25 bhp, 2 stage, cs	Yard
4% H2 Compressor Intercoolers (2)	28,000 Btu/hr, 20 sq ft, cs	Yard
4% H2 Surge Drum	7'Dx12', cs	Yard
Liquid N2 Storage Tank	15'Dx15'+ cryogenic insulation, -321°F, ss	Yard
Liquid N2 Vaporizer	25,000 Btu/hr, 12 sq ft, -321°F, ss, special design	Yard
N2 Compressor (2)	110 ACFM suction, 30 bhp, 2 stage, cs	Yard
N2 Compressor Intercoolers (2)	31,000 Btu/hr, 20 sq ft, cs	Yard
N2 Surge Drum	9'Dx20', 120 psig, cs	Yard

CERAMIC UO2/GELATION: SUPPORT SYSTEMS

Equipment Name / Qty	Equipment Description	Location
Process Material Handling Systems	<u>DUF_6 cylinder handling:</u>	
	-3 flatbed trucks	Yard
	-3 20-ton cranes (2 are mobile)	Yard/Proc. Bldg
	-14, 14-ton autoclave cylinder frames with rails for loading / unloading-coated/ carbon steel storage racks for 400 14-ton DUF_6 cylinders	Proc. Bldg
	Two (2) 15-ton cylinder straddle carriers	Proc. Bldg/ Storage Areas
	275 storage saddle/pallets 195 storage racks each for cylinders	Proc. Bldg/ Storage Areas
	<u>UO_2 drum interim handling:</u>	
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg
	<u>Grouted waste & UO_2 drum handling:</u>	
	-3 flatbed trucks	Yard
	-3 30 gal drum automated conveyors, 30 ft. length ea.	Proc. Bldg/ UO_2 Bldg
	-3 forklift trucks (for 30 gal drum pallets)	Proc. Bldg/ UO_2 Bldg
	<u>CaF_2 handling:</u>	
	-2 flatbed trucks	Yard
	-2 55 gal drum roller conveyors, 30 ft. ea.	Proc. Bldg
	-2-forklift trucks (for 55 gal drum pallets)	Proc. Bldg/ CaF_2 Bldg
	<u>Organic sludge waste handling</u>	
	-Sludge container conveyor- 100' long -2 forklift trucks	Yard-Organic Waste Storage Pad
DUF_6 Cylinder Vacuum System	-2 vacuum systems with cold traps, NaF traps and vacuum pumps for pigtail evacuation	Proc. Bldg
Decontamination & Maintenance Systems	-4 decontamination gloveboxes (3'W x 6'L x 7'H) equipped with decon. water, steam, drying air & wash solution stations	Proc. Bldg
Process Control / Monitoring System	-Computer based distributed control system with centralized monitoring stations	Proc. Bldg
	- Closed circuit TV monitoring system for centralized monitoring of DUF_6 cylinder unloading / loading, UO_2 drum handling, waste grouting / LLW packaging and CaF_2 drum handling areas	Proc. Bldg

Equipment Name / Qty	Equipment Description	Location
HF Storage Building Water Spray System	-Building water spray system complete with pumps, piping, vessels, alarms and controls installed in the HF storage tank area to monitor, alarm and actuate a water spray designed to mitigate the effects of an unplanned HF release	HF Bldg & Proc Bldg (HF Areas only)
Sampling / Analytical Systems	-8 local sampling glove boxes with laboratory liquid / powder sample hardware	Proc. Bldg
	-Complete analytical laboratory equipped with laboratory hoods, sinks, cabinets, and analytical equipment to serve facility analytical needs	Proc. Bldg
Low Level Radioactive & Hazardous Waste Management System	-Pretreatment/packaging system to prepare misc. rad / hazardous wastes for shipment off-site for final treatment and disposal. Major equipment consists of: • 1-low level radwaste evaporator w/ condensate / concentrate collection tanks, pumps, instruments, and controls • 2-solid waste sorting gloveboxes • 2-solid waste compactors • 4-drum handling conveyors • 2 forklift trucks • bar code reader / computerized accountability system • 10 ton overhead crane • 1-radwaste drum assay device	Proc. Bldg
Material Accountability System	-Computerized material control and accountability system (hardware & software)	Proc. Bldg
	-Accountability scales for incoming and outgoing 14-ton DUF_6 cylinders and UO_2 drums	Proc. Bldg
	-Bar code readers for DUF_6 cylinder and U_3O_8 / UO_2 tracking	Proc. Bldg/Yard
	-Process uranium monitors and sampling stations for approx. 20 sampling points	Proc. Bldg/ Yard
Plant Monitoring System	Integrated radioactive / hazardous waste building and effluent monitoring system consisting of uranium and hazardous chemical (HF, UF_6, UO_2F_2, NH_3) sensors, alarms, recorders, system diagnostics, etc. with central monitoring / control console	Various
Plant Security Systems	System of intrusion detection, access control, yard lighting / fencing, closed circuit TV monitoring and alarm devices to provide protection against unauthorized access to plant facilities and controlled and hazardous materials	Site Yard

