8. CHEMICAL PROCESS SAFETY

This chapter presents the preliminary chemical process safety assessment for the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF). It describes the chemical processes, major chemicals affecting licensed material and hazardous chemicals produced from licensed material, chemical accident sequences and consequences, process safety information, and safety interfaces.

The preliminary chemical process safety evaluation provides reasonable assurance that the MFFF design provides adequate protection against chemical and radiochemical hazards related to the storage, handling, and processing of licensed material as required by 10 CFR Part 70. The preliminary analyses conducted to date indicate that no additional principal structures, systems, and components (SSCs) are required that are not already identified for control of radiological or other hazards, except as noted in Section 5.5.2.10.6.3. Further chemical process safety evaluation will be performed as part of the detailed design and will be included in the Integrated Safety Analysis (ISA) Summary submitted with the license application for possession and use of special nuclear material (SNM).

8.1 CHEMICAL PROCESS DESCRIPTION

The MOX Fuel Fabrication Building and the Reagent Processing Building form the core group of buildings for plutonium polishing (i.e., aqueous polishing [AP] process) and MOX fuel fabrication (i.e., MOX processing [MP] process). The MOX Fuel Fabrication Building is a multifunctional reinforced-concrete structure containing all of the SNM handling, processing, and fuel fabrication operations. The building is comprised of three major functional, interrelated areas: the MP Area, the AP Area, and the Shipping and Receiving Area. The entire structure and the three component areas are designed for natural phenomena hazards (e.g., earthquakes, floods, tornadoes), as well as potential industrial-type accidents (e.g., load drop, fire) that could impact licensed materials. The Reagent Processing Building, located adjacent to the AP Area of the MOX Fuel Fabrication Building, provides space for storage and mixing of the chemical reagents used in the AP process. Chapter 11 provides detailed descriptions of the MFFF facilities and processes.

8.1.1 Chemical Process Summary

To meet commercial fuel purity specifications, a solvent extraction process is used to separate plutonium from gallium, americium, uranium, and other minor impurities. Polished plutonium oxide (PuO_2) is used to produce MOX fuel. Chemical processes take place as part of the AP and MP processes, supported by chemical preparation in the Reagent Processing Building.

8.1.1.1 Reagent Processing Building

No radioactive materials or radiochemicals are stored, processed, or commingled in the Reagent Processing Building. The floor level of the Reagent Processing Building is slightly above grade and the building has a below-grade collection tank room that receives waste chemicals from the building. The Reagent Processing Building is divided into discrete rooms/areas to segregate chemicals and the associated equipment and vessels to prevent inadvertent chemical interaction. Safety showers and eyewash stations are provided at various locations throughout the facility in accordance with applicable OSHA standards. A loading dock at one end of the Reagent

Processing Building is used for unloading and transfer of chemical containers into and out of the building. Waste chemicals (included those resulting from spills) originating from the Reagent Processing Building are pumped from segregated waste collection tanks to portable containers for proper disposal in accordance with applicable requirements.

Most reagents (e.g., nitric acid, hydrogen peroxide, hydroxylamine nitrate [HAN], hydrazine hydrate, oxalic acid, sodium carbonate, diluent [C10-C13 isoalkane], nitrogen tetroxide, sodium hydroxide, zirconium nitrate, and tributyl phosphate [TBP]) are stored and solutions are prepared in the Reagent Processing Building for use in the AP Area. Nitrates of silver, aluminum, and manganese are stored and prepared in the AP Area. Liquid chemical containers are located inside curbed areas to contain accidental spills. Chemicals are transferred to the AP Area from the Reagent Processing Building via piping located in a concrete, below-grade trench between the two buildings.

Potential impacts of chemical accidents in the Reagent Processing Building on principal SSCs or personnel performing functions related to items relied on for safety (IROFS) are discussed in Chapter 5.

8.1.1.2 Aqueous Polishing Process

The AP process consists of 16 process units or systems (units symbols are indicated in parenthesis):

- Decanning Unit (KDA)
- Milling Unit (KDM)
- Recanning Unit (KDR)
- Dissolution Unit (KDB)
- Dechlorination and Dissolution Unit (KDD)
- Purification Cycle (KPA)
- Solvent Recovery Cycle (KPB)
- Oxalic Precipitation and Oxidation Unit (KCA)
- Homogenization Unit (KCB)
- Canning Unit (KCC)
- Oxalic Mother Liquor Recovery Unit (KCD)
- Acid Recovery Unit (KPC)
- Offgas Treatment Unit (KWG)
- Liquid Waste Reception Unit (KWD)
- Uranium Oxide Dissolution Unit (KDC)
- Sampling System (KPG).

