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DEPLETED URANIUM HEXAFLUORIDE MANAGEMENT PROGRAM

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

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Volume I

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IDENTIFIED on ________ Witness/Panel A. Makhijani
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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

[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.

[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

[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.

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

Section 6.4

U3O8: Defluorination / Anhydrous HF Facility

Draft Engineering Analysis Report
Depleted Uranium Hexafluoride Management Program

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.

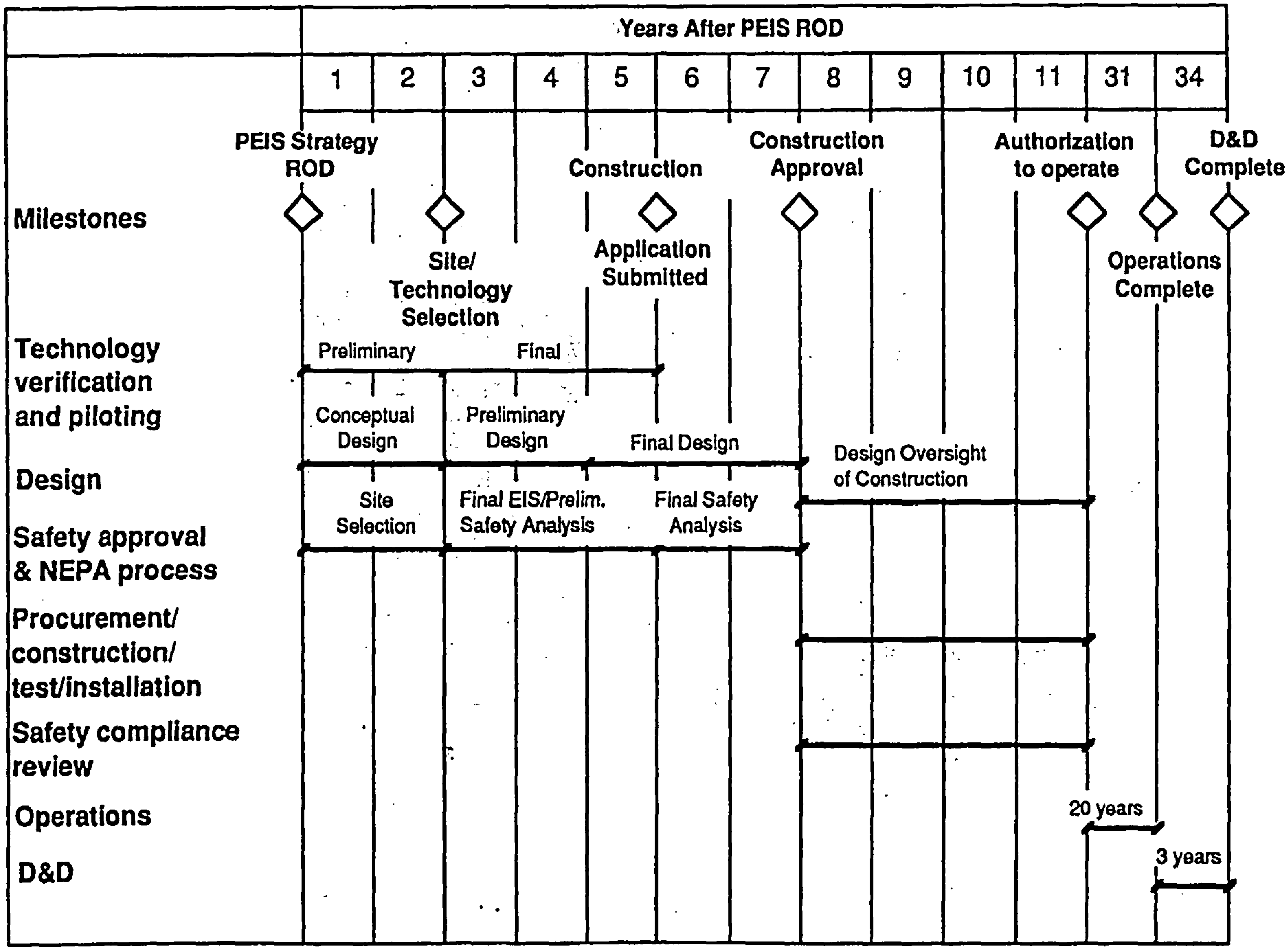


Figure 1-1 Preliminary Project Schedule

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.

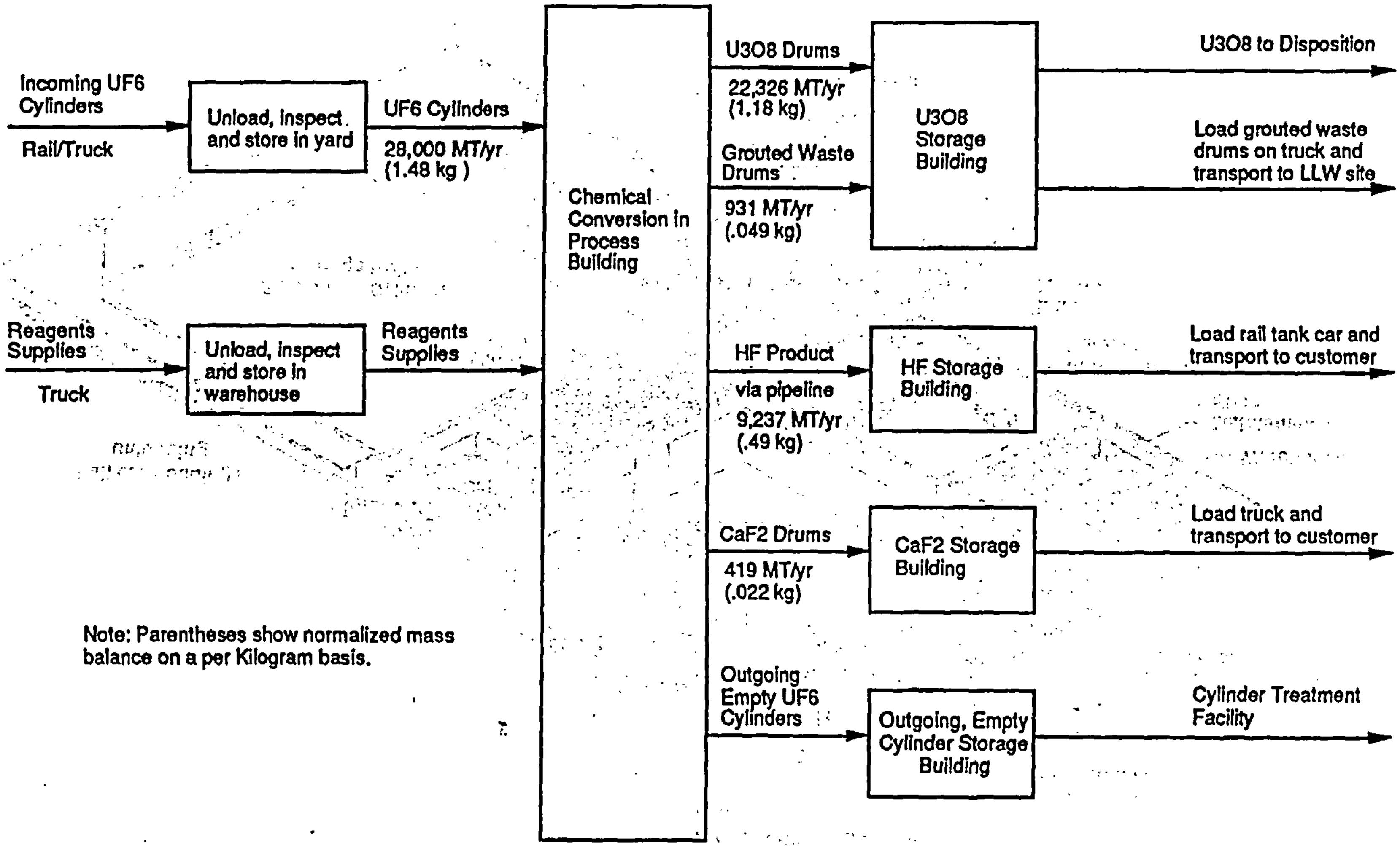


Figure 2-1 Inter-Facility Material Flow Diagram

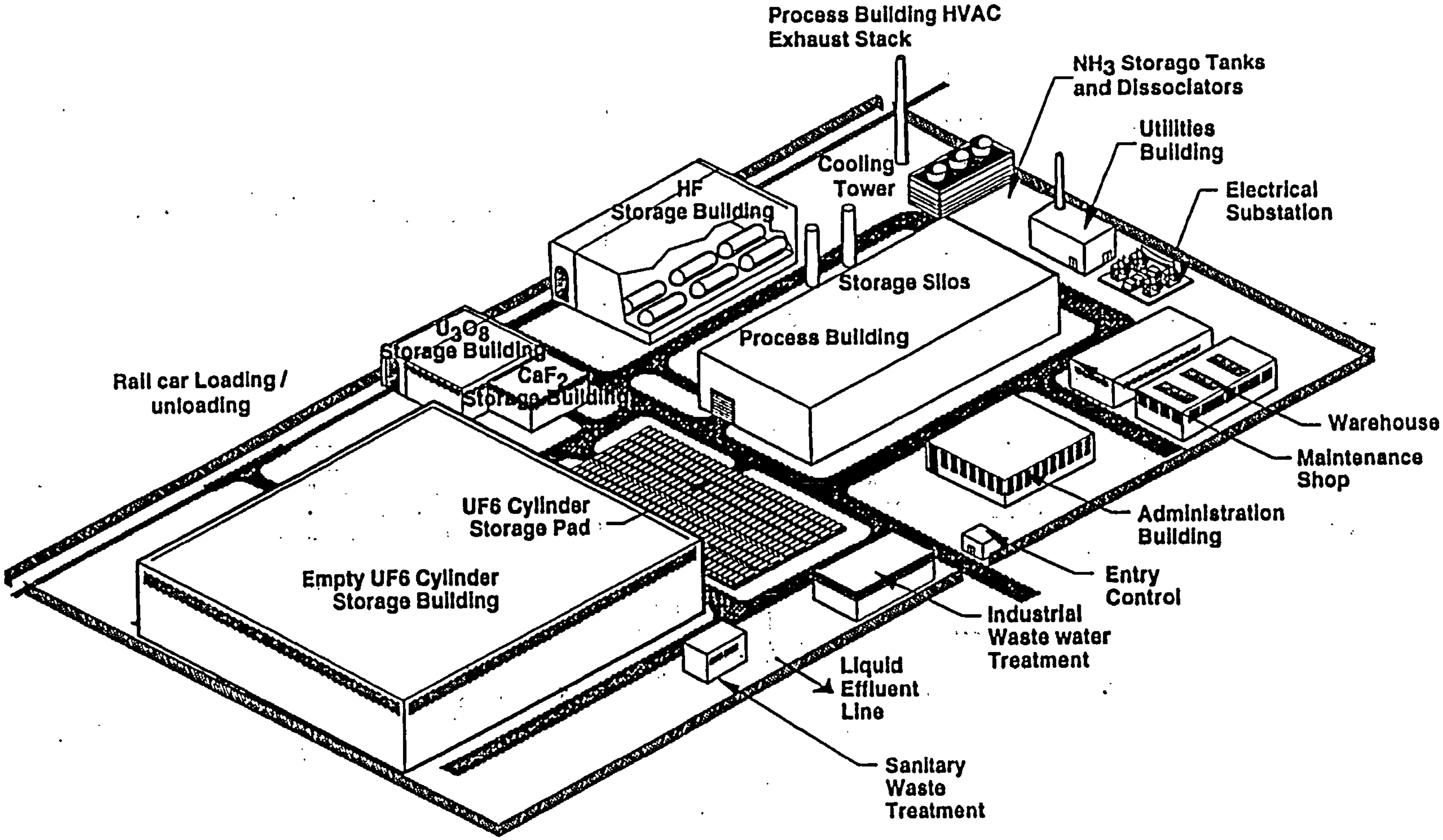


Figure 2-2 Plot Plan
Defluorination / Anhydrous HF Facility

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

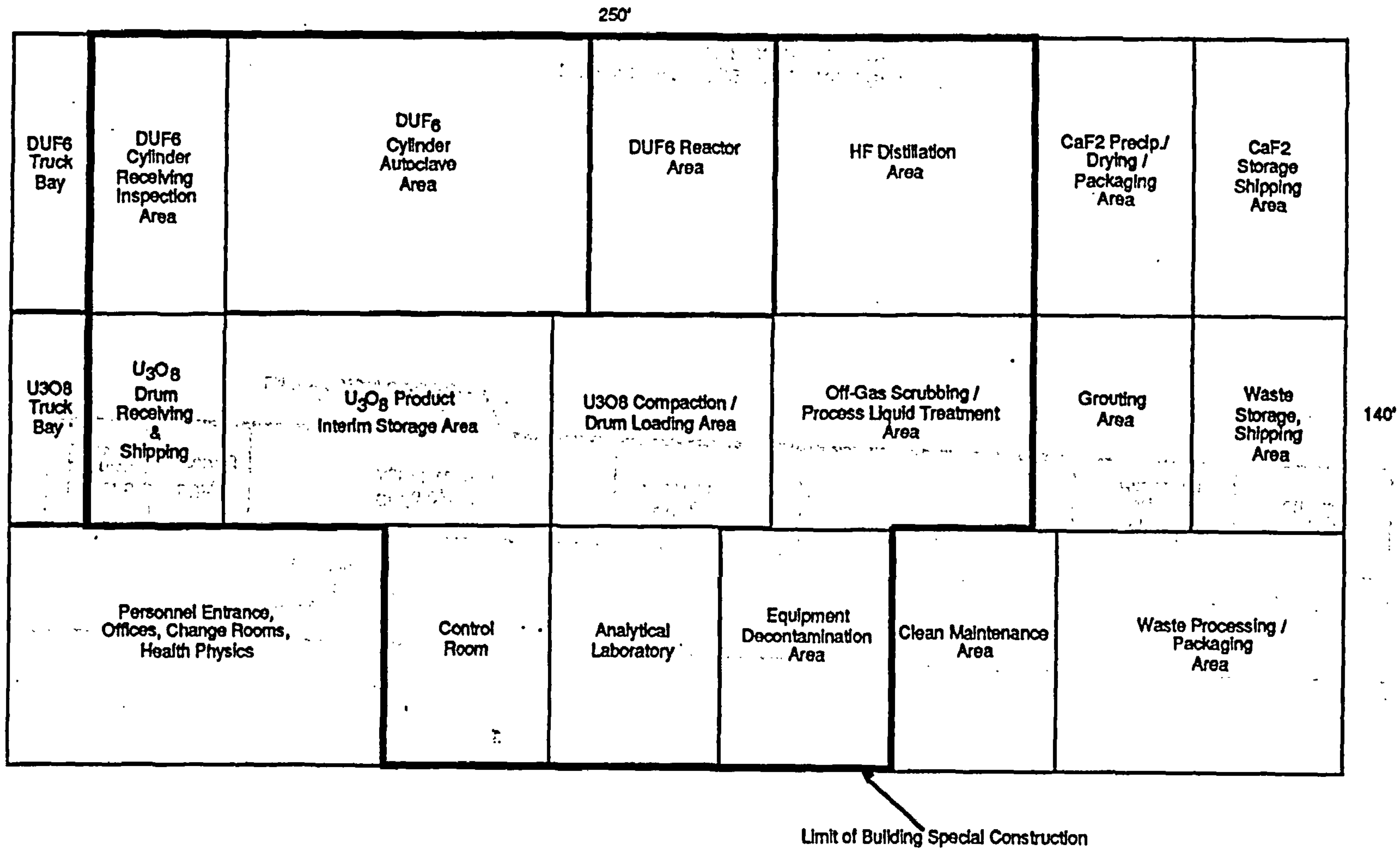


FIGURE 2-3 PROCESS BUILDING LAYOUT
DEFLUORINATION / ANHYDROUS HF

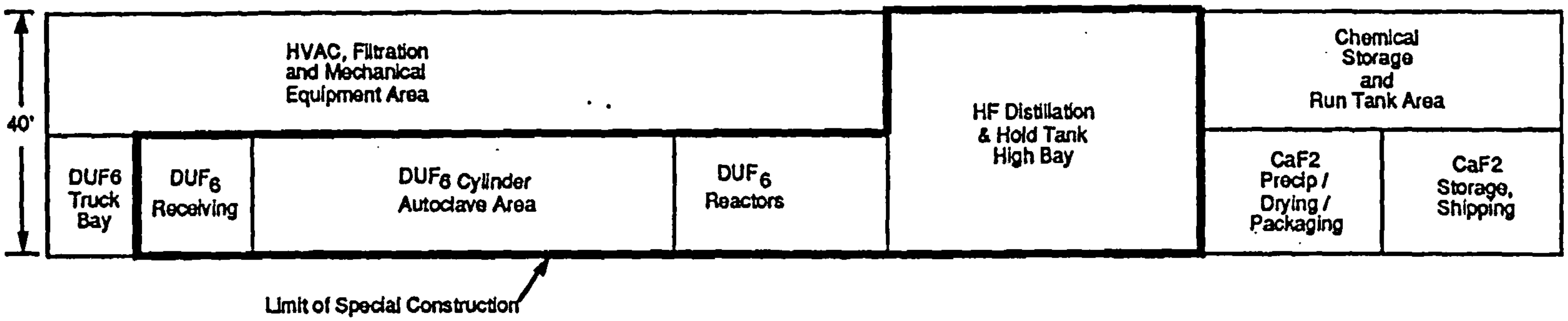


FIGURE 2-4 PROCESS BUILDING SECTION
DEFLUORINATION / ANHYDROUS HF

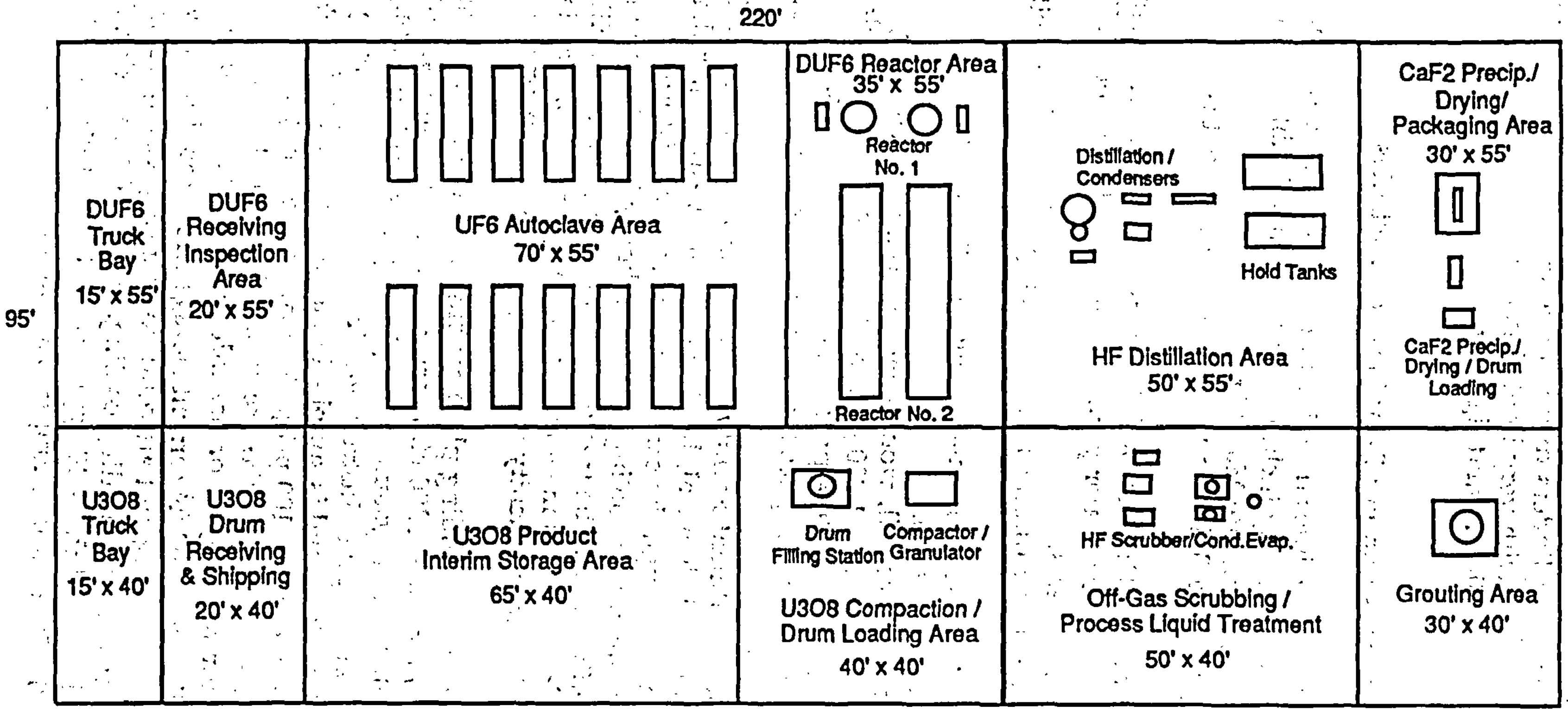


FIGURE 2-5 PROCESS EQUIPMENT ARRANGEMENT DEFLUORINATION / ANHYDROUS HF

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.

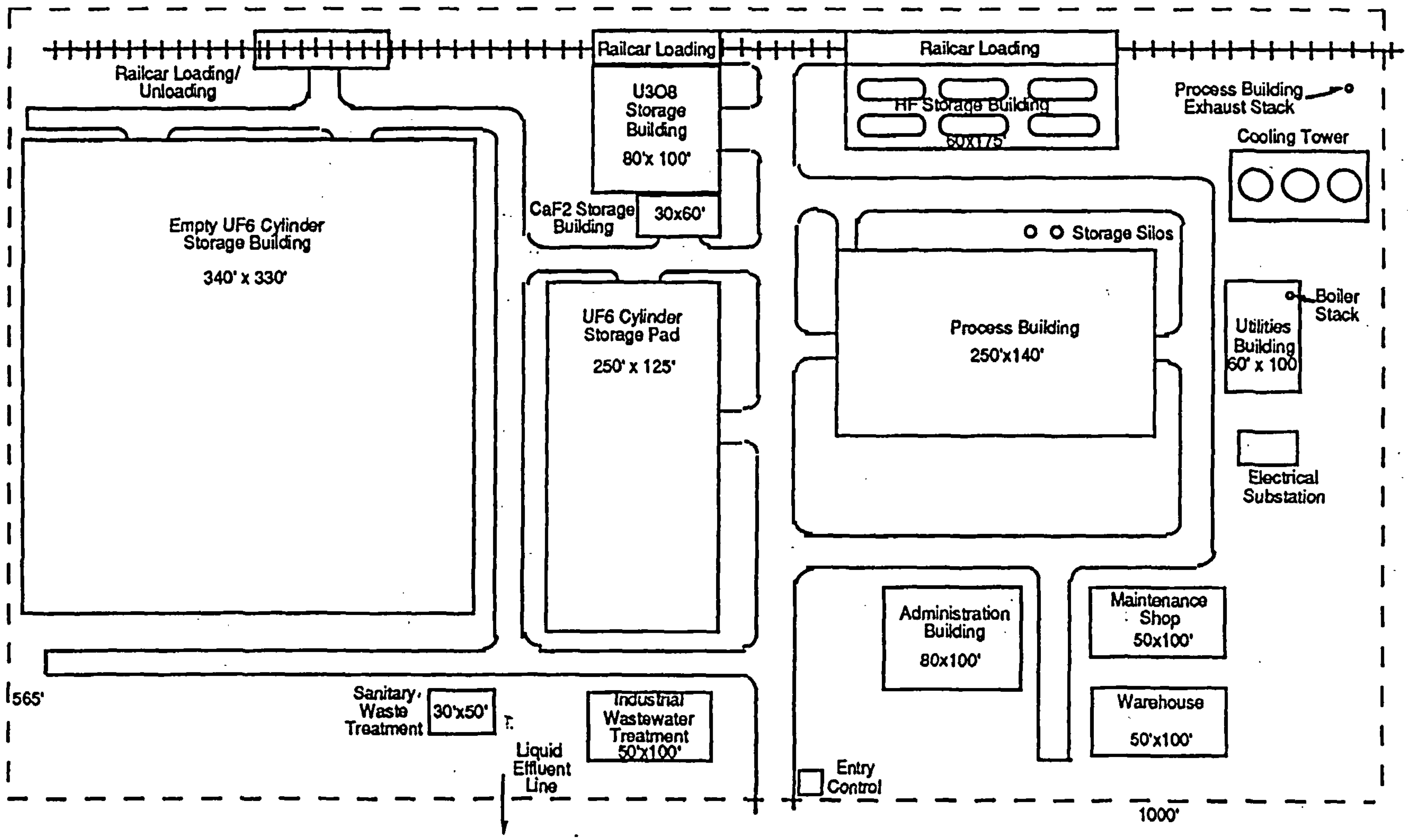


FIGURE 3-1 SITE MAP
DEFLUORINATION / ANHYDROUS HF FACILITY

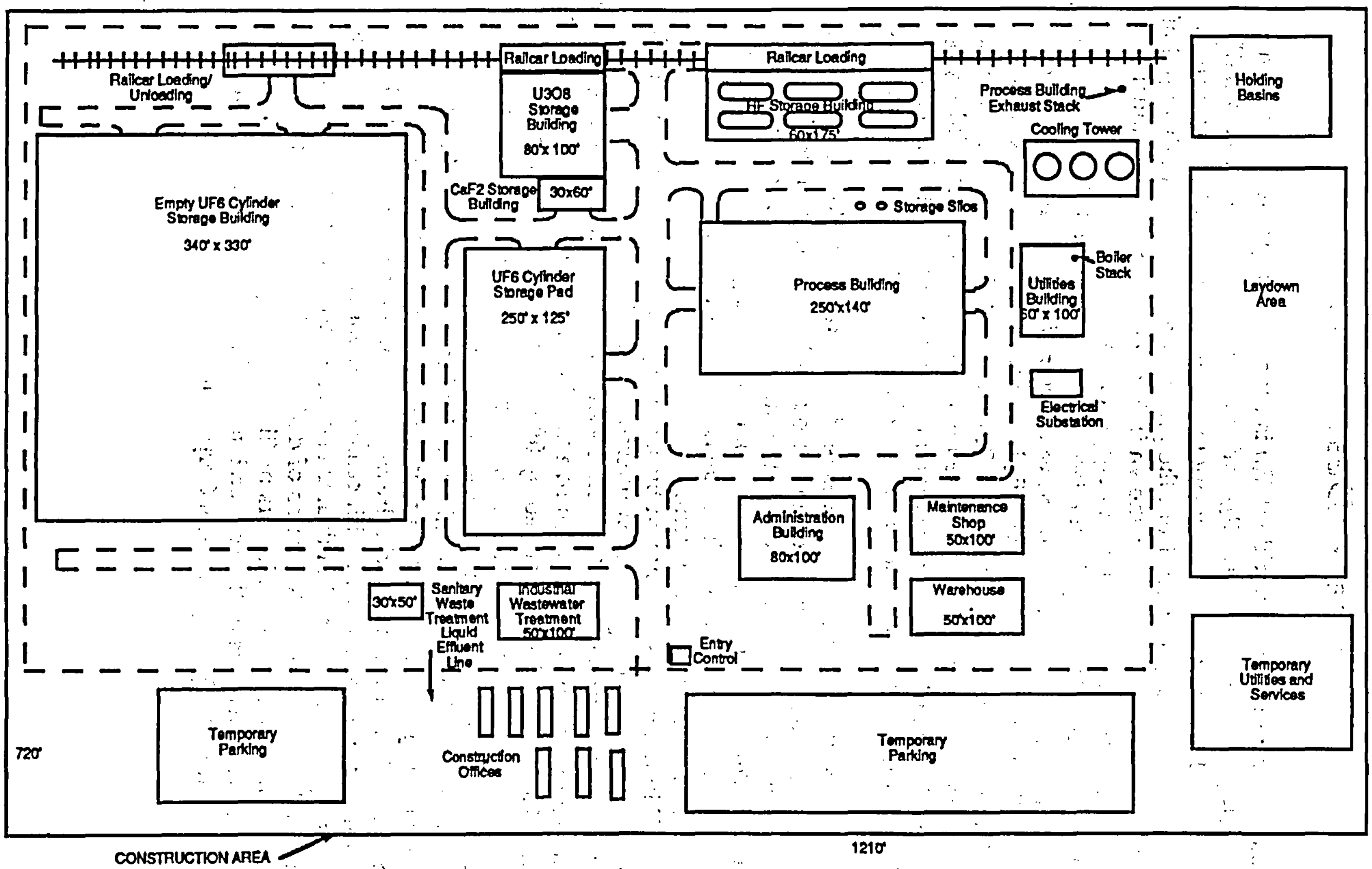


FIGURE 3-2 SITE MAP DURING CONSTRUCTION DEFLUORINATION / ANHYDROUS HF FACILITY

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.

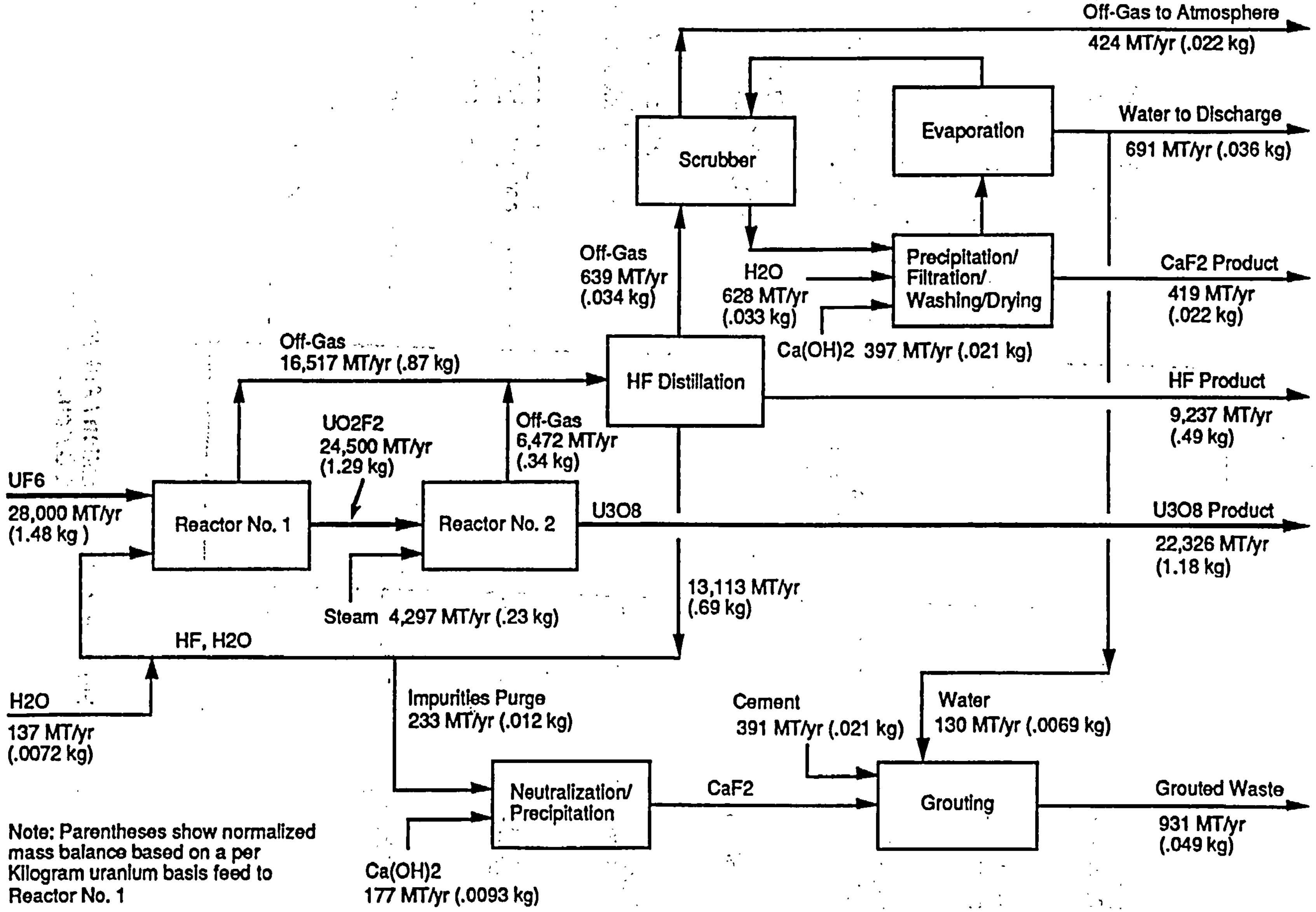
The UF_6 is converted to U_3O_8 in a two-step process. The UF_6 is vaporized using steam heated autoclaves and fed to Reactor No. 1, where it is mixed with 45% HF-water vapor. Solid UO_2F_2 is produced and flows to Reactor No. 2. Vapor containing HF and water flows to the HF distillation column. In the 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.



Note: Parentheses show normalized mass balance based on a per Kilogram uranium basis feed to Reactor No. 1

Figure 4-1 Defluorination / Anhydrous HF Block Flow Diagram

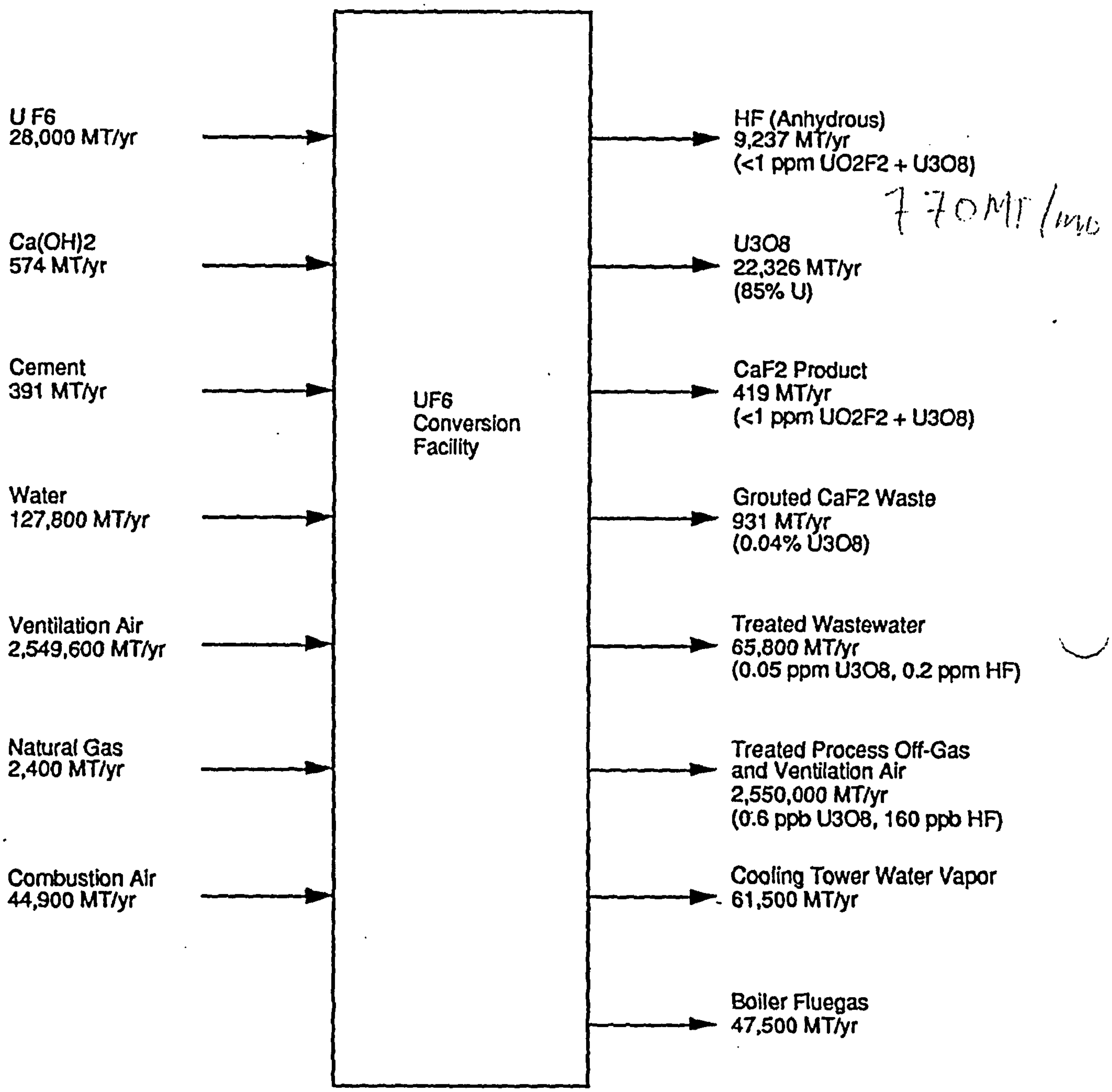


Figure 4-2 Defluorination / Anhydrous HF Input/Output Diagram

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.