Equipment Name / Qty	Equipment Description	Location
Fire Protection Systems	Fire water pump - 3000 gpm elect Fire water pump - 3000 gpm diesel Fire water tanks 2 - 270,000 gal Fire system piping Sprinkler System Alarm system	Yard Yard Yard Yard/Buildings Buildings Buildings
Cold Maintenance Shop	Equip & tools for maintenance and repair of process equipment and controls	Maint. Bldg
Yard Lighting	Lighting for roads	Site Yard
Utility /Services Systems	Boiler - 190,000 lb/hr, 50 psig gas fired Air compressors - 2@ 500 cfm 150 psig Breathing air compressors - 2 @ 100 cfm Air Dryers - desiccant, minus 40°F dew point Demineralized water system - 35,000 gpd Tempered water system- 30,000 gpd Sanitary water treatment system - 6400 gpd Industrial wastewater treatment system - 370,000 gpd Electrical substation - 13,000 kW Emergency generators - 2 @ 1000 kW Uninterruptible Power Supply - 200 kVA Cooling Tower - 150 MM Btu/hr, 15,000 gpm	Util. Bldg Util. Bldg Util. Bldg Util. Bldg Util. Bldg Util. Bldg Sanitary Treatment area Wastewater Treatment area Substation Substation Proc. Bldg Yard
HVAC		
Zone 1 HVAC System	HEPA filtration of exhaust, HEPA filtration of glove box room air supply, negative pressure to room & zone 2, 4-3000 cfm,7 HP exhaust fans	Proc. Bldg gloveboxes & fume hoods
Zone 2 HVAC System	HEPA filtration of exhaust, negative pressure to zone 3, 4-80,000 cfm, 200 HP exhaust fans, 4-80,000 cfm100 HP supply air units	UO_2 Areas DUF_6 Areas Analytical Lab
Zone 3 HVAC System	2-30,000 cfm, 15 HP exhaust fans, 2-30,000 cfm, 25 HP supply air units, 2-10,000 cfm, 10 HP exhaust fans, Process'g 2-10,000 cfm, 15 HP supply air units	Grout Areas CaF_2 Areas Waste Control Room Support Areas
HF Area HVAC	2-20,000 cfm, 15 HP exhaust fans, 2-20,000 cfm, 25 HP supply air units, Emergency shutdown on HF leak	HF Areas
HVAC Chillers	3-625 ton chillers	Proc. Bldg
Circulating Pumps	3-1000 gpm, 40 Hp	Proc. Bldg

Appendix C

Radiation Exposure and Manpower Distribution Estimating Data

Assumptions / Basis for Exposure Tables

Due to the conceptual nature of the facility designs, it is not possible to perform an absolute analysis of worker radiation exposure. However, the data given will allow comparison between the six options as to relative levels of exposure.

The numbers in the 'Source' column refer to the notes at the end of the table, and identify the source which is judged to be the most significant for the particular operation.

The 'Material' column describes the primary containment of the source. Walls between operating areas were not included; it is known that areas such as the control room, laboratory, and offices will be separated from the processing area by one or more walls. Interior walls will be equivalent to 8" of concrete; exterior walls will be the equivalent of 12" of concrete.

Additional notes give the basis for the number of operations per year or the amount of maintenance estimated.

The 'Person Hours' for maintenance shown at the bottom of the Operational Activities table are itemized in the Maintenance Activities table.