The AP process is described in detail in Section 11.3.

8.1.1.3 MOX Fuel Fabrication Process

The MP process involves dry workshops (e.g., powder, pellet, and rod processing) and is described in detail in Section 11.2.

8.1.1.4 Laboratory

Chemical and physical analyses of samples from the MP and AP Areas are conducted in the laboratory. Analyses are required for manufacturing control, nuclear material management, quality control, and safety controls. Production sample analyses are performed at different stations consisting of gloveboxes, and transfers between stations are conducted manually (using a specific container or a vial in a vinyl double sleeve) or pneumatically. Several laboratory benches and fume hoods are provided for checking and distributing chemical reagents for different analytical processes. The laboratory is described in further detail in Section 11.11.

8.1.2 Chemical Process Detail

This section addresses the chemical process descriptions, the names and formulae of chemical reactants and products, and operating conditions. This section also identifies which chemicals come in contact with licensed materials, could impact operations with licensed materials, or are formed as by-products from chemical reactions with licensed materials. (Note that "hazardous chemicals produced from licensed materials," as defined in 10 CFR 70, do not include substances prior to process addition to licensed material or after process separation from licensed material.) The chemical process description at this stage of the design includes sufficient information to allow an understanding of the hazards associated with the chemical process.

8.1.2.1 Reagent Chemicals Process

Chemicals are received in various forms (solid, liquid, and gas) for use in the MFFF process. Most chemicals are stored in the Reagent Processing Building while some are stored in the AP Area or the MP Area. The various chemicals prepared and/or stored in these areas include the following:

- Solids
  - Reagent Processing Building – oxalic acid and sodium carbonate
  - AP Area – silver nitrate, manganese nitrate, plutonium dioxide, and uranium dioxide
  - MP Area – azodicarbonamide, zinc stearate, plutonium dioxide, and uranium dioxide
- Liquids
  - Reagent Processing Building – hydrazine hydrate, hydroxylamine nitrate (HAN), nitric acid (HNO_3), tributyl phosphate (TBP), diluent (C10-C13 isoalkane), hydrogen peroxide, sodium hydroxide, hydrazine nitrate, and zirconium nitrate
  - AP Area – recovered nitric acid, aluminum nitrate solution, silver nitrate solution, manganese nitrate solution, and zirconium nitrate solution
  - MP Area - Isopropanol
- Gases
  - Reagent Processing Building – dinitrogen tetroxide (N_2O_4) (stored in liquefied form)
  - Site – nitrogen, oxygen, hydrogen, argon, P10 (10% methane/90% argon), helium, and 95% argon/5% hydrogen
  - AP Area – nitrogen, oxygen, P10 (10% methane/90% argon), and 95% argon/5% hydrogen

  - MP Area – nitrogen, hydrogen, argon, P10 (10% methane/90% argon), helium, and 95% argon/5% hydrogen.

Storage facilities in the Reagent Processing Building contain the following:

- Drums/tote tanks of the following reagents: 13.6N HNO_3, TBP, diluent, HAN (1.9M), hydrazine hydrate (22% hydrazine in water), sodium hydroxide (10N)
- Cylinders of liquid N_2O_4
- Containers of hydrogen peroxide (30 wt %)
- Storage of material for dissolving solid reagents, including oxalic acid and sodium carbonate.

Tables 8-1a through 8-1e identify the expected chemicals received and distributed to the MFFF process. Chemicals and chemical mixtures in the process generally are used at lower concentrations than the reagent-grade chemicals stored in the Reagent Processing Building or AP Area.

8.1.2.2 Aqueous Polishing Area Chemical Process

Details on the chemical processes found in the AP area are provided in Section 11.3.

8.1.2.3 MOX Processing Area Chemical Process

The chemical processes in the MP area require the blending of uranium and plutonium oxides and the addition of poreformer and lubricant. Details on the MP Area chemical process are provided in Section 11.2.