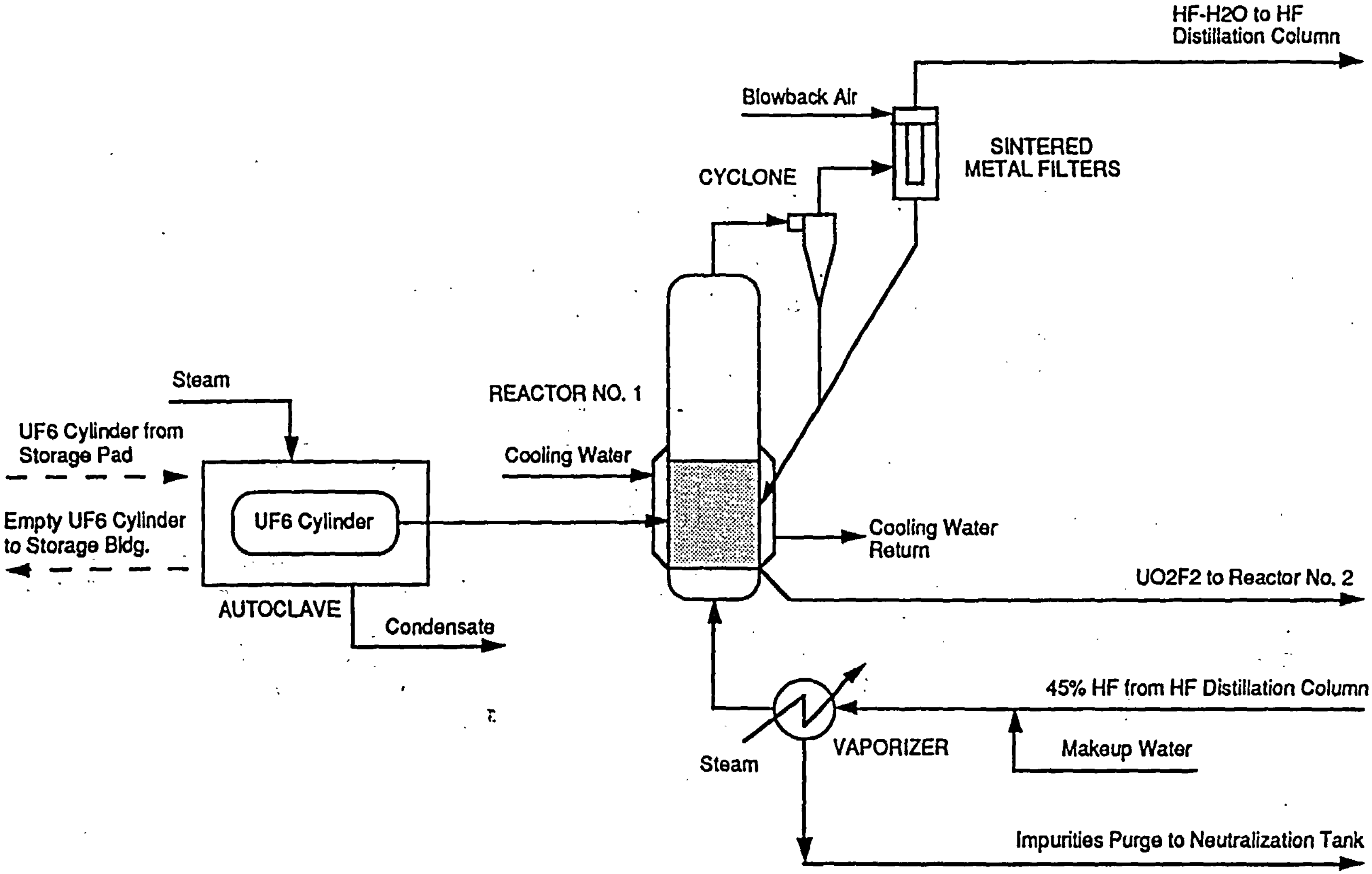


Figure 4-3 Reactor No. 1 Process Flow Diagram

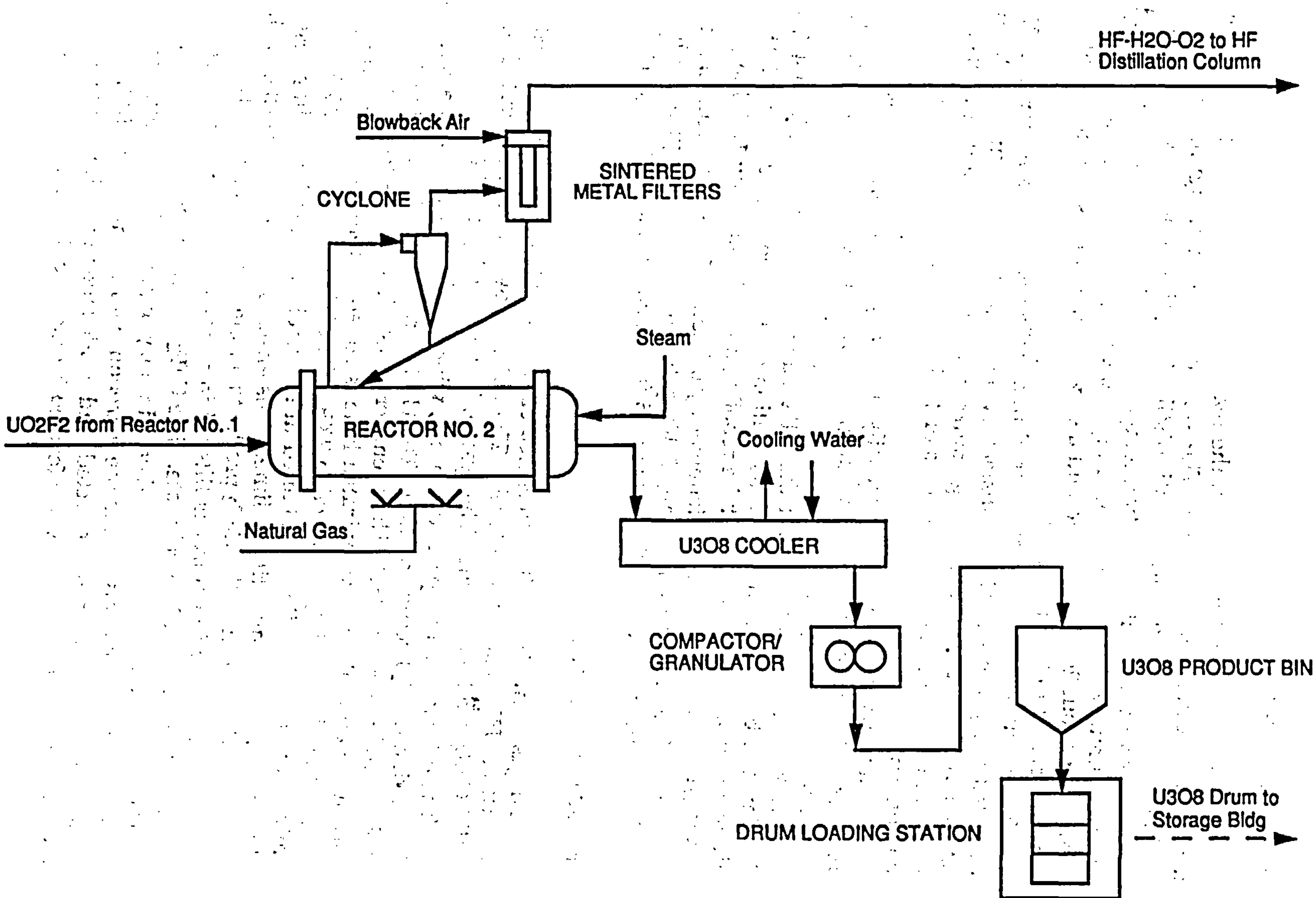


Figure 4-4 Reactor No. 2 Process Flow Diagram

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 $HF + KOH \longrightarrow KF + H_2O$. 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 $2KF + Ca(OH)_2 \longrightarrow CaF_2 + 2KOH$. 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

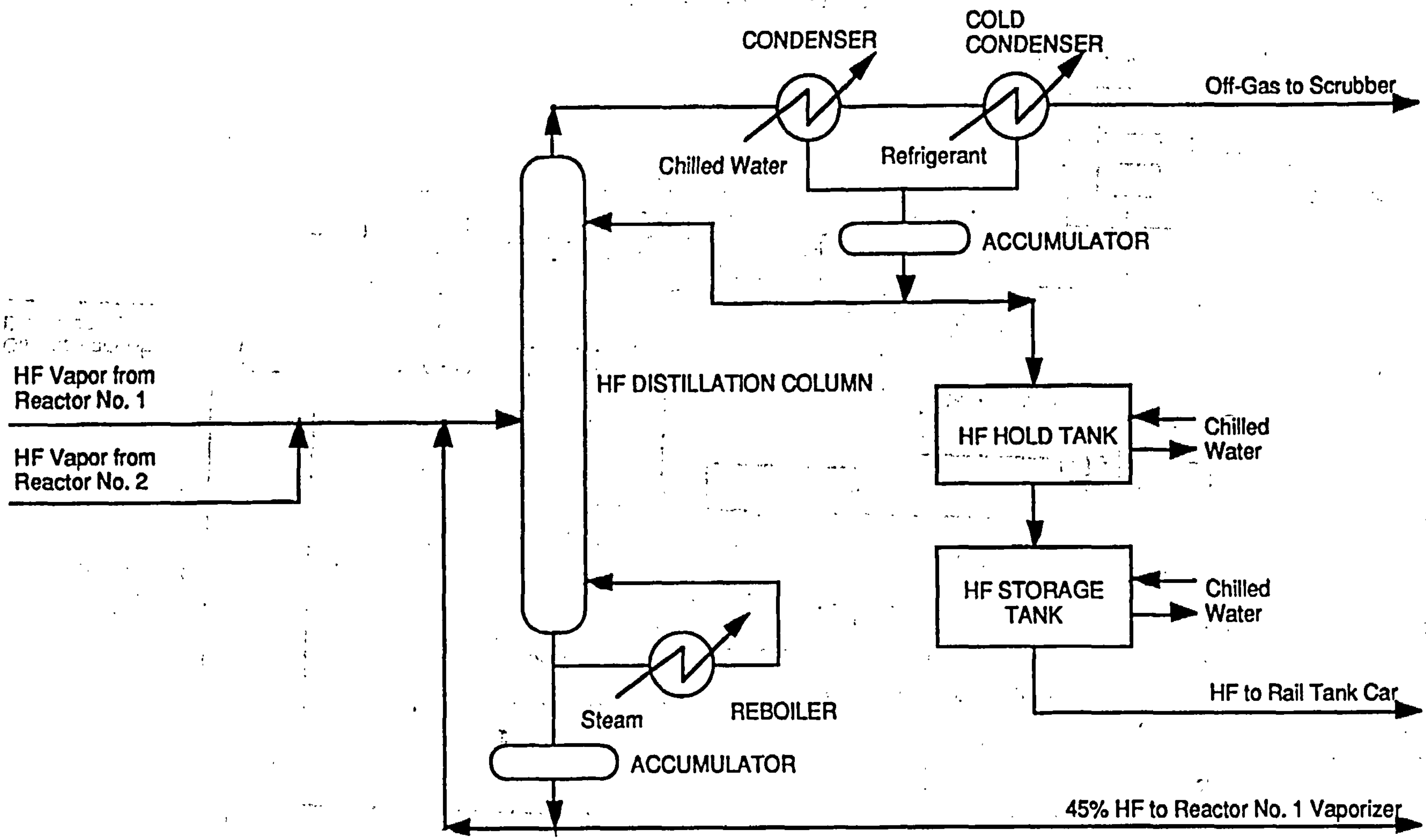


Figure 4-5 HF Distillation Process Flow Diagram

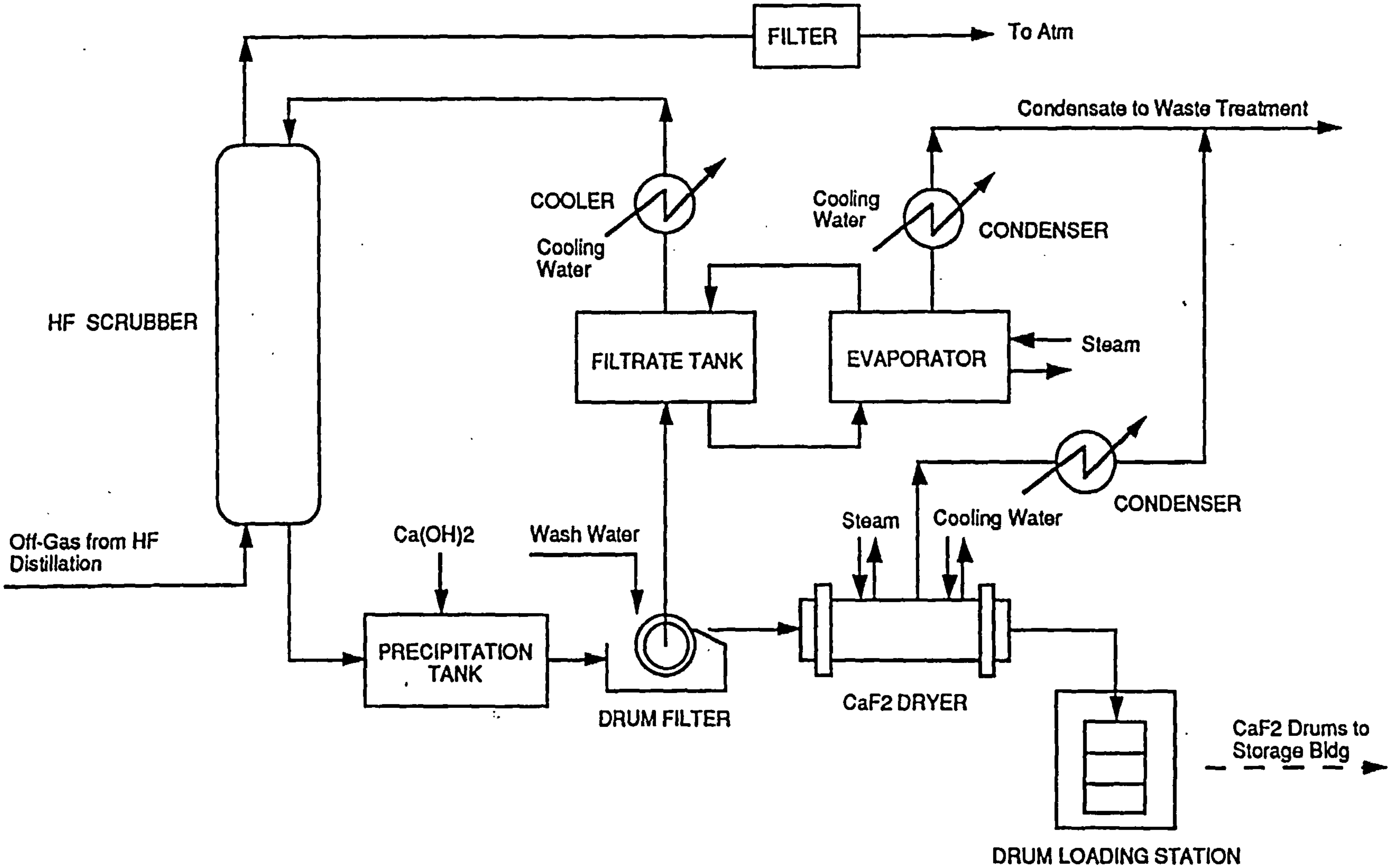


Figure 4-6 HF Scrubber Process Flow Diagram

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

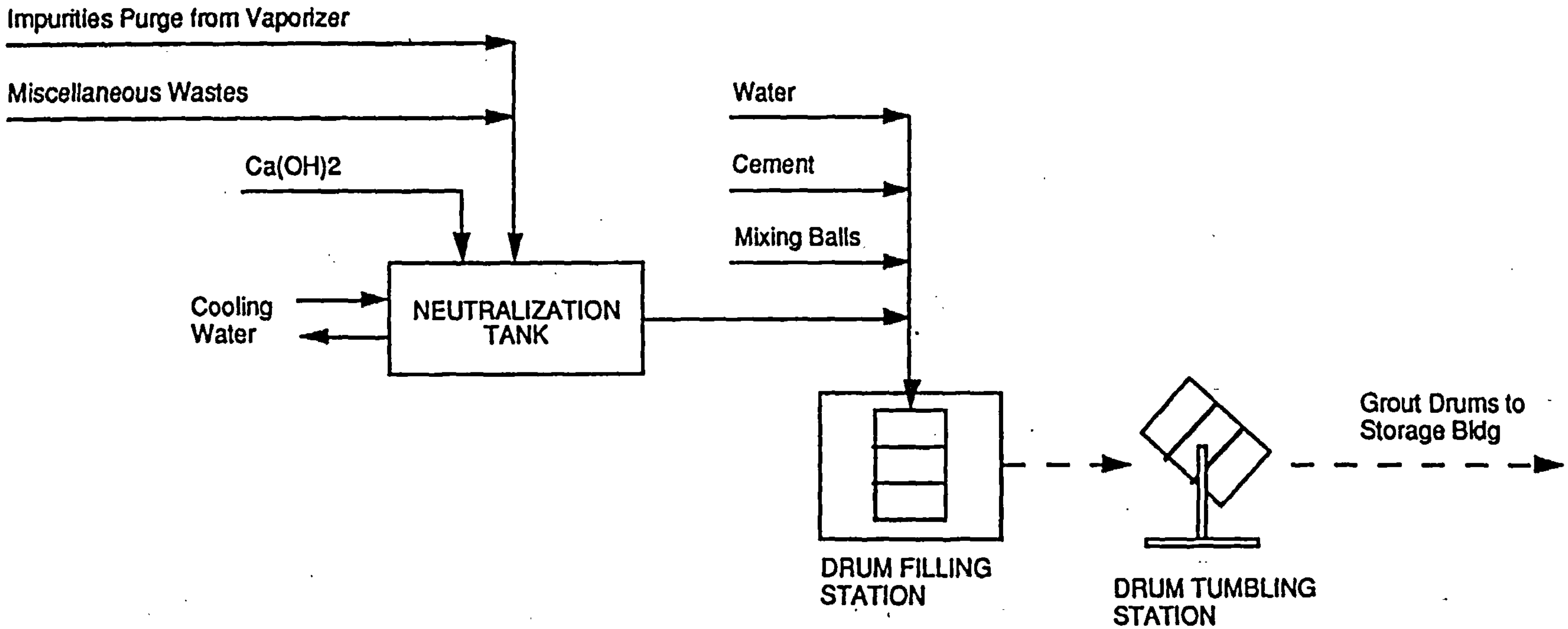


Figure 4-7 Waste Grouting Process Flow Diagram

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.

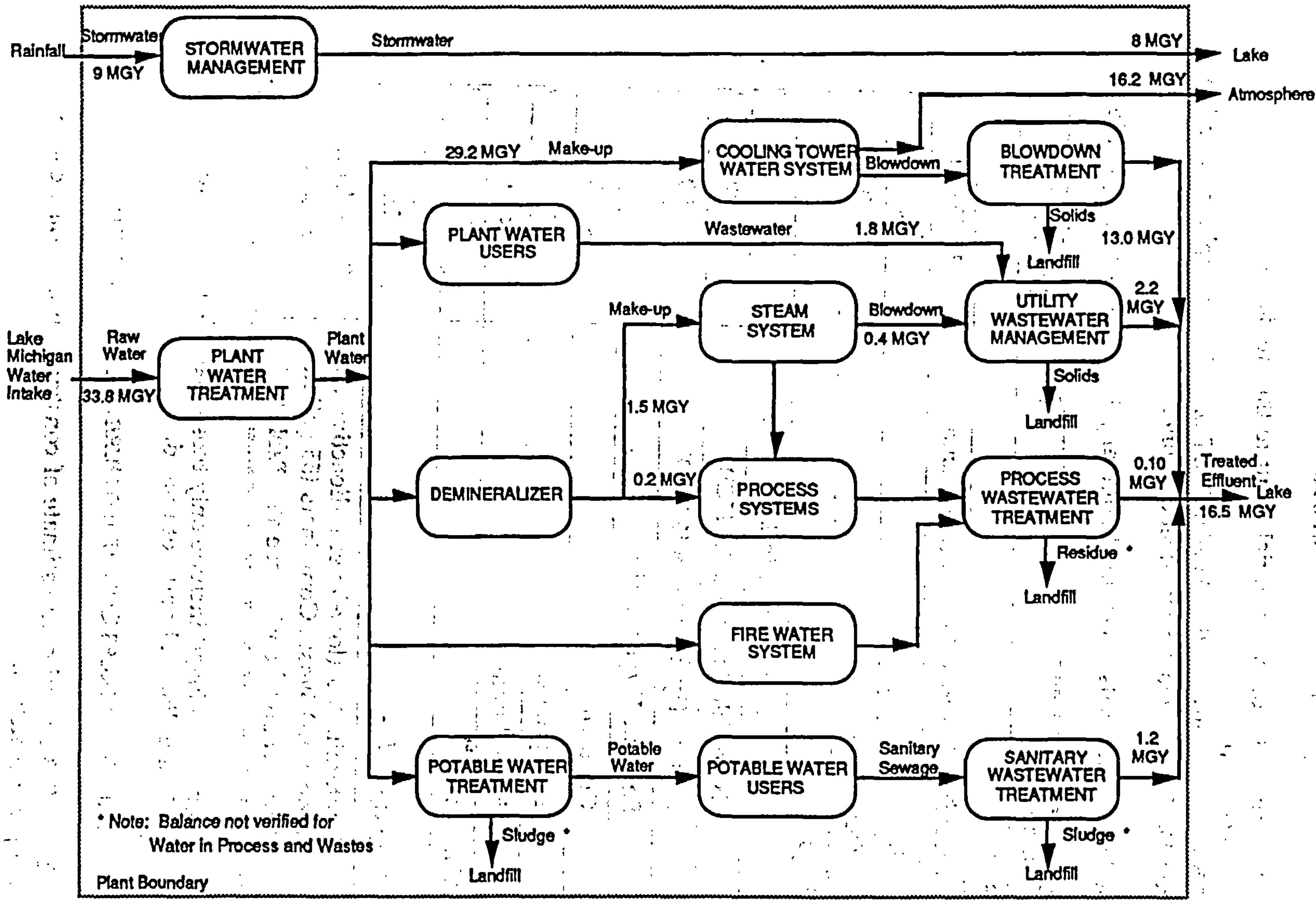


Figure 5-1 Preliminary Water Balance Defluorination / Anhydrous HF

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.

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)

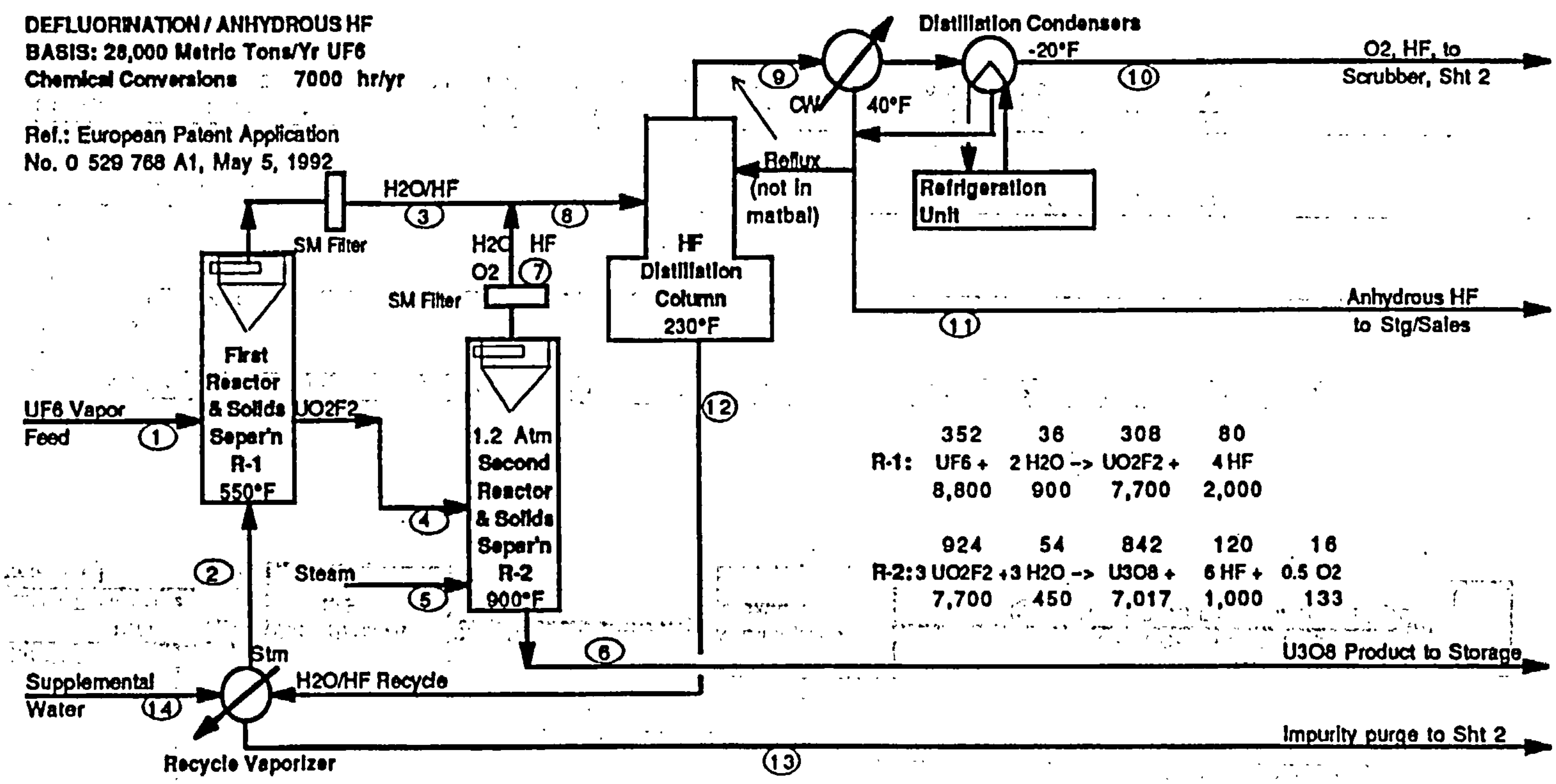
Appendix A

Material Balance

1-Mass Balance lb/hr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Chemical Conversions 7000 hr/yr

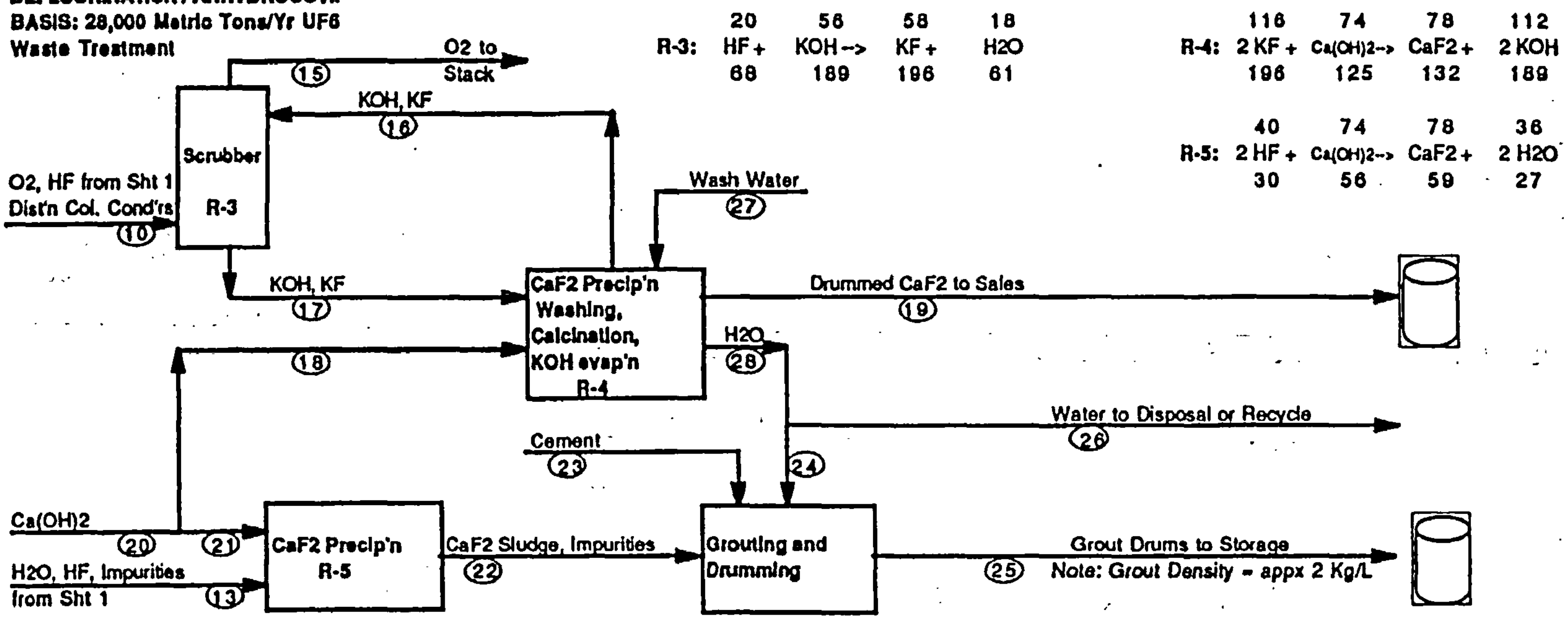
Ref.: European Patent Application No. 0 529 768 A1, May 5, 1992



	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



	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	58											
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				

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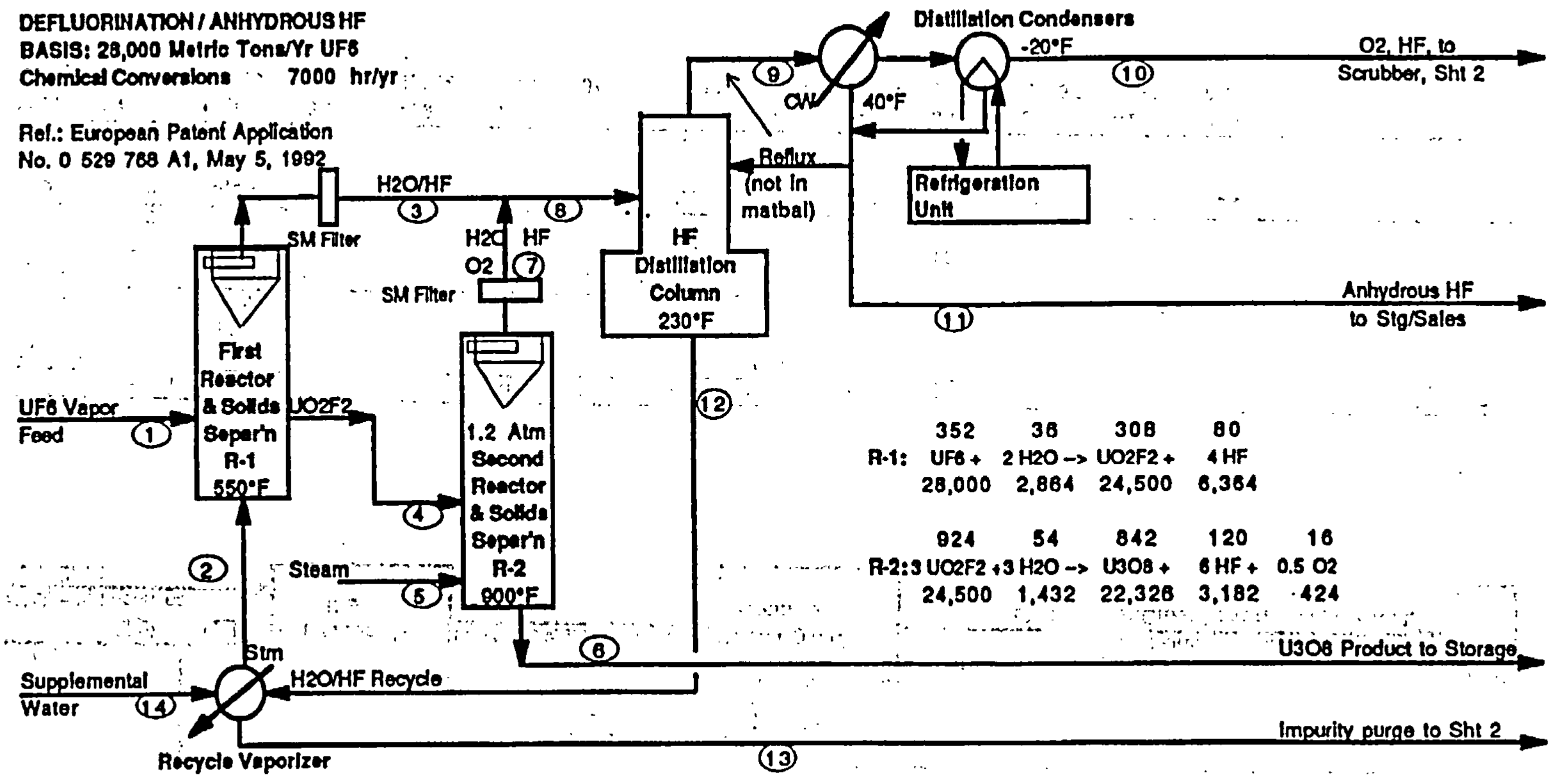
Sheet 2

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:	UF6 +	2 H2O -->	UO2F2 +	4 HF	
	28,000	2,864	24,500	6,364	
	924	54	842	120	16
R-2:	3 UO2F2 +	3 H2O -->	U3O8 +	6 HF +	0.5 O2
	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

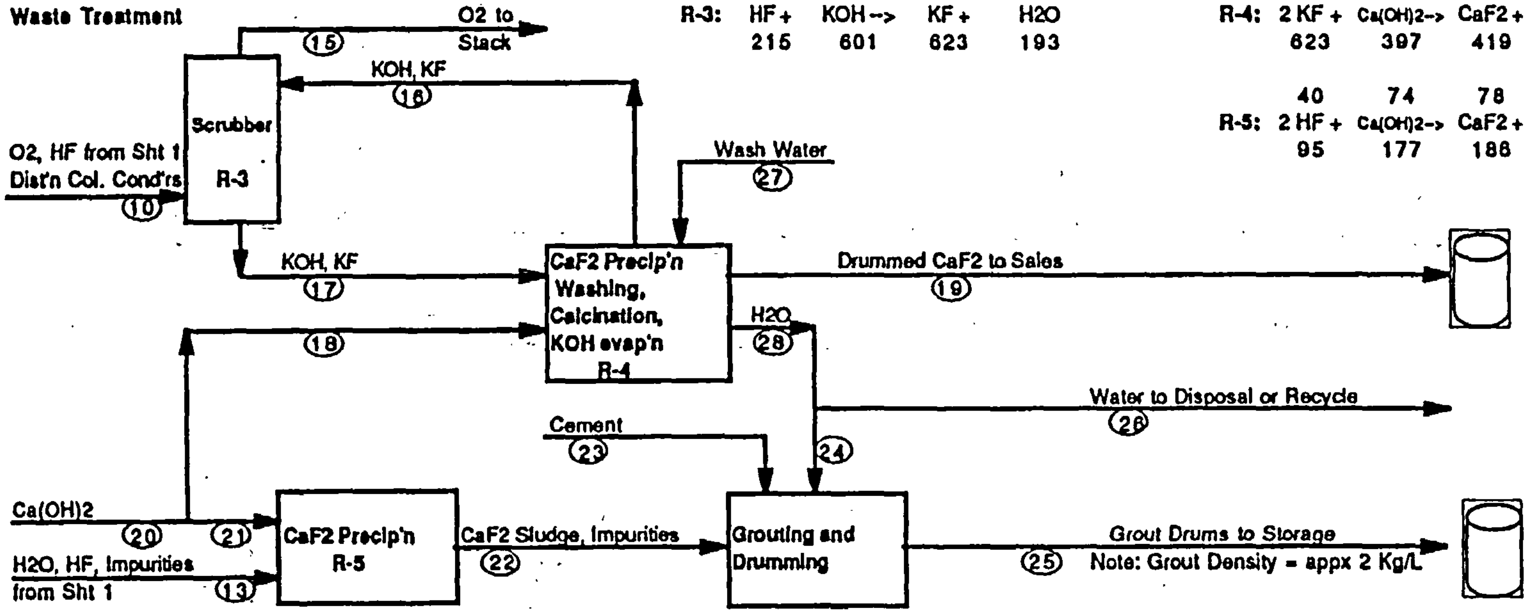
1-Mass Balance MT/yr

DEFLUORINATION / ANHYDROUS HF
BASIS: 28,000 Metric Tons/Yr UF6
Waste Treatment

	20	56	58	18
R-3:	HF +	KOH -->	KF +	H2O
	215	601	623	193

	116	74	78	112
R-4:	2 KF +	Ca(OH)2-->	CaF2 +	2 KOH
	623	397	419	601

	40	74	78	36
R-5:	2 HF +	Ca(OH)2-->	CaF2 +	2 H2O
	95	177	186	86



	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				

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,	Proc. Bldg
	steel shell	Proc. Bldg
Evaporator Condensate Tanks (2)	5'Dx5'H, 750 gal, steel	Proc. Bldg
Condensate Pump	10 gpm, cast iron	Proc. Bldg
CaF_2 Screw Conveyor	6"Dx10'L, steel	Proc. Bldg
CaF_2 Rotary Dryer	1'6"Dx5'L, steel	Proc. Bldg
CaF_2 Drum Filling Station	0.2 drum /hr glovebox	Proc. Bldg
CaF_2 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

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
								14556

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 UF_6 cylinder
2) A single empty UF_6 cylinder
3) There are up to 14 UF_6 cylinders in the autoclave area.
4) There are 195 full UF_6 cylinders in the storage area.
5) There are 195 empty UF_6 cylinders in the storage area.
6) UO_2F_2 reactor; there are 2 reactors.
7) U_3O_8 reactor; there are 2 reactors.
8) U_3O_8 Compactor feed bin; there are 2 bins.
9) U_3O_8 Drum fill bin.
10) Drum of U_3O_8.
11) Each transfer consists of 5 U_3O_8 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, stacker) - 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.

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Section 6.5

U3O8: 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 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 40 CFR 1502 - *Environmental Impact Statement*, 10 CFR 1021, *National*

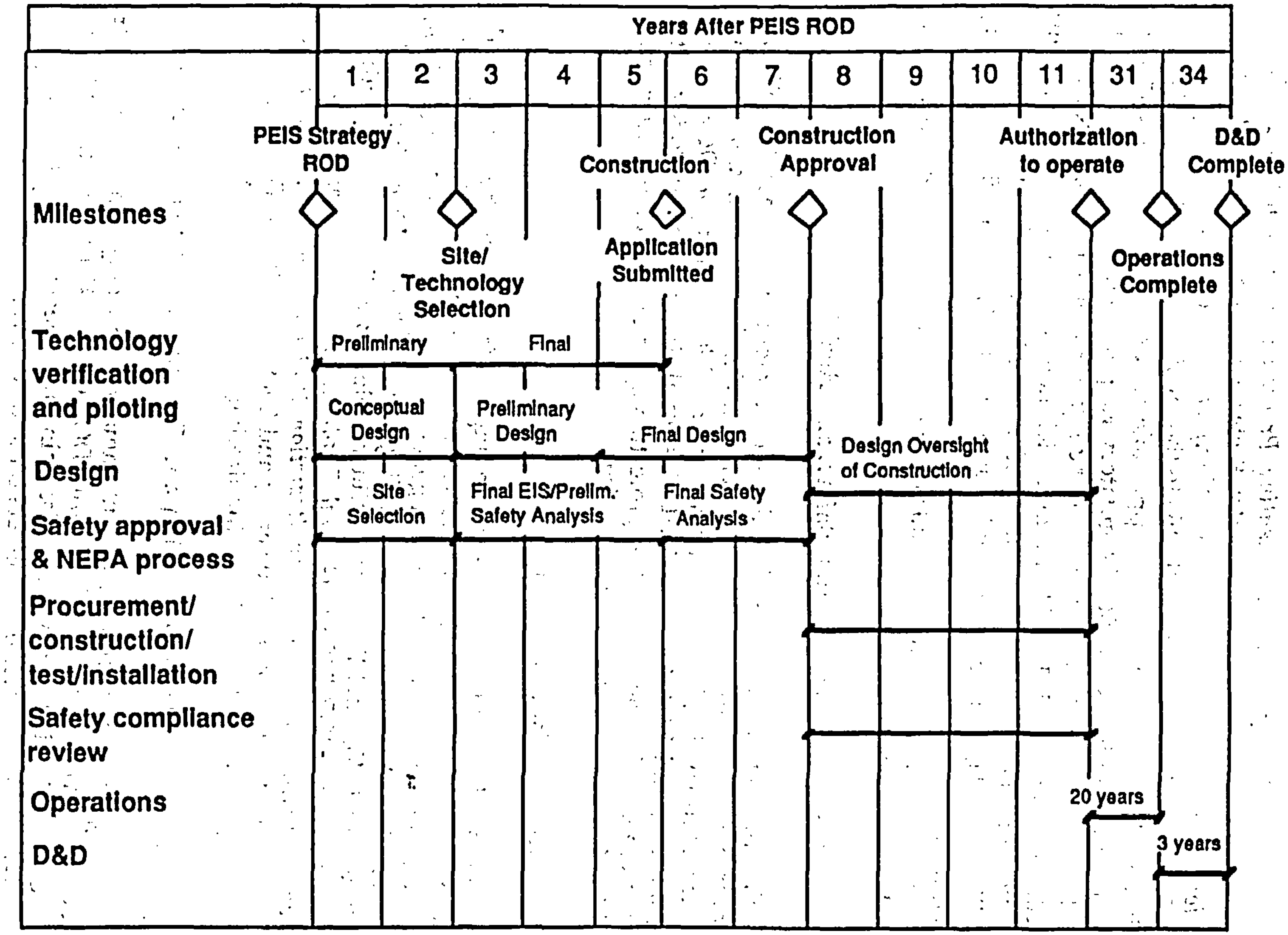

Figure 1-1 Preliminary Project Schedule

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.

