

11.0 PLANT SYSTEMS

11.2 AQUEOUS POLISHING PROCESS AND CHEMISTRY

11.2.1 CONDUCT OF REVIEW

This section of the revised Draft Safety Evaluation Report (DSER) contains the staff's review of the Aqueous Polishing (AP) process safety described by the applicant in Chapter 11.3 of the revised Construction Authorization Request (CAR) (Reference 11.2.3.4), with supporting process safety information from Chapters 5, 8, and 11 of the revised CAR, supplementary information provided by the applicant, and relevant documents available at the applicant's offices but not submitted by the applicant. The staff also reviewed technical literature as necessary to understand the process and safety requirements. The objective of this review is to determine whether the chemical process safety principal structures, systems, and components (PSSCs) and their design bases provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents. The review of AP safety design bases and strategies was closely coordinated with the review of the radiation and chemical safety aspects of accident sequences described in the Safety Assessment of the Design Bases (see Chapter 5.0 of this Revised DSER), the review of fire safety aspects (see Chapter 7.0 of this Revised DSER), and the review of plant systems (see Chapter 11.0 of this Revised DSER).

The staff evaluated the aqueous polishing process and chemistry information in the revised CAR against the following regulations:

- Section 70.23(b) of 10 CFR states, as a prerequisite to construction approval, that the design bases of the PSSCs and the quality assurance program be found to provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.
- Section 70.64 of 10 CFR requires that baseline design criteria (BDC) and defense-in-depth practices be incorporated into the design of new facilities or new processes at existing facilities. With respect to chemical protection, 10 CFR 70.64(a)(5) requires that the Mixed Oxide Fuel Fabrication Facility (MFFF or the facility) design provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemical produced from licensed material. Related to chemical protection, 10 CFR 70.64(a)(3) requires that the facility design provide for adequate protection against fires and explosions, such as those that could be initiated by or involve chemicals at the proposed facility.

The review of the revised CAR focused on the design basis of chemical process safety systems, their components, and other related information. For each chemical process safety system, the staff reviewed information provided by the applicant for the safety function, system description, and safety analysis. The review also encompassed proposed design basis considerations such as redundancy, independence, reliability, and quality. The staff used Chapter 8.0 of NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility," as guidance in performing the review (Reference 11.2.3.6).

As stated in the Memorandum of Understanding between the Nuclear Regulatory Commission and the Occupational Safety and Health Administration: Worker Protection at NRC-licensed Facilities,” (*Federal Register* Vol. 53, No. 210, October 31, 1998, pp. 43950-43951), the NRC oversees chemical safety issues related to: (1) radiation risk produced by radioactive materials; (2) chemical risk produced by radioactive materials; and (3) plant conditions that affect the safety and safe handling of radioactive materials, and, thus, represent an increased radiation risk to workers. The NRC does not oversee facility conditions that result in an occupational risk but do not affect the safe use of licensed radioactive material. The MOU provisions applicable to the proposed MOX facility are now codified in 10 CFR 70.64(a)(5).

The NRC staff reviewed the following areas of the revised CAR applicable to process safety at the construction approval stage and consistent with the level of design (Reference 11.2.3.6, page 8.0-8):

- AP Description.
- Hazardous Chemicals and Potential Interactions Affecting Licensed Materials.
- AP Chemical Accident Sequences.
- AP Chemical Accident Consequences.
- AP Safety Controls.

Additional documentation from the applicant and the literature was reviewed as necessary to understand the process and safety requirements. In addition, the revised CAR incorporates the BDC of 10 CFR 70.64(a) into the design and operations of the proposed facility (see revised CAR, page 5.5-53), and applicable sections of the revised CAR are intended to demonstrate compliance with these BDCs. The staff’s detailed evaluation of the proposed AP process is presented in the sections that follow.

11.2.1.1 System Description of the AP Process

This section provides a description and overview of the AP Process, including design, operational, and process flow information. A summary of the major components and its function is discussed in Section 11.2.1.2

The AP process is designed to receive weapons-grade plutonium from the proposed pit disassembly and conversion facility (PDCF) at Savannah River Site (SRS) and to remove the impurities from the feed plutonium from the PDCF for use in the MP process. There are three major steps in AP:

1. **Dissolution of PuO₂ powder by electrically-generated silver(II) ions:** The dissolution step involves the use of silver as a catalyst, in a nitric acid medium. This route is independent of the powder characteristics. Dissolution is complete and rapid, with the rate determined by the generation of the silver(II) ions, at relatively mild temperatures (68^B-104^B F [20^B-40^B C]). Dechlorination is required prior to dissolution for those powders containing chlorides.
2. **Plutonium purification by solvent extraction:** Purification extracts and recovers plutonium, regenerates the solvent, and recycles nitric acid. Solvent extraction removes impurities such as gallium with very little loss of plutonium to the waste streams.

3. **Conversion into PuO₂ by continuous oxalate calcination:** Precipitation and calcination of the plutonium oxalate is a standard process used to prepare plutonium dioxide fuels.

The proposed design of the AP process is similar to the design currently employed at La Hague's Plutonium Finishing Facilities. Departures from the La Hague design result from United States regulatory requirements, lessons learned at La Hague, or manufacturing and throughput requirements specific to the facility.

11.2.1.2 Major Components and Functions

11.2.1.2.1 Decanning Unit (Unit KDA)

The Decanning Unit consists of a series of workstations and gloveboxes distributed between the MP and AP areas. All cans entering the facility via this unit are initially packaged in 3013 standard containers and meet the 3013 standard. For this reason, the staff notes that such powders have been stabilized and are not pyrophoric or contain significant volatile species.

The three main functions of the Decanning Unit are:

- Density measurement (PDCF powders only).
- Opening of outer, inner, and convenience cans.
- Transfer of powder to a dissolution dosing hopper (PDCF powder) or to a reusable can for the Milling Unit (Alternate Feedstock [AFS] powder).

Density is determined from an X-ray level measurement on the entire, sealed 3013 container. Cans containing PDCF powders with a density less than 7 g/cc are sent to the dissolver for processing. PDCF powders with densities near or over 7 g/cc require ball milling and a subsequent, confirmatory density measurement to meet the less than 7 g/cc limit. All AFS powders are ball milled. In addition, AFS powders are analyzed as follows:

- If chlorinated species are detected, the reusable can is emptied into the dosing hopper of one of the electrolyzers in the Dechlorination and Dissolution Unit.
- If the powder does not contain chlorinated species, the reusable can is returned to the Decanning Unit for feeding into the dosing hopper of the Dissolution Unit's electrolyzer.
- If the powder contains chemical species not compatible with the AP process, the powder is transferred to the Recanning Unit for repackaging.

The plutonium feed design basis is discussed in Section 11.2.1.4.

11.2.1.2.2 Milling Unit (Unit KDM)

The Milling Unit consists of a series of gloveboxes. The functions of the Milling Unit are:

- Mill AFS powders to homogenize the plutonium dioxide and decrease the particle size to a level compatible with the dissolution process;
- Perform density measurements on the milled powders;
- Sample the powder for chemical analysis; and
- Store powders while awaiting analytical results.

As described in Section 11.2.1.2.1, the AFS Powders are analyzed in the laboratory. Depending on the results of those analyses, the powder is transferred to different processes. If the concentration is found to exceed 500 micrograms/gram (500 ppm), the powder is directed to the feeding hopper for one of the two dechlorination hoppers. If the chloride level exceeds the design basis values discussed in Section 11.2.1.4, the reusable can is sent to the Recanning Unit for repackaging in a 3013 container.

11.2.1.2.3 Recanning Unit (Unit KDR)

The Recanning Unit consists of two gloveboxes and two workstations designed to repackage powders that are not compatible with the AP process into 3013 containers. The powder is analyzed prior to transfer out of any unit in the facility. The operations include welding, tightness, and contamination checks.

11.2.1.2.4 Dissolution Unit

The function of the Dissolution Unit is to dissolve PuO_2 powders containing less than 500 ppm chlorides. The PuO_2 is electrolytically dissolved in the Dissolution Unit as a precursor for separating impurities (specifically americium, gallium, and uranium) in the Purification Cycle. Samples from the dilution and sampling tank are analyzed to determine the fissile material content and the required degree of dilution before being sent to the Purification Cycle feed tank.

The dissolution kinetics are improved by augmenting the reaction with a strong oxidizing agent; in this case, by electrolytic dissolution with silver ions ($\text{Ag}[\text{II}]$). Silver ions ($\text{Ag}[\text{II}]$) are electrolytically produced in a cylindrical compartment. The electrolytic dissolution takes place in a 6N nitric acid solution at 86°F (30°C).

Hydrogen peroxide is added to the receiving tank used for interim storage to adjust the oxidation state of the plutonium from (VI) to (IV). A plutonium (IV) oxidation state allows for better extraction and separations processing. The peroxide also reduces any excess $\text{Ag}(\text{II})$ to $\text{Ag}(\text{I})$. The uranium impurity exists as the U-235 isotope (from radioactive decay of Pu-239 and nonseparable portions of the original pit - essentially more than 93 percent uranium enrichment or assay). Consequently, an initial isotopic dilution to around 30 percent assay is made by feeding the appropriate quantity of depleted uranium nitrate solution (0.25 percent U-235) to the receiving tank. Other adjustments (e.g., acidity) may also be made to the solution in the receiving tank to optimize subsequent purification of the plutonium.