GELATION / ANHYDROUS HF - OPERATIONAL ACTIVITIES - 100% CASE

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 37)	SOURCE	DISTANCE (ft)	MATERIAL (Note 38)	THICKNESS	PERSON HOURS
Unload arriving UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Inspect arriving UF6 cylinders	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder to storage	2	0.50	2322	1	6	Steel	1/4"	2322.0
Unload UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Load UF6 cylinder	2	0.50	2322	1	3	Steel	1/4"	2322.0
Transfer UF6 cylinder from storage to process building	2	0.50	2322	1	6	Steel	1/4"	2322.0
Load cylinder into autoclave	1	0.50	2322	1	3	Steel	1/4"	1161.0
Autoclave pressure test	2	1.00	2322	1	15	Steel	1/4"+1/4"	4644.0
Unload autoclave	1	0.30	2322	2	3	Steel	1/4"	696.6
Transfer empty UF6 cylinder to pallet	2	0.25	2322	2	20	Steel	1/4"	1161.0
Transfer empty UF6 cylinder to Storage Building	1	0.25	2322	2	3	Steel	1/4"+1.25	580.5
Store empty UF6 cylinder in Storage Building	1	0.25	2322	2	3	Steel	1/4"	580.5
Full UF6 cylinder storage surveillance	1	0.50	2190	1,4	3	Steel	1/4"	1095.0
Autoclave surveillance	1	0.25	1752	1,2,3	3	Steel	1/4"	438.0
Prepare empty UF6 cylinder for shipment	2	0.50	2322	35	3	Steel	1/4"	2322.0
Load empty UF6 cylinder for shipment	3	0.50	2322	35	6	Steel	1/4"	3483.0
UO2F2 reactor surveillance	1	0.50	1752	6	3	Monel	3/4"	876.0
U3O8 reactor surveillance	1	0.50	1752	7	3	Inconel	1.5"	876.0
U3O8 Dissolution	2	0.5	1752	8,9,10	3	Stl,SS,Stl	3/8,1/4,3/8"	1752.0
300µ Gelation	2	7000	Continous	(14,15,16,17)a	3	SS,SS,Stl,Stl	1/4"	14000.0
1200µ Gelation	2	7000	Continuous	(14,15,16,17)b	3	SS,SS,Stl,Stl	1/4"	14000.0
TCE Cleanup	2	7000.00	Continuous	10,14b	20,20	SS,SS	3/8",1/4"	14000.0
Gel Washing & Drying	2	7000.00	Continuous	18,19,20,21	3	Steel	3/8",1/4"	14000.0
Sintering	6	1.00	10863	22,23	3	Stl,Stl+FireBrck	1/4",3/8"+2"	65178.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 37)	SOURCE	DISTANCE (ft)	MATERIAL (Note 38)	THICKNESS	PERSON HOURS
Product Blending	2	0.10	21000	24	3	Steel	1/4"	4200.0
Ammonia Recovery surveillance	2	0.10	1752	1,2,3	140	Steel	1/4"+1/4"	350.4
H2 Compressor surveillance	1	0.10	1752	23,24	16	Stl+FireBrck,Stl	3/8"+2",1/4"	175.2
N2 Compressor surveillance	1	0.10	1752	21,22	16	Steel	1/4",1/4"	175.2
HF distillation surveillance	1	0.50	1752	1,2,3	16	Steel	1/4"+1/4"	876.0
Off-gas Scrubbing surveillance	1	0.25	1752	1,2,3	38	Steel	1/4"+1/4"	438.0
Process Liquid Treat. surveillance	1	0.25	1752	10	60	Stnls Steel	3/8"	438.0
CaF2 processing surveillance	1	0.50	1752	1,2,3	36	Steel	1/4"+1/4"	876.0
Waste grouting surveillance	1	0.50	1752	36	3	Steel	1/4"	876.0
UO2 interim storage surveillance	1	0.50	2190	31	3	Steel	0.06"	1095.0
UO2 storage building surveillance	1	0.50	2190	32	3	Steel	0.06"	1095.0
CaF2 interim storage surveillance	1	0.50	2190	25	16	Steel	1/4"	1095.0
CaF2 storage building surveillance	1	0.20	2190	32	20	Steel	0.06"	438.0
HF building surveillance	1	0.50	2190	21	150	Steel	1/4"	1095.0
Transfer UO2 drums to interim storage	2	0.50	4200	27,28	3	Steel	0.06"	4200.0
Transfer UO2 drums to storage building	2	0.50	4200	27,28	3	Steel	0.06"	4200.0
Load UO2 drums for shipment offsite	1	1.00	750	30,32	3	Steel	0.06"	750.0
Transfer CaF2 drums to interim storage	2	0.50	165	25	30	Steel	1/4"	165.0
Transfer CaF2 drums to storage area	2	0.50	165	25	30	Steel	1/4"	165.0
Load CaF2 drums for shipment offsite	1	1.00	29	32	20	Steel	0.06"	29.0
HF loading for shipment offsite	2	10.00	243	21	150	Steel	1/4"	4860.0