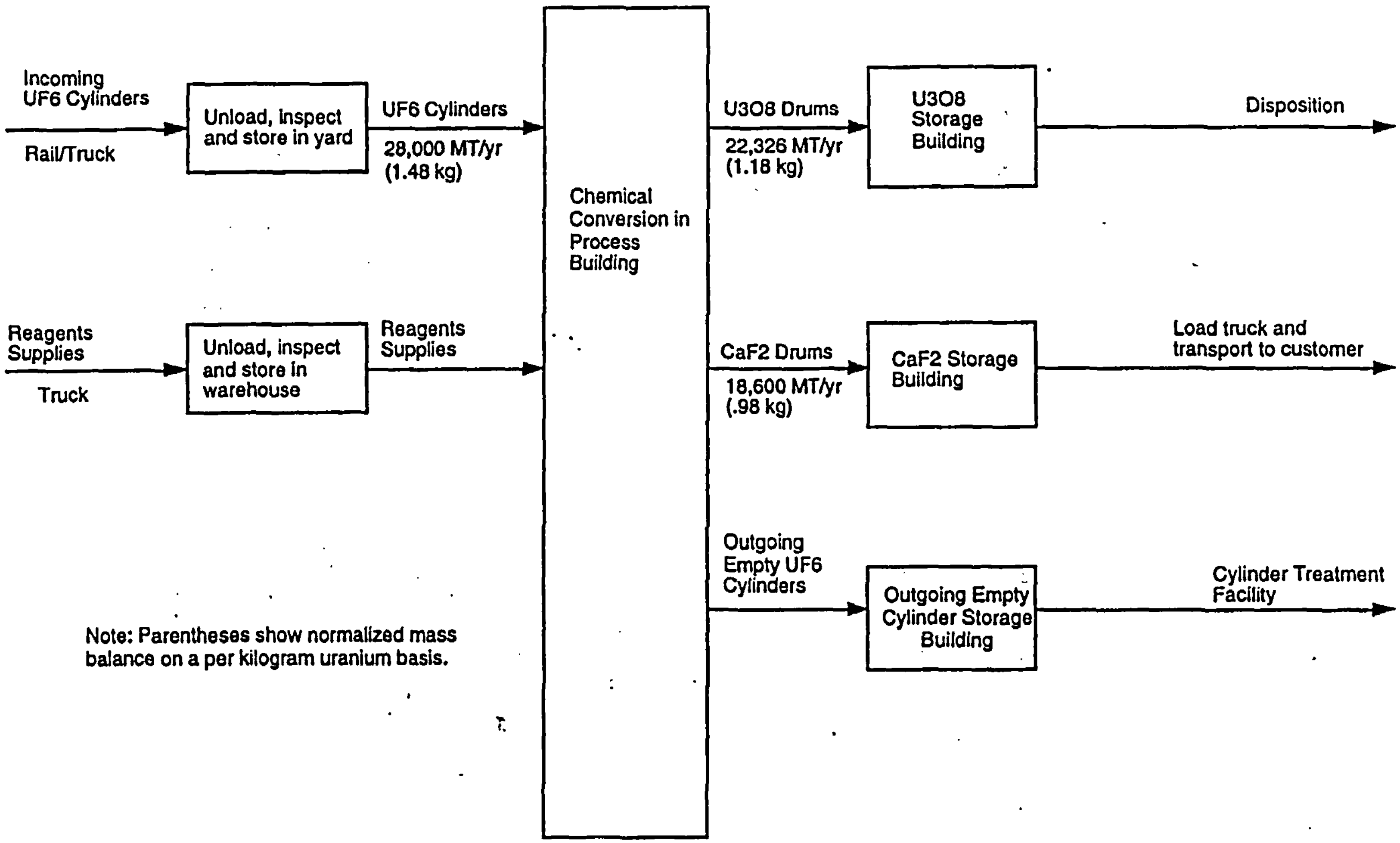

Figure 2-1 Defluorination / HF Neutralization Material Flow Diagram

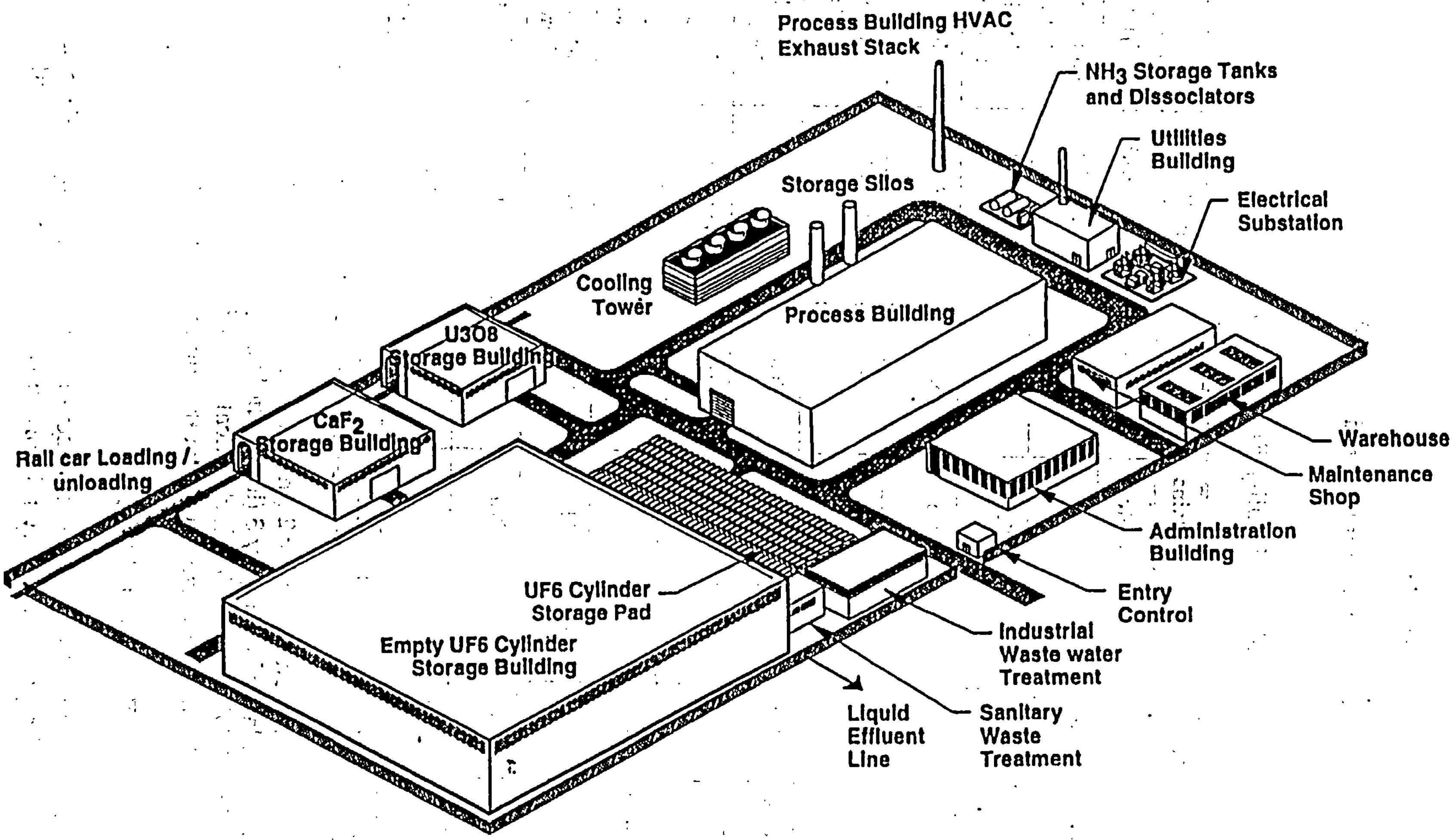

Figure 2-2 Plot Plan
Defluorination / HF Neutralization Facility

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

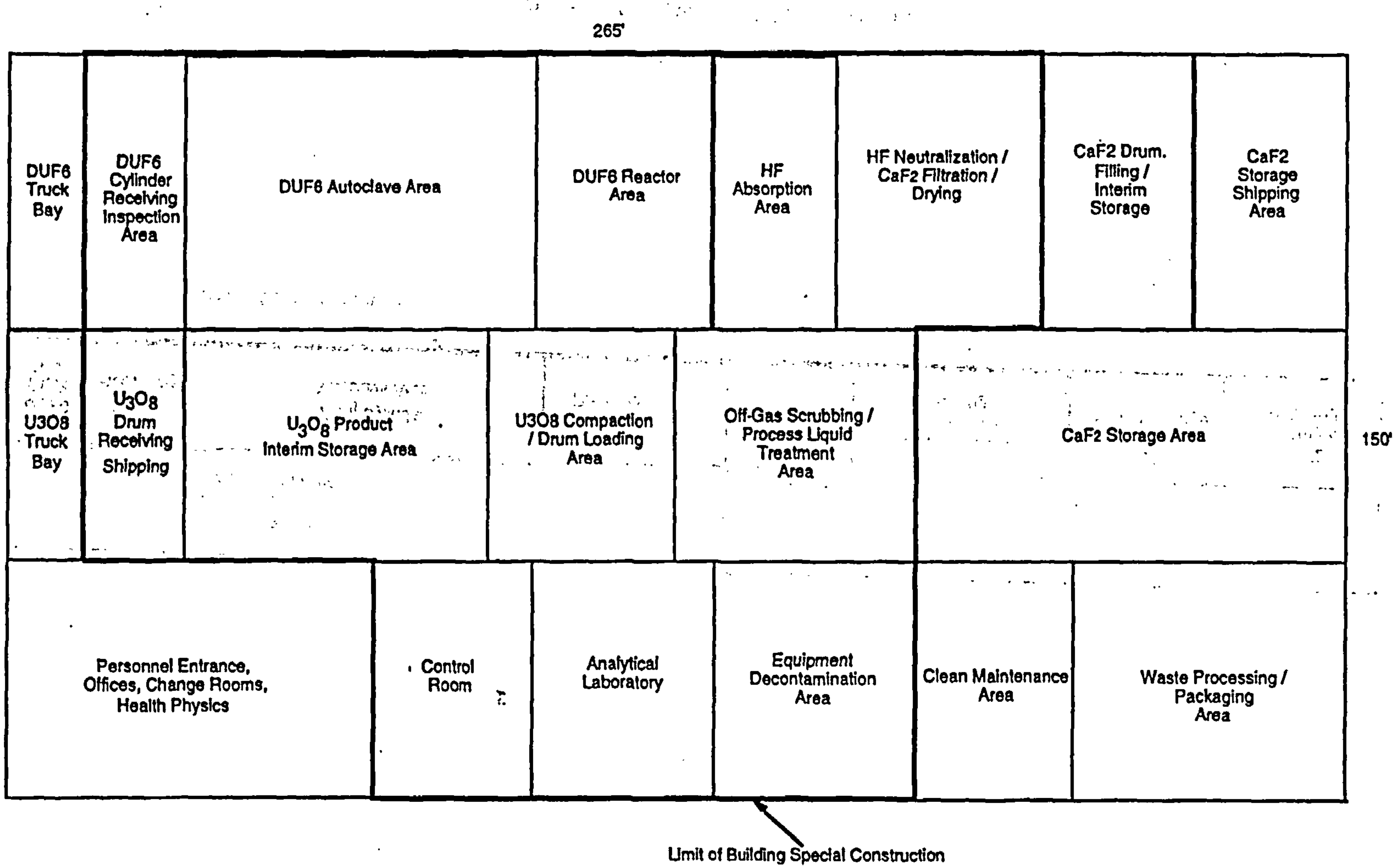

FIGURE 2-3 PROCESS BUILDING LAYOUT
DEFLUORINATION / HF NEUTRALIZATION

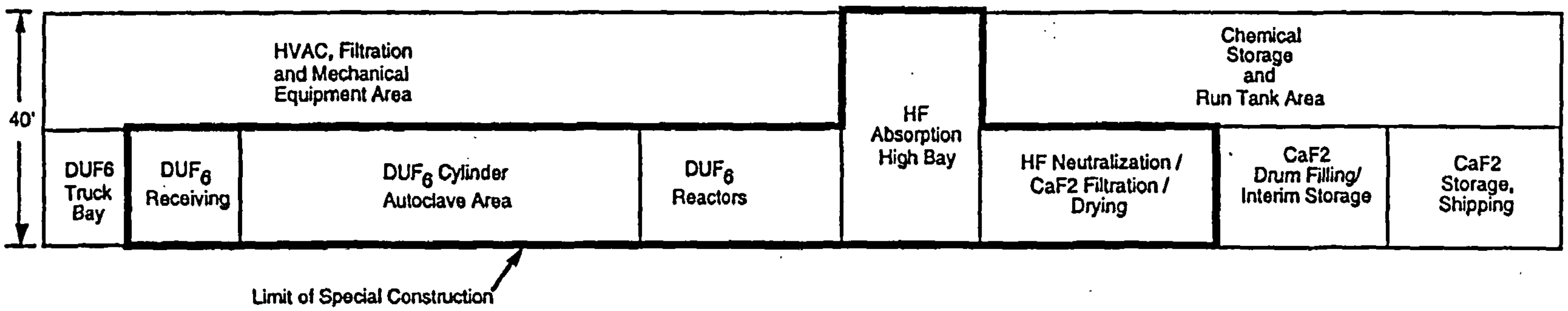

FIGURE 2-4 PROCESS BUILDING SECTION DEFLUORINATION/HF NEUTRALIZATION

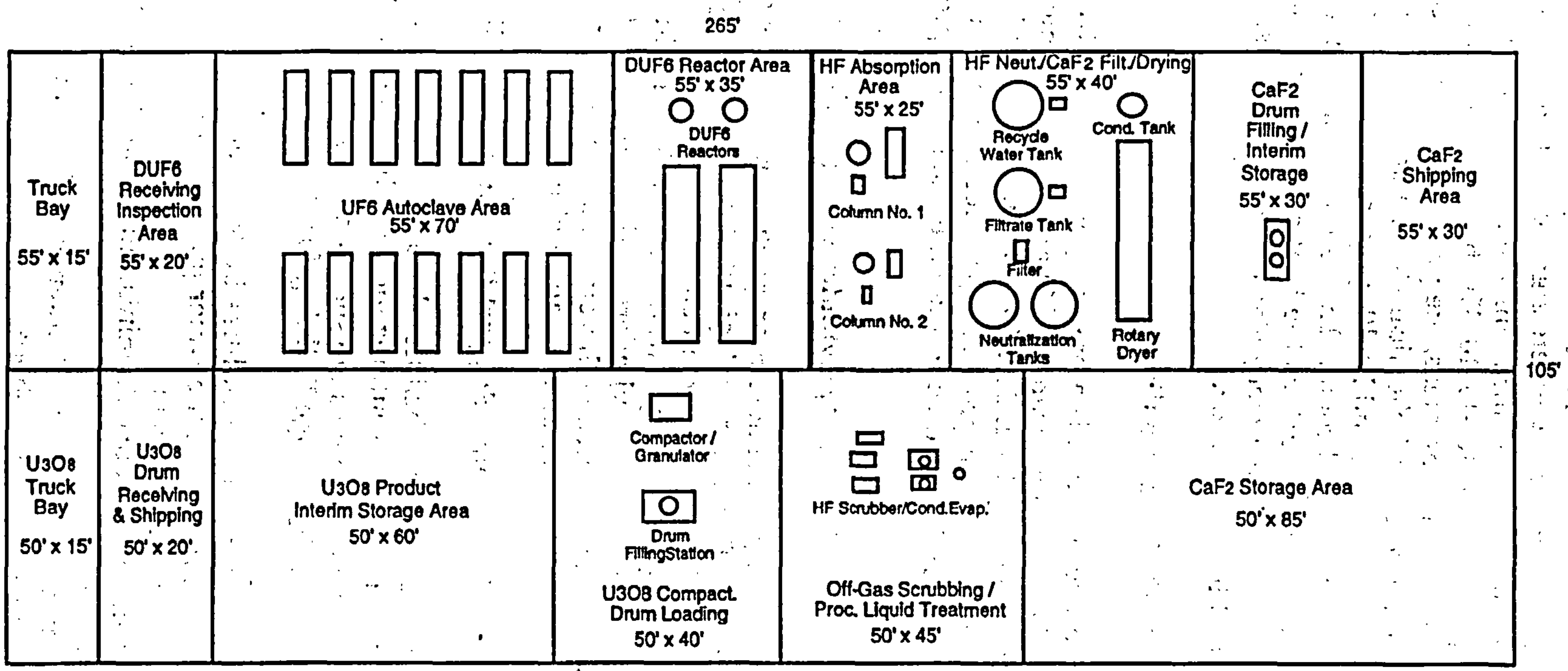

FIGURE 2-5 PROCESS EQUIPMENT ARRANGEMENT
DEFLUORINATION / HF NEUTRALIZATION

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.

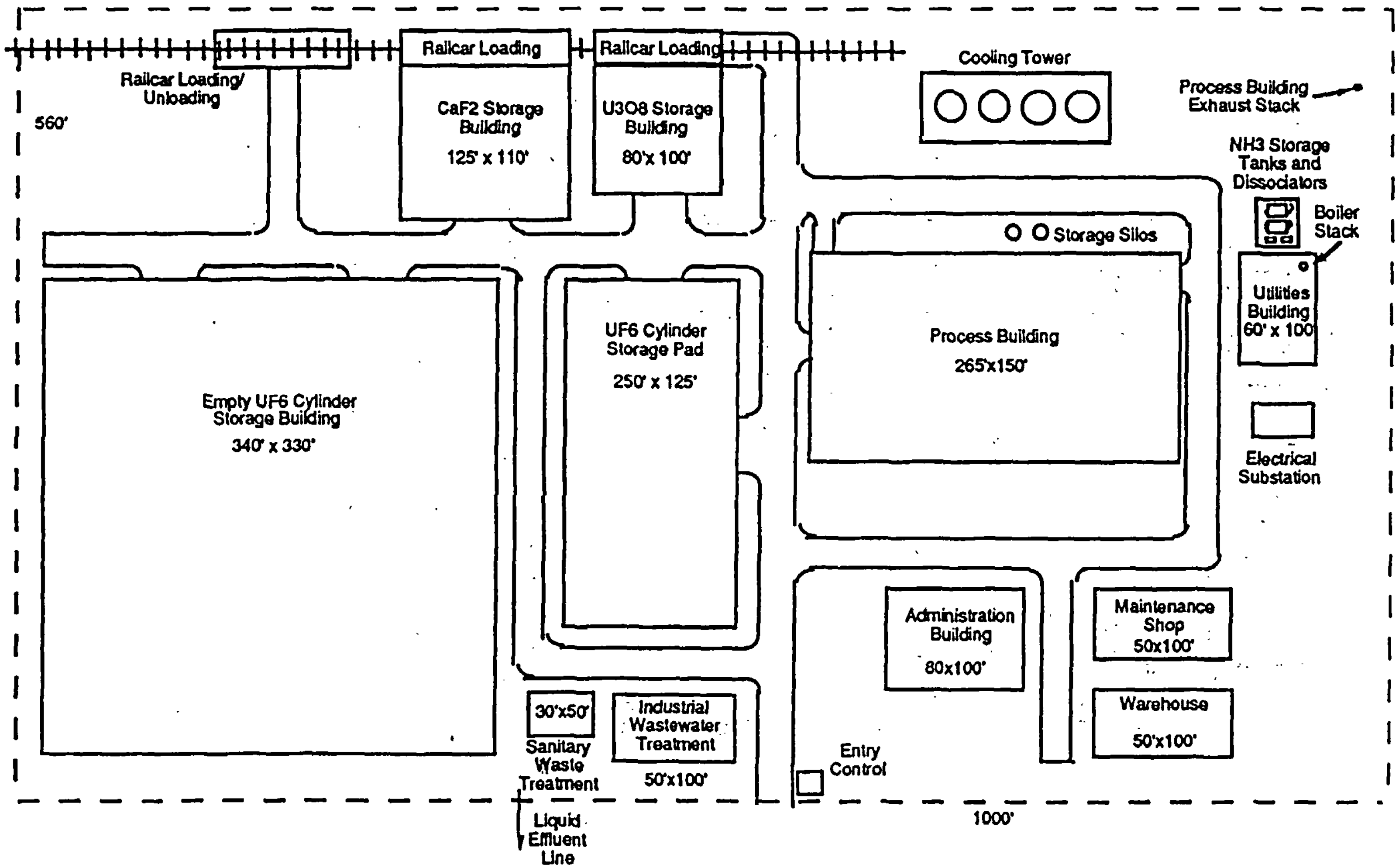

FIGURE 3-1 SITE MAP
DEFLUORINATION / HF NEUTRALIZATION

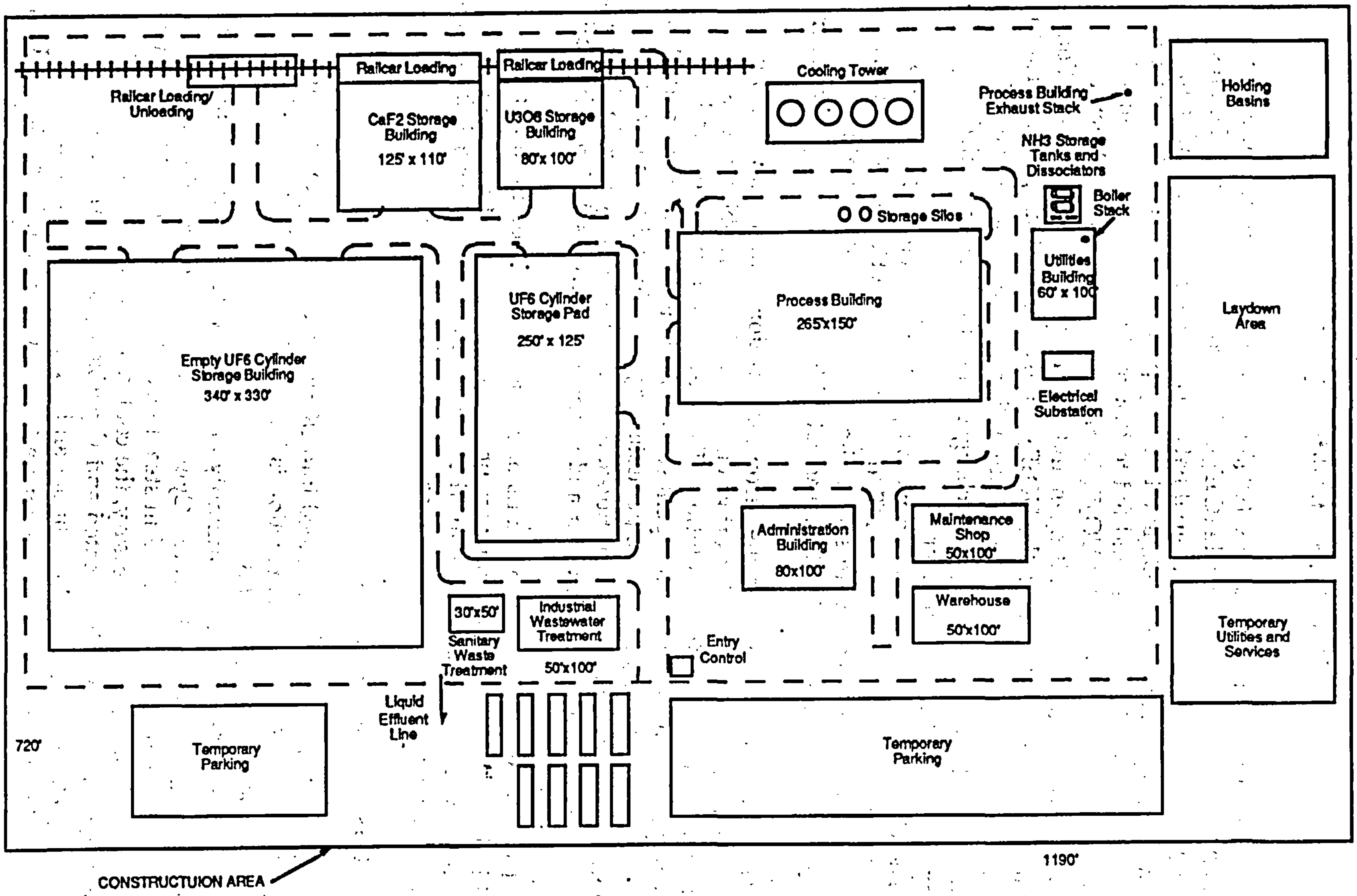

FIGURE 3-2 SITE MAP DURING CONSTRUCTION
DEFLUORINATION / HF NEUTRALIZATION

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.

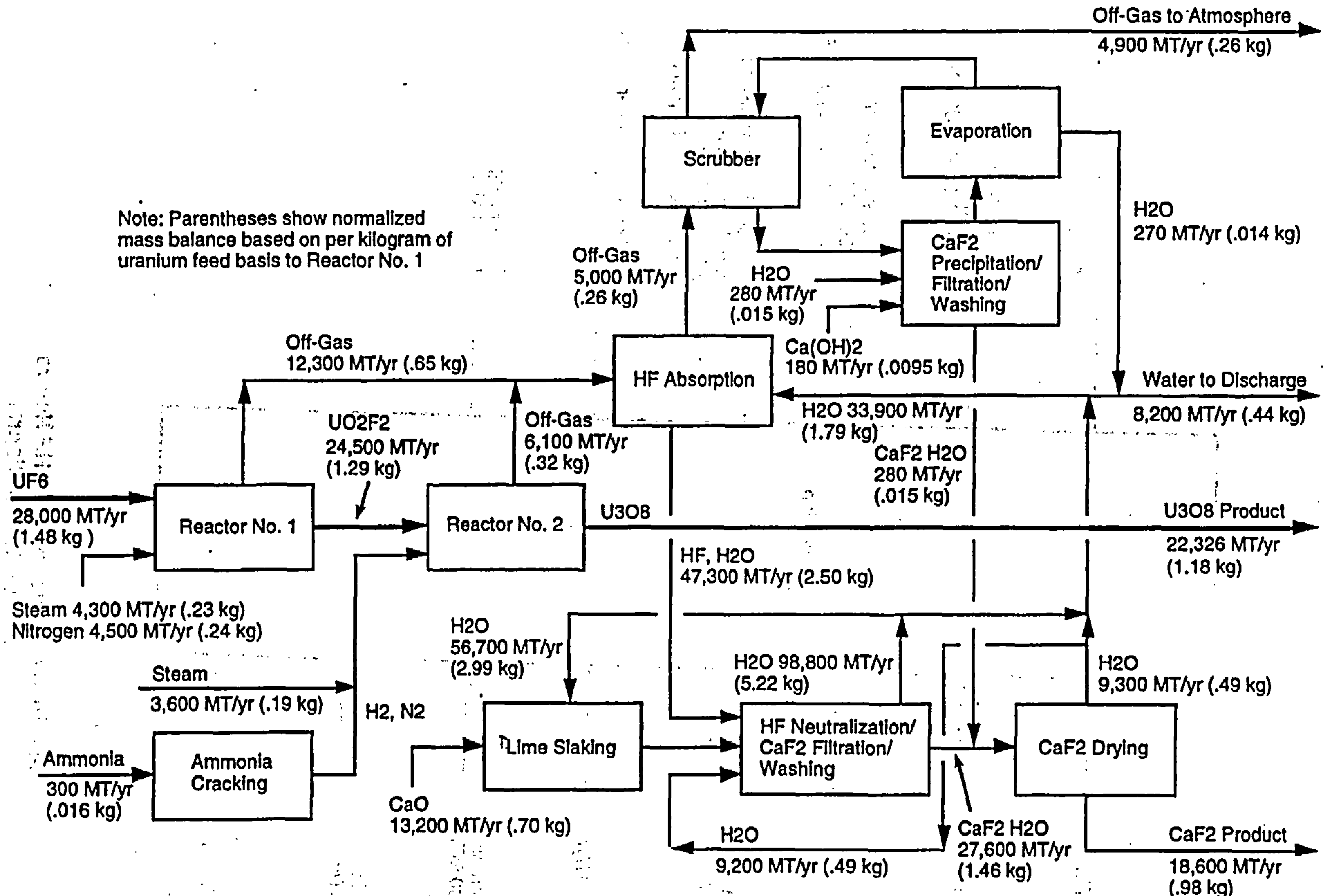

Figure 4-1 Defluorination/HF Neutralization Block Flow Diagram

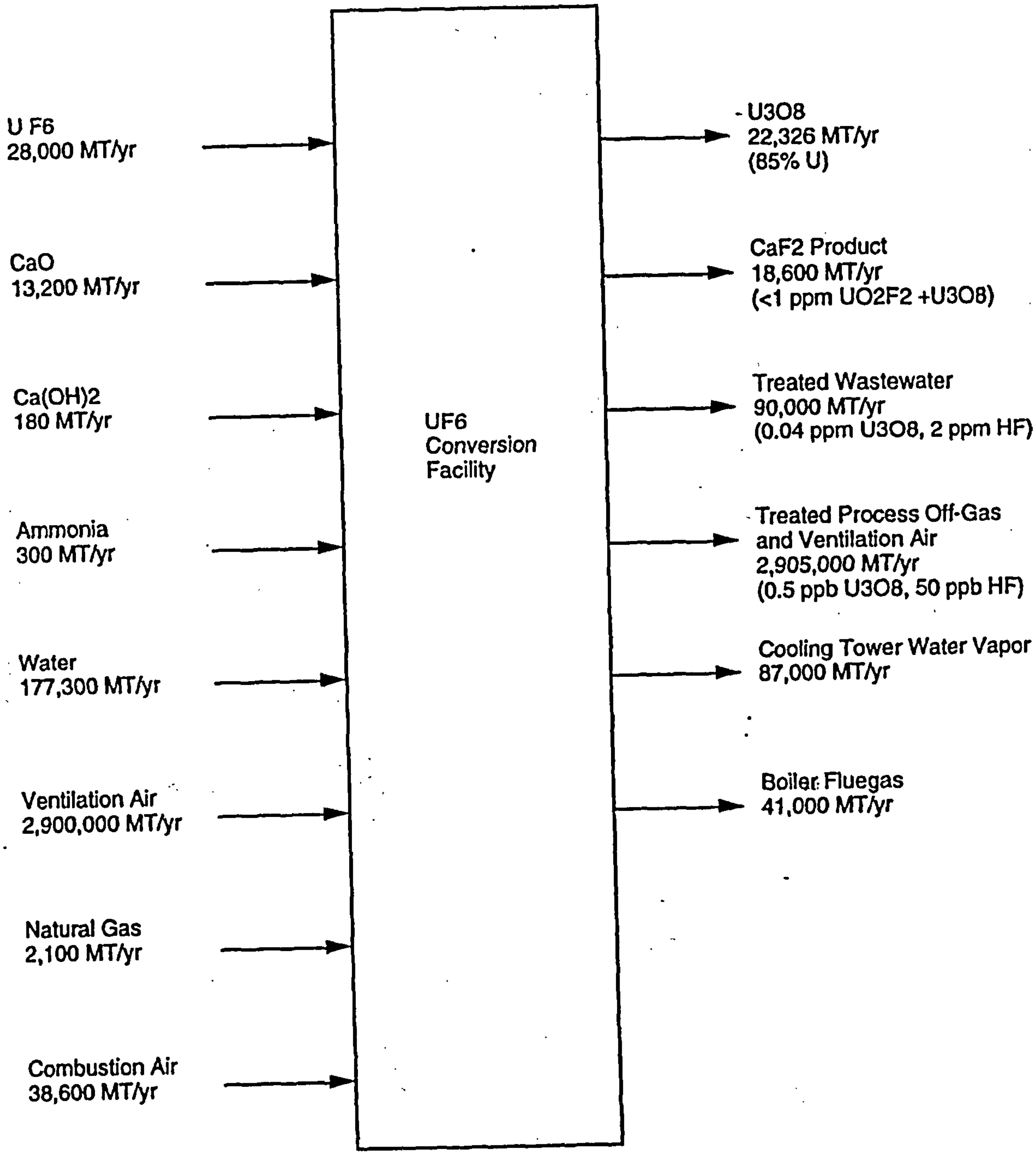

Figure 4-2 Defluorination / HF Neutralization Input / Output Diagram

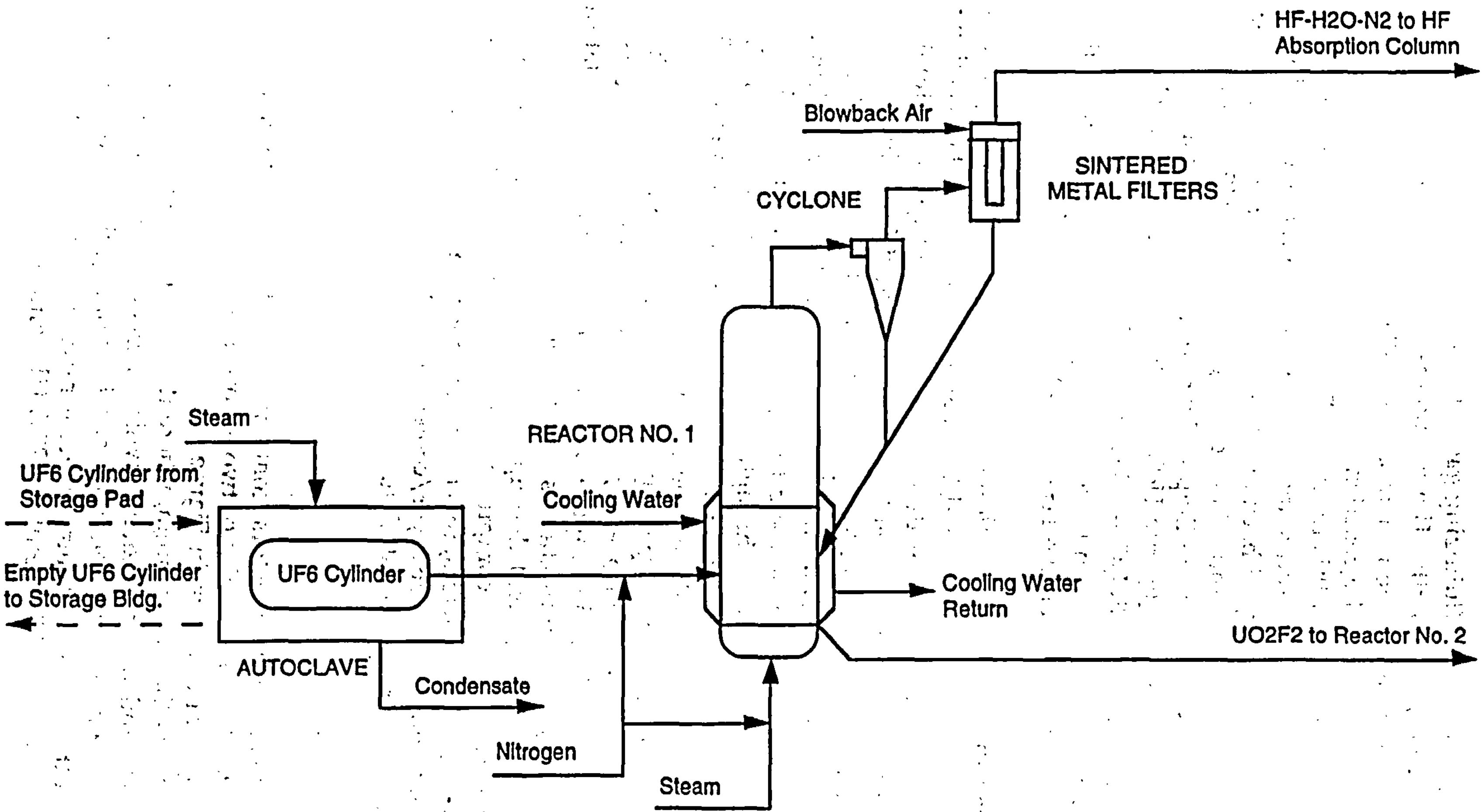

Figure 4-3 Reactor No. 1 Process Flow Diagram

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 $3UO_2F_2 + 3H_2O \longrightarrow U_3O_8 + 6HF + 0.5O_2$. A stoichiometric amount of hydrogen is added to react with the oxygen, so the overall reaction is $3UO_2F_2 + 2H_2O + H_2 \longrightarrow U_3O_8 + 6HF$. 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 $2NH_3 \longrightarrow N_2 + 3H_2$. 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

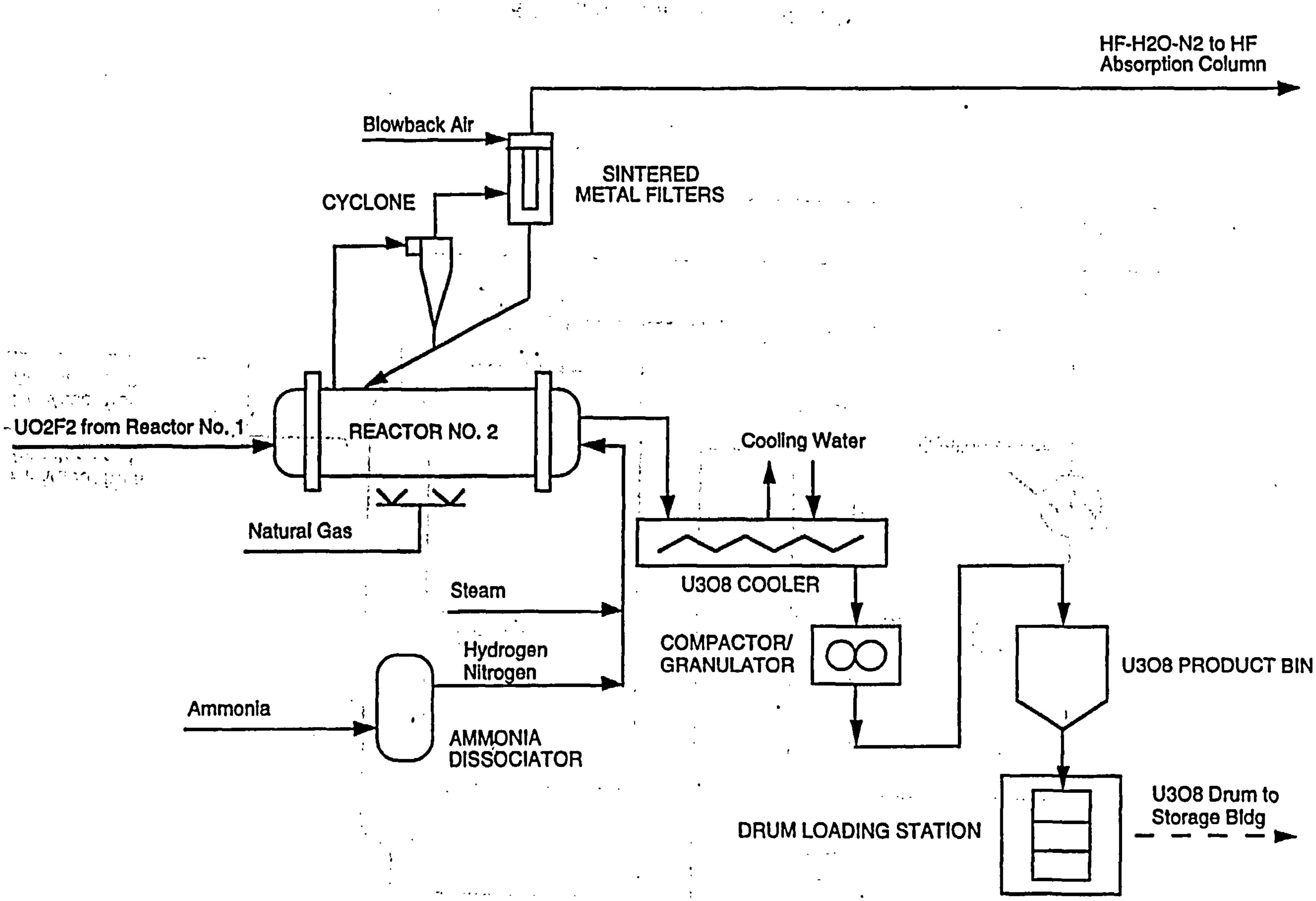

Figure 4-4 Reactor No. 2 Process Flow Diagram

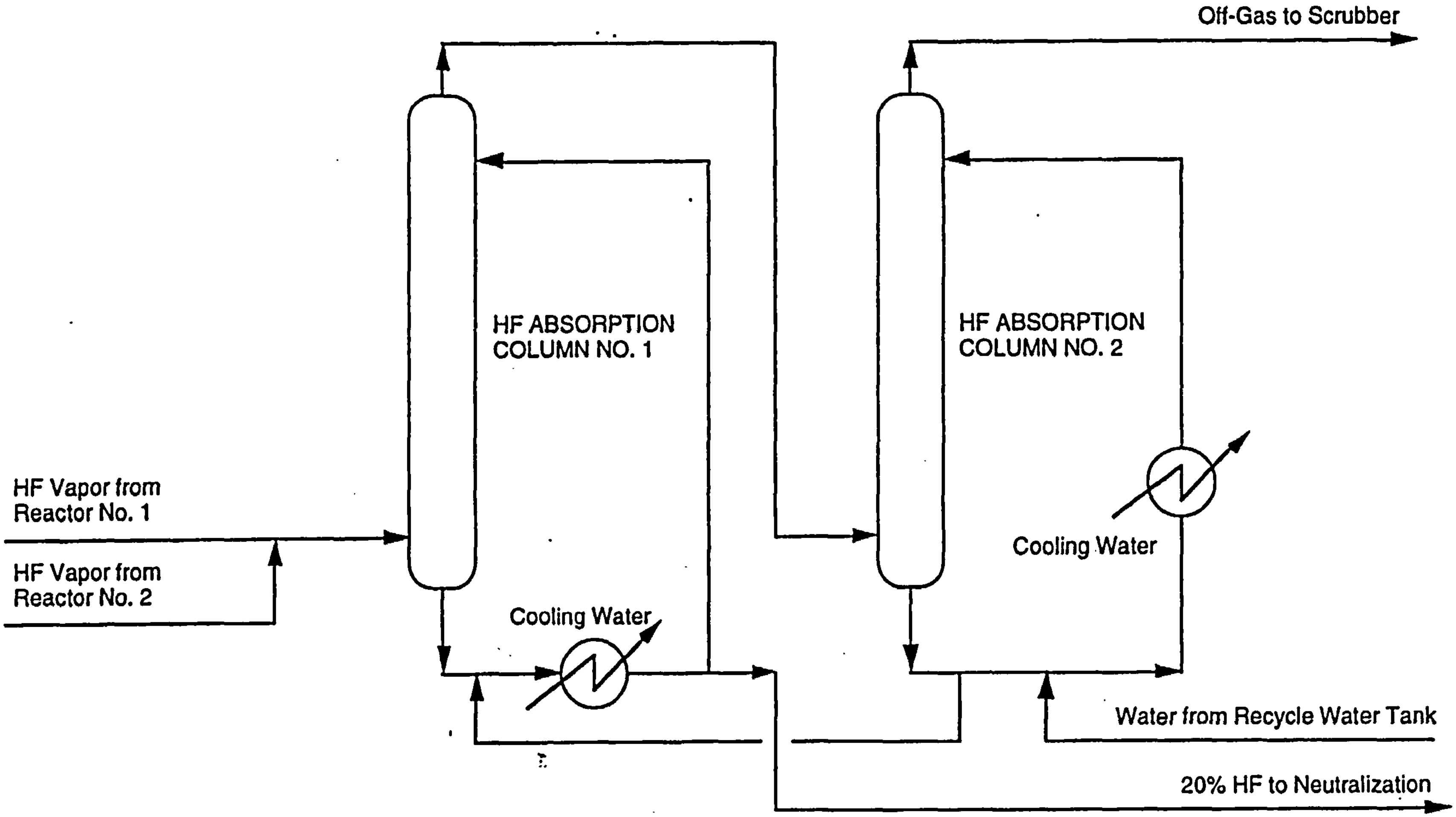

Figure 4-5 HF Absorption Process Flow Diagram

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 $HF + KOH \rightarrow KF + H_2O$. 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 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