8.1.3 Process Chemistry

The descriptive equations and other process chemistry information are provided in Section 11.3.

8.1.4 Chemical Process Equipment, Piping, and Instrumentation

Principal SSCs associated with chemical processing are identified in Chapter 5.

8.1.5 Chemical Process Inventories

The chemical inventory information in Tables 8-2a through 8-2d provides a summary of anticipated onsite inventories. Additional information associated with chemical inventories is provided in Section 11.3.

Common hazardous materials (e.g., vehicle fuel) and commonly used small quantities of solvents and gases are also used onsite. Specific inventories will be identified in the detailed design.

8.1.6 Chemical Process Ranges and Limits

Process ranges and limits are discussed in Section 11.3.

8.2 HAZARDOUS CHEMICALS AND POTENTIAL INTERACTIONS

This section identifies the major chemicals stored and used at the MFFF, identifies potential interactions among these chemicals, and discusses potential unusual and unexpected reactions.

8.2.1 Chemicals

Process chemicals used during normal operation are listed in Tables 8-1a through 8-1e. The tables are divided by plant area: Table 8-1a lists process chemicals present in the Reagent Processing Building; Table 8-1b lists the process chemicals present in the Aqueous Polishing Building; and Table 8-1c lists the chemicals present in the MOX Processing Building. Tables 8-1d and 8-1e identify the chemicals currently anticipated in the Laboratories and Gas Storage Area, respectively.

Maximum anticipated onsite chemical inventories are presented in Tables 8-2a through 8-2d. Table 8-2a identifies the major chemical inventories associated with tanks, vessels, and containers located in the Reagent Processing Building, Aqueous Polishing Building, and MOX Processing Building. Other smaller tanks, vessels, and containers within the Reagent Processing Building, Aqueous Polishing Building, and MOX Processing Building are not included in Table 8-2a since, for the purpose of chemical accident analyses, the chemical quantities are bounded by those values listed in Table 8-2a. Tables 8-2b, 8-2c, and 8-2d identify the chemical inventories currently anticipated in the Secured Warehouse (uranium dioxide), Laboratories, and Gas Storage Area, respectively.

Table 8-3 identifies significant reaction products and intermediate chemicals produced as a result of AP processing. There are no significant chemical reaction byproducts as a result of MP processing.

8.2.2 Chemical Interactions

Human error or equipment malfunction could result in inadvertent chemical interactions and initiate hazardous reactions. General hazardous chemical characteristics and incompatibilities with the associated materials/process conditions are identified for AP and MP process chemicals in Table 8-4. Sampling of chemical reagents upon receipt, control of chemical preparation in accordance with operating procedures by trained personnel, proper handling and storage, and the proper selection of process materials of construction minimize the potential for unexpected chemical interactions. To mitigate the risk to principal SSCs associated with inadvertent chemical interactions, most chemical reagents for the AP process are prepared in the Reagent Processing Building and distributed to the AP Area.

Chemically induced explosion events originating within the MFFF, as well as those associated with support facilities, are discussed in Section 5.5.2.4. Hazards and operability studies (HAZOPs) and other evaluations will be prepared as part of the ISA during the detailed design to support the identification of other inadvertent chemical interactions. A complete chemical interaction evaluation will be provided in the license application for possession and use of SNM.

8.2.3 Unusual and Unexpected Reactions

The primary chemical reactions associated with AP processing are described in Section 11.3. Table 8-3 identifies normal reaction products and intermediate chemicals produced as a result of AP processing. There are no significant chemical reaction byproducts as a result of MP processing.

In general, AP chemical reactions produce the following by-products: carbon dioxide, carbon monoxide, chlorine, hydrogen, nitrogen oxides, nitrogen, nitric acid, oxygen, sodium chloride and water. Alkaline wastes containing decomposition products of TBP and other chemical by-products are produced in the Solvent Recovery Unit and processed in the waste processing unit. The following plutonium and uranium compounds are formed as process intermediates: plutonium nitrate, plutonium oxalate, and uranyl nitrate, in addition to polished plutonium oxide that results from AP processing.