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 37)	SOURCE	DISTANCE (ft)	MATERIAL (Note 38)	THICKNESS	PERSON HOURS
Transfer grouted drums to storage area	2	0.50	320	29,33	3	Steel	0.06"	320.0
Load grouted drums for shipment offsite	1	1.00	56	29,34	3	Steel	0.06"	56.0
Organic Sludge Handling/Shipping	2	7000.00	continuous	1,2,3	140	Steel	1/4"+1/4"	14000.0
Nitric Acid receiving	2	1.00	348	24	90	Steel	1/4"	696.0
HMTA receiving	2	1.00	204	21	100	Steel	1/4"	408.0
Urea receiving	2	1.00	88	20	16	Steel	1/4"	176.0
LLW processing, packaging, and shipping	4	8.00	1100	26	20	Steel	3/8"	35200.0
Process control room operations	10	8.00	1100	17b	20	Steel	1/4"	88000.0
Laboratory operations	5	8.00	1100	21	30	Steel	1/4"	44000.0
HP	4	8.00	1100	1,2,3	30	Steel	1/4"	35200.0
Management / Professionals	24	8.00	250	14b	50	Stnls Steel	1/4"	48000.0
Accountability	4	2.00	1100	3,4,32	3	Steel	1/4",0.06"	8800.0
Industrial and sanitary waste treatment	4	8.00	1100	4,5	50	Steel	1/4"	35200.0
Utilities operations	6	8.00	1100	26	200	Steel	3/8"	52800.0
Administration	34	8.00	250	16	100	Steel	1/4"	68000.0
Guardhouses / Process Bldg.	8	8.00	1100	4	250	Steel	1/4"	70400.0
Maintenance								47148.0
								730771.4

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 37)	SOURCE	DISTANCE (ft)	MATERIAL (Note 38)	THICKNESS	PERSON HOURS

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 580 empty UF6 cylinders in the storage building.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) U3O8 Storage Bin; there are 2 bins
9) Dissolver and Weigh Bin inventory; there are 2 dissolvers/weigh bins
10) ADUN Denitriting Tank inventory; there are 4 tanks
11) ADUN Cooler inventory
12) ADUN Storage Tank inventory
13) ADUN Feed Tank inventory
14a) 300μ Gelation Column inventory
14b) 1200μ Gelation Column inventory
15a) 300μ Gelation Filter inventory
15b) 1200μ Gelation Filter inventory
16a) 300μ Gel Dryer inventory
16b) 1200μ Gel Dryer inventory
17a) 300μ Gel Product Bin inventory
17b) 1200μ Gel Product Bin inventory
18) Sphere Wash Feed Tank inventory
19) Sphere Weigh Feeder inventory
20) Sphere Washer inventory
21) Sphere Dryer, Dryer Feed Tank & Weigh Feeder inventory
22) Dried Sphere Weigh Feeder inventory
23) Sintering Furnace inventory
24) Blend Feed Tanks (300μ & 1200μ), Sphere Weigh Feeder/Blender inventory
25) UF6 Cylinders in Shipping/Receiving Area
26) Dried 1200μ & 300μ Sphere Feed Bin inventory
27) Drum of UO2.
28) Each transfer consists of 5 UO2 drums.
29) Drum of grouted waste.
30) There are 28 UO2 drums per shipment.

ACTIVITY	NUMBER OF WORKERS PER OPERATION	TIME PER OPERATION (hr)	OPERATIONS PER YEAR (Note 37)	SOURCE	DISTANCE (ft)	MATERIAL (Note 38)	THICKNESS	PERSON HOURS