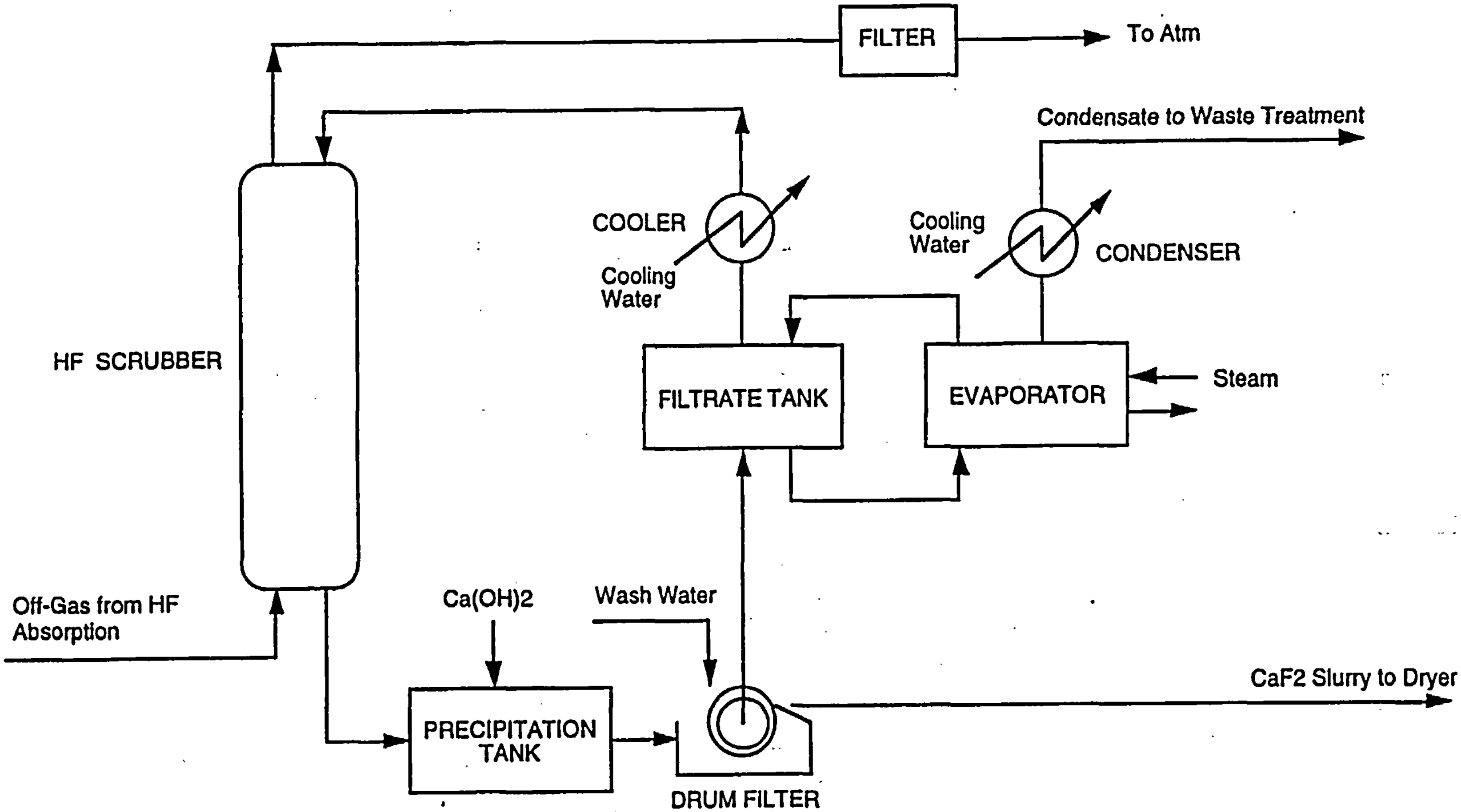

Figure 4-6 HF Scrubber Process Flow Diagram

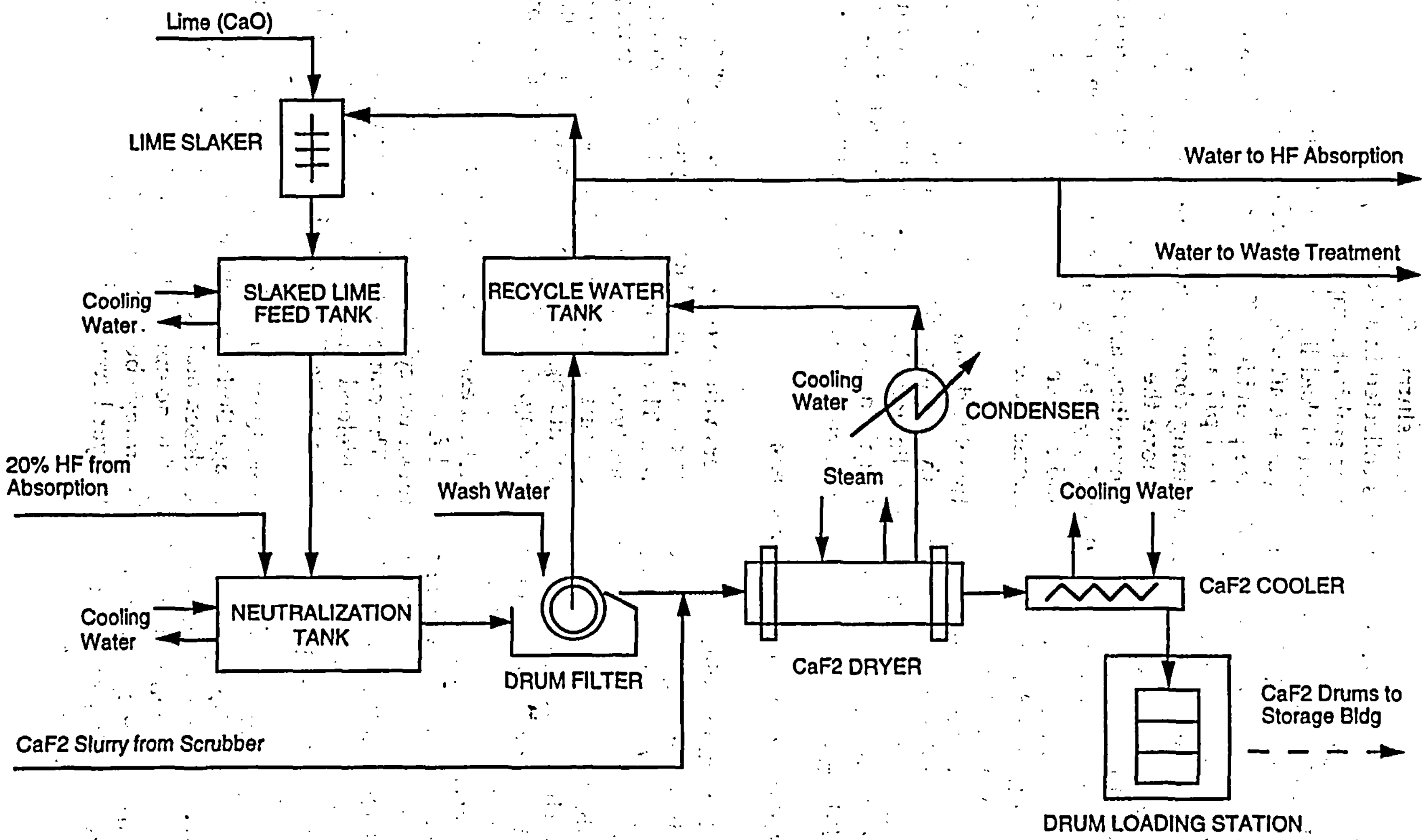

Figure 4-7 HF Neutralization Process Flow Diagram

form a 25 wt% $Ca(OH)_2$ slaked lime slurry. The chemical reaction is $CaO + H_2O \longrightarrow Ca(OH)_2$. 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 $2HF + Ca(OH)_2 \longrightarrow CaF_2 + 2H_2O$. 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.

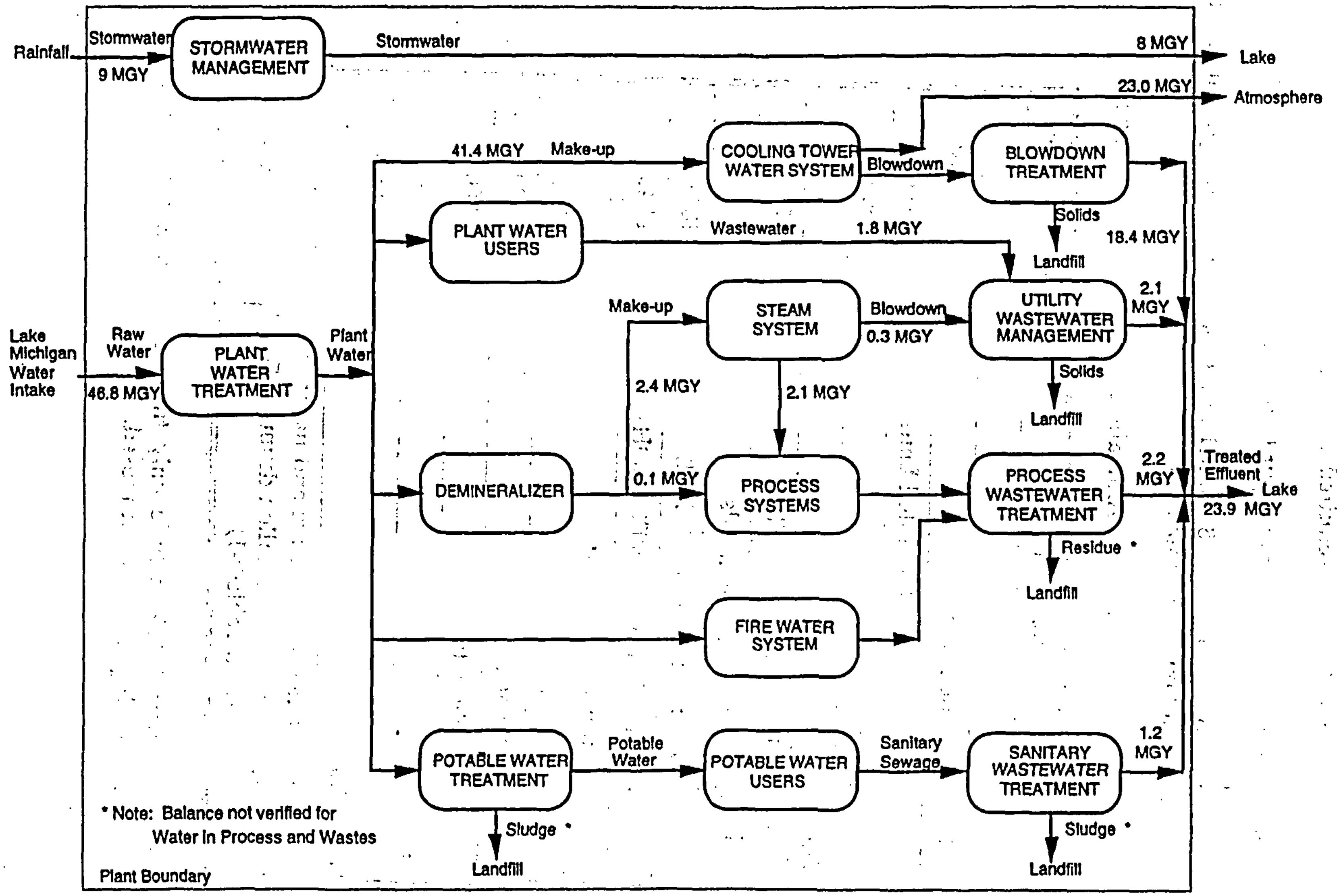

Figure 5-1 Preliminary Water Balance Defluorination / HF Neutralization

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)
CRITERIA 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.

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11.0 Glossary

List of Acronyms

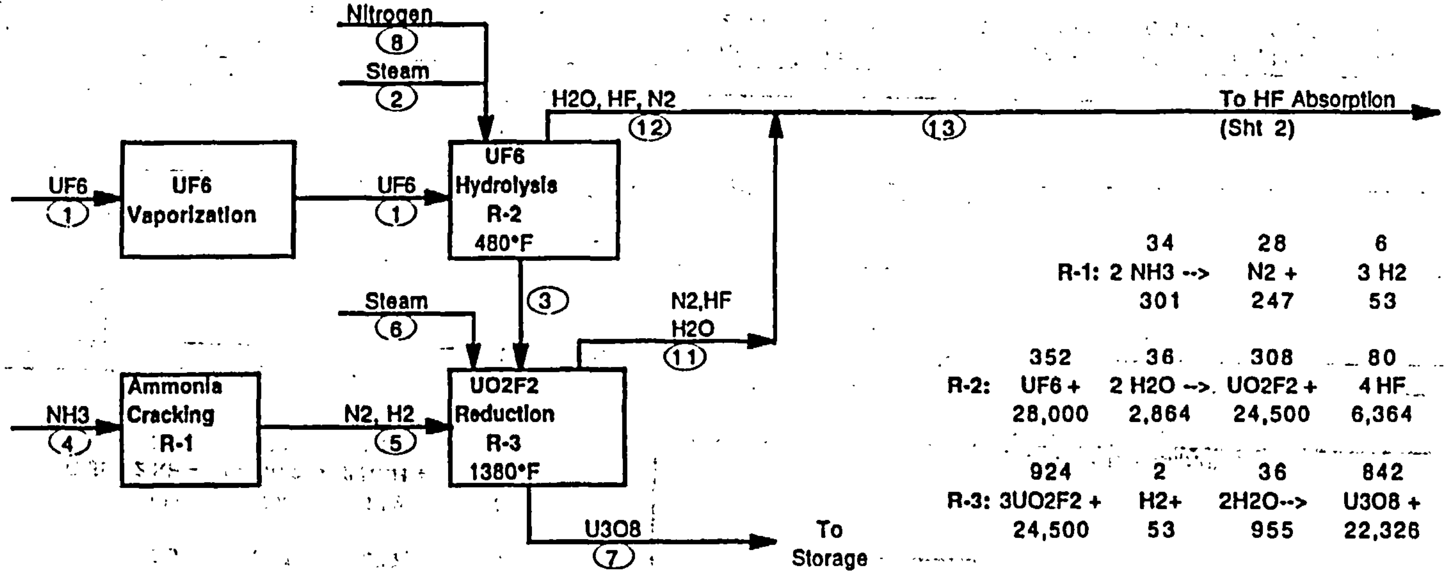
ANSI	American National Standards Institute
atm	atmosphere
CaF_2	calcium fluoride
CAR	Cost Analysis Report
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department 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

DEFLUORINATION / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions

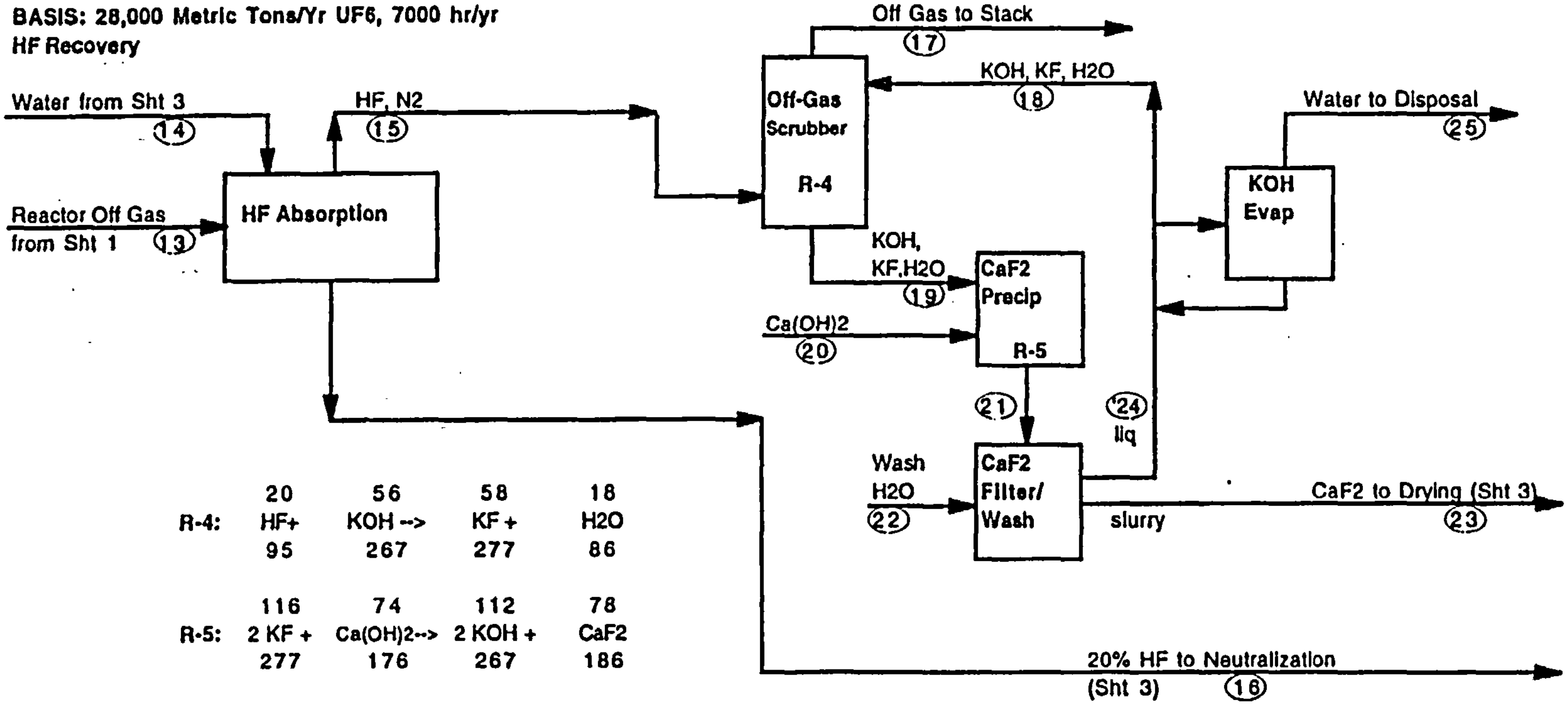


	34	28	6		
R-1:	2 NH3 -->	N2 +	3 H2		
	301	247	53		
	352	36	308	80	
R-2:	UF6 +	2 H2O -->.	UO2F2 +	4 HF	
	28,000	2,864	24,500	6,364	
	924	2	36	842	120
R-3:	3UO2F2 +	H2+	2H2O-->	U3O8 +	6 HF
	24,500	53	955	22,326	3,182

	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													
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



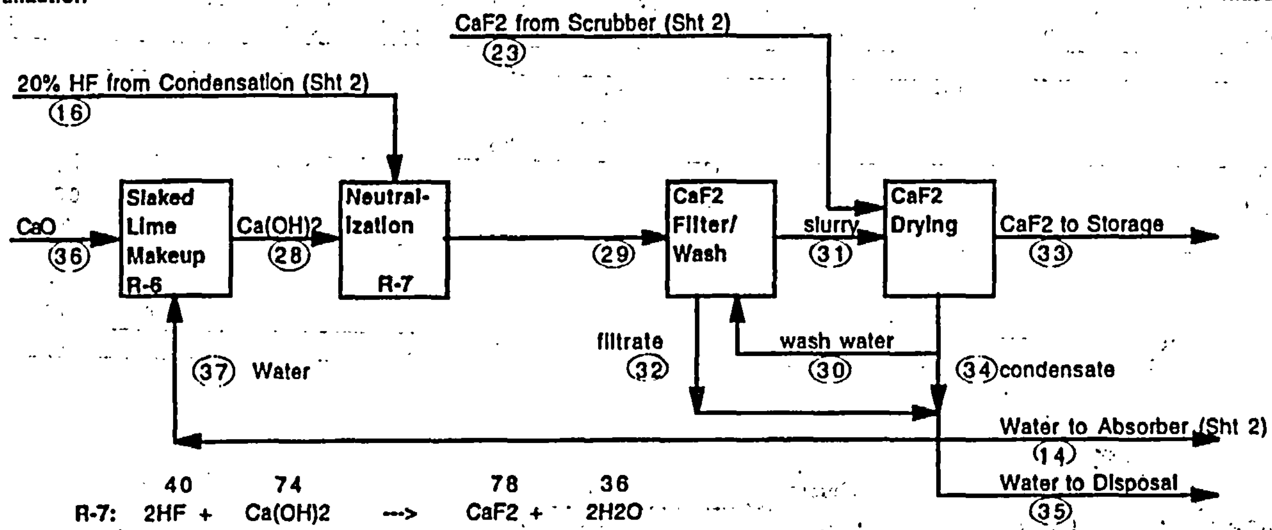
	20	56	58	18
R-4:	HF+	KOH -->	KF +	H2O
	95	267	277	86

	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



R-7: 2HF + Ca(OH)2 ---> CaF2 + 2H2O

	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
Mol Wt	40	74		78	36
R-7	9,450	17,483		18,428	8,505

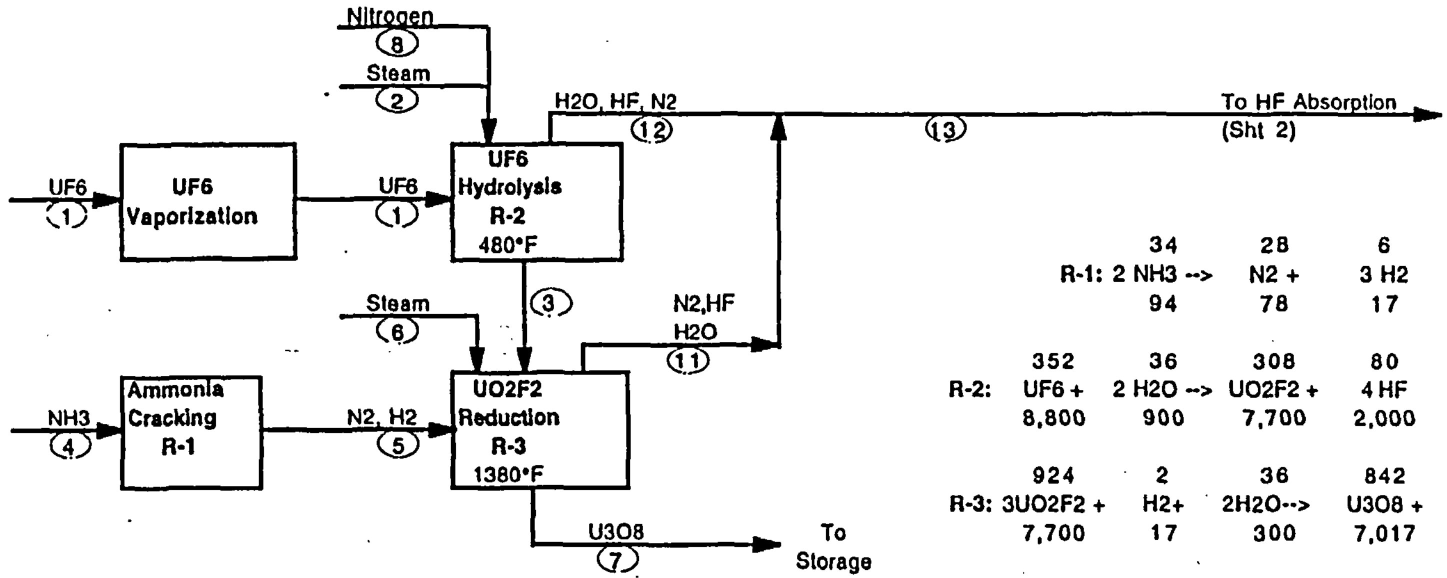
R-6: CaO + H2O ---> Ca(OH)2

	CaO +	H2O	--->	Ca(OH)2
Mol Wt	56	18		74
R-6	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

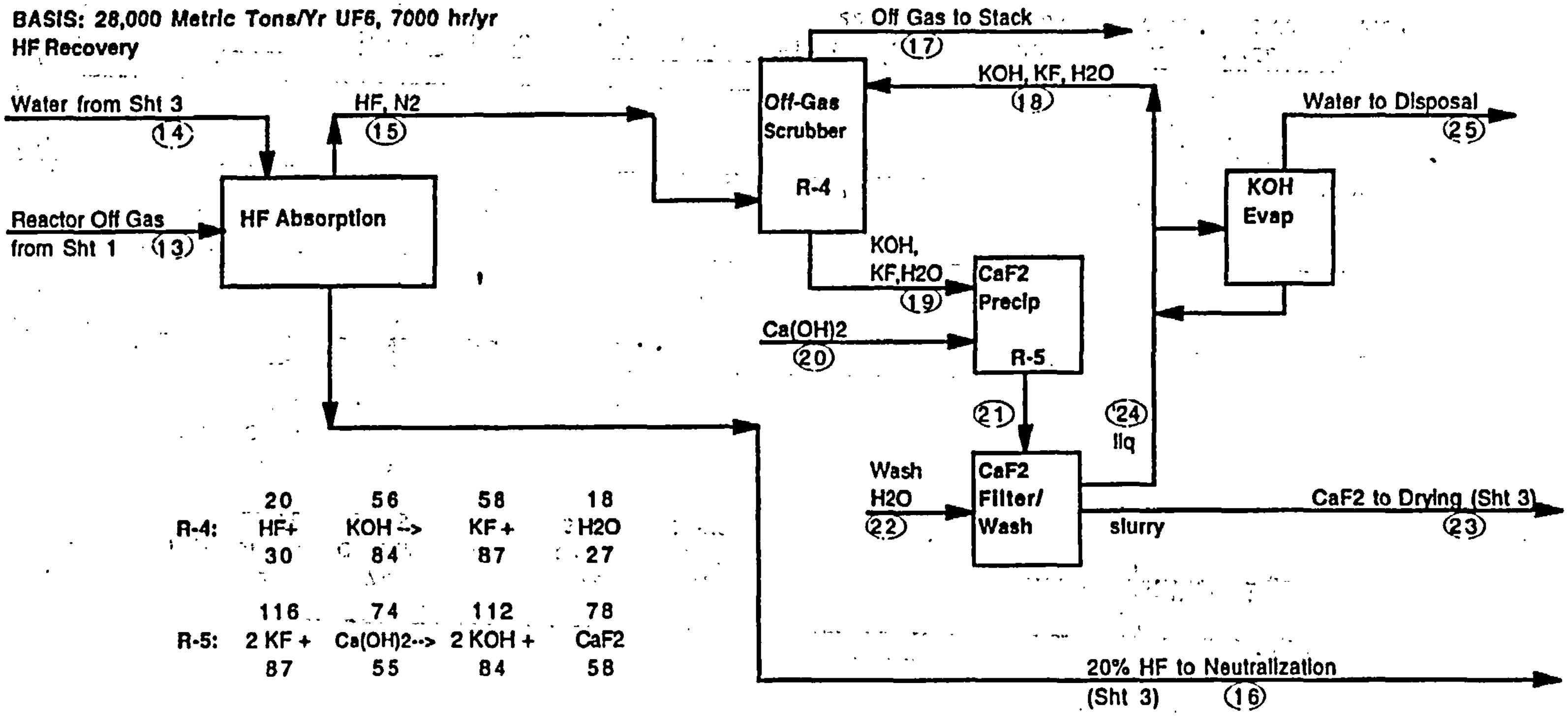


	34		28	6	
R-1:	2 NH3 -->		N2 +	3 H2	
	94		78	17	
	352	36	308	80	
R-2:	UF6 +	2 H2O -->	UO2F2 +	4 HF	
	8,800	900	7,700	2,000	
	924	2	36	842	120
R-3:	3UO2F2 +	H2+	2H2O-->	U3O8 +	6 HF
	7,700	17	300	7,017	1,000

	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

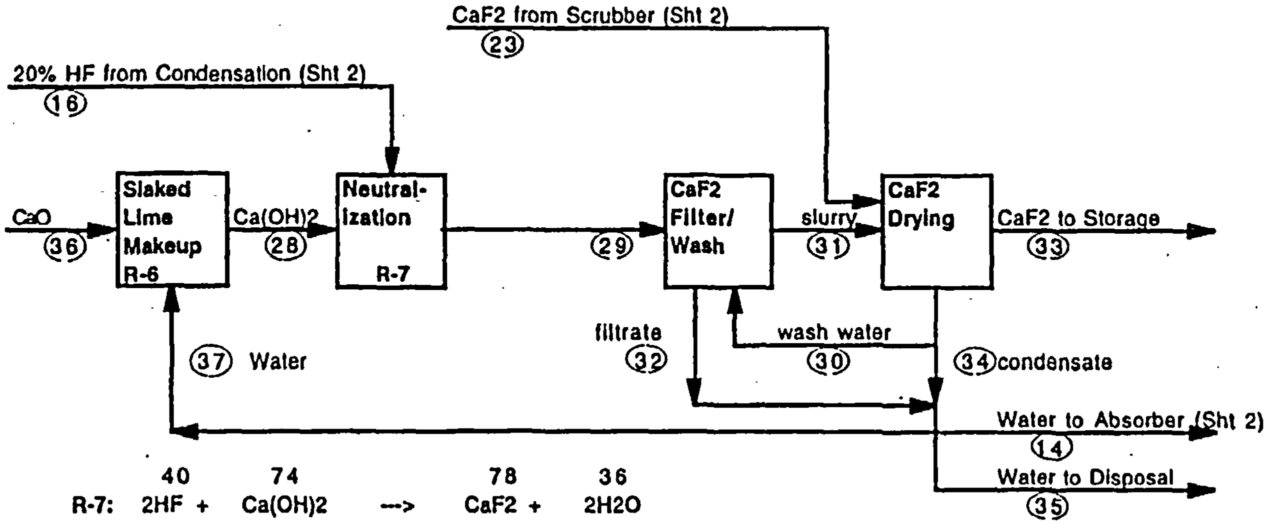


	Mol Wt	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
Ca(OH)2	74							55	0					
CaF2	78								58		58			
KOH	56					105	21		105			105		
KF	58					9	96		9			9		
HF	20		30.0	2,970	0.03									
H2O	18	10,656	62	11,880	62	14,985	15,012		15,012	88	29	15,071	85	
H2	2		0		0									
N2	28		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:	$2HF$ +	$Ca(OH)_2$	--->	CaF_2 +	$2H_2O$
	2,970	5,495		5,792	2,673

	56	18		74
R-6:	CaO +	H_2O	--->	$Ca(OH)_2$
	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

<u>Assumptions / Basis for Exposure Tables</u>

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

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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"	7288.0
Transfer CaF2 drums to storage area	2	0.50	7288	8,9,16	60	Steel	1/4"	7288.0
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, stacker) - 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.

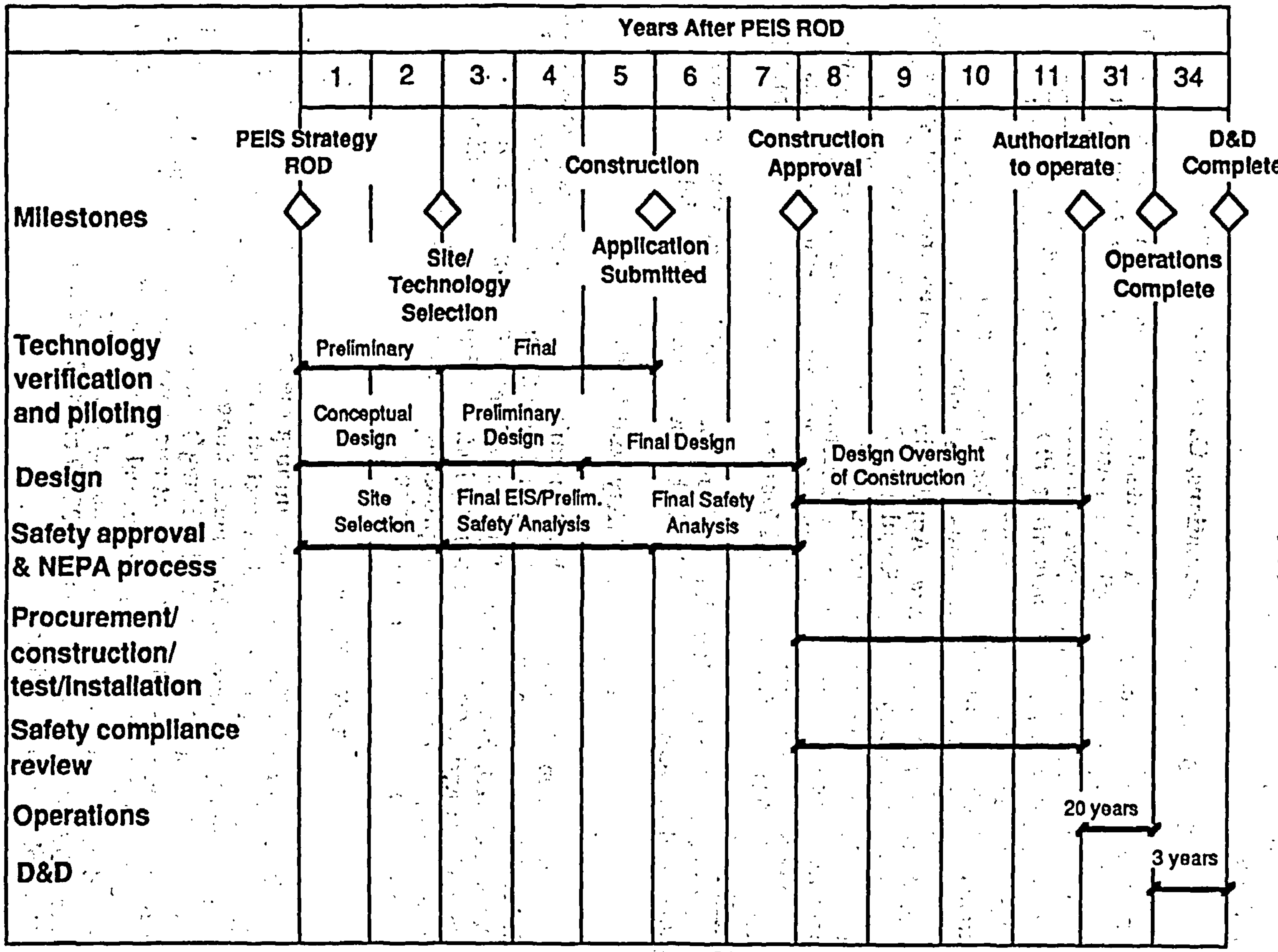


Figure 1-1 Preliminary Project Schedule

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.