11.2.1.2.5 Dechlorination and Dissolution Unit (Unit KDD)

The unit includes two electrolyzers, each smaller than the single electrolyzer in the Dissolution Unit.

The functions of the Dechlorination and Dissolution Unit are to remove chloride ions from the plutonium dioxide powder and then dissolve the material. The unit processes powders with chloride levels exceeding 500 ppm. The unit can also be used to process non-chlorinated feed materials (e.g., the PDCF feed).

Each electrolyzer line includes a scrubbing column for the removal of chlorine. In operation, the electrolyzers are operated in two modes. The first mode is dechlorination; electricity is applied and the chlorine gas is evolved at the anode as follows:



The applicant indicates that the process removes greater than 99% of the initial chloride in the powder, based upon operation with 6 N nitric acid and a temperature of 140^BF (60^BC).

In the second mode of operation (i.e., after chloride removal), the electrolyzer is operated in a manner completely analogous to the Dissolution Unit electrolyzer. Silver ions are fed into the electrolyzer and the powder is dissolved.

11.2.1.2.6 Purification Cycle (Unit KPA)

The Purification Cycle uses a plutonium uranium reduction extraction (PUREX) process (Reference 11.2.3.28). Plutonium nitrate from the Dissolution Unit is received, and plutonium is extracted and scrubbed for impurities. The plutonium with uranium left in the stream is stripped after adjustment of the plutonium valence to the trivalent state. The Purification Cycle includes plutonium reception, recycle, and transfer to the Oxalic Precipitation and Oxidation Unit. The Purification Cycle also controls the solvent and diluent streams to the Solvent Recovery Cycle and the raffinate stream to the Acid Recovery Unit.

The main goal of the Purification Cycle is to separate plutonium from impurities contained in the solution coming from the Dissolution Unit. In the revised CAR, the applicant identified the main functions of the Purification Cycle as follows:

- Receive plutonium nitrate from the Dissolution Unit.
- Perform plutonium extraction and impurities scrubbing.
- Perform plutonium stripping and diluent washing.
- Perform plutonium stripping in plutonium barrier.
- Perform uranium stripping and diluent washing.
- Adjust plutonium to the tetravalent state.
- Receive, control, recycle, and transfer plutonium to the Oxalic Precipitation and Oxidation Unit.
- Wash, control, and transfer raffinates diluent to the Acid Recovery Unit.
- Receive recycled plutonium nitrate from the Oxalic Mother Liquor Recovery Unit.

The selected aqueous-to-organic ratios in the plutonium extraction and plutonium stripping operations enable the process to obtain a plutonium concentration close to 0.34 lb/gal (40 g/L) at the outlet of the Purification Cycle.

11.2.1.2.7 Solvent Recovery Cycle (Unit KPB)

The Solvent Recovery Cycle operates continuously in conjunction with the Purification Cycle. Standard PUREX methods are used to wash the solvent and remove the degradation products.

In the revised CAR, the applicant identified the functions of the Solvent Recovery Cycle as follows:

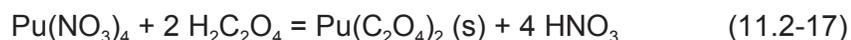
- Recover the used solvent from the Purification Cycle to prevent the accumulation of degradation products.
- Renew the solvent and adjust its tributyl phosphate (TBP) content.
- Store the treated solvent and continuously feed the Purification Cycle.
- Perform a diluent wash operation on the aqueous effluents produced by this operation to remove traces of entrained solvent (note: effluent in this section refers to effluent from individual process units to other process units; the facility discharges no radioactive liquid effluent directly to the environment.)

11.2.1.2.8 Oxalic Precipitation and Oxidation Unit (Unit KCA)

In the revised CAR, the applicant identified the functions of the Oxalic Precipitation and Oxidation Unit as follows:

- Receive purified plutonium nitrate concentrated to approximately 0.34 lb/gal (40 g/L) from the Purification Cycle and prepare uniform batches.
- Precipitate out the plutonium nitrate as oxalate.
- Produce PuO₂ after filtering, drying, and calcining the oxalate. The filtering operation includes drawing off the mother liquors, washing, and dewatering the plutonium oxalate cake.
- Transfer the PuO₂ to the Homogenization Unit, and transfer the mother liquors and the filter washing solutions to the Oxalic Mother Liquor Recovery Unit.
- Ensure reducing agents, hydrazoic acid, and Pu (VI) do not propagate into downstream processing units (e.g., the Oxalic Mother Liquor Recovery Unit).

The precipitation reaction is:



Plutonium nitrate solutions arrive from the Purification Cycle where acidity and valency are adjusted. Solutions are transferred by a pump to two dosing wheels, which supply one precipitator each.

The furnace consists of two main parts: a drying zone where the plutonium oxalate is dried, and a calcining zone where the oxalate is transformed into PuO₂ in an oxidizing atmosphere of oxygen. The overall reaction is:



The staff notes this is plutonium (IV) oxalate which generally requires a higher temperature (400^B-500^BC) for conversion to the oxide than either plutonium (III) or plutonium (VI) oxalates (around 200^BC). Potential concerns and controls for plutonium (VI) oxalate are discussed further in Section 8.1.2.5.1.6. Potential concerns and controls with plutonium(III) oxalate are discussed in Section 11.3 under plutonium pyrophoricity.

The oxalic mother liquors, which are collected in separator pots, flow by gravity to the Oxalic Mother Liquor Recovery Unit. The filtered mother liquors are adjusted to approximately 3.3N with recovered 13.6N nitric acid to avoid any risk of precipitation of plutonium oxalate caused by residual oxalic acid.

The gases produced during drying and calcination of the plutonium oxalate (e.g., CO₂ and steam, NO_x, and trace organics), the excess of oxygen, and the air from upstream and downstream of the process are removed by a negative-pressure circuit. This system is comprised of a filter, a condenser, a demister, an electric heater, two high efficiency particulate air (HEPA) filters, and two fans.

11.2.1.2.9 Homogenization Area (Unit KCB)

The PuO₂ produced in the Oxalic Precipitation and Oxidation Unit is continuously fed by gravity from the calcination furnace into one of the two separating hoppers installed in parallel. The plutonium material balance is determined by weighing the filled cans (Canning Unit) and by determining the plutonium content of the hopper by powder sampling. Sampling ensures that all the finished product specifications are met in each batch of PuO₂ in each hopper and checks the isotopic composition of the PuO₂ for the finished product of each batch in each hopper.

In the revised CAR, the applicant identifies the functions of the Homogenization Unit as follows:

- Receive and homogenize the PuO₂ produced in the Oxalic Precipitation and Oxidation Unit.
- Fill cans with PuO₂ in such a manner that the mass of plutonium per can is constant.
- Prepare samples for laboratory analysis to characterize the batch.
- Perform sample-based residual moisture measurement.
- Perform thermogravimetry analysis.
- Store reference samples.

11.2.1.2.10 Canning Unit (KCC)

The Canning Unit is designed to package PuO₂ powder in reusable stainless steel cans and transfer the cans to the MP PuO₂ Buffer Storage Unit to prepare the MOX powder. It is also used to establish the PuO₂ powder material balance. The PuO₂ powder is gravity-fed from the

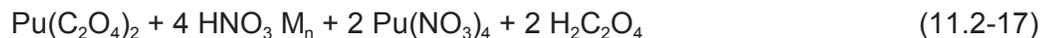
homogenizer at a temperature not exceeding 302°F (150°C). Full PuO₂ cans are transferred pneumatically in a shuttle to the MP PuO₂ Buffer Storage Unit. Cans that are rejected due to overfilling (as indicated by weighing) or unsatisfactory laboratory results are transferred and recycled to the appropriate upstream process.

11.2.1.2.11 Oxalic Mother Liquor Recovery (Unit KCD)

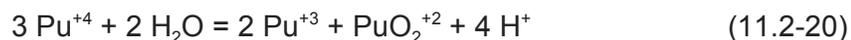
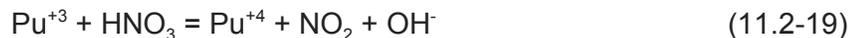
In the revised CAR, the applicant identified the functions of the Oxalic Mother Liquor Recovery Unit as follows:

- Continuously receive oxalic acid mother liquors adjusted to 3.3 N with nitric acid from the Oxalic Precipitation and Oxidation Unit.
- Continuously receive ventilation effluent droplets from the oxidation and degassing columns.
- Concentrate the oxalic mother liquors in a subcritical evaporator to destroy the oxalic acid and purify the overhead product.
- Check and transfer the overhead to the Acid Recovery Unit.
- Monitor and recycle, at a controlled rate, the concentrates to the top of the Purification Cycle.