Several additional hazardous compounds are produced in trace quantities or could be created from off-normal operations. These include the following: hydrazoic acid, azide salts, and plutonium (VI) oxalate. Off-normal process conditions could also lead to "red oil" formation and excessive exothermic reactions involving HAN and nitrous acid. Additional potential process hazards include the flammability of hydrogen generated through the radiolysis of hydrogenated materials, the explosive decomposition of high concentrations of hydrogen peroxide, and the use of a combustible solvent in the Purification Cycle. A description of these hazards and the controls necessary to reduce the associated risk are described in Sections 5.5 and 8.5.

Specific pathways leading to accidents involving these hazards resulting from process failures or personnel errors will be identified and evaluated during hazards and operability studies (HAZOPs) and other evaluations as part of the ISA during the detailed design.

8.3 CHEMICAL ACCIDENT SEQUENCES

According to 10 CFR Part 70, hazardous chemicals produced from licensed materials are identified as "substances having licensed material as precursor compound(s) or substances that physically or chemically interact with licensed materials; and that are toxic, explosive, flammable, corrosive, or reactive to the extent that they can endanger life or health if not adequately controlled. These include substances commingled with licensed material, but do not include substances prior to process addition to licensed material or after process separation from licensed material."

This section provides the methodology and results for the evaluation of chemical consequences that are associated with a release of hazardous chemicals produced from licensed materials as defined by 10 CFR Part 70. The radiological effects of these events and the effects that chemical-related events may have on the safety of radiological material are discussed in Chapter 5.

Hazards that involve only chemicals and that do not affect radiological safety will be addressed in accordance with applicable Occupational Safety and Health Administration (OSHA) requirements. Non-routine work safety will be addressed through the use of work authorization and task analysis or activity-based hazard analysis.

8.3.1 Chemical Accident Sequence Bases

To identify the physical processes that control the nature and rate of vapor generation and release, a range of initial conditions is considered, as well as the failure modes of storage containers and associated systems. The following release scenarios are addressed:

- Leaks and ruptures involving equipment vessels and piping
- Evaporating pools formed by spills and tank failures
- Flashing and evaporating liquefied gases from pressurized storage.

Explosion events that could result in the release of hazardous chemical vapors are addressed in Sections 5.5 and 8.5. The chemical consequences are based on bounding analyses. More detailed accident sequences will be developed in the ISA as necessary.

8.3.2 Unmitigated Sequences

In lieu of a mechanistic calculation of the release, a conservative bounding release model is used to determine the consequences to the site worker (100 meters) and members of the public at the Controlled Area Boundary (CAB) (5.1 miles). Releases are modeled to occur using the total material at risk from the largest single tank or container. Furthermore, no credit is afforded to process equipment installed to remove/scrub some of the potentially released chemicals prior to release from the MFFF.

8.3.3 Estimated Concentrations

Estimates of hazardous chemical concentrations include techniques, assumptions, and models that are consistent with industry practice, are verified and/or validated, and follow the guidance on atmospheric and consequence modeling found in NUREG/CR-6410, *Nuclear Fuel Cycle Accident Analysis Handbook.*

Several different methodologies were applied to the performance of chemical consequence analyses based on the nature of the chemical and the location of the receptor. For calculating airborne concentrations at the CAB involving evaporative releases, the more conservative release rate from the following two separate evaporation models (Kawamura and Mackay 1987, equation 8.3-1 and NUREG/CR-6410, Appendix B, equation 8.3-2) was used as input to the Areal Locations of Hazardous Atmospheres (ALOHA) computer code. These evaporation models, applicable to liquids released at ground level in a pool, are as follows:

$$E=A*K_M*(MW_m * P_v/(R*T)) \qquad (8.3\text{-}1)$$

where
E = evaporation rate (kg/sec)
A = area of the evaporating puddle (m^2)
K_M = mass transfer coefficient (m/sec)

MW_m = molecular weight of the material of interest (kg/kmol)
P_v = vapor pressure (Pa)
R = the gas constant (8314 J/kmol K)
T = ambient temperature (K)

$$Q_o = k_g * A_p * p_v * M/(R * T_p) \qquad (8.3\text{-}2)$$

where
Q_o = rate of evaporation (kg/sec)
k_g = mass transfer coefficient (m/sec)
A_p = area of the pool (m^2)
p_v = vapor pressure (Pa)
M = molecular weight of the material of interest (kg/kmol)
R = the gas constant (8314 J/kmol K)
T_p = temperature of the pool (K)

The mass transfer coefficient is dependent on the air speed over the pool or puddle. For an unmitigated release outdoors, an air speed of 2.2 meters/second is used, which is consistent with 95% "worst-case" meteorological conditions at SRS. For a mitigated release inside the MFFF, a much lower air speed of 0.1 meters/second is used, which is consistent with the maximum volumetric air flow rate through the room in which the pool or puddle is located.