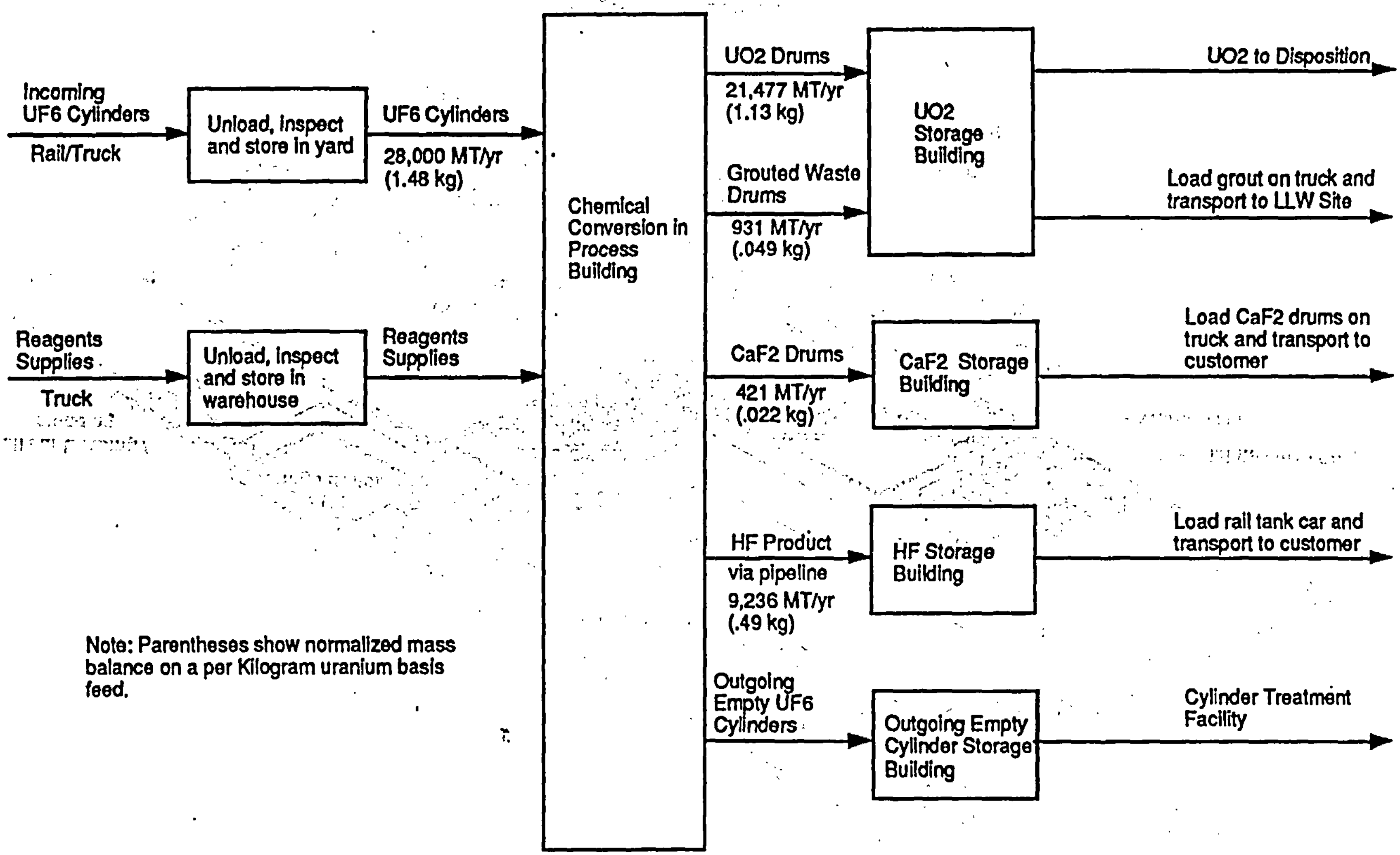


Figure 2-1 Ceramic UO2 / Anhydrous HF Material Flow Diagram

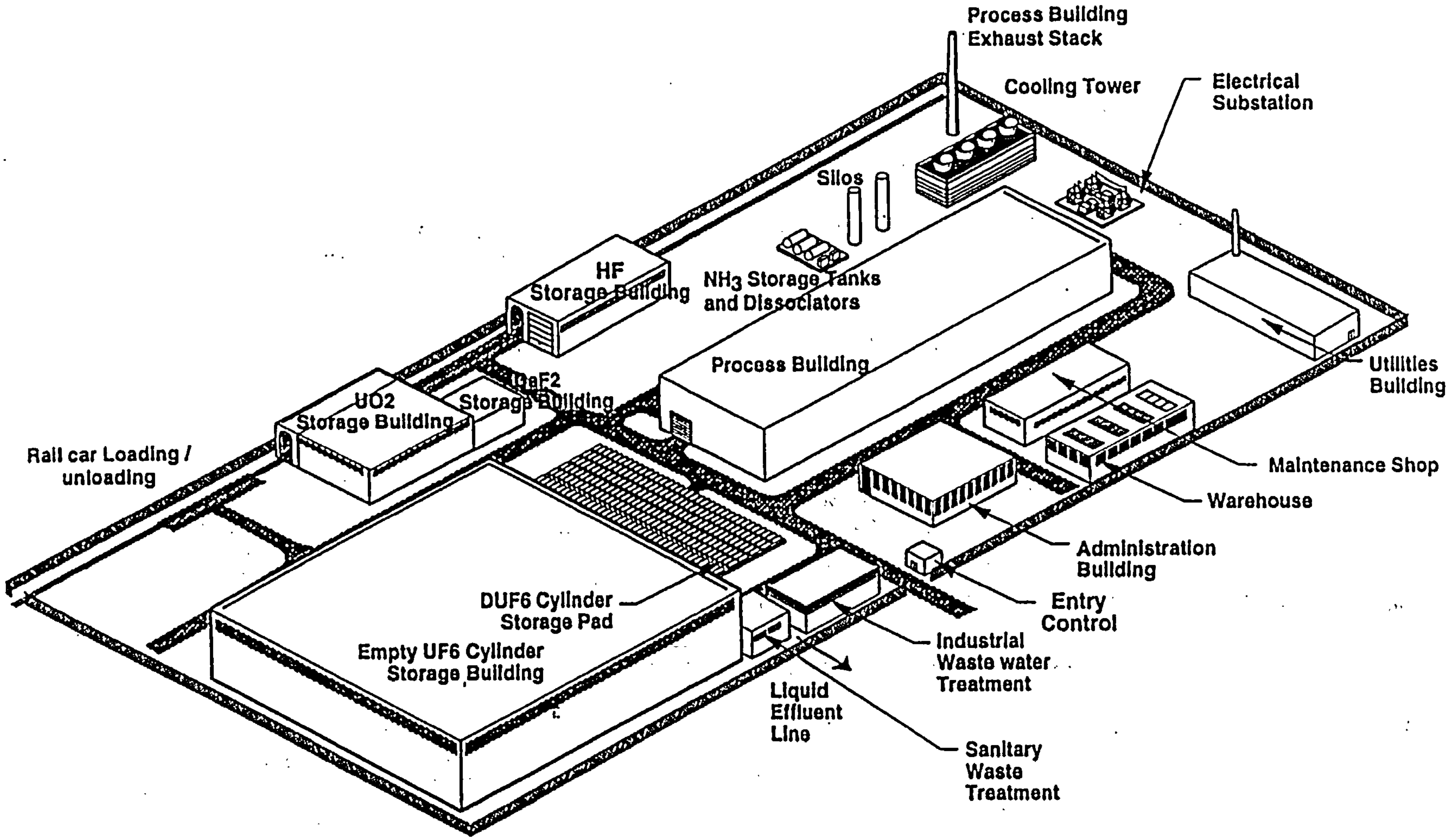


Figure 2-2 Plot Plan
Ceramic UO2 / Anhydrous HF

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

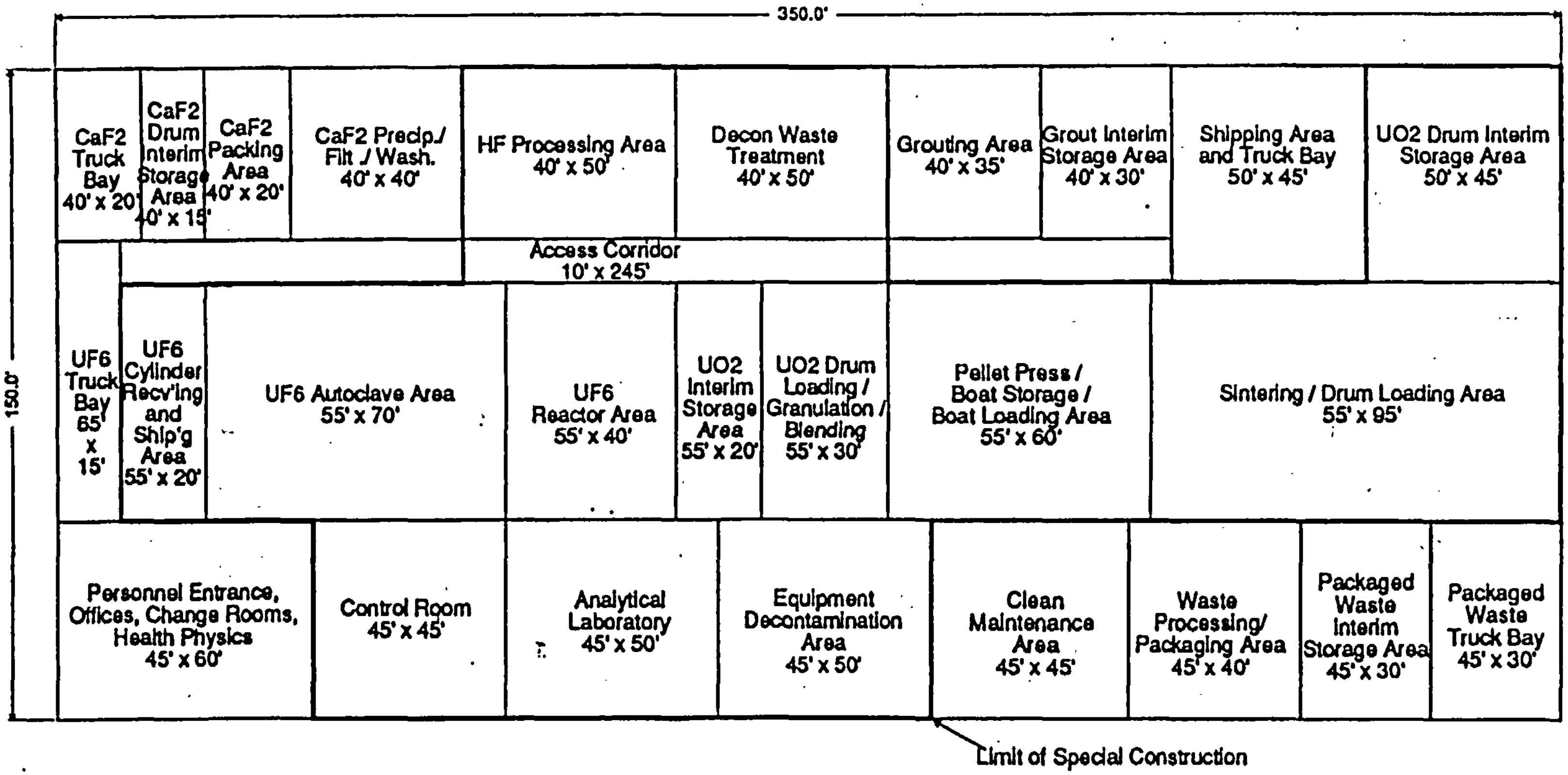


Figure 2-3 Process Building Layout
Ceramic UO2 / Anhydrous HF

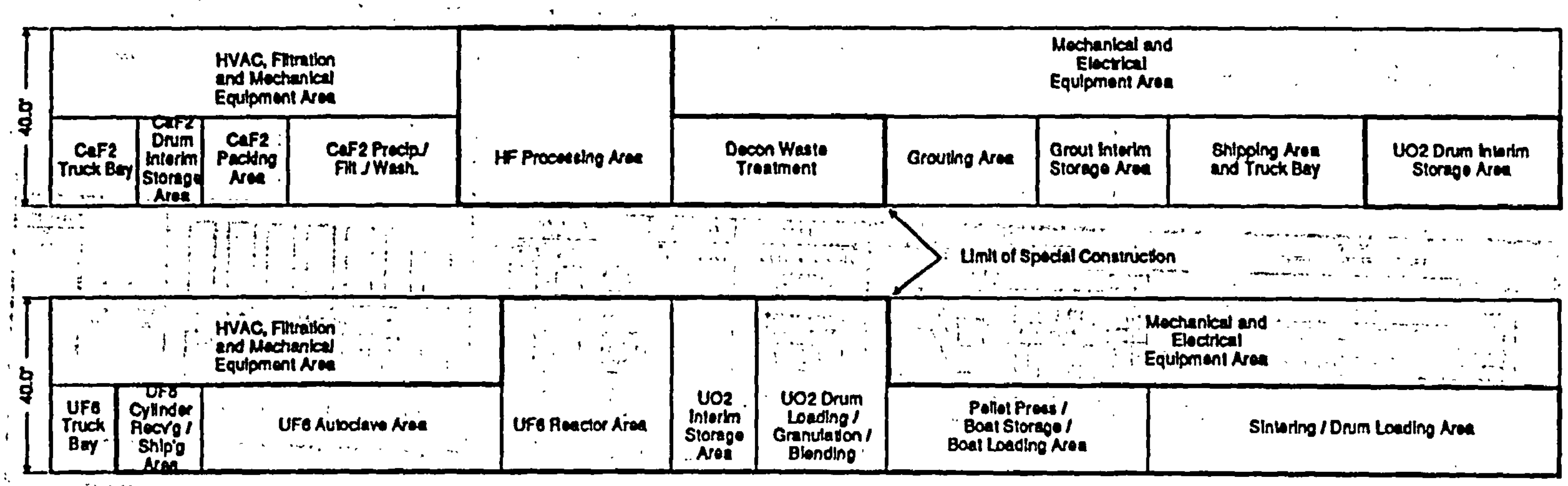


Figure 2-4 Process Building Sections
Ceramic UO2 / Anhydrous HF

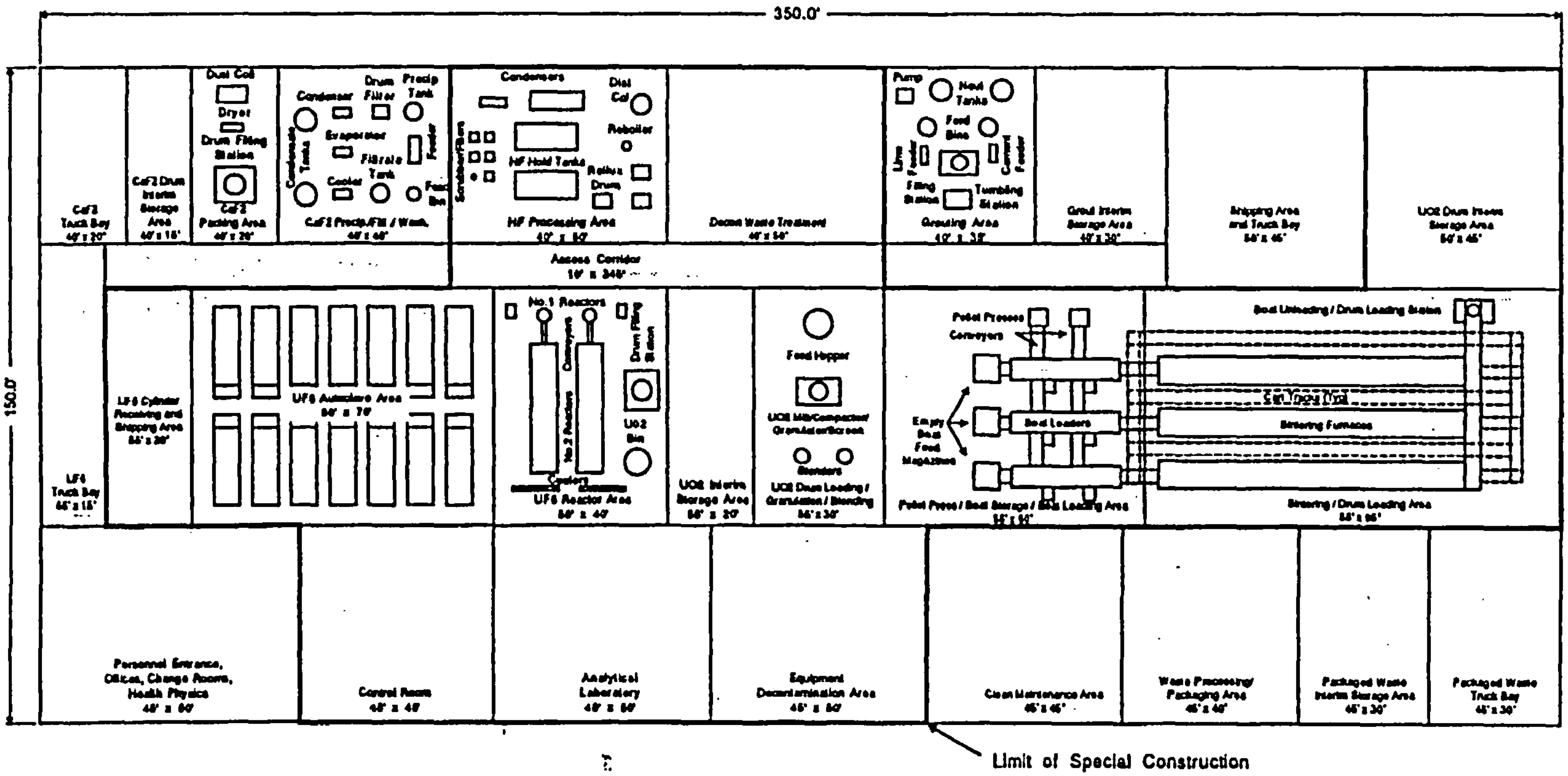


Figure 2-5 Process Equipment Arrangement - Plan
Ceramic UO2 / Anhydrous HF

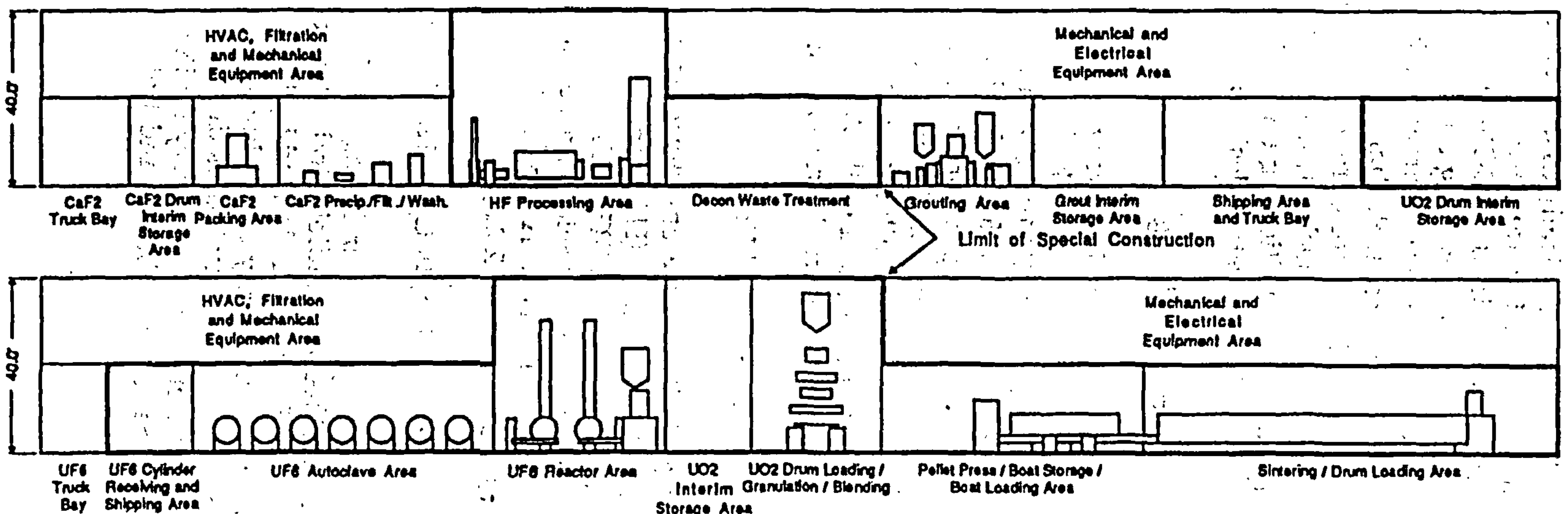


Figure 2-6 Process Equipment Arrangement - Sections
Ceramic UO2 / Anhydrous HF

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.

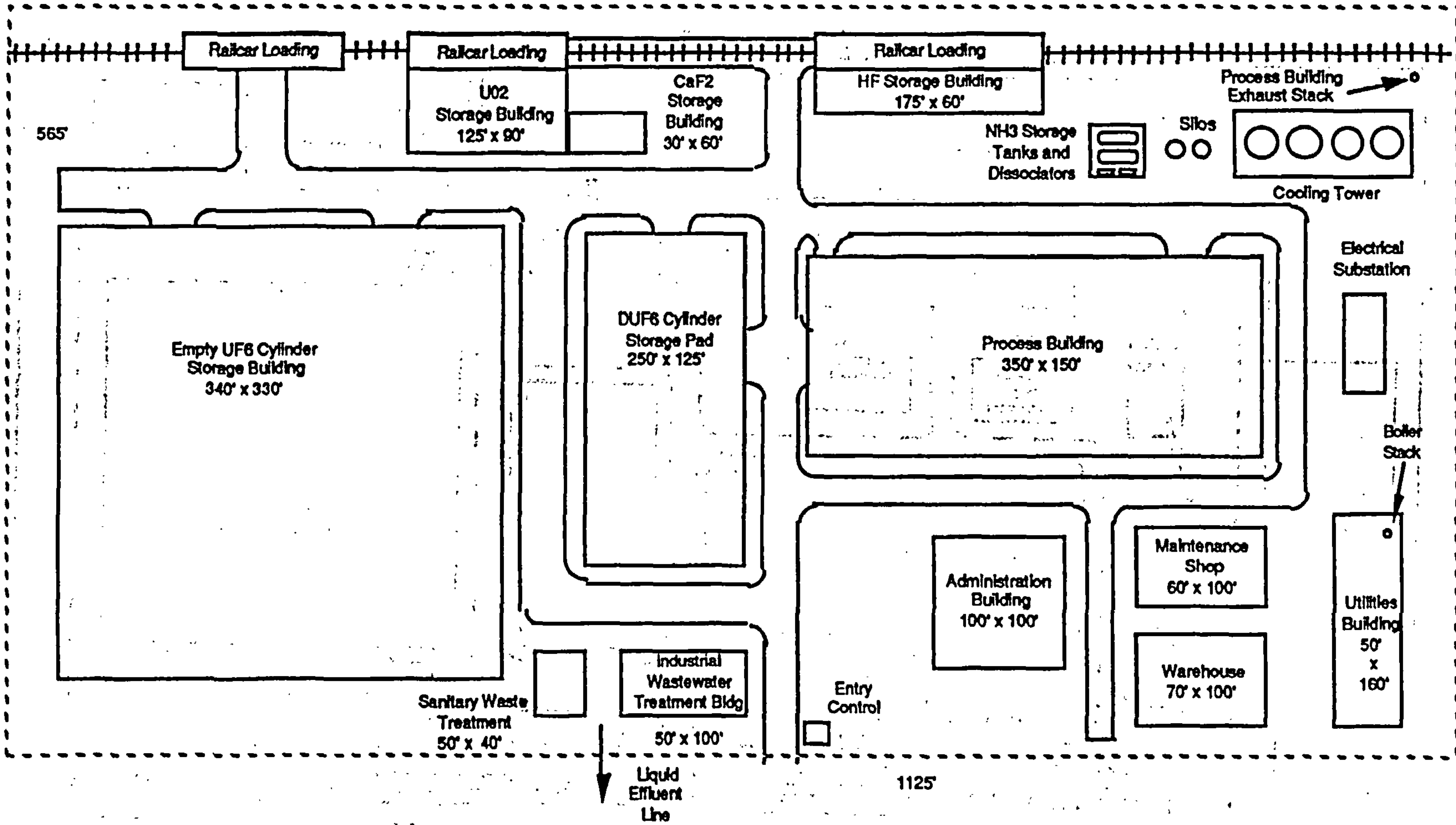


FIGURE 3-1 SITE MAP
CERAMIC UO2 / ANHYDROUS HF

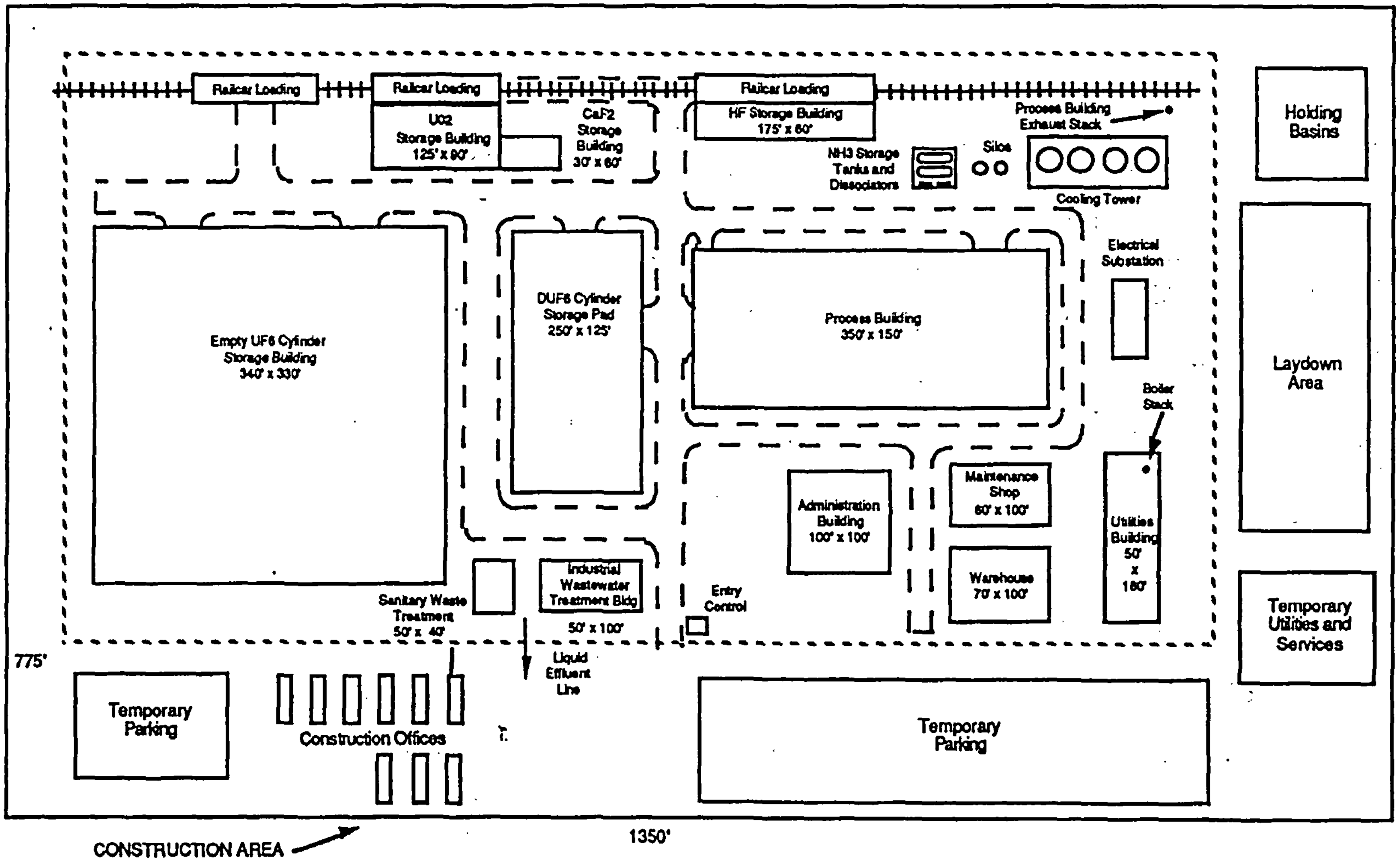


FIGURE 3-2 SITE MAP DURING CONSTRUCTION
CERAMIC UO2 / ANHYDROUS HF

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.

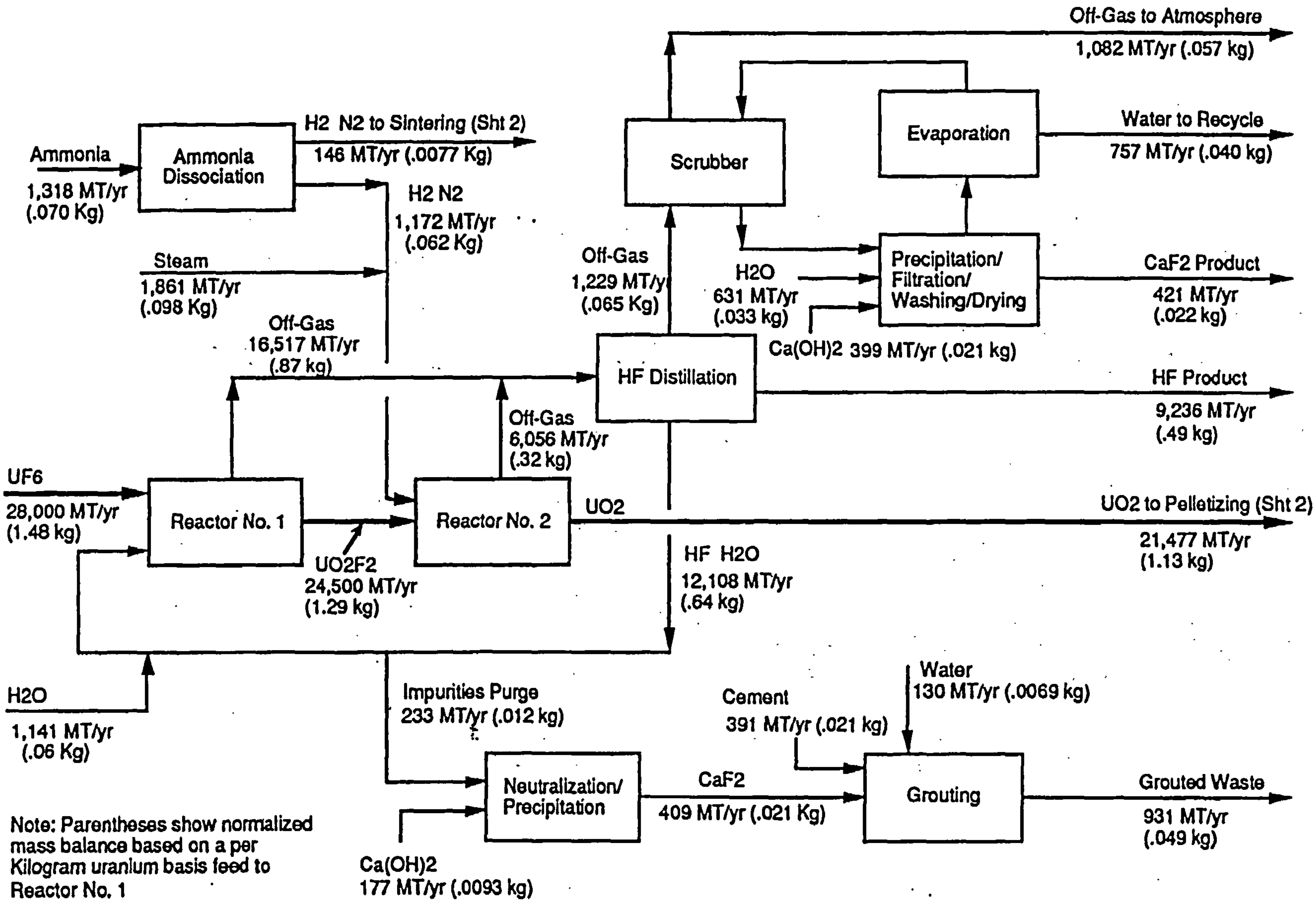
The UF_6 is converted to UO_2 in a two-step process. The UF_6 is vaporized using steam-heated autoclaves and fed to Reactor No. 1, where it is mixed with 45% HF-water vapor. Solid UO_2F_2 is produced and flows to Reactor No. 2. The UO_2F_2 is mixed with a hydrogen, nitrogen and steam mixture to produce 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.

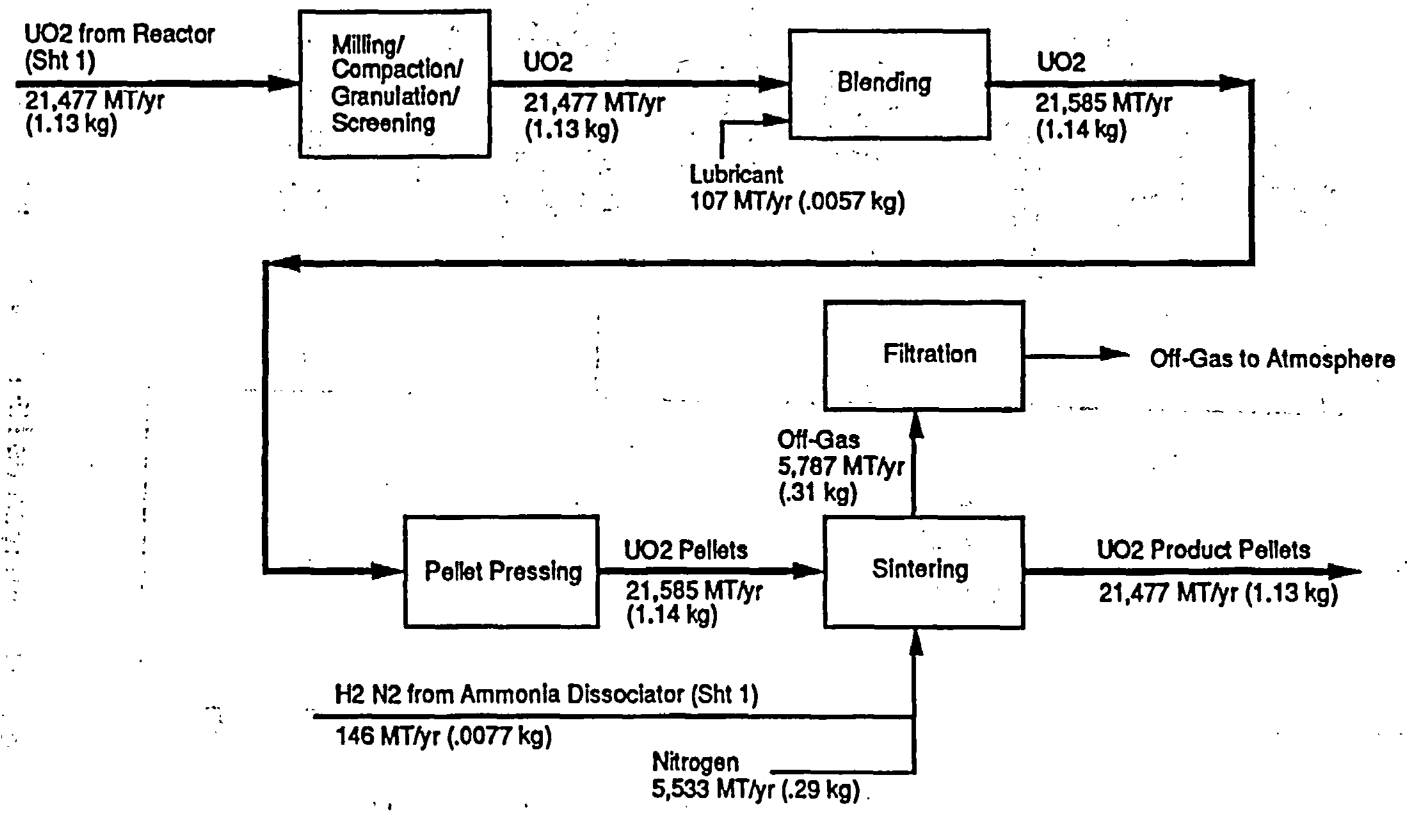
Uncondensed off-gas from the distillation column flows to the scrubber system. The remaining traces of HF in the off-gas are removed by scrubbing with a potassium hydroxide (KOH) solution. The off-gas is then filtered and discharged to atmosphere. The spent scrub solution is treated with hydrated lime ($Ca(OH)_2$) 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

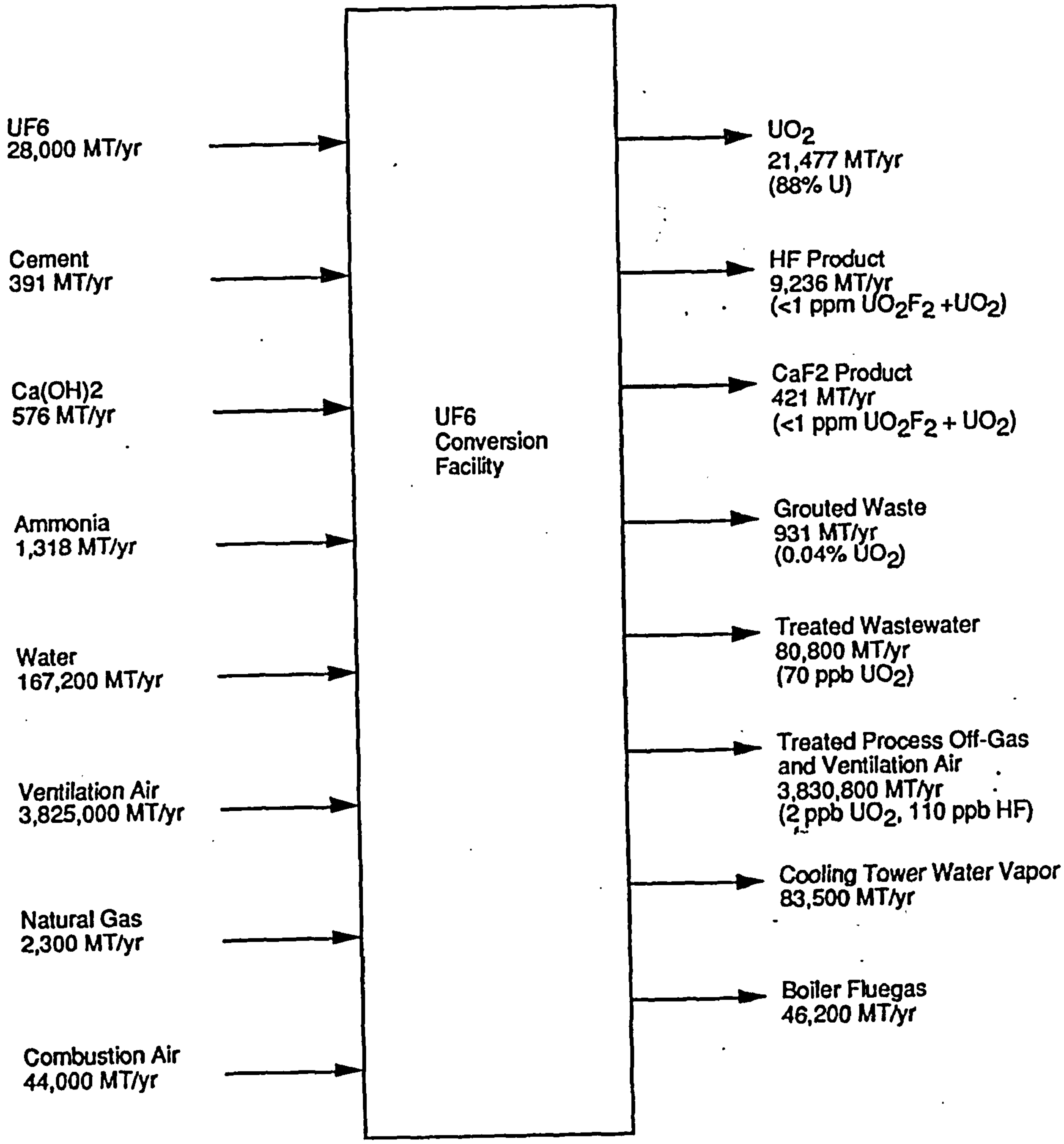


Figure 4-3 Ceramic UO2 / Anhydrous HF Input/Output Diagram

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.

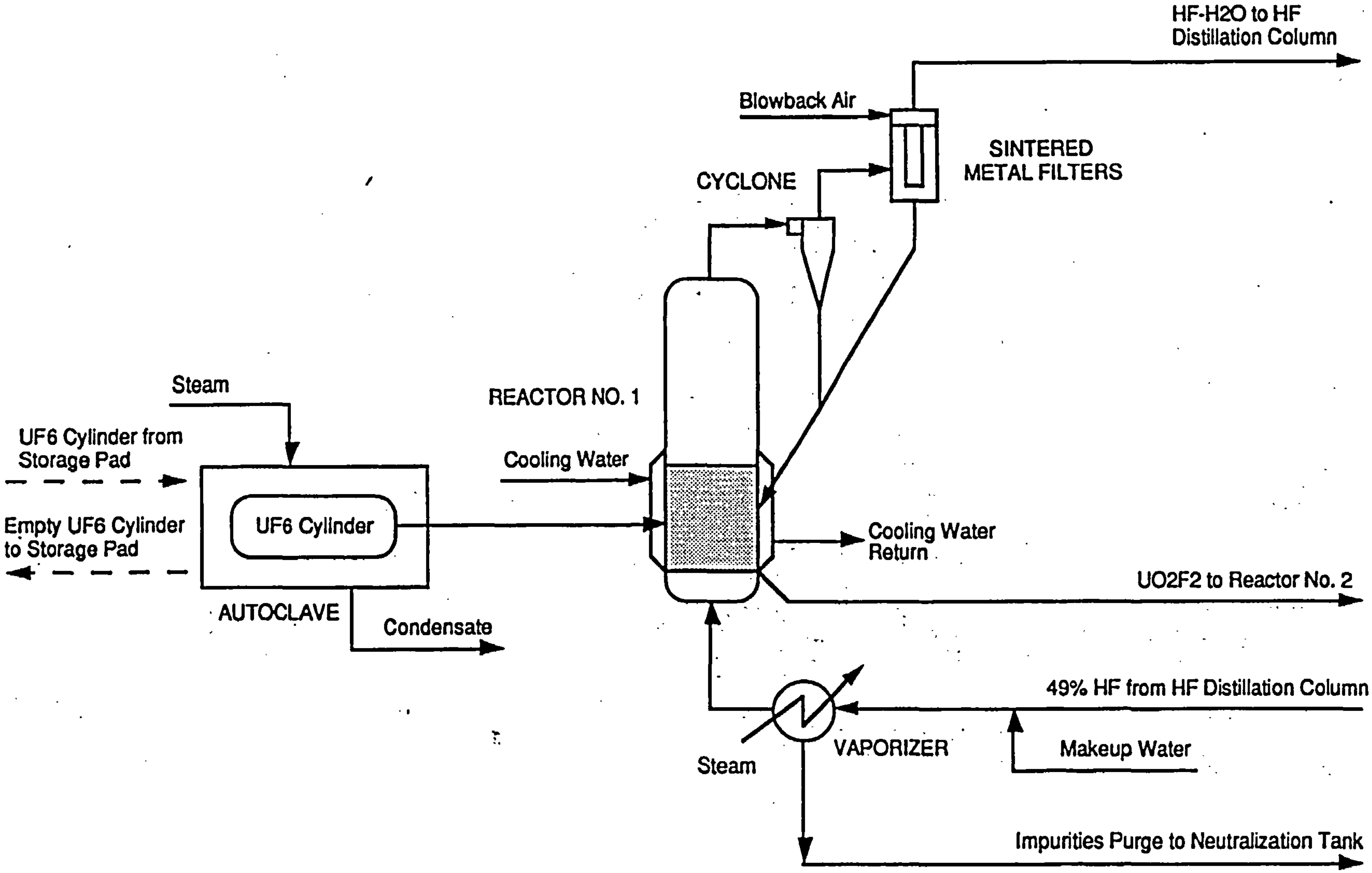


Figure 4-4 Reactor No. 1 Process Flow Diagram

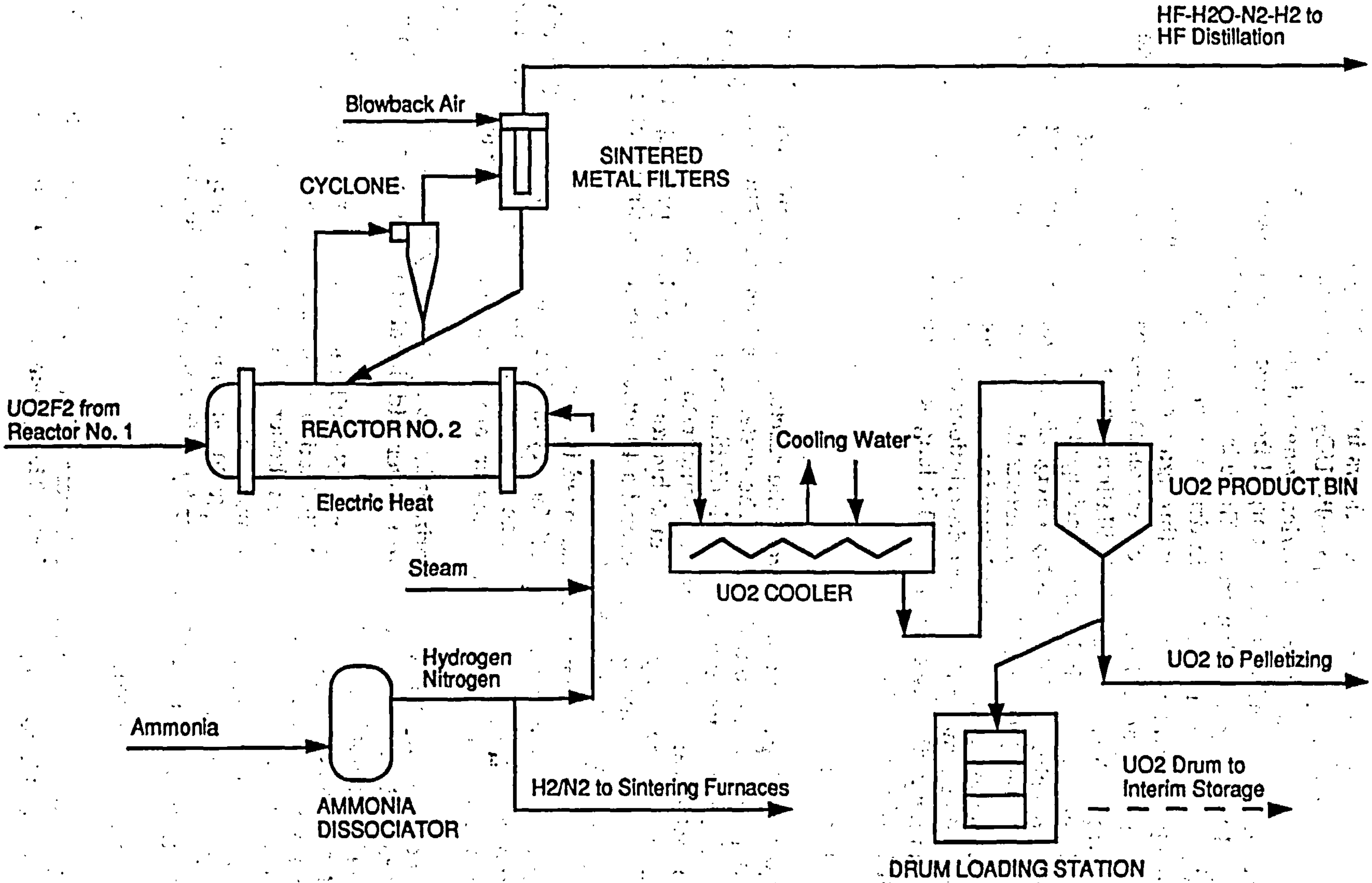


Figure 4-5 Reactor No. 2 Process Flow Diagram

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 $2NH_3 \longrightarrow N_2 + 3H_2$. 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.