The Oxalic Acid Mother Liquor Recovery Unit operates continuously, whereas the Oxalic Acid Precipitation and Oxidation Unit, which produces the oxalic mother liquors, operates in a batch mode. The mother liquor solution flows by gravity into the buffer tanks. After sampling for plutonium concentration, an airlift transfers the solution into a feed tank. These tanks have a geometrically safe, annular design. A double airlift transfers the solution from the feed tank into an evaporator. The evaporator concentrates the liquor and generates a relatively clean overhead product (distillate). In the evaporator, residual plutonium oxalate is converted into plutonium nitrate and oxalic acid. In the presence of manganese(II) ions (added as a catalyst) and excess nitric acid, the resulting free oxalic acid decomposes into carbon dioxide, water, and NO_x. The reactions are:



The evaporator exposes the plutonium nitrate to prolonged boiling (100-135°C) in a highly acidic and oxidizing environment. Consequently, plutonium (IV) and plutonium (III) are oxidized to plutonium (VI) nitrate by reactions such as the following:



The distillate is condensed and cooled, and a small percentage is returned to the evaporator/column system to supply reflux via a pot. The net distillate product is analyzed for the plutonium concentration by an online neutron counter. The applicant states in the revised CAR that, if the concentration is sufficiently low, the distillate is routed to the Acid Recovery

Unit. If the plutonium specification is exceeded, the distillate is transferred to the buffer tanks for recycle and retreatment.

The concentrates are removed from the evaporator by an airlift and placed in small buffer tanks. Due to the oxidation reactions, the plutonium is present in the hexavalent oxidation state (as PuO_2^{+2}). The applicant notes in the revised CAR that, if the residual oxalate concentration meets requirements, then the concentrates are returned to the Purification Unit via an airlift.

11.2.1.2.12 Acid Recovery Unit (KPC)

In the revised CAR, the applicant identifies the following functions for this unit:

- Receive extraction raffinates from the Purification Cycle in batches, and continuously receive oxalic mother liquor distillates from the Oxalic Mother Liquor Recovery Unit and active liquid effluents from the Offgas Treatment Unit equipment ventilation.
- Recover concentrated acid for recycling in the process.
- Recover distillates from the rectification column.

The unit uses evaporation as the principal treatment method. The feed tank receives the following:

- Raffinates from the Purification Cycle in batches
- Oxalic mother liquor distillates (Oxalic Mother Liquor Recovery Unit evaporator 3000) continuously.
- Recombined acid from the Offgas Treatment Unit.
- Effluents from laboratories in batches.

11.2.1.2.13 Silver Recovery Unit (Unit KPF)

The applicant has decided to eliminate this unit for economic reasons.

11.2.1.2.14 Offgas Treatment Unit (KWG)

The Offgas Treatment Unit ventilation system is dedicated to vapors and gases from processing equipment. In the revised CAR, the applicant identifies the functions of this unit as follows:

- Remove plutonium from offgases collected from the Dissolution Unit and from the oxidation and degassing columns (Purification Cycle).
- Recombine the nitrous fumes in a specific NO_x scrubbing column.
- Clean, by water scrubbing, the offgases collected from all the AP units.
- Treat the offgas flow by HEPA filtration before release to the stack.

- Maintain negative pressure in the tanks and equipment connected to the process ventilation system.

A specific Offgas Treatment Unit extraction system is dedicated to the pulsed purification columns, with similar functions:

- Treat offgases by HEPA filtration before release to the stack.
- Maintain negative pressure in the pulsation system and the pulsed columns legs.

The applicant states that specific operating limits and the associated items relied on for safety (IROFS) will be provided in the integrated safety analysis (ISA).

11.2.1.2.15 Liquid Waste Reception Unit (Unit KWD)

The Liquid Waste Reception Unit receives liquid waste from the AP process for temporary storage before sending it to SRS for treatment and processing (revised CAR Sections 11.3.2.14 and 10.1.4). The functions of this unit are to treat the following liquid waste streams:

- The low level liquid waste stream, which is comprised of the following: (1) room HVAC condensate, rinse water from laboratories, and washing water from sanitariums which are potentially non-contaminated and are collected as low-low-level liquid waste; (2) the distillate stream from the acid recovery unit which is contaminated and slightly acidic; (3) miscellaneous floor washes from C2/C3 rooms and overflows or drip tray material from some of the reagent tanks in the AP building; and (4) the chloride stream from the scrubbers used during the dechlorination step for AFS feeds (i.e., from the Dechlorination and Dissolution Unit). ***Text removed under 10 CFR 2.390.**
- The high alpha waste stream is a combination of three waste streams: americium, alkaline waste, and excess acid. The americium stream collects americium and gallium nitrates, and all of the silver used in the dissolution unit, along with traces of plutonium. The alkaline waste stream from the solvent recovery area contains dilute caustic soda (NaOH), sodium carbonate, sodium azide, and traces of uranium and plutonium. The excess acid stream from the acid recovery unit contains high alpha activity excess acid. The high alpha storage tank along with the high alpha buffer storage tank are a holding point for high alpha wastes and provide 90 days of storage. ***Text removed under 10 CFR 2.390.**
- The stripped uranium (< 1% U-235) waste stream receives the contents of the uranium dilution tanks in the purification cycle. ***Text removed under 10 CFR 2.390.**

***Text removed under 10 CFR 2.390.**

11.2.1.2.16 Uranium Dissolution Unit (Unit KDC)

The function of the Uranium Dissolution Unit is to dissolve depleted uranium dioxide powder (0.25% assay) for subsequent use as an isotopic diluent in the AP process.

The first step of the dissolution process is the receipt of drums containing uranium dioxide powder from the MOX Secured Warehouse Building. The drums are emptied into a pouring station inside a glovebox; nitrogen is used as a scavenger to avoid UO_2 oxidation (burnback). The powder is transferred to a receiving hopper, weighed, and placed in a dissolution tank. The powder is dissolved in 13.6 N nitric acid, heated to 95^B C.

After dissolution, the solution is cooled, analyzed, and transferred to an agitated buffer tank. The buffer tank stores the depleted uranium nitrate solution until it is needed for isotopic dilution in the Dissolution Unit, Dechlorination and Dissolution Unit, and the Purification Unit.

Nitrogen oxides produced by the dissolution process are mixed with compressed air, and treated in a dedicated NO_x scrubbing column using water and recirculating solutions (i.e., dilute nitric acid). Excess scrubbing solution overflows back to the dissolution tank. The column is designed for 85.8% NO_x removal. The scrubbed gas subsequently goes to the Offgas Treatment Unit.

11.2.1.2.17 Sampling System

The sampling system is used for radioactive and chemical solutions. The applicant discusses the three liquid sampling system approaches that the applicant intends to use at the facility in revised CAR Section 11.3.2.16 :

Direct sampling:

In direct sampling, the solution is directly extracted from the process equipment by gravity flow or with a recycling pump into a vial. Direct sampling is limited to nonaggressive reagents or effluents of suspect origin. A large sample volume provides a lower detection limit.

Suction sampling:

In suction sampling, a vial is filled by suction through a needle by the vacuum in the vial. Aggressive reagents can be sampled manually but with vacuum vial filling. Particles are not expected in the sampling system because all AP process solutions are expected to be clear. A moving cask is used for suction filling of active liquids.

Remote sampling

With remote sampling, the solution is lifted up by an airlift head from which direct vacuum sampling is carried out. For concentrated radioactive liquid waste, remote sampling under a box is required.

The applicant has stated that all sampling systems will be qualified using engineering studies and/or evaluations.

11.2.1.3 Staff Review of the AP Process System

11.2.1.3.1 Chloride Concentration of AFS Powder (Unit KDM)

The staff found that the 500 ppm limit on chloride concentration is not identified as a design basis yet it is used to direct the powder to processing via the dechlorination electrolyzers (i.e., with a chlorine scrubber) or via the dissolution electrolyzer (i.e., no chlorine scrubber present). The staff notes that 500 ppm is a relatively small number and could lead to a correspondingly, relatively small release (approximately 5-10 grams). However, if a high chloride-containing stream is directed to the dissolution electrolyzer by mistake, an event involving a hazardous chemical release (chlorine gas) from radioactive material could result. Thus, up to 3-5 kilograms of chlorine could be evolved which could have an intermediate consequence on the site worker. The applicant has not identified PSSCs and design bases for such an event. The applicant should provide such information or justify why none are necessary. The staff identifies this as Open Item AP-07.

11.2.1.3.2 Electrolyzer (Unit KDB)

In its review, the staff could not find a clear delineation of the specific design bases associated with this component. A temperature limit is implied, based upon a potential overtemperature event. The applicant provided supplemental information (Reference 11.2.3.1) that discussed a loss of confinement scenario for the electrolyzer, based upon an over-temperature situation caused by a control system failure, electric isolation failure, or a loss of cooling. ***Text removed under 10 CFR 2.390.** The applicant concluded that the event must be either prevented or mitigated, and selected a prevention strategy to reduce the risk to the facility worker, based upon shutdown of the electrolyzer and natural cooling. The applicant identified the safety design basis as the detection of the high temperature (identified as >158°F [70°C]) and shutdown of the electrolyzer and related processes without exceeding any design limits or chemical control limits, using assigned channels on the emergency control system. Shutdown was understood to be termination of the electrical current. The PSSCs identified by the applicant are the temperature and shutdown controls, and the process safety I&C system

The applicant's response further noted that the electrolyzer is geometrically safe to preclude potential criticality events. The applicant mentioned isolation of the anode and cathode and an isolation monitoring system; these are not identified as PSSCs. The applicant also stated the scavenging and emergency air systems would be used to preclude the possibility of explosions, based upon the rate of hydrogen generated by radiolysis. Consequently, the applicant indicated the voltage to the electrolyzer would be limited.