Results from the ALOHA code were then extrapolated to obtain airborne concentrations at the CAB. ALOHA was originally developed by the National Oceanic and Atmospheric Administration for on-scene commanders at a spill site for emergency response applications. In light of this application, and because of the likelihood of changes in atmospheric conditions after a short time, an execution time of one hour is "hardwired" into the code. Assuming worst case meteorological conditions (i.e., wind speed of 2.2 meters per second), a dispersing chemical release can only travel 7.9 km (4.9 miles) in an hour, and cannot reach the CAB in that time. Therefore, the maximum concentration of the released chemical at the CAB is estimated by extrapolation of the maximum ALOHA concentrations for runs at distances of 7.9 km (4.9 miles) and less using curve-fitting techniques.

To calculate airborne concentrations at the CAB for other chemicals with low solute concentrations or low vapor pressures, source terms were generated using a five-factor formula involving the product of the material at risk (MAR), damage ratio (DR), airborne release fraction (ARF), respirable fraction (RF), and leak path factor (LPF). These values were then multiplied by the CAB atmospheric dispersion factor (χ/Q) calculated by the MACCS2 (MELCOR Accident Consequence Code System for the Calculation of the Health and Economic Consequences of Accidental Atmospheric Radiological Releases) code to obtain an airborne concentration at the CAB.

For evaporative releases affecting the site worker, the more conservative release rate from the two separate evaporation models identified above was selected and multiplied by the 100-meter atmospheric dispersion factor (χ/Q) calculated by the ARCON96 (Code System to Calculate

Atmospheric Relative Concentrations in Building Wakes) code to obtain an airborne concentration. To calculate airborne concentrations for other chemicals affecting the site worker, source terms were generated using the same five-factor formula described above. These values were then multiplied by the 100-meter atmospheric dispersion factor (χ/Q) from the ARCON96 code. For chlorine and NO_x releases, release rates were obtained from chemical flow balances for the units where these chemicals are generated from SNM. The applied release rates do not credit the process scrubbers installed to remove a majority of these chemical by-products.

8.3.3.1 Dispersion Modeling

ALOHA is a time-dependent model that treats neutral or heavy gases and a variety of time-dependent sources, including broken pipes, leaking tanks, and evaporating puddles, modeled in consideration of atmospheric turbulence, entrainment, advection, and gravitational spreading. It is the preferred model for calculating chemical concentrations at distances approaching the CAB. The ALOHA computer code was verified and validated prior to its use for the evaluation of MFFF bounding chemical release consequences.

There are two discrete dispersion models in ALOHA: *Gaussian* and *heavy gas*. The Gaussian model was used for determining chemical concentrations at the CAB involving evaporative releases, as it yields conservative results for the applicable scenarios. The Gaussian model predicts dispersion of *neutrally buoyant gases* that have about the same density as air. Wind and atmospheric turbulence move the released gas through the air so that an escaped cloud is blown downwind, with "turbulent mixing" causing it to spread out in the crosswind and upward directions. A graph of gas concentration within any crosswind slice of a moving pollutant cloud looks like a bell-shaped curve, high in the center (where concentration is highest) and lower on the sides (where concentration is lower). At the point of a release, the pollutant gas concentration is very high, since the gas has not diffused very far in the crosswind and upward directions. A concentration graph in a crosswind slice of the cloud close to the source is a spike. As the pollutant cloud drifts farther downwind, it spreads out and the "bell shape" becomes wider and flatter.

MACCS simulates the accidental release of a plume of radiological materials to the atmosphere and estimate consequences associated with the release. The dispersion model in MACCS2 treats atmospheric transport and dispersion of material utilizing a Gaussian plume model with Pasquill-Gifford dispersion parameters and can be used for chemical as well as radiological consequence assessments. The code does not model dispersion close to the source (less than 100 meters from the source).