31) There are up to 72 UO2 drums in interim storage
32) There are up to 1800 UO2 drums in the storage building.
33) Each transfer consists of 7 CaF2 (or grouted waste) drums
34) There are 40 CaF2 (or grouted waste) drums per shipment
35) A single 3 mo. old empty UF6 cylinder
36) Batch of LLW
37) 2322 UF6 cylinders per year
    365 days per yr x 3 shifts per day x 2 per shift = 2190 per year
    365 days per yr x 3 shifts per day x 2 per shift x 0.8 availability = 1752 per year
    365 days per year x 3 shifts per day x 1 per shift = 1100 per year
    2000 hrs/year / 8 hrs/day x 1 per day = 250 per year
    21,000 UO2 drums/yr / 5 drums per transfer = 4200 transfers per year
    21,000 UO2 drums/yr / 28 drums per transfer = 750 shipments per year
    243 railcars/yr of HF
    1152 CaF2 drums/yr / 7 drums per transfer = 165 transfers per year
    1152 CaF2 drums/yr / 40 drums per shipment = 29 transfers per year
    2236 grouted waste drums/yr /7 drums per transfer = 320 transfers per year
    2236 grouted waste drums/yr /40 drums per shipment = 56 transfers per year
    2404 Organic Sludge Containers/yr
    10,863 Sintering batches/yr
    348 railcars/yr of Nitric Acid
    204 railcars/yr of HMTA
    88 railcars/yr of Urea
38) Materials do not include walls between operating areas. Areas such as the control room, laboratory, offices and change rooms will be separated from process area sources by walls.

GELATION / ANHYDROUS HF - MAINTENANCE ACTIVITIES - 100% CASE

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
Autoclaves (14)	2	26	14	1,2,3	3	Steel	1/4"+1/4"	728
Autoclave compressors (14)	2	52	14	1,2,3	3	Steel	1/4"+1/4"	1456
UO2F2 Reactor (Reactor No. 1) (2)	2	52	2	6	3	Monel	3/4"	208
UO2F2 screw conveyor (2)	2	104	2	6	3	Monel	3/4"	416
UO2F2 sintered metal filter (2)	2	4	2	27	1			16
Vaporizer (2)	2	52	2	6	3	Monel	3/4"	208
U3O8 reactor (Reactor No. 2) (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 product cooler (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 sintered metal filter (2)	2	4	2	27	1			16
U3O8 bucket elevator No. 1 (2)	2	104	2	7	3	Inconel	1.5"	416
U3O8 dust collector (1)	2	4	1	27	1			8
Conveyor, U3O8 stg bins to dissolver weigh bins	2	104	1	8	3	Steel	3/8"	208
Dissolver weigh bin (2)	2	26	2	9	1	Stnls Steel	1/4"	104
Dissolver (2)	2	52	2	9	1	Stnls Steel	1/4"	208
Dissolver condenser (2)	2	26	2	9	3	Stnls Steel	1/4"	104
Dissolver bottoms pump (4)	2	52	4	9	5	Stnls Steel	1/4"	416
Dissolver filter (2)	2	26	2	9	6	Stnls Steel	1/4"	104
Dissolver backwash pump (2)	2	52	2	9	6	Stnls Steel	1/4"	208
ADUN denitriting tank (4)	2	26	4	10	1	Stnls Steel	3/8"	208
Urea weigh bin (4)	2	26	4	10	3	Stnls Steel	3/8"	208
Conveyor, Urea storage bin to weigh bin	2	104	1	20	16	Steel	1/4"	208
ADUN pump to Gelation (6)	2	52	6	10	5	Stnls Steel	3/8"	624
NOx Absorber (1)	2	26	1	8,9	12	Steel,Stnls Stl	3/8",1/4"	52
NOx Absorber bottoms cooler (1)	2	26	1	9	12	Stnls Steel	1/4"	52
NOx Absorber bottoms pump (2)	2	52	2	9	12	Stnls Steel	1/4"	208
NOx Abatement heat exchanger (1)	2	26	1	8	15	Steel	3/8"	52