The safety strategy for the site worker and the public relies upon mitigation features. The PSSC is the C3 confinement system, which has the safety function of filtration of radioactive materials from the air prior to release to the atmosphere.

In subsequent discussions (References 11.2.3.11 and 12), the applicant indicated that there will be multiple, redundant temperature sensors located at the highest temperature location(s). These would provide temperature signals to the Process Safety I&C System (a PSSC), which would terminate electrical power. The applicant has also stated the temperature design basis of 70 C incorporates the effects of potential reaction exotherms; the power is actually terminated prior to 70 C.

The NRC staff conducted a review of literature articles on electrical dissolution of plutonium dioxide (References 11.2.3.13-15). Key points from this review are:

- plutonium dioxide from different sources and calcination conditions (e.g., “high-fired”) can be effectively and rapidly dissolved
- multiple reactions are involved
- current efficiencies are in the 30-70% range
- NO_x is formed at the cathode; ammonia/ammonium ions can also be produced
- hydrogen is produced over a wide range of acidities and cathodic materials; at catholyte concentrations below about 2 N HNO₃, measured hydrogen gas concentrations exceeded 1% in the evolved gases. Potential reactions between evolved hydrogen and NO_x were not discussed.
- hydrogen is a concern because of potential flammability in the gas space and hydrogen embrittlement in certain metals used in construction (e.g., titanium).
- polarization curves were not available

Several safety or operational limits are mentioned in the literature, which would require shutting off the power if exceeded. These limits include catholyte density (e.g., an indirect measure of acid concentration), catholyte flow, off-gas hydrogen concentration, off-gas flow, cell temperature, anolyte cooling water flow, catholyte cooling water flow, cell applied voltage, and cell current. Conductivity and radioactivity monitoring for the cooling water were mentioned as a possible alarm condition. The staff also notes that cooling water inflow into the catholyte (e.g., from a leak) would change acid concentrations and potentially increase hydrogen generation rates.

The NRC expressed concerns about the completeness of the response for the electrolyzer, including the design bases, and assurances of adequate safety. The applicant stated that the single failure criteria applied to this area (Reference 11.2.3.1). In response to NRC questions regarding other potential PSSCs and design bases beyond solution temperature (e.g., cooling water/capacity, bulk versus localized measurements, and electrical parameters), the applicant responded that there were no other PSSCs for this unit and that particle size did not matter. Additionally, the applicant was not aware of any specific changes to the electrolyzer’s design because of operational experience from France.

In the revised CAR, an over-temperature event with the electrolyzer is identified in the Loss of Confinement category. The safety strategy for the facility worker utilizes prevention features. The PSSC is the Process Safety Control Subsystem. The safety function is to shut down process equipment prior to exceeding a temperature safety limit. The applicant states that the temperature limit will be established by considering all material limits associated with the glovebox. The applicant intends to perform final calculations and identify specific temperature setpoints during final design based upon the codes and standards identified in Section 11.6.7 of the revised CAR to assure that, subsequent to the shutdown of process equipment, normal convective cooling is sufficient (Reference 11.2.3.12). The staff interprets this as a commitment and concludes that, if normal convective cooling is found to be inadequate by the analysis, the analysis will require the issue to be addressed (e.g., by additional cooling means).

On page 11.6-16 of the revised CAR, setpoint design bases for the Process Safety Control Subsystem are identified as ANSI/ISA-67.04.01-2000. From clarifications provided during the August in-office review (Reference 11.2.3.12), the applicant indicated that the setpoint analysis will consider electrolysis, potential exotherms from reactions, and natural cooling effects. The staff concludes that this approach provides assurance that the design basis temperature of 70^B

C will not be exceeded, provides margin (i.e., vis-a-vis the boiling point of the solution, around 110^BC), and should prevent the over-temperature event. The staff has determined this to be acceptable for the construction permit stage. Thus, Open Issue AP-01 is now considered closed.

11.2.1.3.3 Hydrogen Production (Unit KDB)

The staff review noted that electrolytically generated hydrogen from over-voltage conditions and off-normal concentrations could produce hydrogen concentrations exceeding the lower flammability limit (LFL) if the scavenging air flow is based only upon radiolysis. In addition, over-voltage conditions could produce other undesirable effects such as different reaction products and gases, flow oscillations, sparking, and greater heating.

In the revised CAR, the applicant identifies the design basis for radiolytic hydrogen production as 50% of the LFL. It also identifies the LFL as the safety limit and 25% of the LFL as the projected setpoint. The LFL is identified as 4% of hydrogen in air under normal conditions. A prevention strategy has been selected (see revised CAR page 5.5-33), utilizing the PSSCs of the instrument air system (supplying scavenging air) and the offgas system (providing an exhaust path). The staff review notes that hydrogen is principally generated by radiolysis (on the anode side of the electrolyzer) and electrolysis (on the cathode side of the electrolyzer). The anode and cathode sides of the electrolyzer may be separated by membranes (i.e., the liquid phase) but will likely share a common header for venting to the offgas system.

Page 8-17 of the revised CAR discusses hydrogen produced by electrolysis. The design basis is stated as 50% of the LFL. It also identifies the LFL as the safety limit and 25% of the LFL as the projected setpoint. A prevention strategy has been selected (see revised CAR Section 5.5.2.4.6.13 on page 5.5-40), utilizing the process safety control subsystem as the PSSC. The safety function is to limit the generation of hydrogen from electrolysis by ensuring that the acid normality is sufficiently high and produces an off-gas that does not exceed the design basis (50% of the LFL). Acid normality measurements would be instrumented, perhaps by density measurements, and normality would be maintained by the PSSC of chemical safety controls (Reference 11.2.3.16). The applicant indicated that voltage control might also be used.

The staff review notes that the applicant's stated safety limit does not incorporate a safety factor or margin. The staff further notes that the general industrial practice is to use 25% of the LFL or less as the design basis for flammable gases in air (References 11.2.3.17 and 11.2.3.18) compared to 50% of the LFL identified by the applicant. A 25% limit is mentioned in revised CAR Section 11.9.5.1 for radiolytically generated hydrogen in and around process type systems, using scavenging air. During offnormal or accident conditions, scavenging air is provided by the PSSC of the Emergency Scavenging Air Subsystem of the Instrument Air System. This emergency scavenging air is provided to those vessels where radiolytic hydrogen generation could exceed 4% hydrogen (the ambient LFL) in 7 days or less if venting and dilution were not maintained; the design basis for the scavenging air would still be 1% hydrogen (i.e., 25% of the ambient LFL).

As part of its review, the staff considered the following:

- The NRC used 25% of the LFL for hydrogen in a manner analogous for tank ullages in a radiochemical plant review (Reference 11.2.3.17). Consideration for this limit included NFPA code evaluation, radiolysis, chemical reactions, and uncertainties in ventilated process equipment in radiochemical facilities.

- The NRC inspects fuel cycle facilities based upon not exceeding 25% of the LFL.
- The DOE uses 25% of the LFL for waste tanks and facilities at Savannah River and Hanford in a manner analogous to design basis.
- The Savannah River Site has hydrogen monitors installed in many ventilated tanks; these are set to alarm at 10% of the LFL (Reference 11.2.3.18).

NFPA 69 and 801 (References 11.2.3.5 and 19) emphasize 25% of LFL as an acceptable safety limit. The NFPA allows exceptions provided they are justified (e.g., well defined systems and chemistry, multiple continuous monitoring); such exceptions can allow concentrations up to 60% of the LFL.

The staff restates the need for a flammable gas design basis explicitly for the dissolution units that is justified, incorporates potential unknowns from chemical reactions and electrolysis, and provides adequate margin. The applicant has not provided an adequate safety design basis for the gas spaces in the electrolyzer and the ullage spaces in the dissolution unit. In addition, the applicant has not provided information regarding the design basis for controlling the electrolytic generation of hydrogen. Based on the applicant's hazard and accident analysis, the applicant should provide additional design basis information for flammable gases and vapors around the electrolyzers and associated systems or provide justification that it is not necessary. The staff identifies this as an open item AP-02.

The staff has reviewed the setpoints for the hydrogen detectors. The staff notes that the standards used are used extensively in industry. The staff finds the setpoints acceptable for the construction permit stage. The staff notes that a setpoint is not a design basis.