The dispersion model in the ARCON96 code is used for distances close to the release point. ARCON96 empirically accounts for building wake effects occurring under all meteorological conditions and plume meander, which occurs during light-wind stable conditions. It is the only model that is available that accounts for both the vertical and horizontal components of building wake effects and the effects of plume meander. Plume meander occurs under very stable light wind speed conditions (e.g., F stability class with wind speed of 2.2 meters/second). The magnitude of plume meander decreases with distance from the release, higher wind speeds, and more unstable conditions. All of the meander factor decays within 1 kilometer. The building wake effect also decays as the distance from the release location increases, but it increases with wind speed and more unstable conditions. The faster the wind speed, the larger the aerodynamic effect on the wind field of the building structure.

8.3.4 Concentration Limits

Chemical concentration limits are required to be established to evaluate the potential consequences to the public and to workers for an accidental release of chemicals. Three levels, High (H), Intermediate (I), and Low (L), based on 10 CFR §70.61, are used to define these limits.

Limits are based on Acute Exposure Guideline Level (AEGL) values and Emergency Response Planning Guideline (ERPG) values. Since AEGL and ERPG values are not established for all MFFF chemicals, Temporary Emergency Exposure Limits (TEELs) have been adopted for use in chemical consequence analysis. TEELs were adopted by the U.S. Department of Energy (DOE) Subcommittee on Consequence Assessment and Protective Action (SCAPA). The SCAPA-approved methodology was used to obtain hierarchy-derived TEELs.

The original TEEL methodology used only hierarchies of published concentration limits (i.e., Permissible Exposure Levels [PELs] or Threshold Limit Values – Time-Weighted Averages [TLV-TWAs], Short-Term Exposure Levels [STELs], and Immediately Dangerous to Life and Health [IDLH] values) to provide estimated values approximating ERPGs. The expanded method for deriving TEELs also includes published toxicity data (TD_{LO}, TC_{LO}, LD_{50}, LC_{50}, LD_{LO}, and LC_{LO}). Hierarchy-based values take precedence over toxicity-based values, and human toxicity is preferred to animal toxicity data. Subsequently, default assumptions based on statistical correlation of ERPGs at different levels (e.g., ratios of ERPG-3s to ERPG-2s) were used to calculate TEELs where there were gaps in the data. The TEEL hierarchy/toxicity methodology was used to develop community exposure limits for over 1,200 chemicals to date. The following are the TEEL definitions:

- **TEEL-0** – The threshold concentration below which most people will experience no appreciable risk of health effects.
- **TEEL-1** – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odor.
- **TEEL-2** – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action.
- **TEEL-3** – The maximum concentration in air below which it is believed nearly all individuals could be exposed without experiencing or developing life-threatening health effects.

TEEL values for MFFF chemicals are listed in Table 8-5. Chemical consequence categories for comparison to 10 CFR §70.61 are provided in Table 8-6.

8.4 CHEMICAL ACCIDENT CONSEQUENCES

8.4.1 Analysis

Consequence analysis follows the guidance found in NUREG/CR-6410. Conservatism is embedded in the source term and the ground-level release models.

The analysis to determine the effects at the CAB to the public is based on the following assumptions:

- A wind speed of 2.2 meters per second and F stability class, indicative of 95% "worst-case" meteorological conditions at SRS;

  Note: The 95% wind speed of 2.2 meters per second was calculated from the 95% χ/Q value from the ground-level release application of the ARCON96 code applied at a distance of 100 meters. The ARCON96 code was driven by five years of hourly SRS meteorological data. The calculation assumes an F-stability class to quantify σ_y and σ_z. The 100-meter distance is selected because it represents the site worker location. This technique yields a site-specific 5% meteorological condition (F stability class @ 2.2 m/second wind speed) that is more applicable than adopting the 40 CFR §68.22 meteorology, which is generalized for the entire United States.

- A wind direction that transports the puff kernel and/or plume centerline directly over the receptor of concern (conservative), thereby eliminating any crosswind dispersion;

- An ambient temperature of 25°C (77°F) and 50 percent humidity; representative of late-spring to early-autumn conditions;

- A ground level release (conservative);

- No mechanical or buoyancy plume rise (conservative);

- A rural (i.e., flat terrain) topography (conservative);

  Note: The forest canopy morphology at SRS is more accurately characterized as urban terrain relative to atmospheric turbulence intensity.