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
NOx Abatement trim heater (1)	2	26	1	9	18	Stnls Steel	1/4"	52
NOx Abatement cooler (1)	2	26	1	8	12	Steel	3/8"	52
NOx Abatement catalyst bed (1)	2	26	1	9	9	Stnls Steel	1/4"	52
NOx recycle blower (2)	2	52	2	8	15	Steel	3/8"	208
HEPA filter (2 banks)	2	4	2	1,2,3	30	Steel	1/4"+1/4"	16
Off Gas blower (2)	2	52	2	1,2,3	30	Steel	1/4"+1/4"	208
Recovered acid transfer pump (2)	2	52	2	10	12	Stnls Steel	3/8"	208
Dissolver acid transfer pump (2)	2	52	2	10	12	Stnls Steel	3/8"	208
Nitric acid transfer pump (2)	2	52	2	24	80	Steel	1/4"	208
HMTA pneumatic conveyor (1)	2	104	1	18	16	Steel	3/8"	208
HMTA solids feeder (1)	2	52	1	18	16	Steel	3/8"	104
HMTA transfer pump (1)	2	52	1	18	16	Steel	3/8"	104
ADUN cooler (1)	2	26	1	11	1	Stnls Steel	1/4"	52
ADUN transfer pump (1)	2	52	1	12	6	Stnls Steel	3/8"	104
HMTA feed pumps (4+6)	2	52	10	13	6	Stnls Steel	1/4"	1040
ADUN feed pumps (4+6)	2	52	10	13	6	Stnls Steel	1/4"	1040
300μ sphere Gelation column	2	26	6	14a	1	Stnls Steel	1/4"	312
300μ sphere Gel filter	2	52	6	15a	1	Stnls Steel	1/4"	624
300μ sphere Gel dryer	2	52	6	16a	1	Steel	1/4"	624
300μ sphere Dryer air blower	2	52	6	16a	5	Steel	1/4"	624
300μ sphere Dryer air heater	2	26	6	16a,17a	5	Steel	1/4",1/4"	312
300μ sphere Dryer 32°F condenser	2	26	6	16a	5	Steel	1/4"	312
300μ sphere Dryer -20°F condenser	2	26	6	16a	5	Steel	1/4"	312
300μ sphere Gel conveyor	2	104	1	17a,18	5	Steel	1/4",3/8"	208
300μ sphere TCE feed pump	2	52	6	14a	6	Stnls Steel	1/4"	624
300μ sphere TCE heater	2	26	6	14a	5	Stnls Steel	1/4"	312
1200μ sphere Gelation column	2	26	4	14b	1	Stnls Steel	1/4"	208
1200μ sphere Gel filter	2	52	4	15b	1	Stnls Steel	1/4"	416

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
1200μ sphere Gel dryer	2	52	4	16b	1	Steel	1/4"	416
1200μ sphere Dryer air blower	2	52	4	16b	5	Steel	1/4"	416
1200μ sphere Dryer air heater	2	26	4	16b,17b	5	Steel	1/4",1/4"	208
1200μ sphere Dryer 32°F condenser	2	26	4	16b	5	Steel	1/4"	208
1200μ sphere Dryer -20°F condenser	2	26	4	16b	5	Steel	1/4"	208
1200μ sphere Gel conveyor	2	104	1	17b,18	5	Steel	1/4",3/8"	208
1200μ sphere TCE feed pump	2	52	4	14b	6	Stnls Steel	1/4"	416
1200μ sphere TCE heater	2	26	4	14b	5	Stnls Steel	1/4"	208
TCE evaporator feed pump (1)	2	52	1	10	25	Stnls Steel	3/8"	104
TCE evaporator (1)	2	26	1	10	20	Stnls Steel	3/8"	52
TCE evaporator circulation pump (1)	2	52	1	10	20	Stnls Steel	3/8"	104
Condenser (1)	2	26	1	10	16	Stnls Steel	3/8"	52
TCE transfer pump (1)	2	52	1	14b	9	Stnls Steel	1/4"	104
Stripping column feed pump (1)	2	52	1	14b	10	Stnls Steel	1/4"	104
Stripping column air blower (1)	2	52	1	14b	15	Stnls Steel	1/4"	104
Stripping column (1)	2	26	1	14b	15	Stnls Steel	1/4"	52
Water transfer pump (1)	2	52	1	14b	22	Stnls Steel	1/4"	104
Carbon adsorber (2)	2	13	2	14b	30	Stnls Steel	1/4"	52
Regeneration condenser (1)	2	26	1	14b	38	Stnls Steel	1/4"	52
Conveyors, Gelation to wash tanks (2)	2	104	2	18	3	Steel	3/8"	416
Conveyor, Wash feed tank to weigh feeders (6)	2	104	6	18	3	Steel	3/8"	1248
Sphere weigh feeder (6)	2	52	6	19	1	Steel	1/4"	624
Sphere washer (6)	2	52	6	20	1	Steel	1/4"	624
Wash solution transfer pump (12)	2	52	12	20	6	Steel	1/4"	1248
Wash solution feed pump (12)	2	52	12	20	6	Steel	1/4"	1248
Washed sphere transfer pump (12)	2	52	12	20	3	Steel	1/4"	1248
Sphere dryer weigh feeder (6)	2	52	6	21	1	Steel	1/4"	624
Sphere dryer (6)	2	52	6	21	1	Steel	1/4"	624