11.2.1.3.4 Titanium Reactions (Unit KDB)

The staff evaluation found that the applicant's proposed AP process uses oxidation-reduction chemistry based upon the silver (I) to silver(II) couple. Silver(II) is corrosive and special alloys are necessary for the electrolyzer equipment. The applicant stated (Reference 11.2.3.1) that it intends to use titanium for the electrolyzer circuit and associated equipment that could be exposed to silver(II) ions. The applicant identifies a negligible corrosion rate for titanium in the presence of silver(II) and nitric acid. The applicant intends to destroy silver(II) (i.e., by conversion into silver(I)) prior to the solutions contacting other equipment in the process that are fabricated out of 300 series stainless steels. Destruction would be accomplished by the addition of peroxide, which reduces the silver(II) back to silver(I).

The staff finds that a higher alloy material, such as titanium (Reference 11.2.3.13-15), is needed for adequate corrosion resistance in the presence of aggressive conditions that are likely to exist in this electrolyzer. However, titanium is a reactive metal and industry has developed guidelines for the safe use of such alloys, particularly for protection during wet/dry cycling and heating (References 11.2.3.20-26). In addition, each electrolyzer operates with several hundred amps of current and multiple tens of volts. This is more than enough to be an ignition source and is comparable to or exceeds most typical welding supplies. There are no PSSCs and design bases identified by the applicant for electrical parameters on the electrolyzer. Thus, hot sparks cannot be discounted. Titanium exposed to hot sparks can ignite and burn, and there have been incidents of uncontrolled fires in titanium heat exchanger tube bundles (Reference 11.2.3.21). Titanium in heat exchanger tubes and in packing has ignited in chemical process industry applications.

Titanium reactions and/or fires are not listed as examples in Event types GB-1 and AP-5 of the revised CAR. It does not appear that the PSSCs relied upon for events AP-5 and GB-1 (C-3 confinement system and a fire suppression system) will necessarily mitigate the effects of a titanium fire for the site worker and public due to: the high temperatures involved; large "smoke" evolution and TiO_x embers and their effects on the filters; obvious boiling of solutions and entrainment of radioactive materials; and the rapidity of reactions and their effect on facility workers. All of these are likely to result in higher consequences. Finally, hot titanium may interact with other materials in the electrolyzer/glovebox area including nitrates/nitric acid, water in the solutions (which would produce hydrogen), hydrogen generated by electrolysis and radiolysis, and plutonium dioxide. Hydrogen embrittlement of titanium has been identified in the literature (Reference 11.2.3.15) as a concern with electrolytic dissolution of plutonium dioxide. Hydrogen embrittlement would both weaken the metal and increase its reactivity. The affinity of titanium for hydrogen and its potential reactivity with oxidizers (e.g., nitric acid) is also noted in the titanium Material Safety Data Sheet (Reference 11.2.3.25).

Furthermore, suppression systems (e.g., CO_2 , inergen) may exacerbate the titanium fire condition due to chemical interactions. For example:

(1) titanium combines readily with oxygen, nitrogen, and hydrogen at temperatures considerably below its melting point ($3,140^{\circ}F$). In reference to the inadvertent use of water for titanium fire suppression or electrolyzer solution water contacting hot titanium, NFPA 481 (Reference 11.2.3.20) states "the great affinity of high temperature titanium for oxygen will free a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces."

(2) the suppression system employed in glovebox areas is a clean agent (inergen). Inergen is composed of 52% nitrogen, 40% argon, and 8% CO_2 . As noted previously and in the fire protection literature, CO_2 and nitrogen actually react with hot titanium. NFPA 2001 (Reference 11.2.3.27) prohibits the use of clean agents on reactive metals, such as titanium, uranium, and plutonium, unless the clean agent has been tested to the satisfaction of the AHJ (Authority Having Jurisdiction).

Staff finds that the applicant should address titanium metal fire hazards in the safety assessment. The applicant's hazard and accident analysis did not include events involving titanium, such as titanium fires. Accident events should be evaluated and PSSCs identified, if necessary. The staff identifies this as Open Item AP-03.

11.2.1.3.5 Loss of Confinement (Unit KDB)

In Table 5.5-10 of the revised CAR, the applicant has identified a control strategy for loss of confinement events (leaks) of AP process vessels and pipes in process cells. This control strategy uses the process cell and its associated ventilation system as the PSSC for loss of confinement events. The applicant intends to contain fluid leaks within the cell and any airborne contamination would be treated with HEPA filtration prior to exhaust. For facility workers, the PSSC of process cell entry controls prevents the entry of personnel into process cells during normal operations and ensures that workers do not receive a dose in excess of limits while performing maintenance. The PSSC of the process cell entry controls has the safety function of containing leaks within the cell. The actual fluid leaks would not be prevented. There are no PSSCs identified for the site worker and the public.

The process cell ventilation system passive boundary is identified as the PSSC for environmental protection, with the safety function to provide filtration to limit the dispersion of radioactive material. The staff review identified a potential event involving an acute chemical exposure to facility and site workers from hazardous chemicals produced from licensed materials that leak from AP process vessels during such a loss of confinement event. Such a leak could occur due to erosion/corrosion of the vessels and piping. As discussed in Section 8.1.2.4.1, the applicant has proposed controls for chlorine and nitrogen tetroxide. However, the staff is also concerned about a liquid phase leak. The leak would consist of radioactive nitrate solutions which, once released from the vessels and pipes, would expose a large liquid surface area that allows a nitric acid and NO_x release into the cell's atmosphere. This material would not be removed by the HEPA filters on the exhaust system and would be released to the atmosphere.

The applicant indicated the distance from the point of one of these in-cell releases to the worker is approximately equal to the 100 meter distance to the site worker, and, hence, consequence estimates of such releases for the site worker should bound any consequences for the facility worker (Reference 11.2.3.16). The staff agrees with this qualitative distance analysis. This closes part of Open Item AP-13 from the original DSER. However, for 100-200 gallons of radioactive nitrate solutions, site worker limits could be exceeded for several hundred meters. Some of the solutions might be at temperatures above ambient which could result in worker limits being exceeded for larger distances. Thus, the performance requirements of 10 CFR 70.61(b)(4) and 10 CFR 70.61(c)(4) might not be met. As discussed in Section 8.1.2.4.1, the applicant has used lower air speeds with a velocity dependent evaporation model; some of the air speeds are as low as 0.01 m/sec (for comparison, a slight breeze is 1-2 m/sec). This issue is now included in Open Item CS-05, and Open Item AP-13 is closed.

As discussed in Section 8.1.2.4.1, the applicant has not identified a control strategy for this event involving the leak of radioactive nitric acid/nitrate solutions. The staff identifies this as an open issue, followed in Section 8.1.2.4.1 as Open Item CS-05. The applicant should identify a control strategy for this event, with PSSCs and design bases as necessary, or justify why none are required. At a minimum, this potentially impacts the following units: dissolution, dechlorination and dissolution, oxalic precipitation and oxidation, oxalic mother liquor, acid recovery, and liquid waste reception.

11.2.1.3.6 Oxalic Precipitation Concerns (Unit KCA)

The applicant has identified six categories of hazard events associated with the oxalic precipitation and oxidation unit. The types of events postulated in this unit include fire, explosion, loss of confinement, external exposure, load handling and criticality. The safety strategy, including the PSSCs and design basis safety functions for controlling events within these categories, is discussed in Revised DSER Chapter 5.

The staff notes that the applicant's description mentions acidification of the residual mother liquors to avoid the precipitation and unanticipated accumulation of residual plutonium by the oxalate. This indicates a potential for a safety function (i.e., avoid plutonium precipitation and potentially related accident scenarios, such as erosion or plugging that could lead to loss of confinement). The staff notes that the applicant is not relying on concentration control to prevent a nuclear criticality in this unit. The applicant has not proposed a control strategy, and any needed PSSCs and design bases, for hazardous chemical releases from the potential loss of confinement of radioactive materials in this unit. See the discussion on loss of confinement, above, for a description of the Open Item. (Open Item CS-05).

In addition, the staff notes the calciner uses oxygen. The applicant has committed to standards (see revised CAR, Section 11.9.4) for oxygen use and furnace applications. However, the calciner is likely to include components, such as bearings and seals, that have requirements to maintain their integrity. These components may be adversely affected and lose confinement integrity if operated at above ambient temperatures in the presence of air or oxygen. The applicant has identified nitrogen cooling of the calciner bearings as a means to protect them, presumably from the oxygen-rich environment, but has not identified this as a safety function. The issue of whether the nitrogen system is a PSSC because of its bearing cooling function has been discussed in Revised DSER Section 11.9. The applicant has not proposed a control strategy, or any PSSCs and design bases, for hazardous chemical releases from the potential loss of confinement of radioactive materials in this unit (i.e., the loss of confinement would allow an untreated flowpath (bypassing the Offgas Treatment System) for chemical releases from the nitric acid solutions, nitrate/oxalate mixture, and calciner gases).

The applicant has not identified a design basis for the plutonium dioxide powder produced by oxalic acid precipitation and oxidation. The staff is concerned that, without controls, the oxide powder may be substoichiometric or have entrained or absorbed solutions subject to radiolysis, and, thus, be pyrophoric and present a hazard.