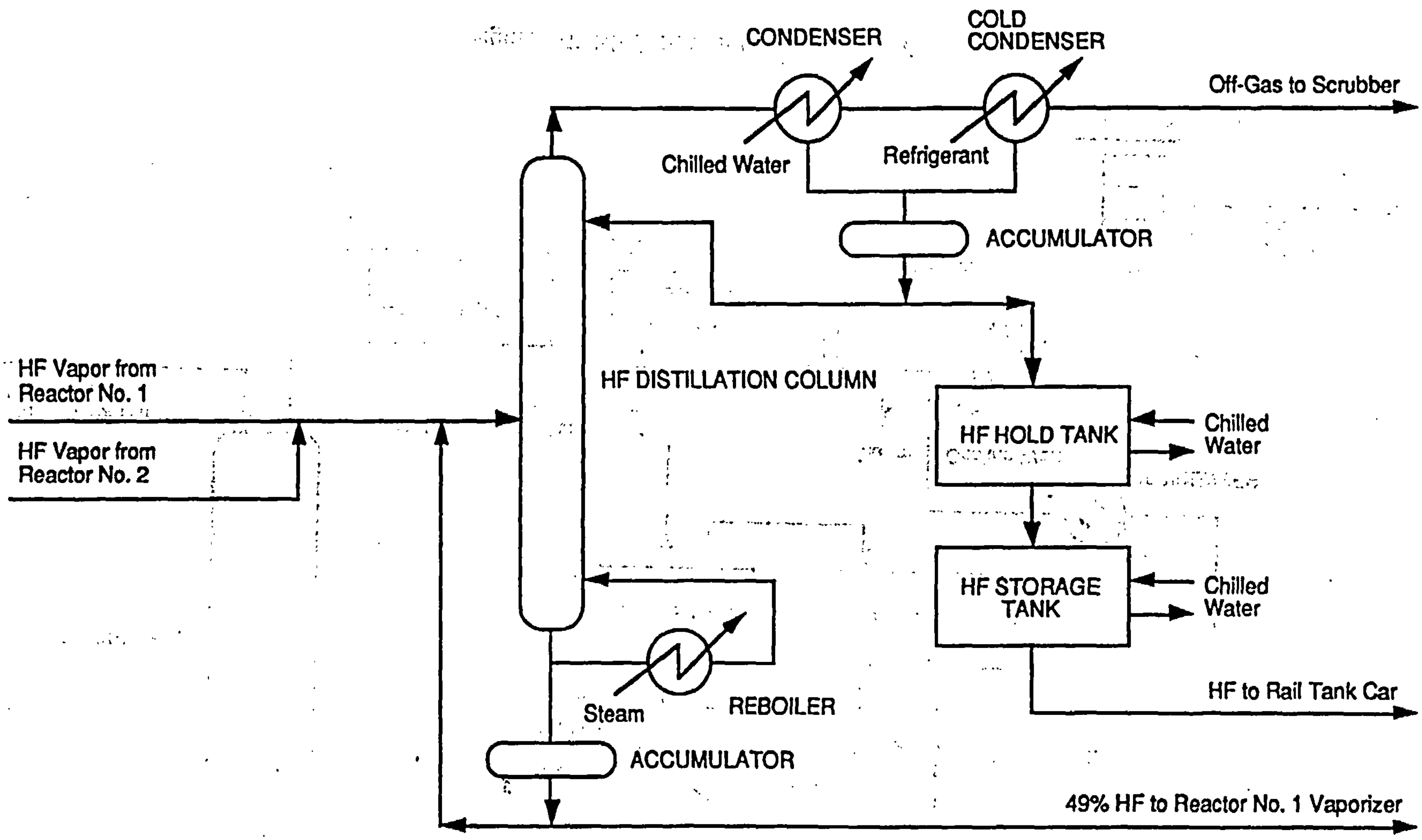


Figure 4-6 HF Distillation Process Flow Diagram

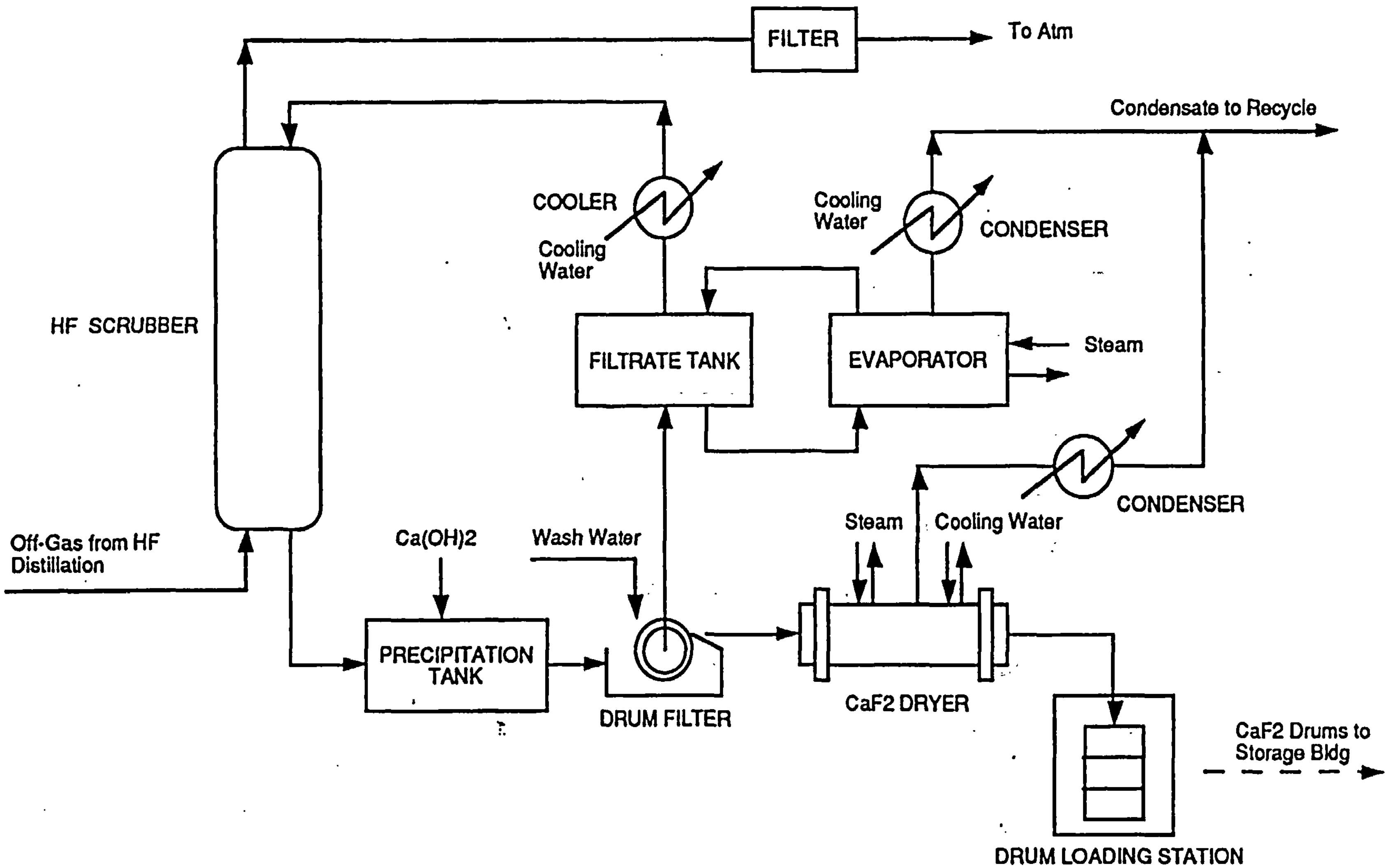


Figure 4-7 HF Scrubber Process Flow Diagram

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 $HF + KOH \rightarrow KF + H_2O$. 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 $2KF + Ca(OH)_2 \rightarrow CaF_2 + 2KOH$. 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.

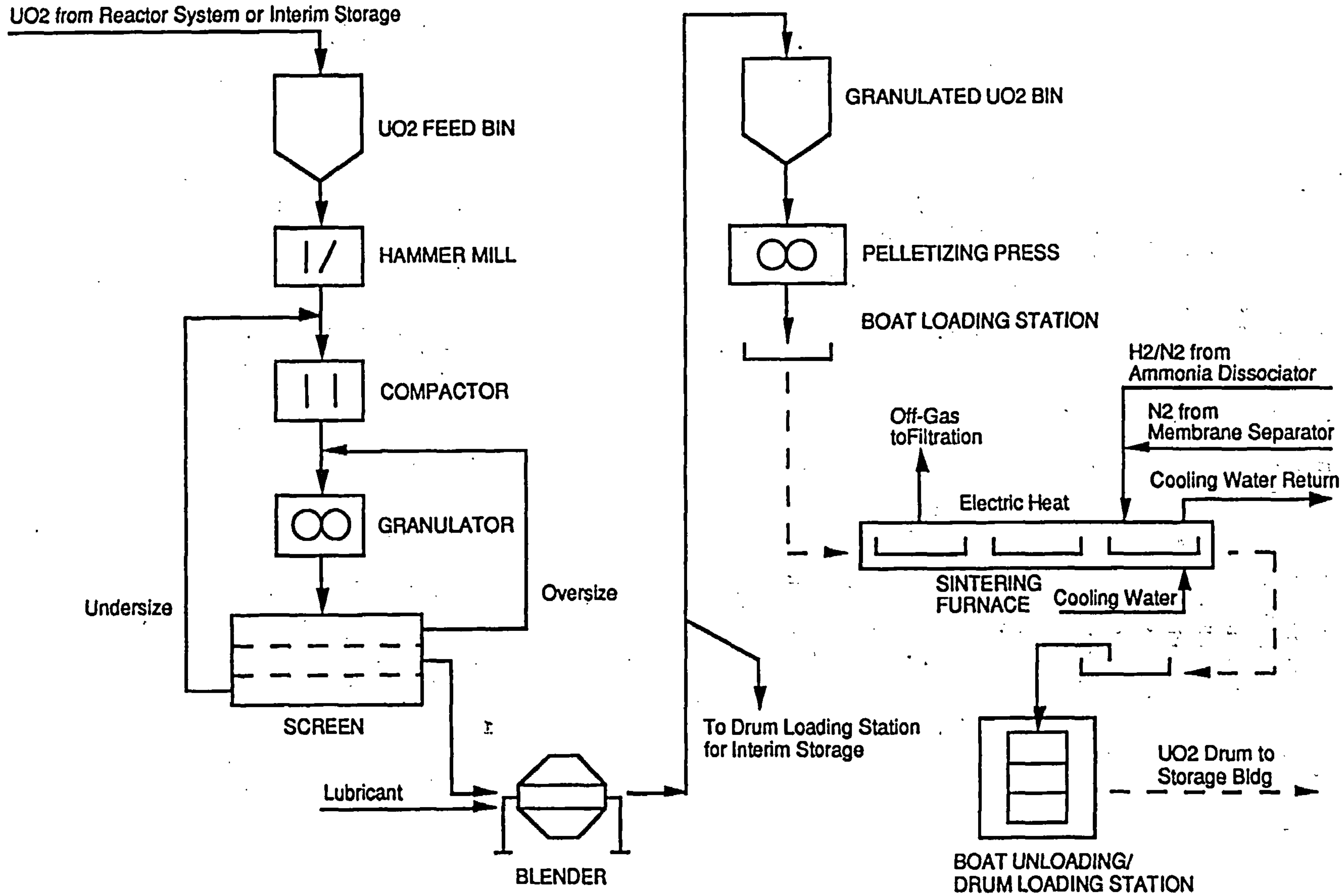


Figure 4-8 UO2 Pelletizing/Sintering Process Flow Diagram

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 $HF + Ca(OH)_2 \longrightarrow CaF_2 + 2H_2O$. The slurry is then mixed with cement and water in a drum to form a grout. After solidification, the waste 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).

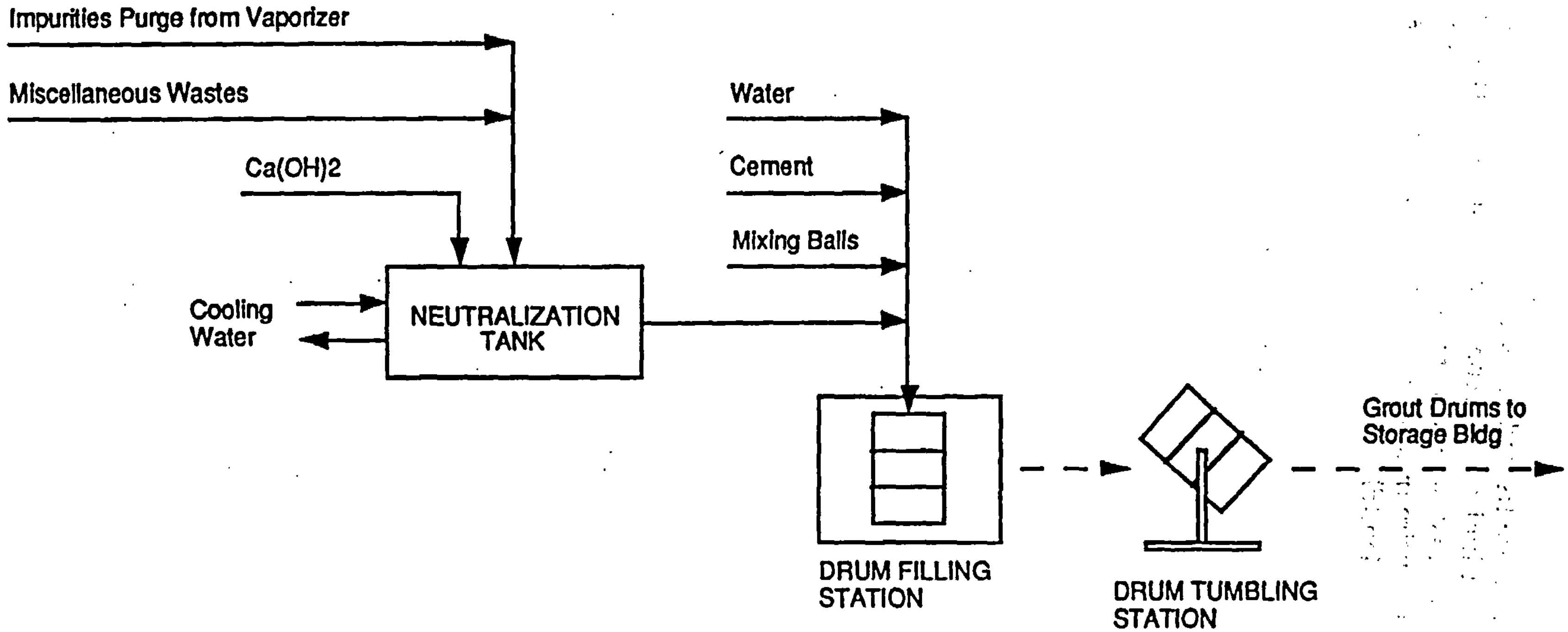


Figure 4-9 Waste Grouting Process Flow Diagram

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.

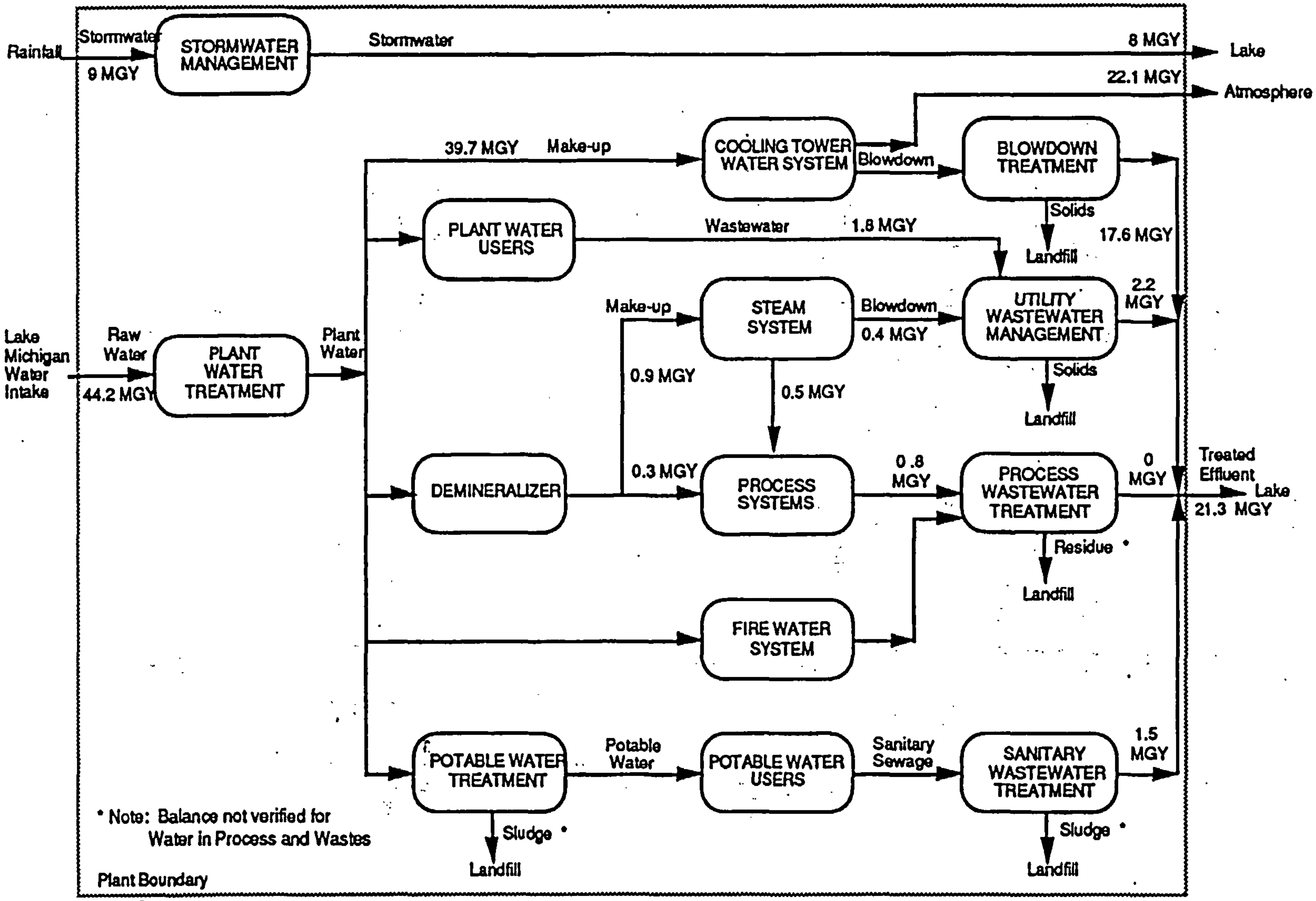


Figure 5-1 Preliminary Water Balance Ceramic UO2/Anhydrous HF

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)

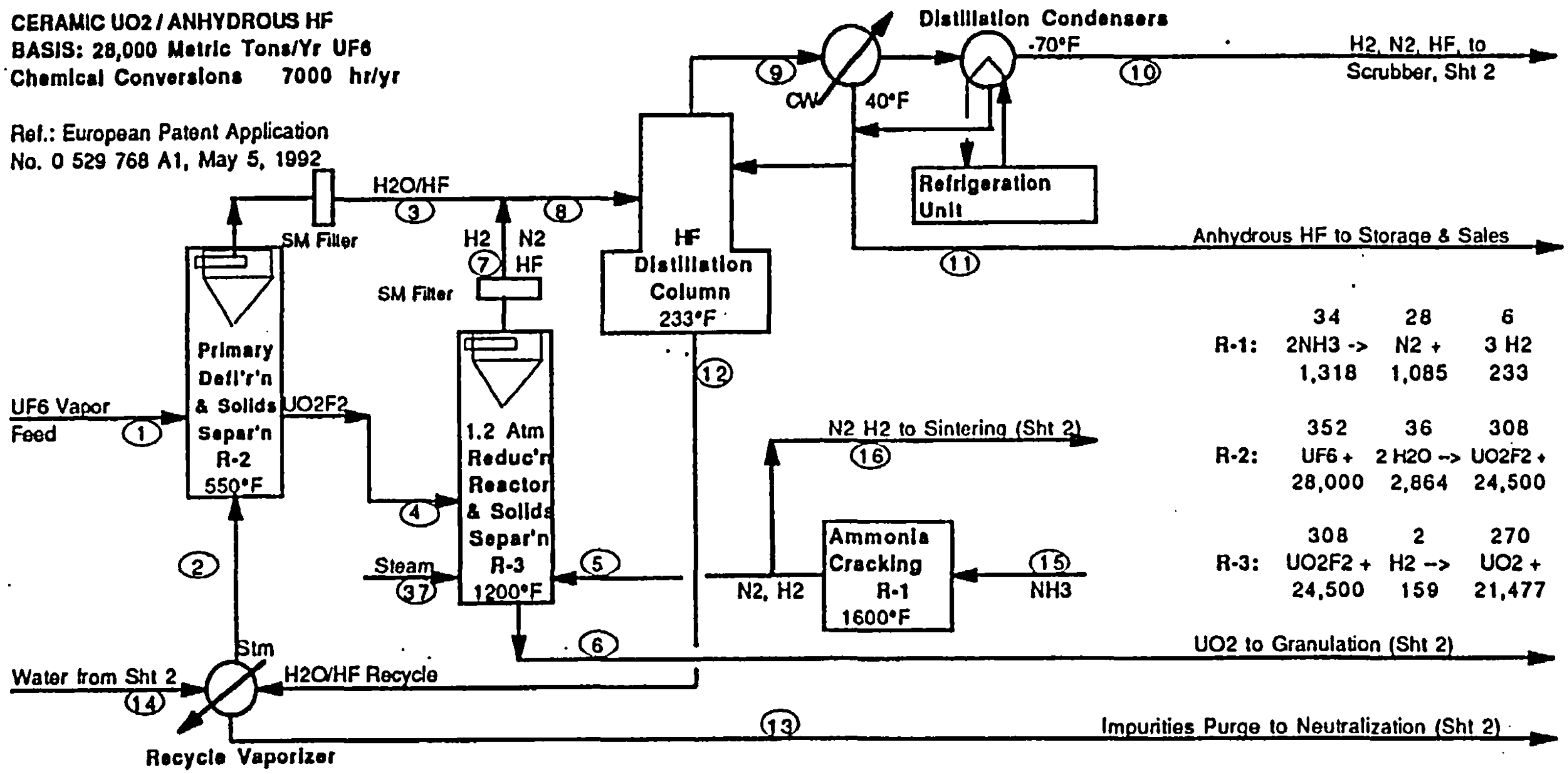
Appendix A

Material Balance

5-Mass Ba... MT/yr

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

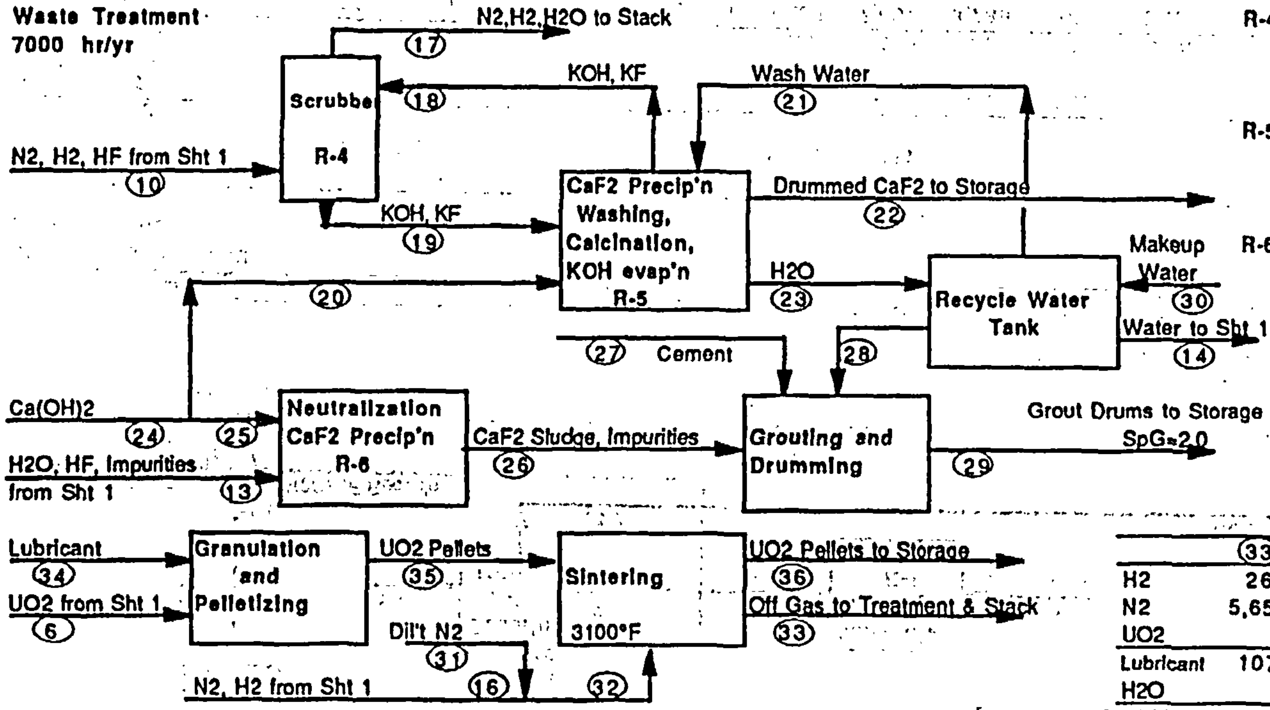


	34	28	6	
R-1:	2NH3 ->	N2 +	3 H2	
	1,318	1,085	233	
	352	36	308	80
R-2:	UF6 +	2 H2O ->	UO2F2 +	4 HF
	28,000	2,864	24,500	6,364
	308	2	270	40
R-3:	UO2F2 +	H2 -->	UO2 +	2 HF
	24,500	159	21,477	3,182

* 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



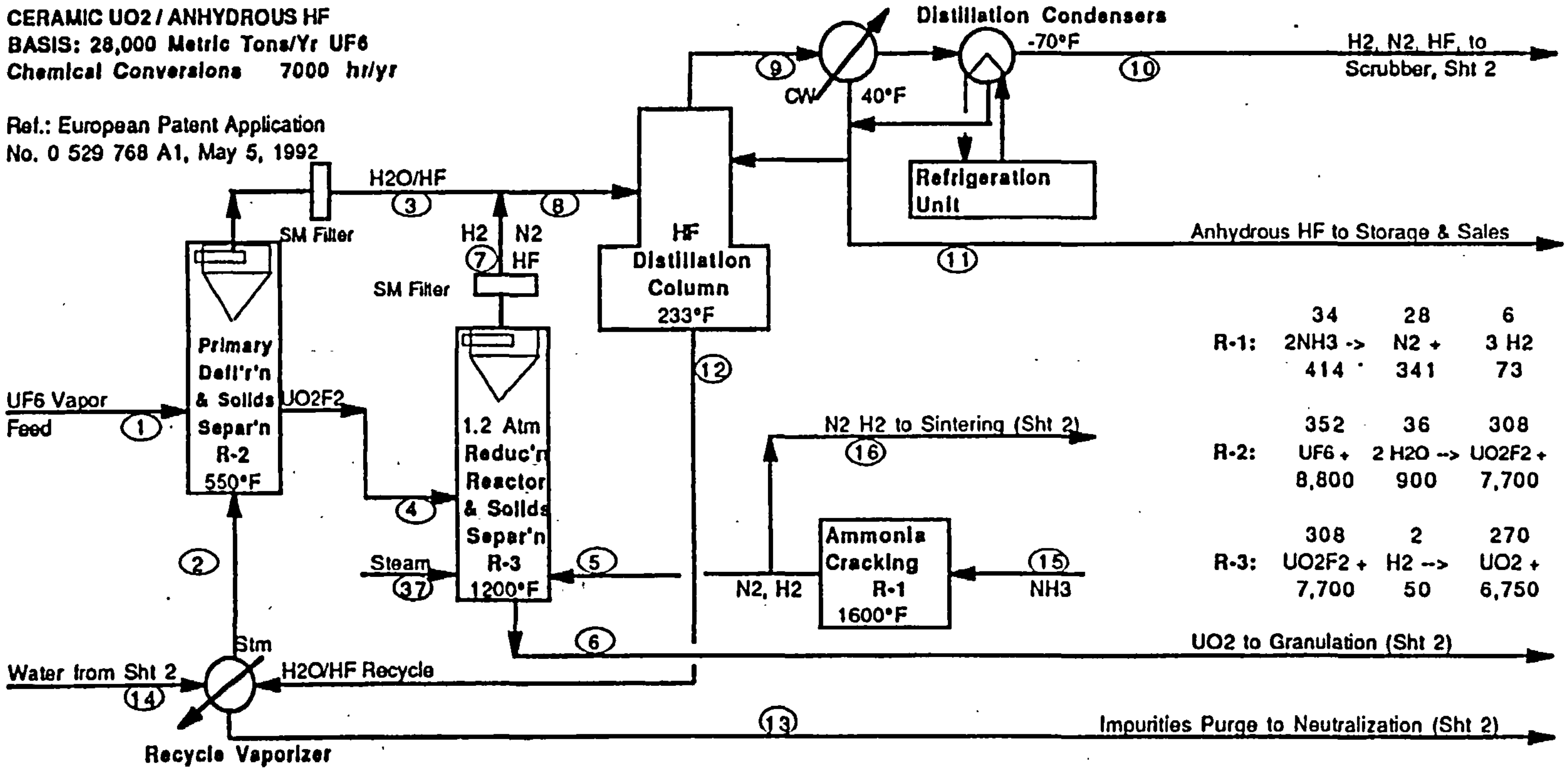
	20		56		58		18
R-4:	HF +		KOH -->		KF +		H2O
	216		604		626		194
	116		74		78		112
R-5:	2 KF +		Ca(OH)2-->		CaF2 +		2 KOH
	626		399		421		604
	40		74		78		36
R-6:	2 HF +		Ca(OH)2-->		CaF2 +		2 H2O
	95		177		186		86

	(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

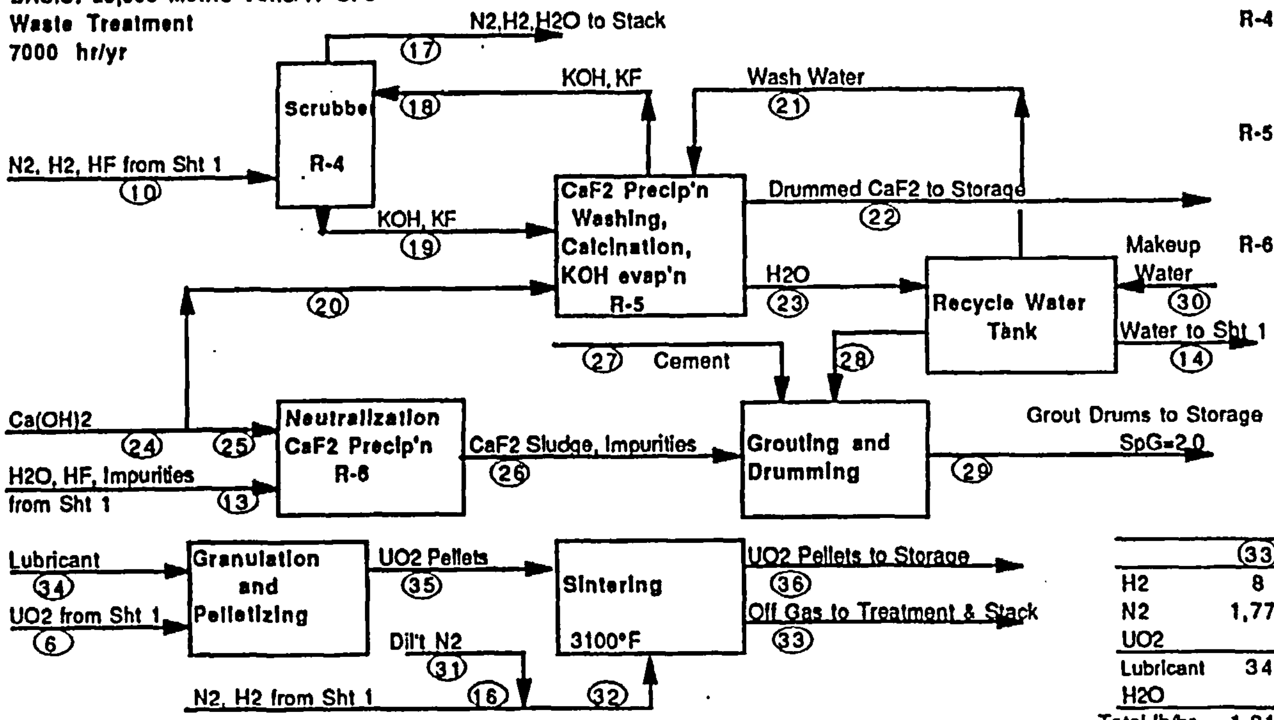


	34	28	6	
R-1:	2NH3 ->	N2 +	3 H2	
	414	341	73	
	352	36	308	80
R-2:	UF6 +	2 H2O -->	UO2F2 +	4 HF
	8,800	900	7,700	2,000
	308	2	270	40
R-3:	UO2F2 +	H2 -->	UO2 +	2 HF
	7,700	50	6,750	1,000

Does not include reflux (applies to 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

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	<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 pellet 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
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	Yard
	Fire water pump - 3000 gpm diesel	Yard
	Fire water tanks 2 - 270,000 gal	Yard
	Fire system piping	Yard/Buildings
	Sprinkler System	Buildings
	Alarm system	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	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 - 3500 gpd	Util. Bldg
	Sanitary water treatment system - 4100 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 60,000 gpd	Wastewater Treatment area
	Electrical substation - 4000 kW	Substation
	Emergency generators - 2 @ 500kW	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, 2-3000 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

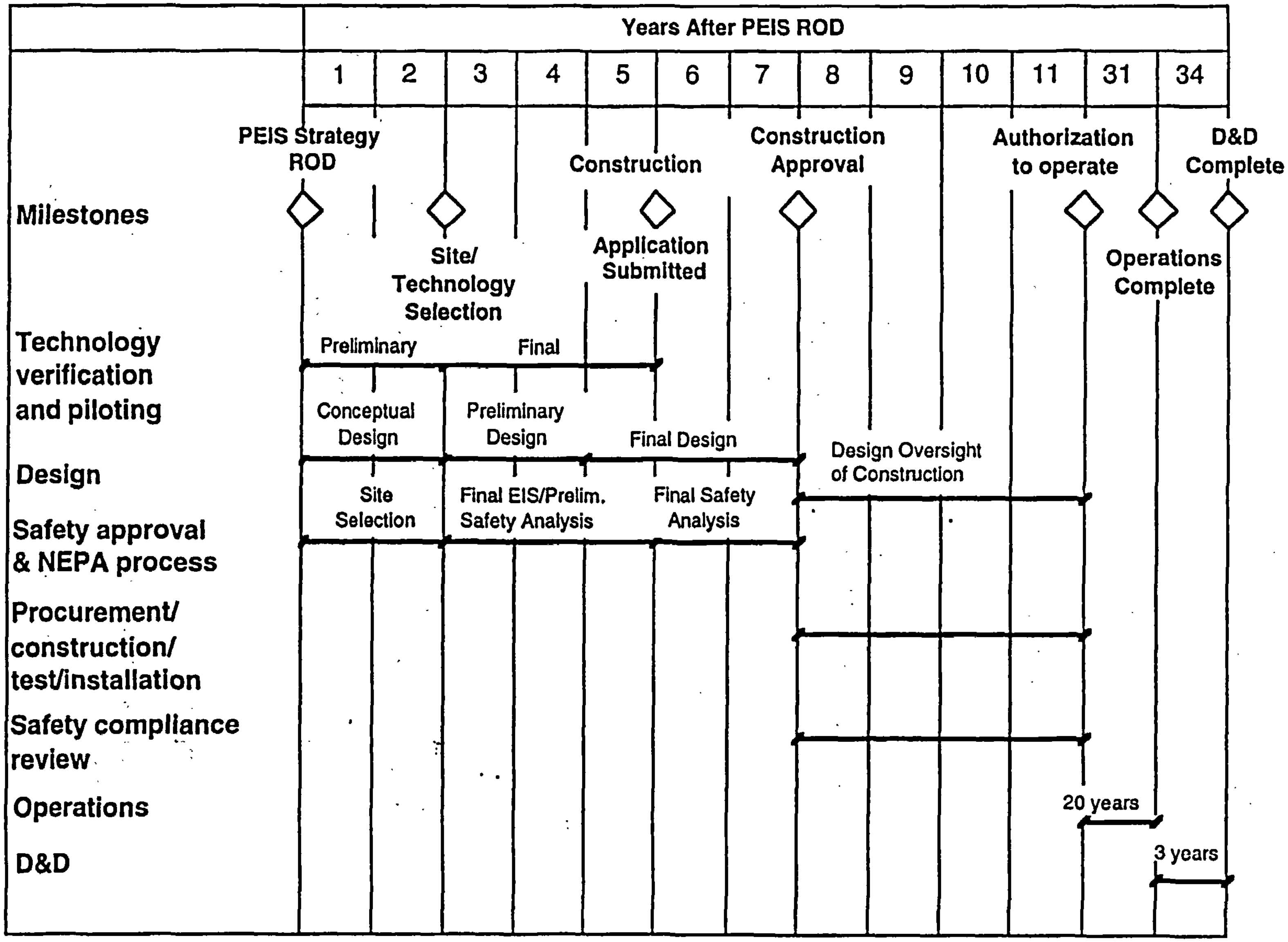


Figure 1-1 Preliminary Project Schedule

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.