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
Dryer blower (6)	2	52	6	20	6	Steel	1/4"	624
Dryer heater (6)	2	26	6	20,21	6	Steel	1/4",1/4"	312
Dryer condenser (6)	2	26	6	21	35	Steel	1/4"	312
Conveyor, Dryer to bin (6)	2	104	6	21	3	Steel	1/4"	1248
NH3 Stripper feed pump (2)	2	52	2	1,2,3	140	Steel	1/4"+1/4"	208
NH3 Stripper (1)	2	26	1	1,2,3	140	Steel	1/4"+1/4"	52
NH3 Stripper feed exchanger (1)	2	26	1	1,2,3	140	Steel	1/4"+1/4"	52
NH3 Stripper condenser (1)	2	26	1	1,2,3	140	Steel	1/4"+1/4"	52
NH3 Stripper reboiler (1)	2	26	1	1,2,3	140	Steel	1/4"+1/4"	52
NH3 Stripper overhead pump (2)	2	52	2	1,2,3	140	Steel	1/4"+1/4"	208
NH3 Stripper bottoms pump (2)	2	52	2	1,2,3	140	Steel	1/4"+1/4"	208
Wiped Film evaporator (3)	2	52	3	1,2,3	140	Steel	1/4"+1/4"	312
Wiped Film evaporator feed pump (5)	2	52	5	1,2,3	140	Steel	1/4"+1/4"	520
Wiped Film evaporator bottoms pump (6)	2	52	6	1,2,3	140	Steel	1/4"+1/4"	624
Wiped Film evaporator condenser (3)	2	26	3	1,2,3	140	Steel	1/4"+1/4"	156
Wiped Film evaporator condensate pump (6)	2	52	6	1,2,3	140	Steel	1/4"+1/4"	624
Dried sphere weigh feeders (11)	2	52	11	22	1	Steel	1/4"	1144
Mobile sintering boats (50)	2	4	50	21	36	Steel	1/4"	400
Sintering furnace (11)	2	52	11	23	1	Steel+Firebrick	3/8"+2"	1144
Sphere weigh feeders (2+2)	2	52	4	24	1	Steel	1/4"	416
Sphere blenders (2)	2	52	2	24	1	Steel	1/4"	208
Ammonia dissociator (1)	2	26	1	1,2,3	90	Steel	1/4"+1/4"	52
H2 compressors (2+2)	2	52	4	23,24	16	Stl+FrBrick,Stl	3/8"+2",1/4	416
H2 coolers (1+2)	2	26	3	23,24	16	Stl+FrBrick,Stl	3/8"+2",1/4	156
								0
Liquid N2 vaporizer (1)	2	26	1	21,22	16	Steel	1/4"	52
N2 compressor (2)	2	52	2	21,22	16	Steel	1/4"	208
N2 compressor intercoolers (2)	2	26	2	21,22	16	Steel	1/4"	104

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
HF distillation column (1)	2	26	1	1,2,3	16	Steel	1/4"+1/4"	52
HF distillation reboiler (1)	2	26	1	1,2,3	22	Steel	1/4"+1/4"	52
40 °F condenser (1)	2	26	1	1,2,3	10	Steel	1/4"+1/4"	52
-20 °F condenser (1)	2	26	1	1,2,3	16	Steel	1/4"+1/4"	52
HF distillation reflux pump (1)	2	52	1	1,2,3	22	Steel	1/4"+1/4"	104
30 °F chiller (1)	2	52	1	7	16	Inconel	1.5"	104
-30 °F chiller (1)	2	52	1	7	16	Inconel	1.5"	104
-20 °F chiller (1)	2	52	1	7	16	Inconel	1.5"	104
HF distillation bottoms pump (1)	2	52	1	1,2,3	25	Steel	1/4"+1/4"	104
HF transfer pump (1)	2	52	1	1,2,3	20	Steel	1/4"+1/4"	104
HF loading pump (1)	2	52	1	21	150	Steel	1/4"	104
HF scrubber (1)	2	26	1	1,2,3	38	Steel	1/4"+1/4"	52
Off-gas heater (1)	2	26	1	1,2,3	60	Steel	1/4"+1/4"	52
Off-gas HEPA filters (2)	2	4	2	1,2,3	60	Steel	1/4"+1/4"	16
Off-gas exhausters (2)	2	52	2	1,2,3	60	Steel	1/4"+1/4"	208
Lime feeder (1)	2	104	1	1,2,3	34	Steel	1/4"+1/4"	208
Drum filter (1)	2	26	1	1,2,3	36	Steel	1/4"+1/4"	52
Vacuum pump (1)	2	52	1	1,2,3	36	Steel	1/4"+1/4"	104
Scrub solution cooler (1)	2	26	1	1,2,3	45	Steel	1/4"+1/4"	52
Scrub solution pump (1)	2	52	1	1,2,3	45	Steel	1/4"+1/4"	104
Evaporator (1)	2	26	1	1,2,3	50	Steel	1/4"+1/4"	52
Condenser (1)	2	26	1	10	45	Stnls Steel	3/8"	52
Condensate pump (1)	2	52	1	10	45	Stnls Steel	3/8"	104
CaF2 screw conveyor (1)	2	104	1	1,2,3	36	Steel	1/4"+1/4"	208
CaF2 rotary dryer (1)	2	104	1	1,2,3	36	Steel	1/4"+1/4"	208
CaF2 dust collector (1)	2	4	1	1,2,3	60	Steel	1/4"+1/4"	8