11.2.1.3.7 Oxalic Mother Liquor Recovery (Unit KCD)

Prior experience with evaporators indicates the potential for the unintended accumulation of either solvent or plutonium, or both. The accumulation of material can result from changes in system chemistry (Reference 11.2.3.9). Such unintended accumulation can pose three hazards; inadvertent criticality, erosion-corrosion from accumulated solids, and the potential for red oil events.

The applicant has identified six categories of hazard events associated with this unit. The types of events postulated in this unit include fire, explosion, loss of confinement, external exposure, load handling and criticality. The safety strategy, including the PSSCs and design basis safety functions for controlling events within these categories, is discussed in Revised DSER chapter 5.

The staff notes that the applicant's description mentions acidification of the residual mother liquors to avoid the precipitation and unanticipated accumulation of residual plutonium by the oxalate. This indicates a potential safety function (i.e., avoid plutonium precipitation and potentially related accident scenarios, such as erosion or plugging that could lead to loss of confinement). The staff notes that the applicant is not relying on concentration control to prevent a nuclear criticality in this unit. The applicant has not proposed a control strategy, or any PSSCs and design bases, for hazardous chemical releases from the potential loss of confinement of radioactive materials in this unit. At a minimum, this applies to:

- The distillate product stream.
- The plutonium-containing stream returned to purification.
- The evaporator itself and associated vessels.

11.2.1.3.8 Acid Recovery Unit (Unit KPC)

The acid recovery evaporators operate on the stream containing americium, uranium, and traces of plutonium. This is essentially a high-alpha contaminated stream and effective decontamination between the concentrates (bottoms products) and the distillate (overheads product) has safety implications. The NRC would anticipate separation requirements and/or specifications for these evaporators and their products. This is related to 10 CFR Part 20 and will be reviewed as part of the review of the license application.

11.2.1.3.9 Red oil hazard

The staff concludes that the red oil phenomena, as discussed in Revised DSER chapter 8, applies to the following components of the AP process:

Oxalic Precipitation and Oxidation unit (Unit KCA): A red oil phenomena involving a calcining furnace was reported by Savannah River Site (SRS). The oxalic precipitation and oxidation unit includes a calcining furnace that will process materials similar to those processed at SRS. However, the applicant did not identify a red oil hazard in this unit.

Oxalic Mother Liquor Recovery unit (Unit KCD): Red oil phenomena are associated with evaporators that might contain PUREX processing chemicals. The oxalic mother liquor recovery unit uses an evaporator to concentrate oxalic mother liquors and destroy the oxalic acid. However, the applicant did not identify a red oil hazard in this unit.

Acid Recovery unit (Unit KPC): The feed stream to the Acid Recovery unit ultimately comes from the purification cycle and may contain traces of TBP, the solvent, and their (usually nitrated) degradation products. DOE experience with such streams indicate concerns with autocatalytic reactions, including potential explosions, at higher temperatures. A temperature limit of 135°C is identified by the applicant. However, as discussed in Revised DSER Chapter 8.1.2.5, the phenomena can initiate at lower temperatures and thus, there is clear emphasis in other applications for lower temperatures and additional controls for safety purposes. The staff concludes that red oil phenomena applies to this unit and that the applicant's hazard and accident analysis is not complete with respect to analyzing red oil phenomena.

Purification, Solvent Recovery, and Offgas Treatment Units (Units KPA, KPB, KWG): The staff concludes that the red oil phenomena and HAN reactions can occur in the purification cycle, solvent recovery cycle, and offgas treatment unit. The staff further concludes that the applicant's hazard and accident analysis is not complete with respect to analyzing red oil phenomena and HAN reactions.

Therefore, the staff concludes that the applicant should address red oil phenomena in the safety assessment of the design bases for these units. See Revised DSER Chapter 8 for discussion of red oil phenomena and HAN reactions. The open item related to these findings is tracked as Open Item CS-01. The applicant has committed to providing additional justification for red oil and HAN (Reference 11.2.3.10).

11.2.1.3.10 Offgas Treatment Unit (Unit KWG)

The applicant identified the offgas treatment unit as a PSSC with the safety function of providing an exhaust path for the removal of gases in process vessels (revised CAR Section

5.6). Mechanical design bases are identified in revised CAR Section 11.4.11.1.11. These include the following:

- Two stages of HEPA filters.
- Spark arrestors and prefilters in each final filtration assembly.
- Each HEPA stage field tested to have an efficiency of 99.95%.
- Fire rated dampers between designated fire areas.
- In-place HEPA filter testing capability in accordance with ASME N510 for the final filtration assemblies.
- Final filters and ductwork remain structurally intact during and after design basis earthquakes and withstand the effects of tornados.

The staff is concerned that other safety functions and design bases may be needed. The staff would anticipate, for example, design basis for measuring and detecting overpressure, flammable vapors, and hydrogen, and perhaps specific considerations for venting potentially reactive systems (such as red oil and HAN). Specific design basis values would be identified. The staff notes additional functions of this unit might include:

- Continuity of the first confinement barrier.
- Recombination of nitrous fumes (N_2O_4) in a specific NO_x scrubbing column.
- Remove, by water scrubbing, acidic gases collected from AP process units.
- HEPA filtration of the offgases (prior to stack release).
- HEPA filtration of offgases from the pulsed purification columns (prior to stack release).
- HEPA filtration of offgases from the calcination furnace (prior to stack release).

The staff also requested information on the “filtering line.” The applicant provided additional information and identified the following design features of the offgas unit (Reference 11.2.3.1, RAI 142; revised CAR Sections 11.3.2.11 and 11.3.2.13):

- Bubbling air scavenges tank ullage to maintain hydrogen concentrations at 1 percent or less.
- The system operates below the flash point of solvent vapors.
- Supplemental air is added to the system to further dilute any potential combustible concentration of gases and to maintain minimum volumetric throughput for the scrubbing and washing columns.
- The material of construction is stainless steel to resist the corrosive atmosphere.

- The HEPA filters are constructed of acid resistant materials.

The offgas system handles vapors and gas mixtures that are potentially combustible in air streams, such as hydrogen, hydrazine, and dodecane (the solvent). The applicant identifies a setpoint/ design basis/ safety limit of 25 percent of the LFL in air for hydrogen in Reference 11.2.3.1, RAI response 142 (Reference 11.2.3.33). In RAI response 122 (References 11.2.3.1 and 11.2.3.33), the applicant also identifies a limit of 25 percent of the LFL for hydrogen in air from radiolysis in vessels containing plutonium. The applicant has not identified a design bases limit for hydrogen and has not provided a design basis for other flammable gases and vapors. The staff identified design basis information associated with flammable gases as an open item. The applicant needs to provide additional design basis information for the offgas unit to maintain potentially flammable gases and vapors at safe concentrations below their LFLs at all times, along with PSSCs, or provide sufficient justification that none are necessary. This is identified as Open Item AP-08.

The staff notes that a limit of 25 percent of the LFL in air is routinely used by designers and operating facilities, and is embodied in codes and standards (see Reference 11.2.3.5, Section 5-3.2). Per NFPA 801 (Reference 11.2.3.5), suitable means shall be provided for analyzers, instrumentation, and alarms.

In Reference 11.2.3.1, response to RAI 142 (Reference 11.2.3.33), the applicant does not identify temperatures below the flashpoint of solvent vapors. No design bases or PSSCs are identified for the offgas treatment unit. The staff identified design basis information associated with solvent vapor temperature limits in the offgas system as an open item. The applicant needs to provide additional design basis information and any additional PSSCs for the offgas unit in order to maintain the temperature below the flashpoint of solvent vapors at all times, or provide sufficient justification that none are necessary. This is identified as Open Item AP-09.

The process handles gases and vapors that are potentially reactive and toxic, such as nitrogen tetroxide, nitric acid, NO_x , and hydrazine. The unplanned evolution of these gases - from and through radioactive solutions - via the offgas treatment unit could have potentially detrimental consequences that would likely exceed the performance requirements of 10 CFR Part 70 at considerable distances from the proposed facility. In addition, the applicant has identified removal of hazardous chemicals as a function of the offgas unit for protection of the HEPA filters (References 11.2.3.31 and 11.2.3.32). The staff identified design basis information associated with the offgas treatment and removal of potentially toxic and reactive gases as an open item. The applicant needs to provide additional design basis information to provide adequate removal of potentially reactive and toxic gases and maintain the first confinement barrier or provide sufficient justification that none are necessary. This is identified as Open Item AP-10.

11.2.1.3.11 Corrosion Control (Units KDB, KDD)

Lower alloys can be inadvertently exposed to aggressive conditions. For example, stainless steel would likely experience uneven pitting corrosion that could lead to premature leaks and failures if it is routinely exposed to low concentrations of silver(II) ions. The applicant has proposed a generic corrosion control program as a PSSC. This appears to be based upon general corrosion. The pitting corrosion that could occur from silver(II) ions might not be detected prior to failure by the proposed PSSC of a general corrosion control program, and, thus, the potential exists for the corrosion leak to release plutonium compounds (i.e., a loss of confinement).