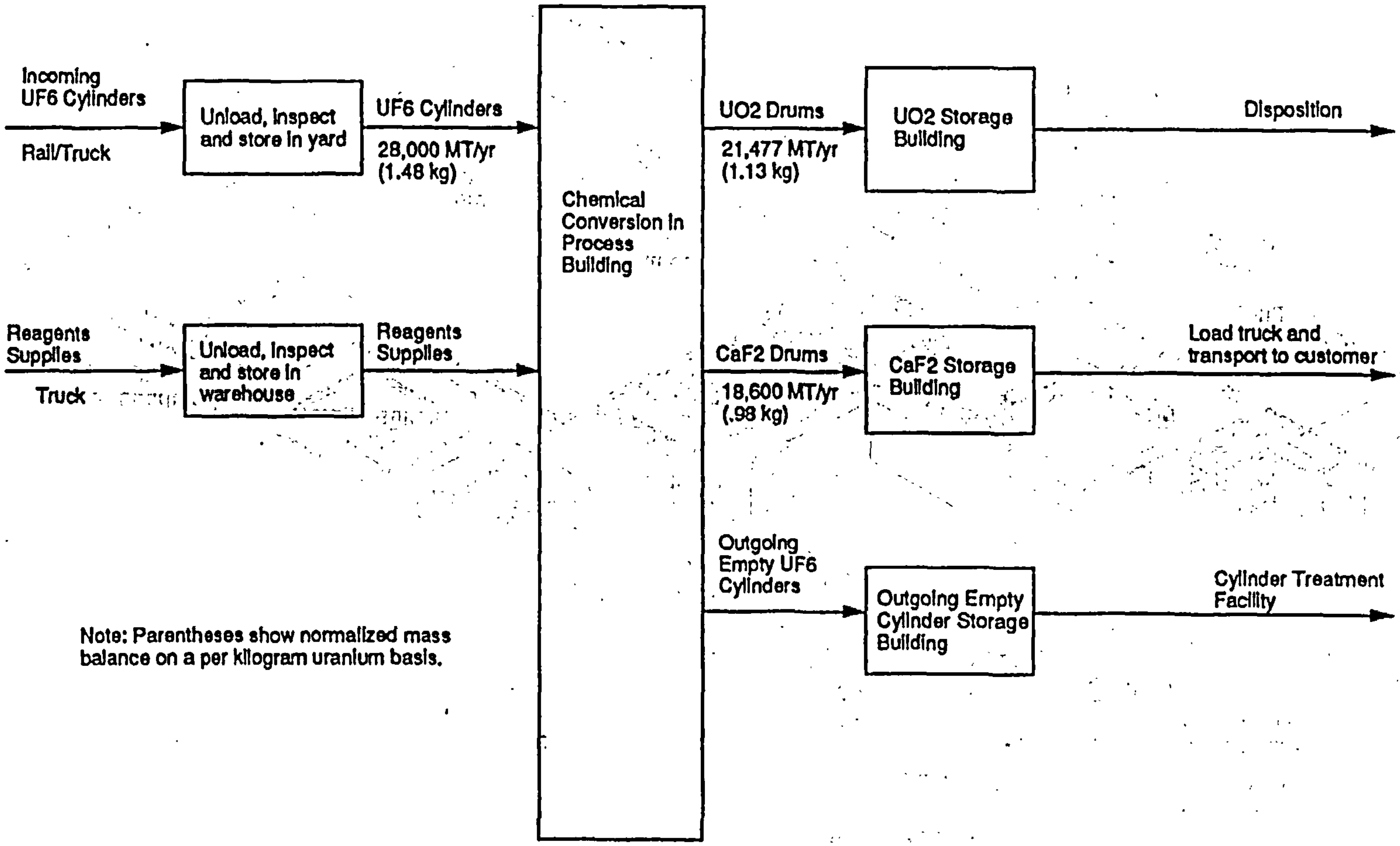


Figure 2-1 Ceramic UO2 / HF Neutralization Material Flow Diagram

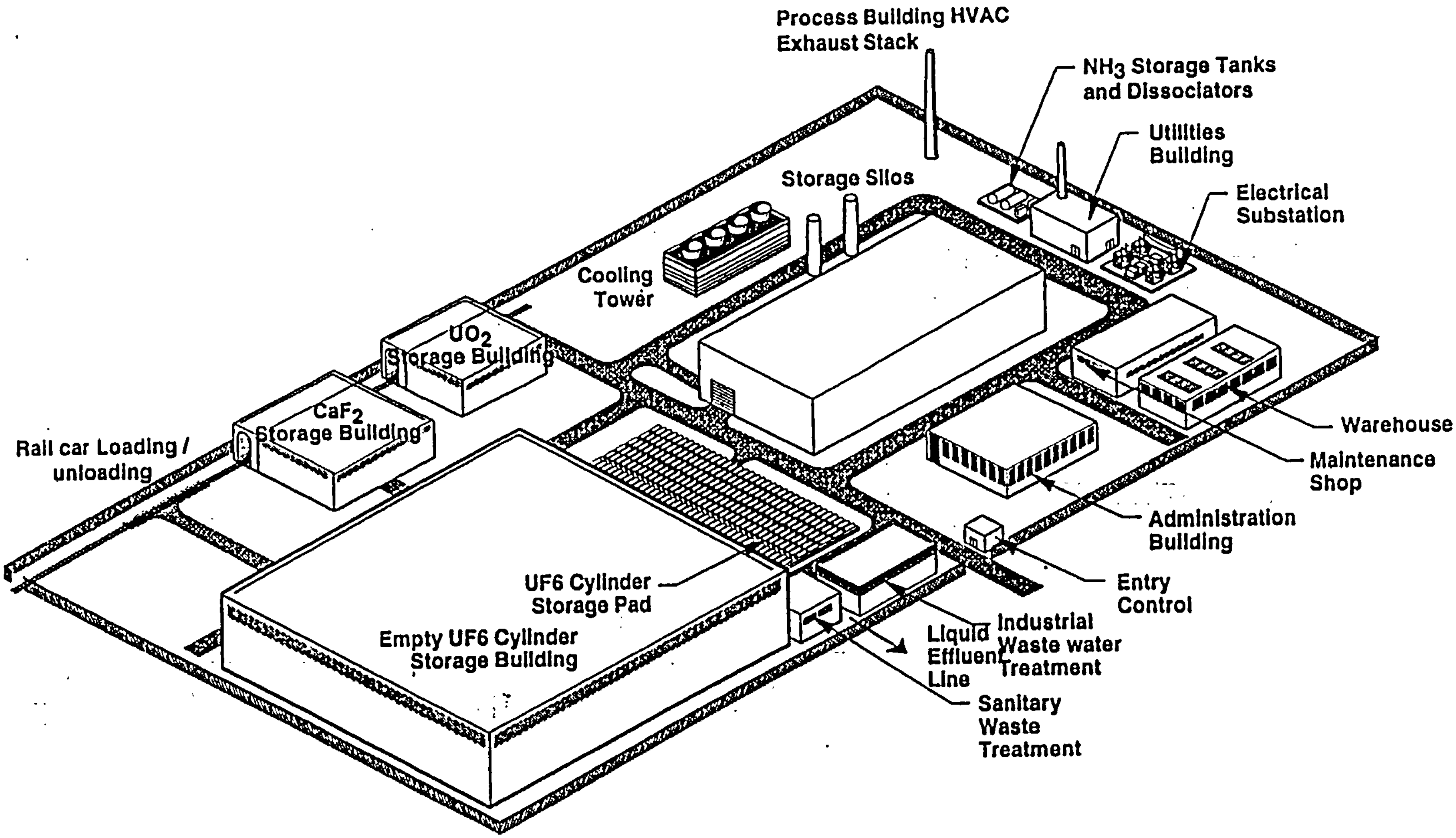


Figure 2-2 Plot Plan
Ceramic UO_2 / HF Neutralization Facility

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

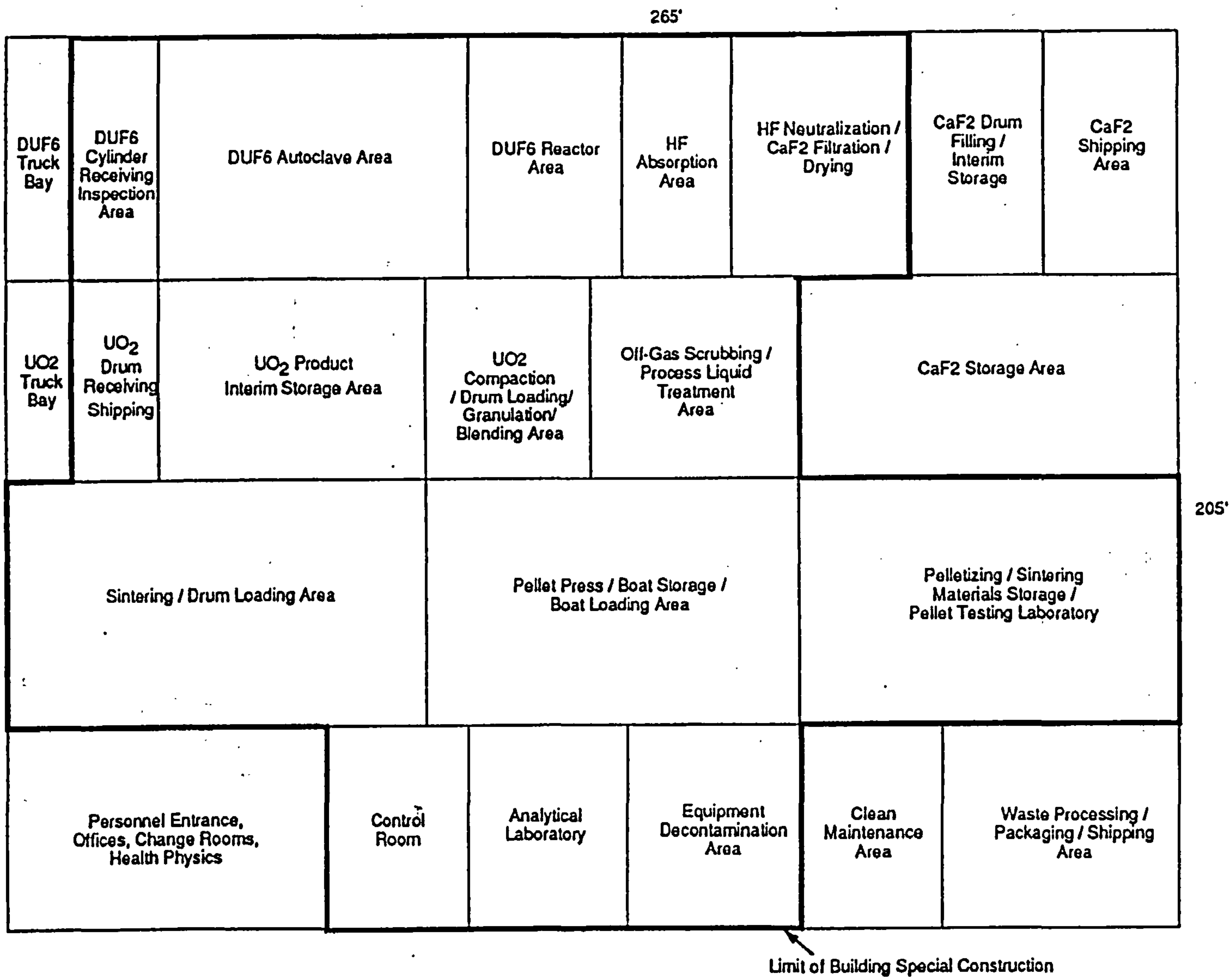


Figure 2-3 Process Building Layout
Ceramic UO2 / HF Neutralization

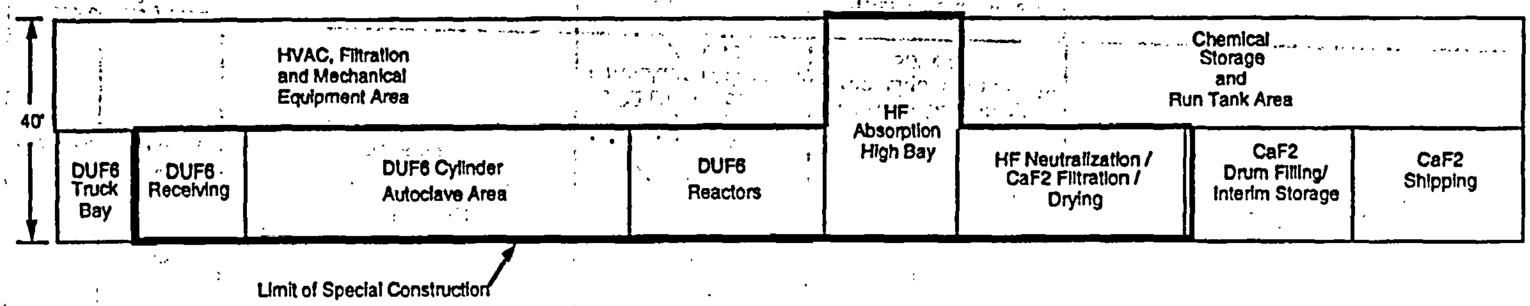


Figure 2-4 Process Building Section Ceramic UO2 / HF Neutralization

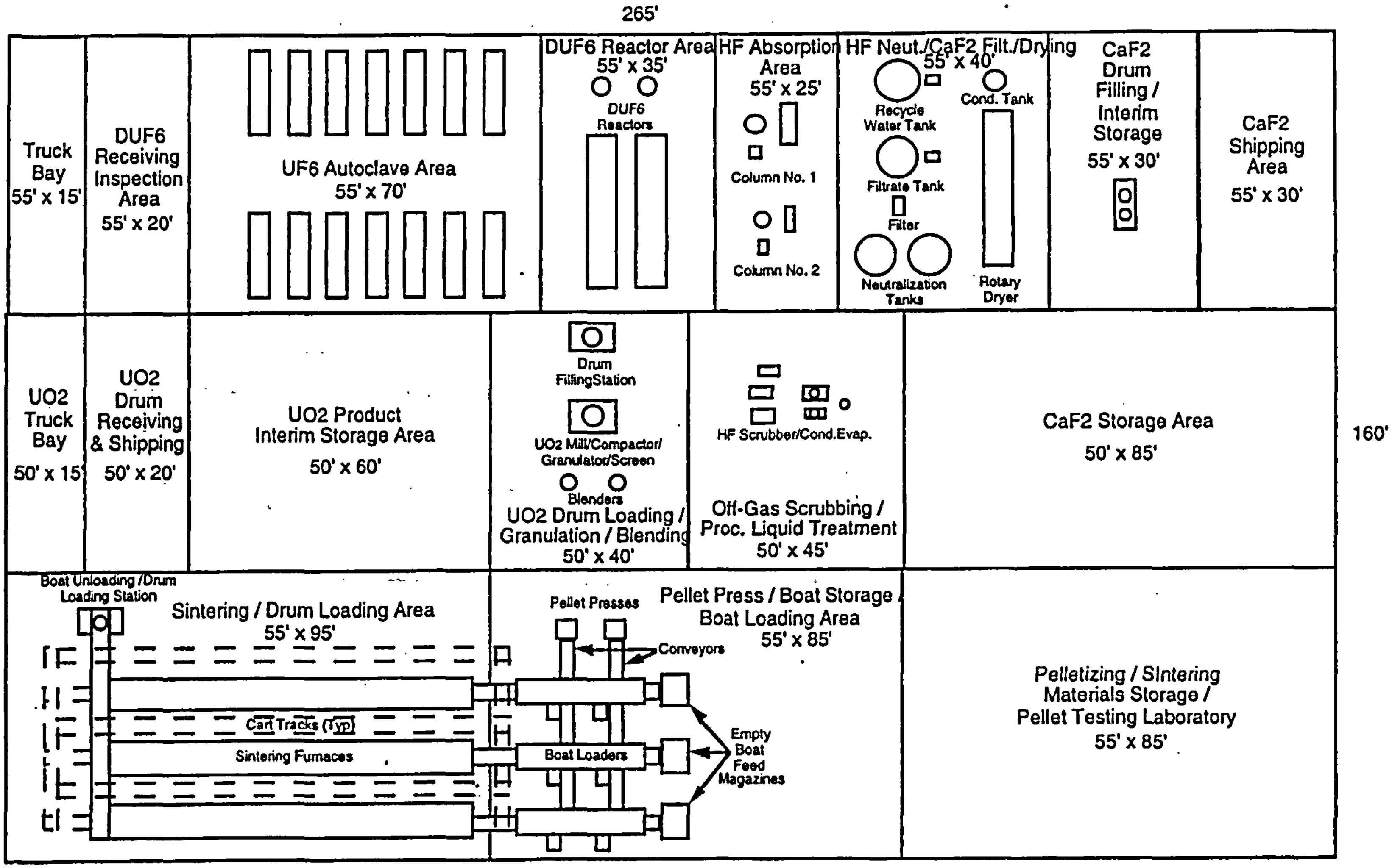


Figure 2-5 Process Equipment Arrangement Ceramic UO2 / HF Neutralization

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 nighttime 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.

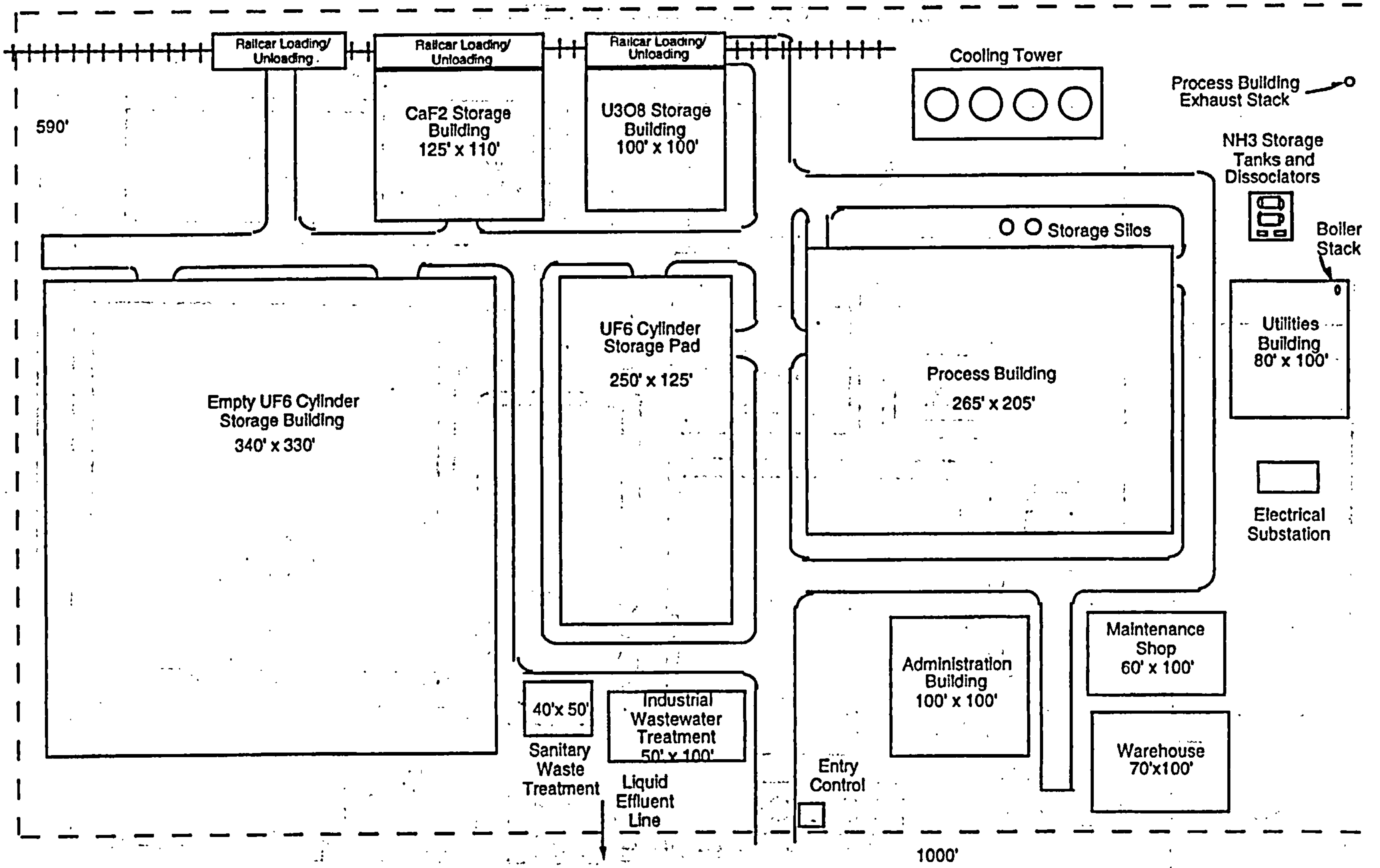


FIGURE 3-1 SITE MAP
CERAMIC UO_2 / HF NEUTRALIZATION FACILITY

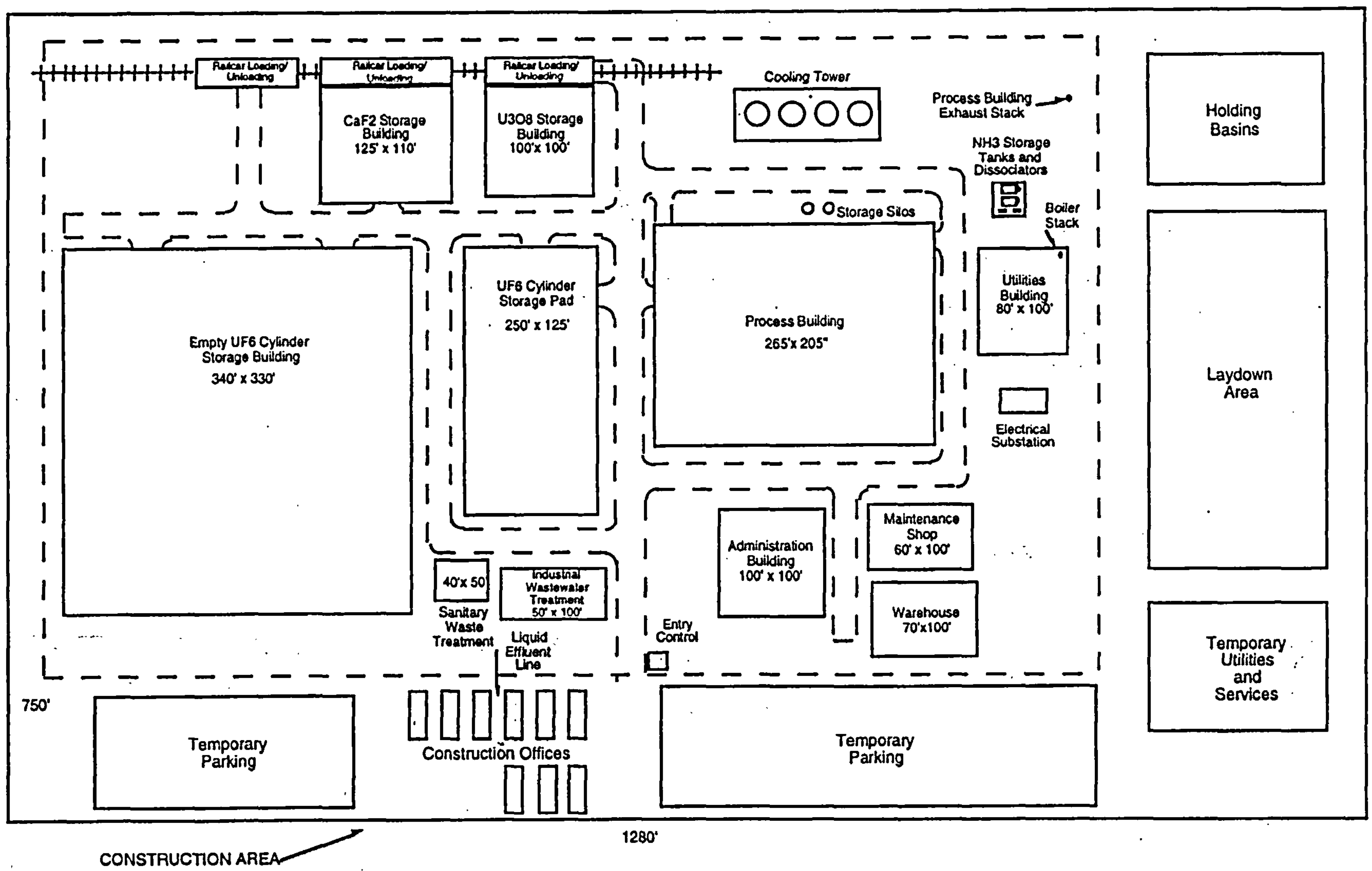


FIGURE 3-2 SITE MAP DURING CONSTRUCTION
CERAMIC UO_2 / HF NEUTRALIZATION FACILITY

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.

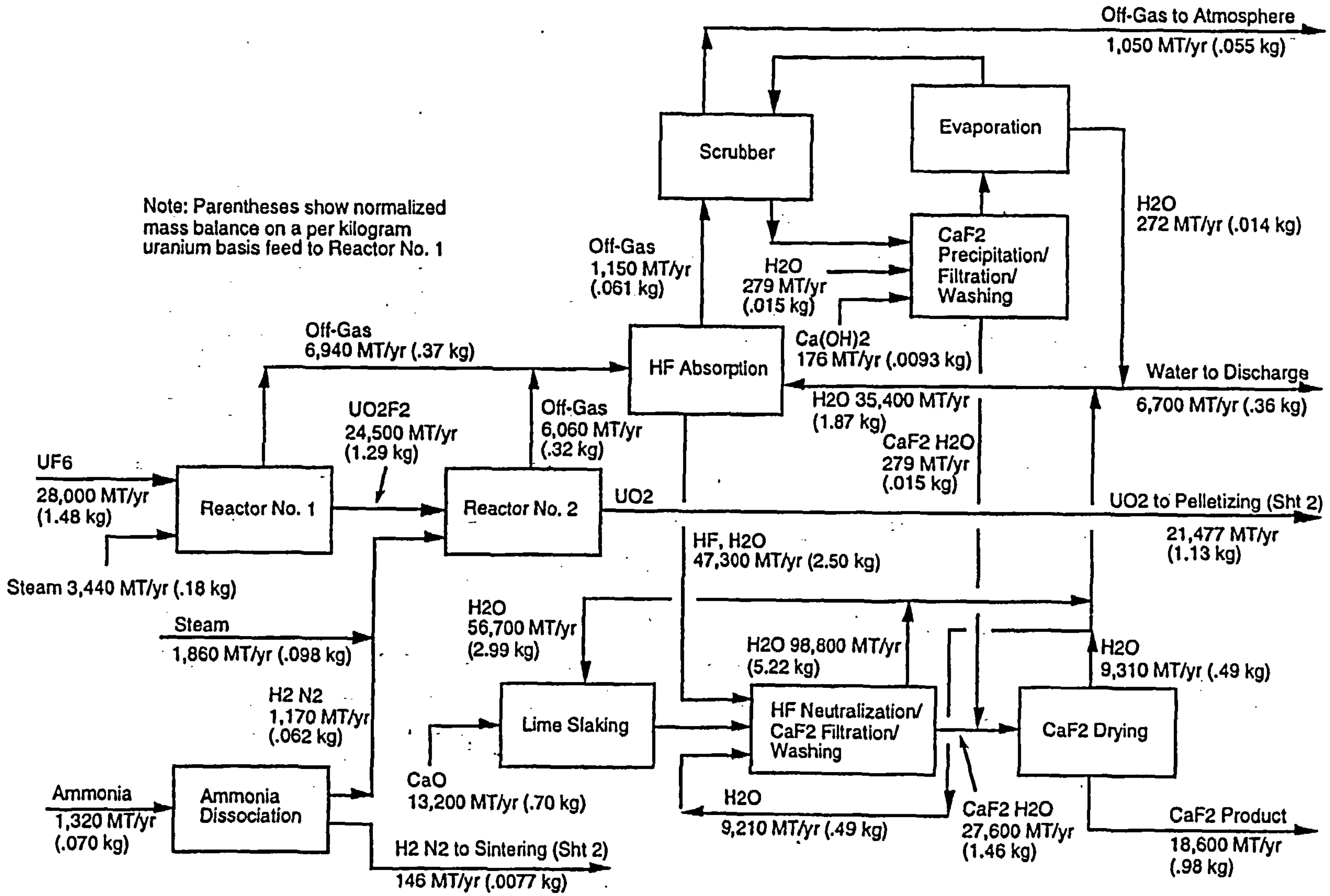
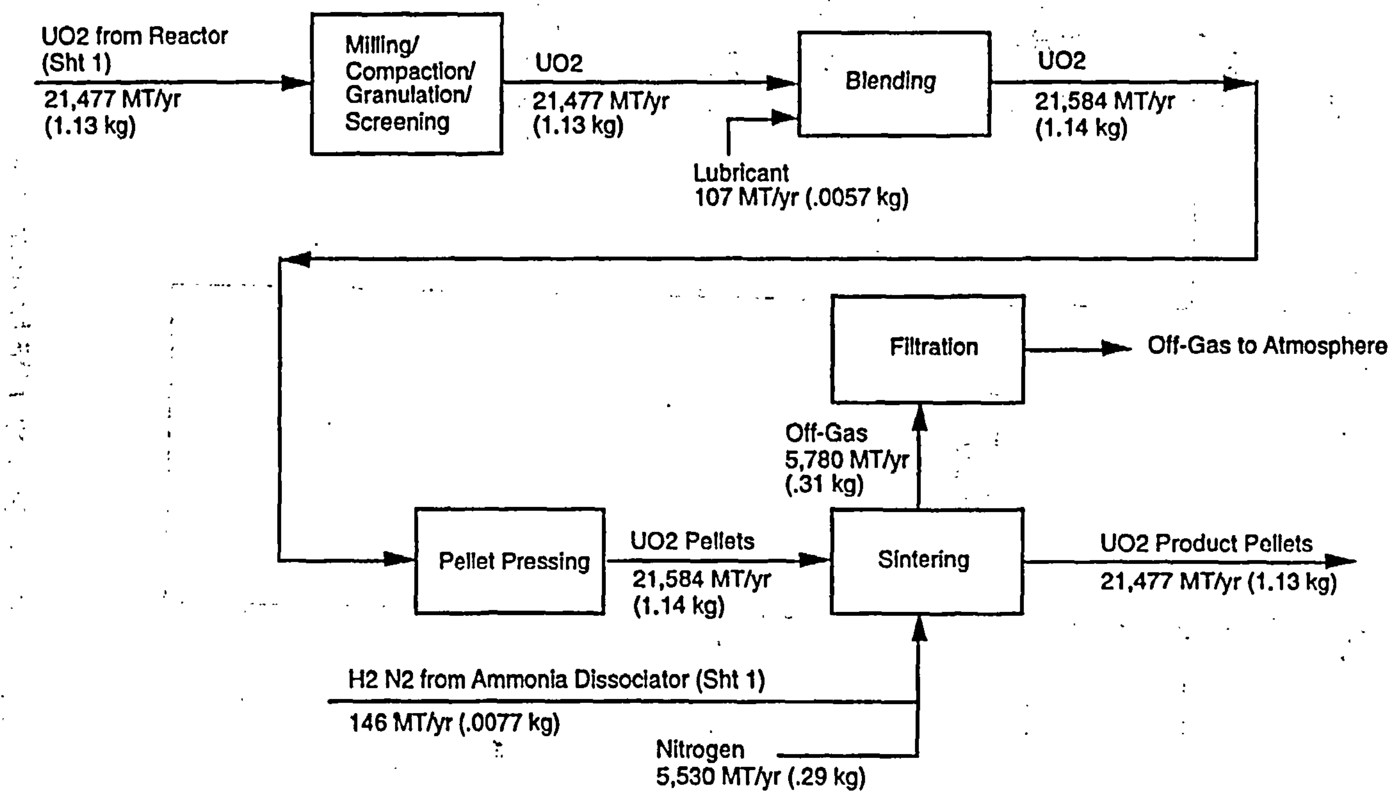


Figure 4-1 Ceramic UO2 / HF Neutralization Block Flow Diagram - Sheet 1



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

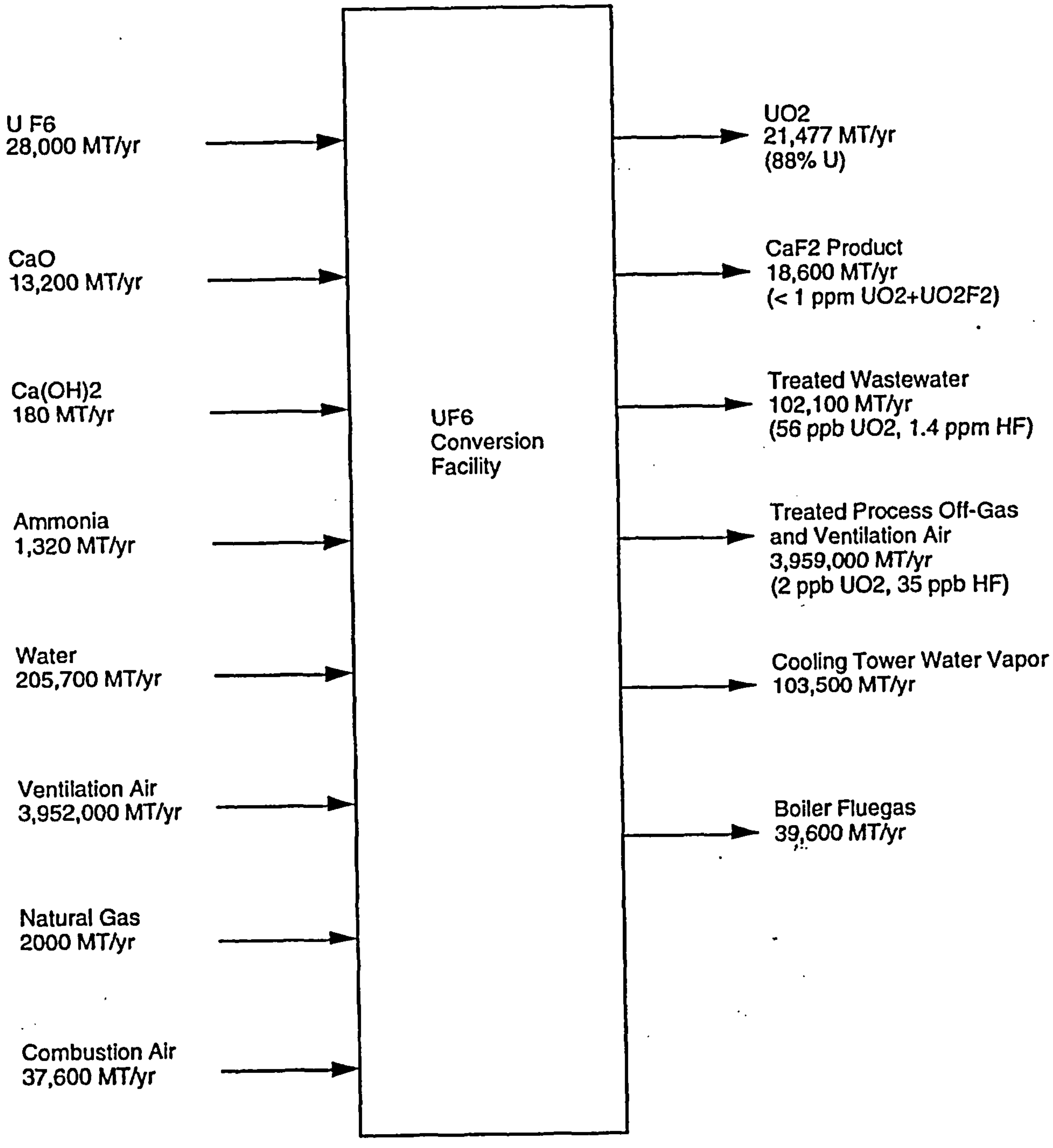


Figure 4-3 Ceramic UO2 / HF Neutralization Input/Output Diagram

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 $UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$. 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 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 $UO_2F_2 + H_2 \rightarrow UO_2 + 2HF$. 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 $2NH_3 \rightarrow N_2 + 3H_2$. 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.

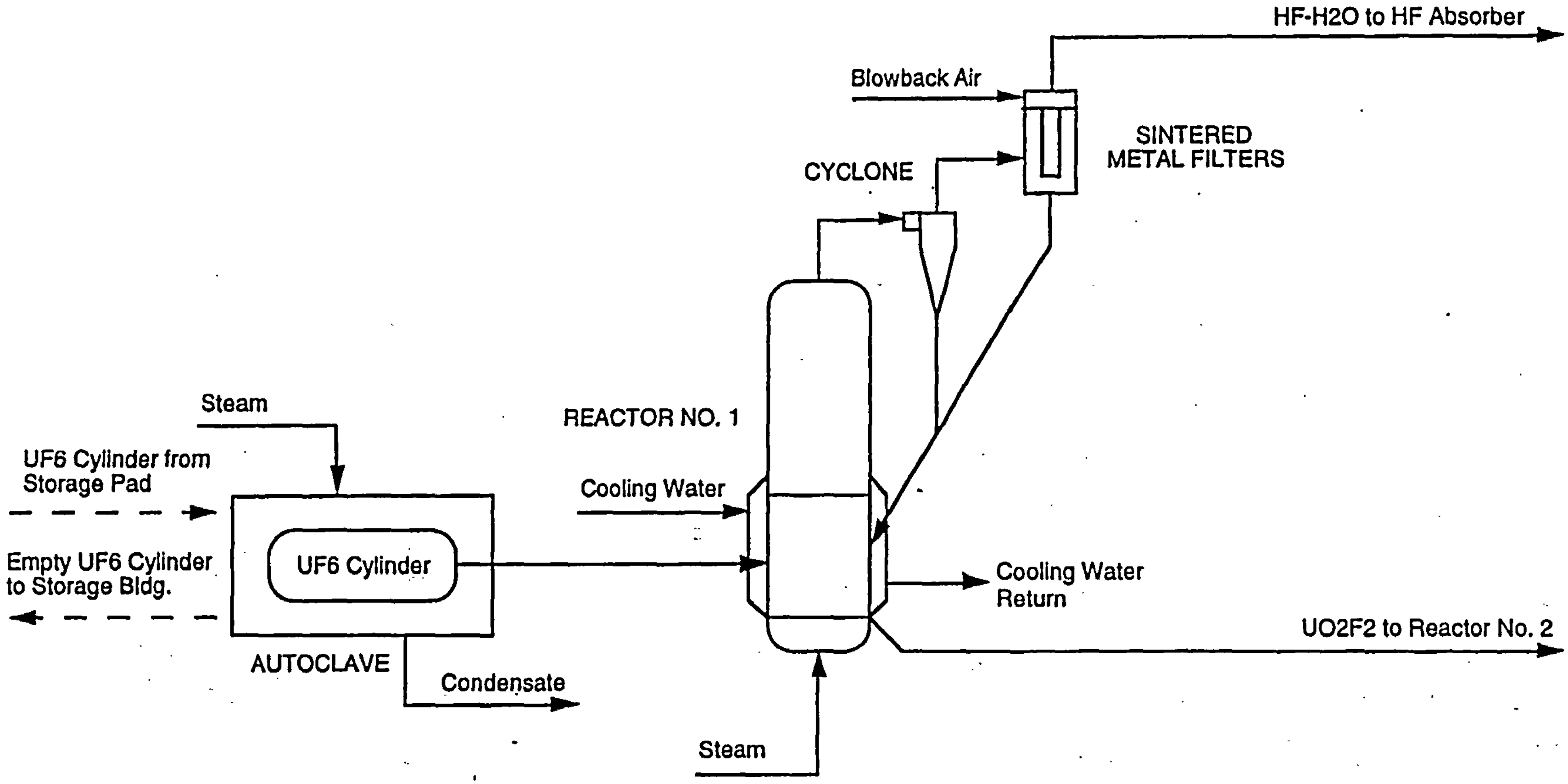


Figure 4-4 Reactor No. 1 Process Flow Diagram

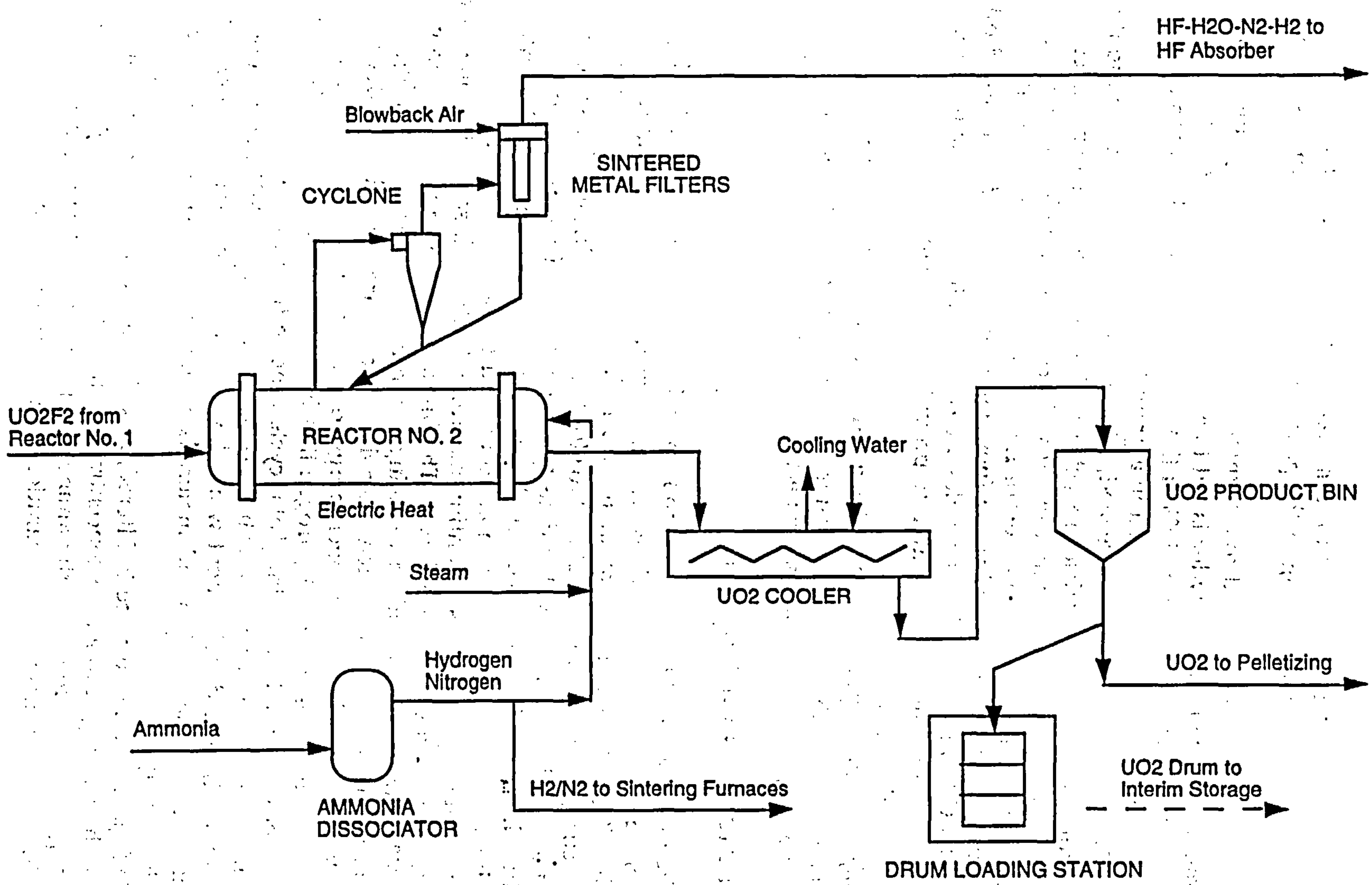


Figure 4-5 Reactor No. 2 Process Flow Diagram

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.