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR
Lime feeder (1)	2	104	1	1,2,3	50	Steel	1/4"+1/4"	208
Neutralized waste feed pump (1)	2	52	1	1,2,3	55	Steel	1/4"+1/4"	104
Cement feeder (1)	2	104	1	1,2,3	40	Steel	1/4"+1/4"	208
Grout mixing / drum tumbling station (1)	2	52	1	1,2,3	40	Steel	1/4"+1/4"	104
Lime pneumatic conveyor (1)	2	104	1	1,2,3	30	Steel	1/4"+1/4"	208
Cement pneumatic conveyor (1)	2	104	1	1,2,3	30	Steel	1/4"+1/4"	208
HVAC equipment	2	520	1	1,2,3	30	Steel	1/4"+1/4"	1040
Boiler, Water Systems, other Utilities	2	52	3	26	200	Steel	3/8"	312
Waste water treatment equipment	1	2190	1	4	50	Steel	1/4"	2190
Sanitary waste treatment equipment	1	2190	1	5	50	Steel	1/4"	2190
Admin building	1	1000	1	16	100	Steel	1/4"	1000

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EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR

1) A single full UF6 cylinder
2) A single empty UF6 cylinder
3) There are up to 14 UF6 cylinders in the autoclave area.
4) There are 195 full UF6 cylinders in the storage area.
5) There are 580 empty UF6 cylinders in the storage building.
6) UO2F2 reactor; there are 2 reactors.
7) U3O8 reactor: there are 2 reactors.
8) U3O8 Storage Bin; there are 2 bins
9) Dissolver and Weigh Bin inventory; there are 2 dissolvers/weigh bins
10) ADUN Denitriting Tank inventory; there are 4 tanks
11) ADUN Cooler inventory
12) ADUN Storage Tank inventory
13) ADUN Feed Tank inventory
14a) 300μ Gelation Column inventory
14b) 1200μ Gelation Column inventory
15a) 300μ Gelation Filter inventory
15b) 1200μ Gelation Filter inventory
16a) 300μ Gel Dryer inventory
16b) 1200μ Gel Dryer inventory
17a) 300μ Gel Product Bin inventory
17b) 1200μ Gel Product Bin inventory
18) Sphere Wash Feed Tank inventory
19) Sphere Weigh Feeder inventory
20) Sphere Washer inventory
21) Sphere Dryer, Dryer Feed Tank & Weigh Feeder inventory
22) Dried Sphere Weigh Feeder inventory
23) Sintering Furnace inventory
24) Blend Feed Tanks (300μ & 1200μ), Sphere Weigh Feeder/Blender inventory
25) UF6 Cylinders in Shipping/Receiving Area

EQUIPMENT	NUMBER OF WORKERS	HOURS PER COMPONENT PER YEAR (Note 28)	NUMBER OF COMPONENTS	SOURCE	DISTANCE (ft)	MATERIAL (Note 29)	THICKNESS	PERSON HOURS PER YEAR

26) Dried 1200μ & 300μ Sphere Feed Bin Inventory

27) Loaded filter/bag.

28) Average of 2 hours per week on conveyor systems
Average of 1 hour per week on active components (pumps, compressors, equip. with motors) - Includes Instrumentation
Average of 1/2 hour per week on passive components (autoclaves, coolers, columns, scrubbers, condensers) - Includes Instrumentation
10 hours per week on HVAC components
6 hours per day on waste water treatment components
6 hours per day on sanitary waste treatment components
1000 hours per year on the administration building

29) Materials do not include walls between operating areas.