In Reference 11.2.3.1, the applicant's mentions the use of stainless steel to resist corrosion in the offgas system and acid resistant materials in the HEPA filters. Corrosion resistant materials would be needed to maintain confinement of radioactive and chemical species. The staff concludes the design basis function of the corrosion function of the fluid transport system PSSC should address instrumentation and/or monitoring of components that could be exposed to aggressive species in the Offgas unit. The revised CAR identifies two administrative PSSCs that apply to corrosion. The first is chemical safety control. One of its safety functions is to ensure control of the chemical makeup of the reagents and to ensure segregation/separation of vessels/components from incompatible chemicals' i.e., planned corrosion exposures. The second PSSC is entitled material maintenance and surveillance programs (revised CAR Section 5.6.2.4). The safety function of this PSSC is to detect and limit the damage resulting from corrosion. As discussed in revised CAR Section 5.6.2.4, this PSSC can identify corrosion problems within the facility prior to catastrophic failures occurring (the "big" leaks). The PSSC is not required to prevent corrosion that could result in small leaks. Small is not defined but is inferred to be a small percentage of inventory. The staff concludes that this information provided in the revised CAR adequately addresses the staff's concerns about corrosion monitoring for preventing major failures. The staff finds this to be acceptable for the construction permit stage. This closes Open Items AP-04 and AP-11.

11.2.1.3.12 Liquid Waste (Unit KWD)

In revised CAR Section 10.1.4, the applicant discusses waste minimization and waste management. Liquid and solid wastes produced at the proposed facility will be transferred to the SRS for processing and disposal. DCS has worked closely with SRS during the facility design phase and has provided SRS with waste characterization information. SRS has reviewed and evaluated the information in the context of the existing Waste Acceptance Criteria (WACs). DCS is committed to meeting the SRS WAC or providing a stream that qualifies for a WAC Deviation and Exemption. The facility waste streams meet the SRS WAC except for the chloride stream. Based upon an evaluation by SRS (Reference 11.2.3.4), the chloride concentration is sufficiently close to the WAC that a WAC Deviation and Exemption for the SRS Effluent Treatment Facility (ETF) will be issued. The WAC for the SRS Waste Solidification Building (WSB) has not been issued, but the applicant states the interface between it and SRS will ensure that the WSB is designed to manage the facility high alpha waste stream and the depleted uranium stream. This was part of Open Item AP-05 in the original DSER. This portion of Open Item AP-05 (now designated as AP-05a) is considered closed.

The applicant states the alkaline waste stream will be acidified in a separate neutralization tank prior to being mixed with the diluted uranium nitrate in the high alpha waste tanks. Neutralization and acidification is performed to eliminate the potential for an explosion from azide formation that may form under alkaline conditions. In acidic media, the azides have a solubility limit greater than their concentration. Since the solubility limits of azides in alkaline media are lower, the alkaline media is neutralized to increase the solubility limits. This ensures that the azides do not precipitate and create an explosion potential. Chapter 8 of the revised CAR and supplemental information provided by the applicant identified pH control as serving a safety function. See Chapter 8.0 of this Revised DSER for further discussion of azide formation and an evaluation of the controls proposed by the applicant.

The applicant has identified the High Alpha Activity and Stripped Uranium waste transfer lines as PSSCs (Sections 5.5.2.3.6.5 and 10.5.2). These are double walled stainless steel pipes seismically qualified and designed with leak detection. The lines will be designed to accommodate mechanical and seismic loads. For load handling events, the safety strategy

relies upon prevention. The PSSCs are the waste transfer lines. The safety function is to protect the lines from activities taking place outside the MFFF building. For external events (e.g., external fires, explosions, extreme winds, tornadoes, missiles, rain, and snow/ice loadings), the safety function is to prevent damage to the line. The design basis for both functions is ASME B31.3 for process piping. ASME B31.3 requires consideration of loads in the design of piping. The staff analysis notes the code, the proposed approach with the waste transfer lines (i.e., double walled with leak detection), and the prevention strategy provide reasonable assurance that the design will not be damaged and release radionuclides outside of the MFFF building. The staff finds this acceptable. This was identified as Open Item AP-06. This item is now closed.*

The staff notes that an explicit inventory limit is not specified. Currently, the facility is designed to accommodate up to 90 days equivalent of most waste solutions (e.g., of the values in Table 11.2-4; the storage of the LLW destined for the ETF will likely be less than 90 days equivalent), although the applicant anticipates there will be transfers of liquid wastes every two weeks. The applicant has indicated the facility will shut down before exceeding the liquid waste storage capacity. The staff interprets this to mean active waste generating operations would be curtailed at some setpoint before the tankage is completely full, until the potential backlog of waste at the facility is cleared. Actual setpoints would be defined at the ISA stage. The staff finds this approach acceptable for the construction permit application.

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Both are bounded by the safety assessment, and, thus, the staff finds this acceptable for the construction authorization. This was identified as Open Item AP-05a. This item is now closed.

11.2.1.3.13 Sampling systems

Revised CAR Table 11.3-34 classifies the sampling systems. Revised CAR Section 11.11 provides information on the laboratory and indicates that a significant number of samples are required. The staff notes that laboratory personnel will most likely conduct the sampling. The applicant has provided information on a PSSC entitled laboratory material controls that limits quantities of hazardous and radioactive materials in the laboratory. Revised CAR Section 5.6.2.7 also states that procedures will be developed to establish limits on sample size and to ensure laboratory operations are performed in accordance with safe laboratory operating practices. The staff finds that the outline of the sampling approaches appears to follow typical practices used in the chemical and nuclear industries.

In addition, DCS has indicated that all sampling, with the exception of samples with very low levels of radioactivity, will be conducted within gloveboxes and that there are no bag-in/bag-out operations because the sample containers would be pneumatically transferred (flown) from stations within the gloveboxes to the laboratory. The revised CAR identifies gloveboxes as PSSCs, with the safety function of maintaining confinement integrity for design basis impacts (Section 11.4.11.2). Laboratory material controls addressed the handling of the samples within the laboratory. Only the low level waste samples would not be handled within gloveboxes and, qualitatively, the staff concludes this does not to present a challenge to the performance requirements of 10 CFR 70.61. The staff finds that the applicant has identified PSSC and design basis information and finds this issue has been adequately addressed for the construction permit stage. This closes Open Item AP-12.

11.2.1.4 Design Basis of the PSSCs and Applicable Baseline Design Criteria

The plutonium isotopic composition design basis for alternate feed source (AFS) and PDCF/ARIES feeds is identified by the applicant as follows (revised CAR Section 11.3.7):

- $^{236}\text{Pu} < 1$ ppb, at the origin of pit
- $^{238}\text{Pu} < 0.05$ percent
- $90 \text{ percent} < ^{239}\text{Pu} < 95 \text{ percent}$
- $5 \text{ percent} < ^{240}\text{Pu} < 9 \text{ percent}$
- $^{241}\text{Pu} < 1$ percent during lifetime of plant
- $^{242}\text{Pu} < 0.1$ percent.

The feed chemical impurities design bases were identified by the applicant and are listed in Tables 11.2-1 and 11.2-2. The radionuclide impurities design bases are listed in Table 11.2-3.

Table 11.2-1: Design Basis for Chemical Impurities in PDCF Feed Plutonium Dioxide

Chemical Component	Maximum Content (µg/g Pu)	Maximum Exceptional Content (µg/g Pu)	Chemical Component	Maximum Content (µg/g Pu)	Maximum Exceptional Content (µg/g Pu)
Ag	NA	10,000	Mg	500	10,000
Al	150	10,000	Mn	100	1,000
B	100	1,000	Mo	100	1,000
Be	100	2,500	N	400	400
Bi	100	1,000	Na	300	10,000
C	500	1,500	Nb	100	3,500
Ca	500	10,000	Ni	200	2,500
Cd	10	1,000	P	200	1,000
Cl	(+F < 250)	500	Pb	200	1,000
Co	100	10,000	S	250	1,000
Cr	100	500	Si	200	200
Cu	100	500	Sm	2	1,000
Dy	1	1,000	Sn	100	2,500
Eu	1	1,000	Ti	100	2,500
F	(+Cl < 250)	350	Th	100	100
Fe	500	2,500	V	300	2,500
Ga	12,000	12,500	W	200	2,500
Gd	3	250	Zn	100	1,000
In	20	1,000	Zr	50	1,000
K	150	10,000	Boron Equivalent	NA	
Li	400	10,000	Total Impurities	18,837	
NA = Not applicable or not available					
Maximum Exceptional Value means the maximum anticipated value for that element, with all others at the maximum value.					