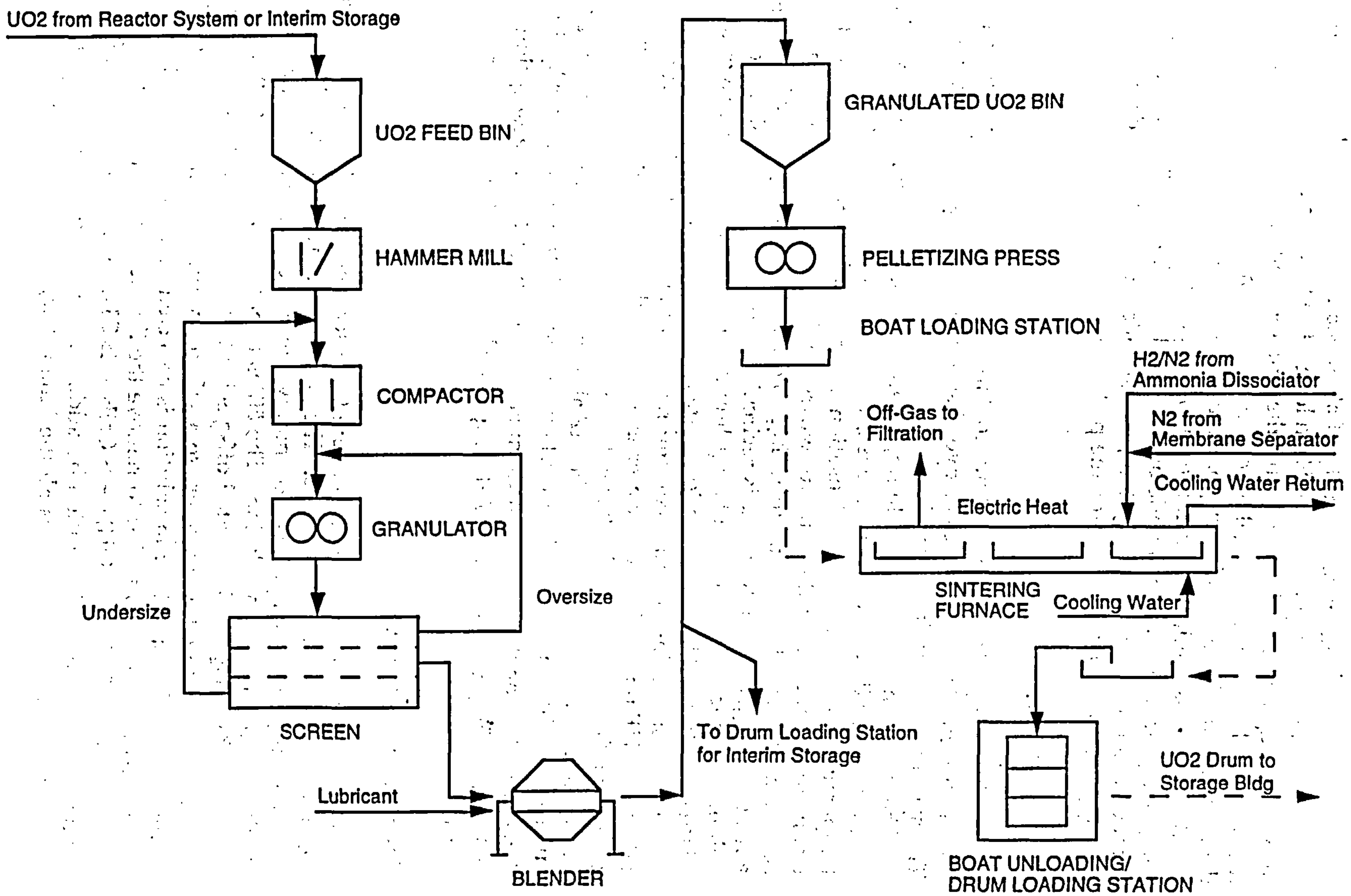


Figure 4-6 UO2 Pelletizing/Sintering Process Flow Diagram

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 $HF + KOH \longrightarrow KF + H_2O$. 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

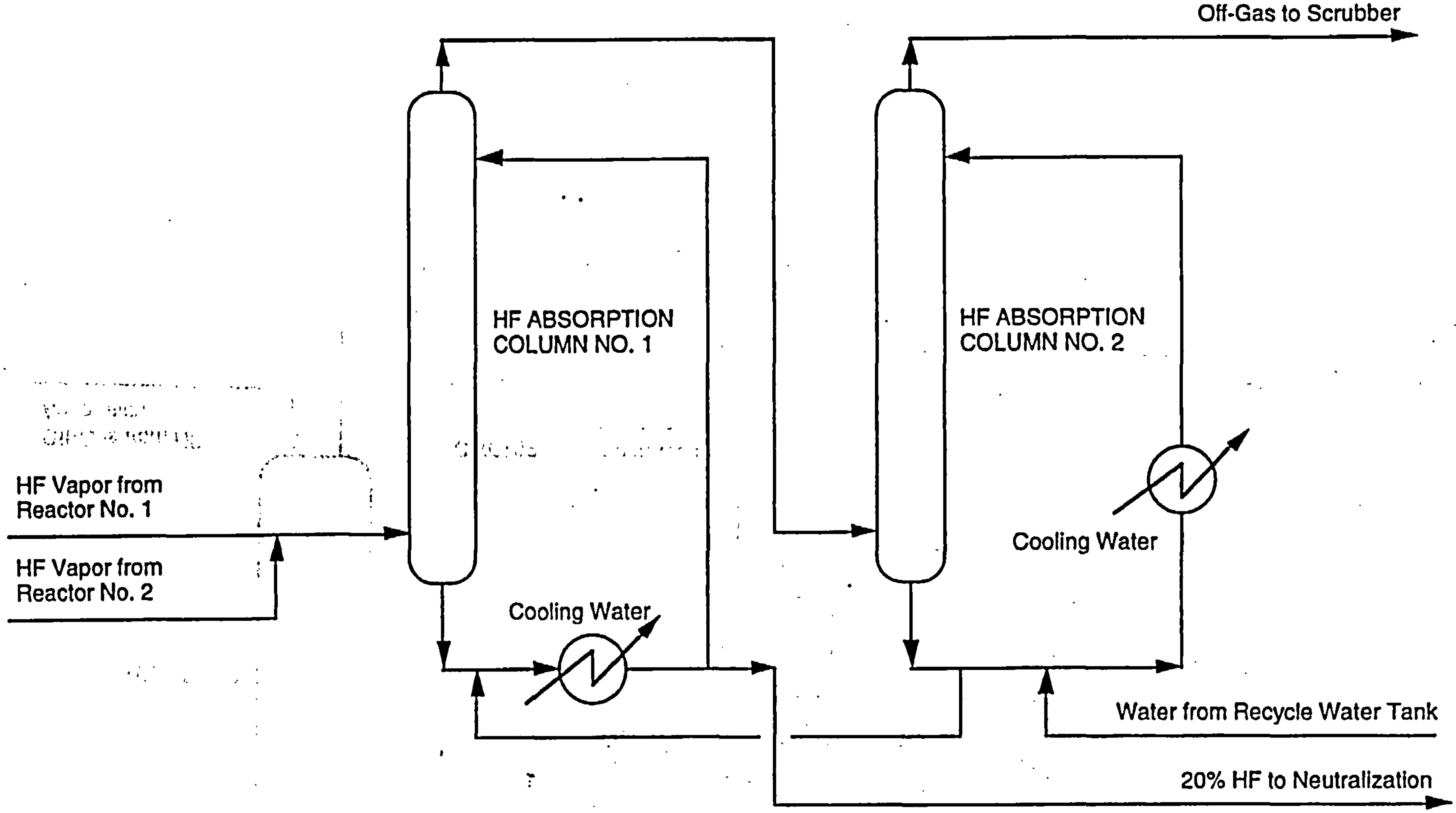


Figure 4-7 HF Absorption Process Flow Diagram

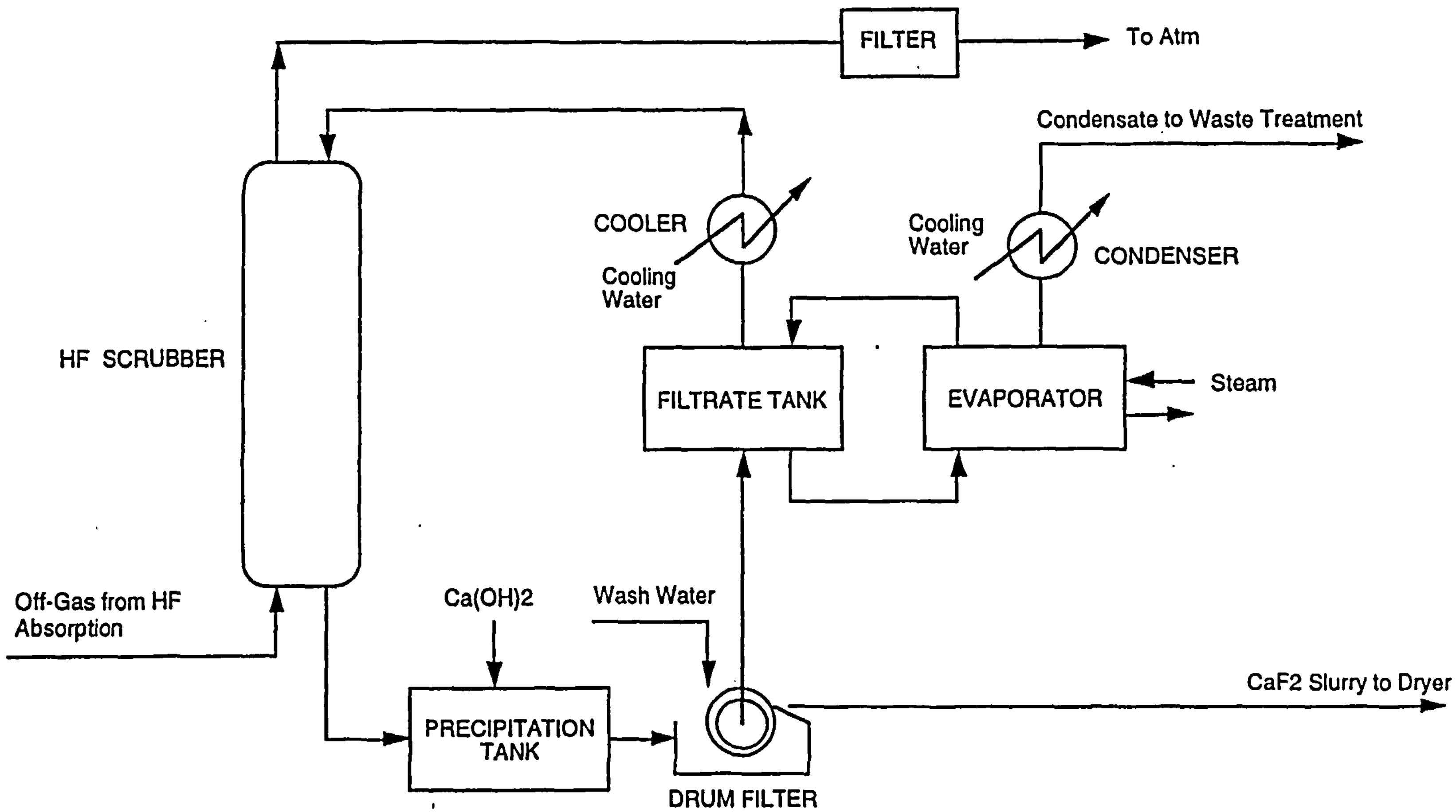


Figure 4-8 HF Scrubber Process Flow Diagram

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 $CaO + H_2O \longrightarrow Ca(OH)_2$. 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 $2HF + Ca(OH)_2 \longrightarrow CaF_2 + 2H_2O$. 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,

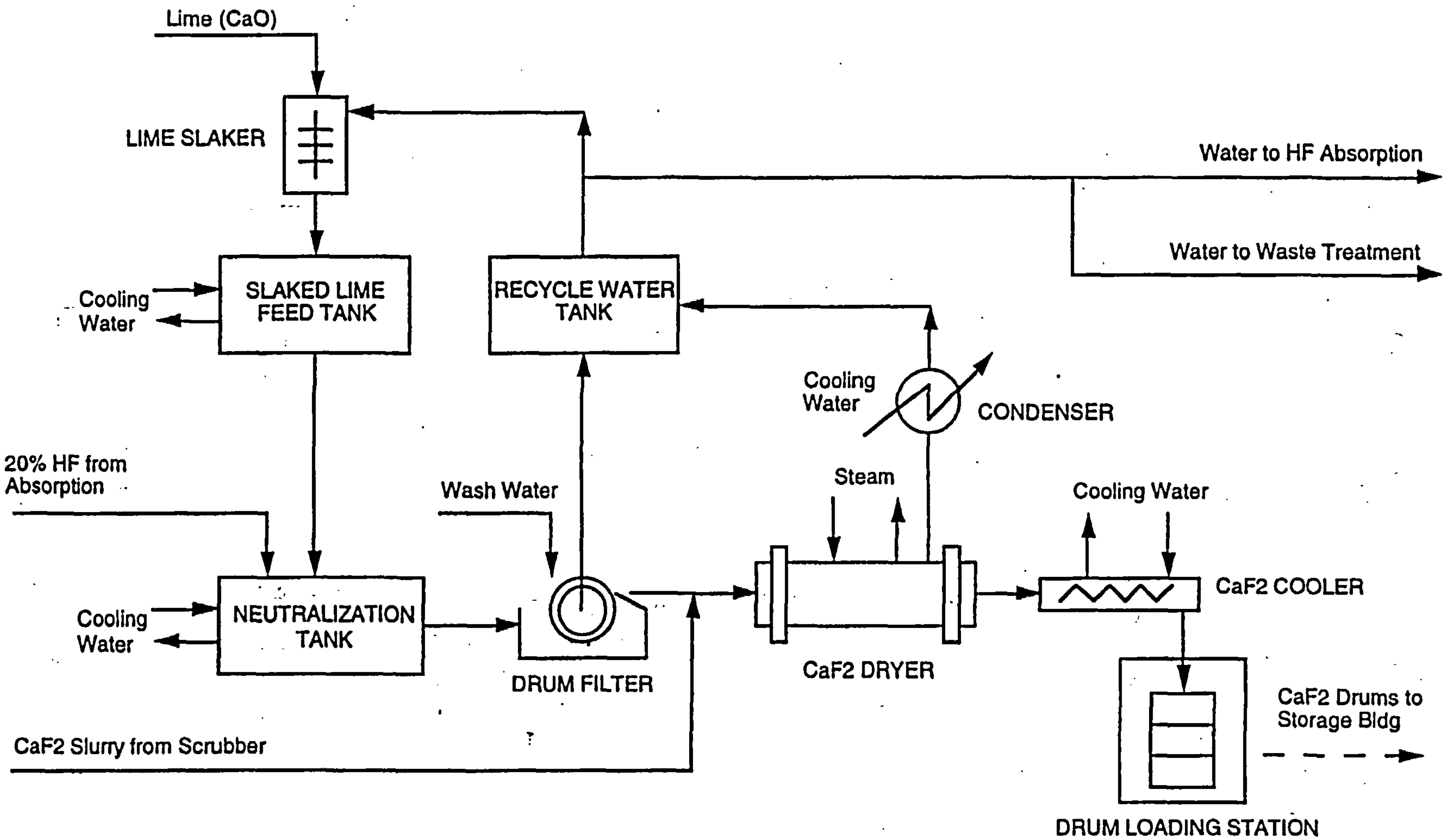


Figure 4-9 HF Neutralization Process Flow Diagram

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.

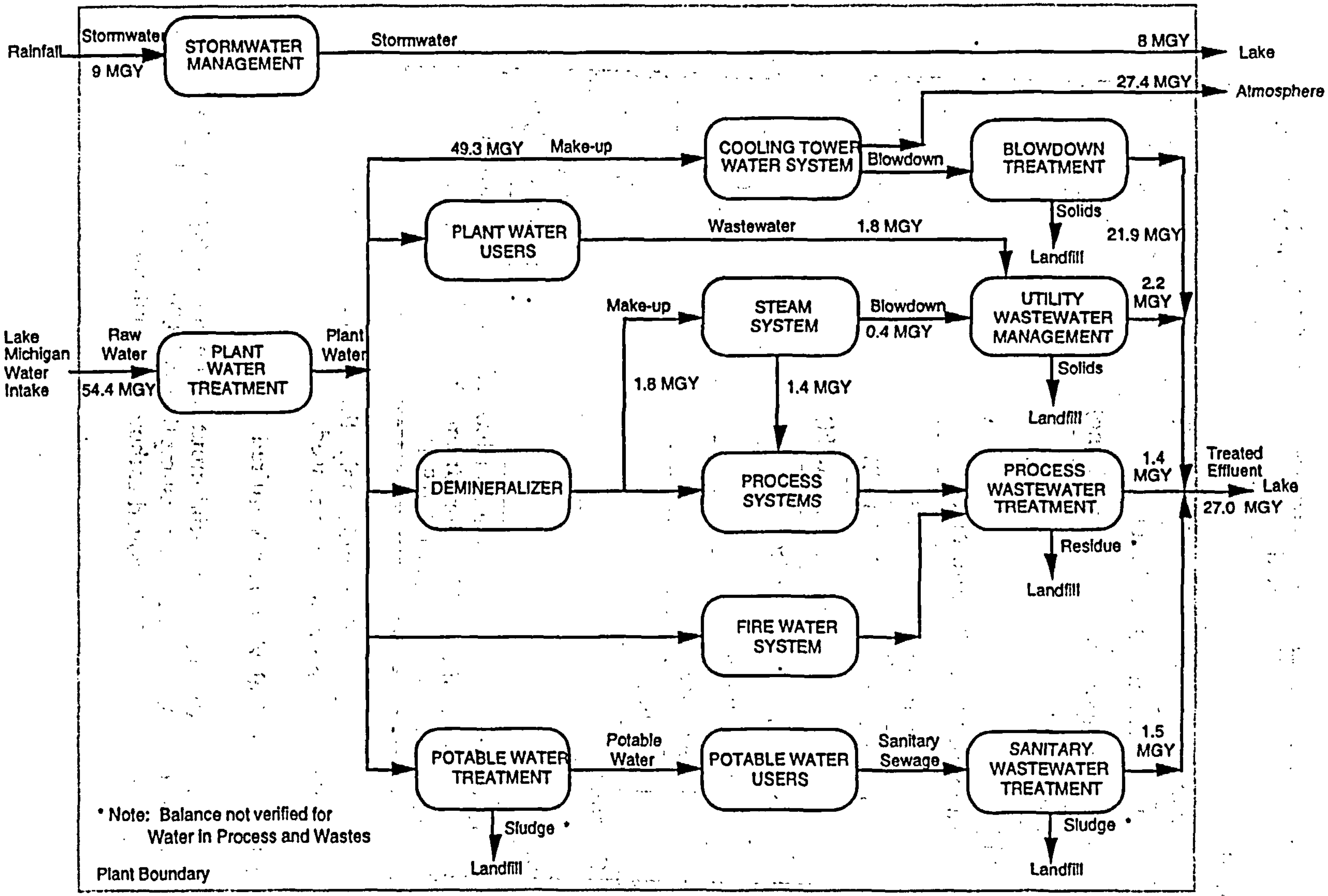


Figure 5-1 Preliminary Water Balance
Ceramic UO2 / HF Neutralization

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.

10.0 References

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11.0 Glossary

List of Acronyms

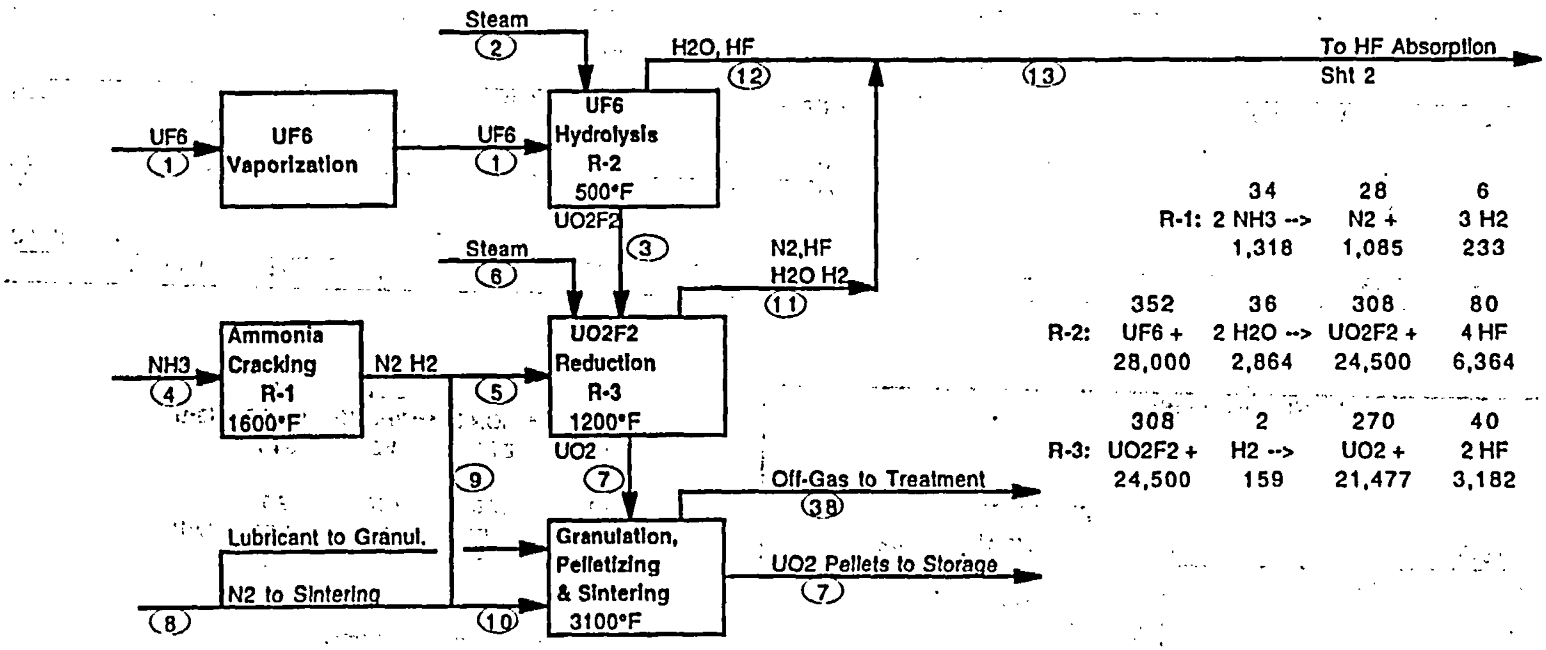
ANSI	American National Standards Institute
CaF_2	calcium fluoride
Ci	curie(s)
cfm	cubic feet per minute
CFR	Code of Federal Regulations
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DOT	Department of Transportation
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 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
Chemical Conversions

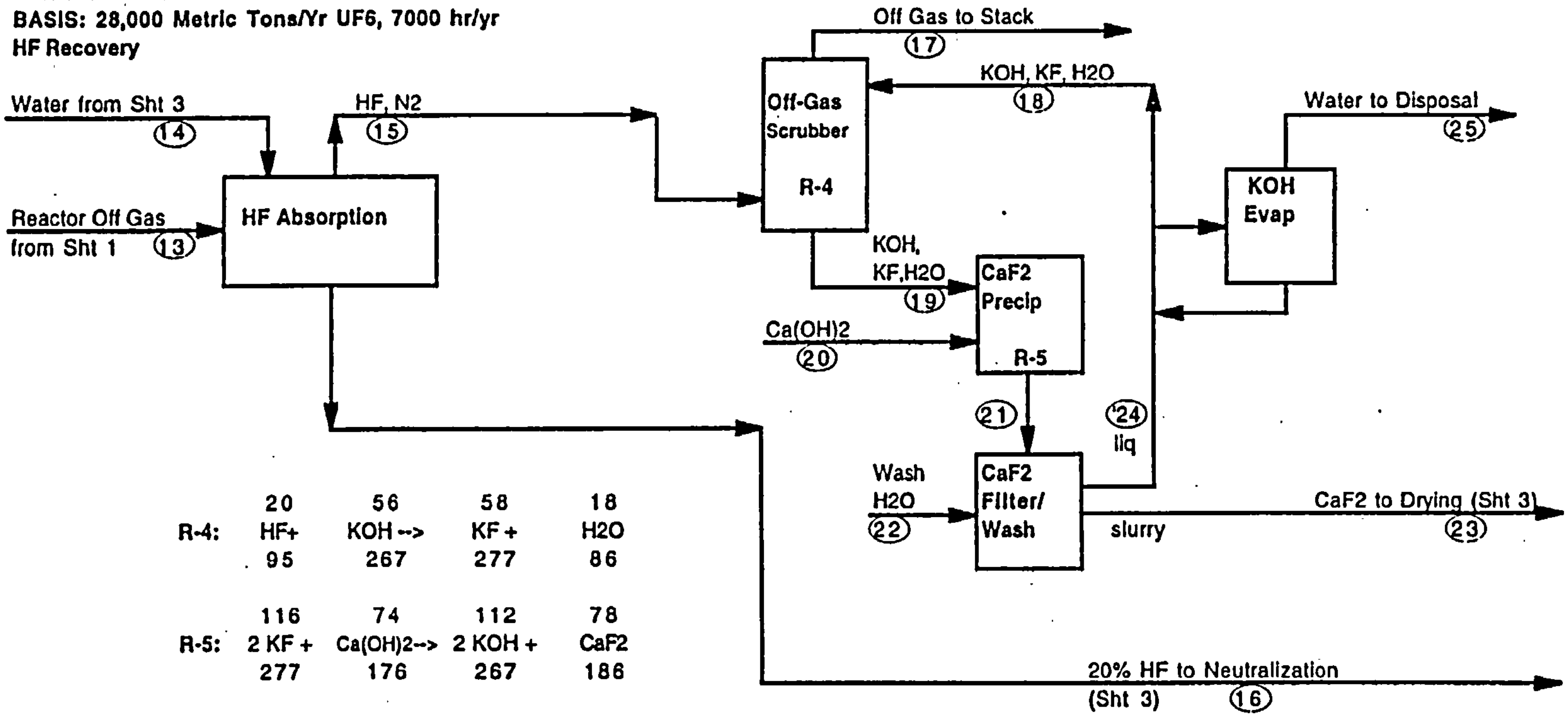


		34	28	6
R-1:		2 NH3 -->	N2 +	3 H2
		1,318	1,085	233
	352	36	308	80
R-2:	UF6 +	2 H2O -->	UO2F2 +	4 HF
	28,000	2,864	24,500	6,364
	308	2	270	40
R-3:	UO2F2 +	H2 -->	UO2 +	2 HF
	24,500	159	21,477	3,182

	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

4-Mass Balance MT/yr

CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery



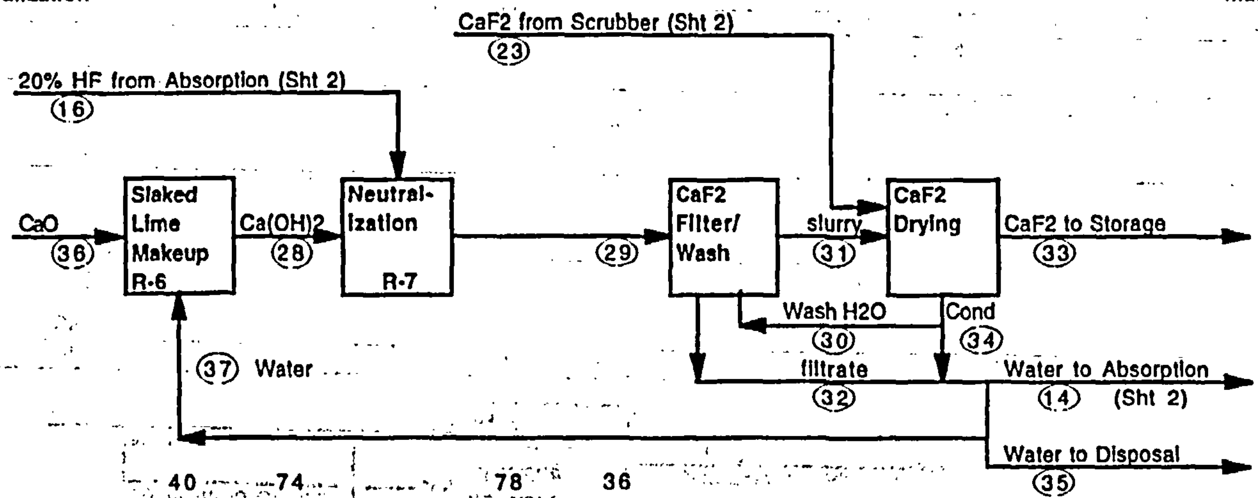
	20	56	58	18
R-4:	HF+	KOH -->	KF +	H2O
	95	267	277	86
	116	74	112	78
R-5:	2 KF +	Ca(OH)2-->	2 KOH +	CaF2
	277	176	267	186

	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	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

Sheet 2

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



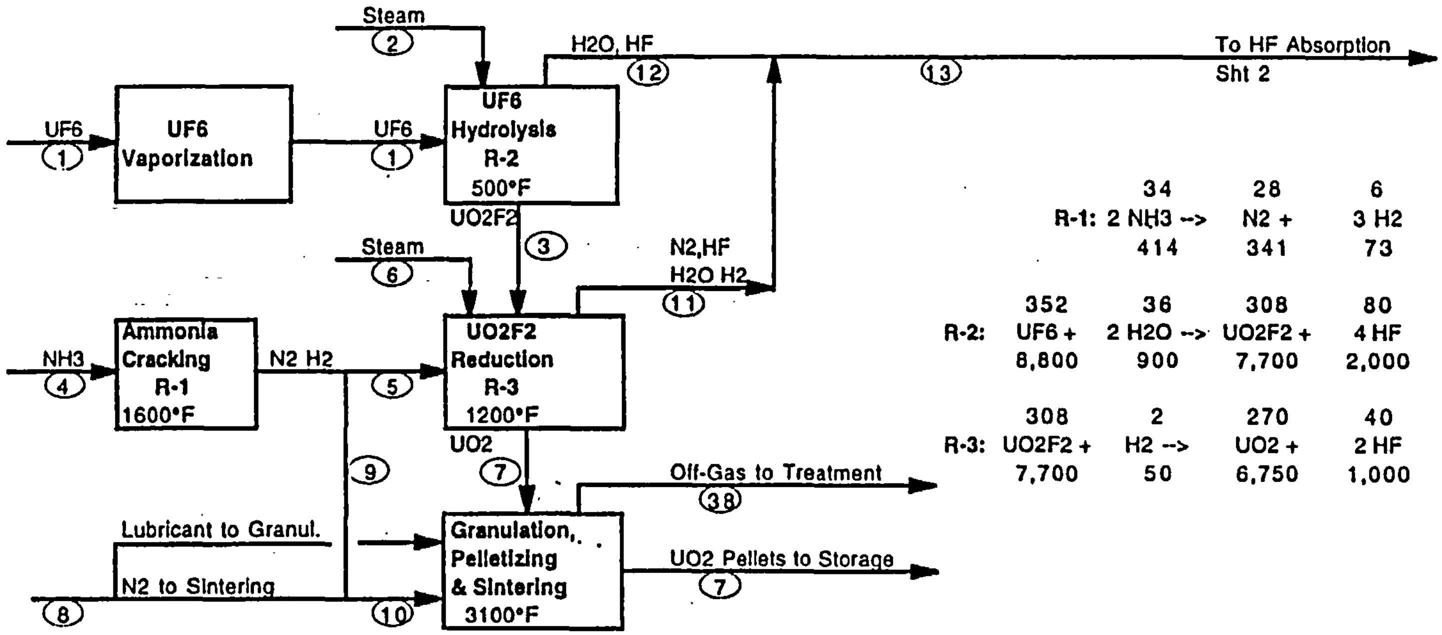
	40	74		78	36
R-7:	2HF +	Ca(OH)2	--->	CaF2 +	2H2O
	9,450	17,483		18,428	8,505

	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												5,853
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

4-Mass Balance lb/hr

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

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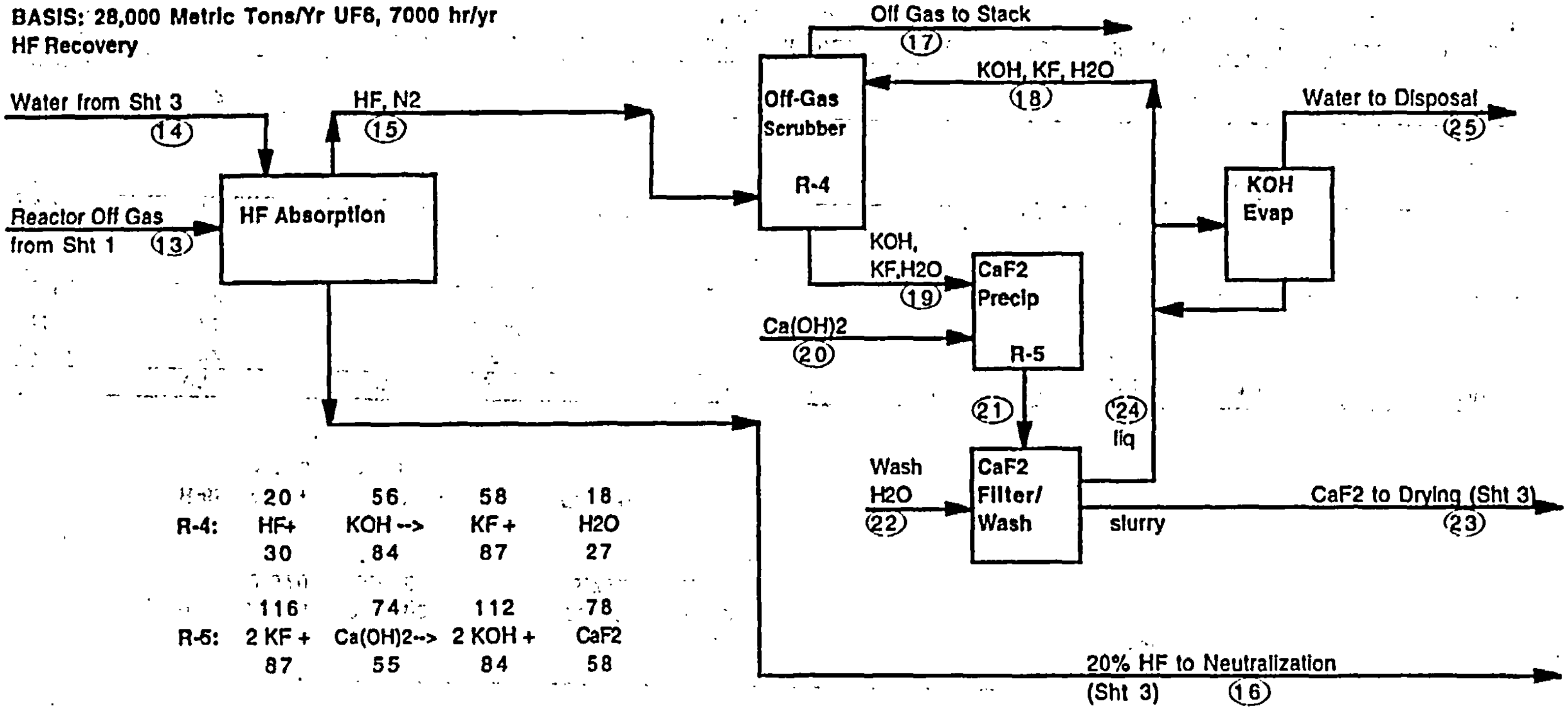
Sheet 1

CERAMIC UO2 / HF NEUTRALIZATION
BASIS: 28,000 Metric Tons/Yr UF6, 7000 hr/yr
HF Recovery



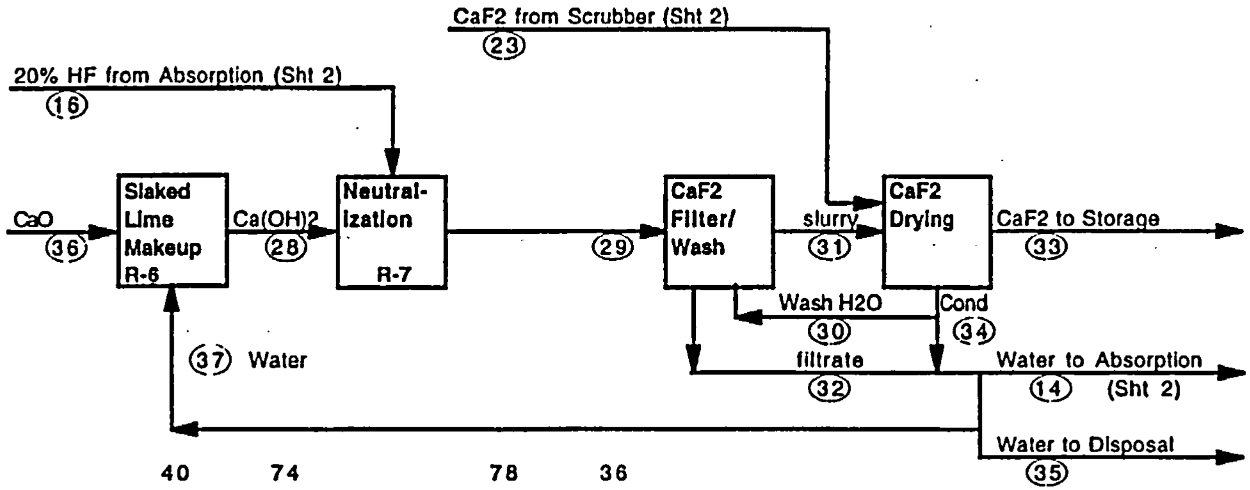
	20	56	58	18
R-4:	HF+	KOH -->	KF +	H2O
	30	84	87	27

	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	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 accountablility 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	Yard/Buildings
	Sprinkler System	Buildings
	Alarm system	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	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 - 4100 gpd	Sanitary Treatment area
	Industrial wastewater treatment system - 80,000 gpd	Wastewater Treatment area
	Electrical substation - 3200 kW	Substation
	Emergency generators - 2 @ 500kW	Substation
	Uninteruptible Power Supply - 100 kVA	Proc. Bldg
	Cooling Tower - 31 MM Btu/hr, 3100 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, 2-3000 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

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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.