Table 11.2-2: Design Basis for Chemical Impurities of AFS Plutonium Dioxide Feed Material

Chemical Component	Maximum Content for most (~75%) of Items (µg/g Pu)	Maximum Content exceeded only by 2% of Items (µg/g Pu)	Chemical Component	Maximum Content for most (~75%) of Items (µg/g Pu)	Maximum Content exceeded only by 2% of Items (µg/g Pu)
Ag	NA	10,000	I	NA	100
Al	4,000	15,000	In	20	2,500
Am	7,000 (100% ²⁴¹ Am)	7,000 (100% ²⁴¹ Am)	K	220,000	(Ca+K+Mg+Na) #40% Net weight
As	NA	100	La	NA	5,000
Au	NA	100	Li	5,000	10,000
B	100	1,000	Mg	70,000	(Ca+K+Mg+Na) #40% Net weight
Ba	5,000	10,000	Mn	1,000	2,000
Be	100	5,000	Mo	100	(Mo+Zr)<5,000
Bi	1,000	1,000	N	400	5,000
C	2,000	10,000	NO ₃	NA	5,000
Ca	120,000	(Ca+K+Mg+Na) #40% Net weight	Na	130,000	(Ca+K+Mg+Na) #40% Net weight
Cd	1,000	1,000	Nb	100	3,500
Ce	NA	500	Ni	5,000	15,000
Cl	200,000	330,000	Np	500	1,000
Co	5,000	10,000	P	1,000	(P+S)#10,000
Cr	3,000	8,000	Pb	200	5,000
Cu	500	3,000	Pd	NA	100
Dy	NA	NA	Pt	NA	100
Er	NA	500	Rb	100	5,000
Eu	NA	NA	S	330	(P+S)#10,000
F	1,000	7,000	SO ₄	1,000	(P+S)#10,000
Fe	5,000	18,000	Sb	NA	100
Ga	12,000	15,000	Si	5,000	10,000
Gd	250	250	Sm	NA	NA
Ge	NA	100	Sn	1,000	10,000
Hf	50	1,000	Sr	5,000	10,000
Hg	NA	100	Ta	4,000	10,000

Chemical Component	Maximum Content for most (~75%) of Items (µg/g Pu)	Maximum Content exceeded only by 2% of Items (µg/g Pu)	Chemical Component	Maximum Content for most (~75%) of Items (µg/g Pu)	Maximum Content exceeded only by 2% of Items (µg/g Pu)
Ti	100	3,000	V	300	1,000
Th	100	300	W	4,000	10,000
Tl	NA	100	Y	200	10,000
Enriched U (EU)	EU#30% Net weight	EU#30% Net weight Annual max. value: 50 kg (²³⁵ U:93.2%)	Zn	1,000	10,000
Depleted U (DU), Natural U (NU)	[TBD]	500,000	Zr	50	(Mo+Zr)#5,000

Table 11.2-3: Radionuclide Impurities in the Feed Plutonium Dioxide

PDCF Type

Impurity	Isotope	Maximum Content µg/g Pu
Americium	²⁴¹ Am: 100%	7,000 µg/g Pu (Note 1)
Uranium (HEU)	²³⁵ U: 93.2%	Standard value: 5,000 µg/g Pu Maximum value: 20,000 µg/g Pu for 10% of the delivered cans during one year Annual maximum value = 17 kg (Note 2)
<p>Note 1: At the plutonium design basis feed rate of 3.5 MTHM/yr, the americium annual quantity becomes 24.5 kg/yr. Note 2: The uranium standard maximum value corresponds to 17.5 kg/yr, while 10% at 20,000 and 90% at 5,000 [micrograms U/g Pu] correspond to 22.75 kg/yr.</p>		

AFS Type

Impurity	Isotope	Maximum Content µg/g Pu
Americium	²⁴¹ Am: 100%	11,000 µg/g Pu
Enriched Uranium	²³⁵ U: 93.2%	Maximum value: 30% of can net weight Annual maximum value = 50 kg
Depleted Uranium and Natural Uranium	²³⁵ U: 93.2%	Maximum value: 42% of can net weight (with 5% of Enriched Uranium)

The americium content design basis for PDCF/ARIES feed material is identified by the applicant as follows:

$$\frac{{}^{241}\text{Am}}{\text{Pu total} + {}^{241}\text{Am}} < 0.7 \text{ percent during the lifetime of the plant}$$

The feed PuO₂ powder to the AP process in the facility has a maximum density of less than 7 g/cc. Plutonium dioxide powder entering the facility can have a density up to 11.46 g/cc. Therefore, after receipt and storage, a density measurement is made. If necessary, a milling step is performed to ensure the density is below 7 g/cc.

The applicant states that feed materials which have an impurity content that exceeds a value listed in Tables 11.2-1, 11.2-2, and 11.2-3 can, in some cases, be processed at the proposed facility. The applicant will evaluate these batches for safety prior to acceptance for processing at the facility.

The NRC staff noted that these parameters and the values listed in Tables 11.2-1, 11.2-2, and 11.2-3 for the plutonium feed to the facility may affect the design and the safe operation of the facility. The applicant has identified these as design bases. The PSSC is chemical safety controls and the safety function is, "Ensure control of the chemical makeup of the reagents and ensure segregation/separation of vessels/components from incompatible chemicals." Per the staff review, this is an administrative control based upon analysis of the feed to the facility. The staff also concludes exceptional batches of plutonium dioxide that have impurity contents exceeding the design bases will be evaluated per the facility change process in 10 CFR 70.72. The staff concludes this approach provides assurance that the design basis plutonium feed parameters will not be exceeded and finds this to be acceptable for the construction permit stage. This part of Open Item AP-07 is considered closed. Section 11.2.1.3.1 discusses the remaining open part of AP-07.

The applicant has stated the Baseline Design Criteria (BDC) specified in 10 CFR 70.64(a) are incorporated into the design and operation of the facility (revised CAR Section 5.5.5.4). The applicant states information demonstrating compliance with these criteria is provided in the applicable chapters of the revised CAR. For chemical protection, 70.64(a)(5) states:

"Chemical protection. The design must provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from licensed material."

Chapter 8 of the SRP contains guidance and references to other peer reviewed work on the subject of chemical safety. To date, the applicant has not provided sufficient information to meet the requirements of 10 CFR 70.64(a)(5). The staff review using the SRP has identified open items and the staff concludes the applicant has not satisfied this BDC.

Related to chemical protection, the explosion protection BDC is stated as part of the fire protection BDC in 70.64(a)(3):

"Fire protection. The design must provide for adequate protection against fires and explosions."

Chapters 7 and 8 of the SRP describes the fire protection/explosion BDC and include guidance and references to other peer reviewed work on the subject. As discussed in Chapters 7, 8, 11.2, and 11.3, the staff review, using the SRP, has identified open items with respect to fire and explosions and the staff concludes the applicant has not satisfied this BDC.

11.2.2 EVALUATION FINDINGS

In Section 11.2.7 of the revised CAR, DCS provided design basis information for the AP process that it identified as PSSCs for the facility. Based on that the staff's review of the revised CAR and supporting information provided by the applicant relevant to the AP process, the staff finds that, due to the open items discussed above and listed below, DCS has not met the BDC set forth in 10 CFR 70.64(a)(3), for explosions, and (a)(5), for chemical safety. Further, until the open items are closed, the staff cannot conclude, pursuant to 10 CFR 70.23(b), that the design bases of the PSSCs identified by the applicant will provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

The open items are as follows:

- With respect to the electrolyzer, the applicant's hazard and accident analysis did not consider fires and/or explosions caused by ignition of flammable gases generated by chemical reactions and or electrolysis, such as from an overvoltage condition. This applies to the dissolution units (Revised DSER Section 11.2.1.3.3) (AP-2).
- The applicant's hazard and accident analysis did not include events involving titanium, such as titanium fires. Accident events should be evaluated and PSSCs identified as necessary. This applies to the dissolution unit (Revised DSER Section 11.2.1.3.4) (AP-3).
- Design bases have been identified for the plutonium feed to the facility. However, PSSCs and design bases should be identified for chloride containing feed material (e.g., AFS powder) so that it goes to the appropriate electrolyzer or a justification provided that it is not necessary (Revised DSER Section 11.2.1.3.1) (AP-7).
- The applicant needs to provide additional design basis information for the offgas unit to maintain potentially flammable gases and vapors at safe concentrations below their LFLs at all times, along with PSSCs, or provide sufficient justification that none are necessary (Revised DSER Section 11.2.1.3.10) (AP-08).
- A design basis and PSSCs are needed for maintaining temperatures below the solvent flashpoint (Revised DSER Section 11.2.1.3.10) (AP-09).
- Provide a design basis and PSSCs for protecting the HEPA filters from chemicals, such as removal of potentially toxic or reactive gases in the Offgas unit (Revised DSER Section 11.2.1.3.10) (AP-10).

The following open items in the April 30, 2002, draft Safety Evaluation Report, have been closed: AP-1, AP-4, AP-5a, AP-5b, AP-6, AP-11, AP-12, AP-13. See Appendix B.

DCS provided information on Open Item AP-2 (Reference 11.2.3.34). Because the information was recently received, it has not been included in this revision of the DSER.

11.2.3 REFERENCES

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- 11.2.3.13. L.A. Bray, J.L. Ryan, and E.J. Wheelwright, "Electrochemical Process for Dissolving Plutonium Dioxide and Leaching Plutonium from Scrap or Wastes," AIChE Symposium Series 254, Volume 83, Electrochemical Engineering

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