- Neutrally buoyant gas model (conservative).

  Note: Heavy gas models result in lower downwind concentrations, which are less conservative. This is due to density differences (e.g., Colenbrader model within ALOHA) that entrain clean air within the sides of the pancake-like dense gas plume.

These bounding assumptions envelop uncertainties inherent in realistic analyses.

Data in Tables 8-2a through 8-2d were used to perform chemical consequence analyses associated with the largest credible unmitigated spill or loss of containment accident involving each of these chemicals. Airborne concentrations were calculated at distances correlating to the site worker (100 meters) and members of the public (CAB). These concentrations were then compared to the TEELs presented in Table 8-5. From this comparison, a consequence category was established (low, intermediate, high) using the guidance outlined in Table 8-6. These consequence categories correspond to those identified in 10 CFR §70.61.

It should be noted that for the chemicals identified in Tables 8-2a through 8-2d whose onsite inventory is not yet established or is based on preliminary data, the analysis is based on a conservative projection for that chemical. Nonhazardous chemicals and gases identified in Table 8-2d were not evaluated. Except for oxygen, exposure to these gases poses an asphyxiant hazard only. Gas concentrations at asphyxiation levels are not credible at the distances corresponding to the CAB. Gas concentrations at asphyxiation levels may be credible for very large leaks at the distance corresponding to the site worker. Oxygen has no established toxicity limit.

Results of the chemical consequences calculation indicate that for all chemicals to which the requirements of 10 CFR §70.61 apply, unmitigated consequence categories fall within the acceptable range for site workers and members of the public, with the exception of those releases described in Section 5.5.2.10.6.3. Thus, no principal SSCs are required for the protection of site workers and members of the public, except as identified in Section 5.5.2.10.6.3.

Nitric acid leaks or spills in the Aqueous Polishing area of the MFFF were also modeled at temperatures up to the boiling point of nitric acid. The evaporation rate of the nitric acid was calculated utilizing an indoor wind speed of approximately 0.01 meters/second. The consequences of these nitric acid leaks or spills over the full range of temperatures were calculated to be low for the site worker and members of the public.

Uranium dioxide powder releases from the Secured Warehouse, including evaluations of fire and seismic events, are calculated to be low consequence events for the site worker and members of the public. More detailed analyses based on final design and operations are in progress to confirm the results for the site worker. If features such as combustible load controls are required to meet the criteria for the site worker, the features will be identified as IROFS in the ISA.

For the facility worker, the chemical consequences are estimated to be low, except as identified in Section 5.5.2.10. Calculations will be performed for the ISA to confirm this estimate. Principal SSCs have been defined for radiological events, and these SSCs are expected to be applicable to process units where chemicals mix with radiological material, except as identified in Section 5.5.2.10. Furthermore, for chemical exposures that could affect the facility worker in performing a required safety function in the Emergency Control Room, the Emergency Control Room Air Conditioning System is identified as a principal SSC (see Section 5.5.2.10). In the unlikely event that the ISA performed as part of detailed design identifies events that are not bounded, additional SSCs will be identified to ensure that chemical risks are acceptable.

8.4.2 Latent Impacts

The risk of cancer can be estimated by combining information about the carcinogenic potency of a chemical and exposure to the substance. For potential carcinogens, risks are estimated as the incremental probability of an individual cancer over a lifetime as a result of exposure to the potential carcinogen. The carcinogenic risks are estimated by multiplying the cancer toxicity parameter (potency slope factor), which is the upper 95% confidence limit of the probability of a carcinogenic response per unit intake over a lifetime of exposure. The two important parameters or measures for describing carcinogenic effects are the individual cancer risk and the estimated number of cases (i.e., the cancer burden). Latent risk, including mutagenic and terotogenic effects, will be covered in the license application for possession and use of SNM.

8.4.3 Uncertainty

Estimates of risks are often accompanied by uncertainty because of the complexity of the postulated scenarios and physical models used to describe them. At this stage of the design, conservative models were utilized for the chemical releases with the intent to bound any anticipated uncertainty. Uncertainties associated with more detailed consequence analyses performed for the ISA will be described in the license application for possession and use of SNM.

8.5 PROCESS SAFETY INFORMATION

8.5.1 Process Safety Controls

The MFFF includes three basic facilities:

- **Reagent Processing Building** – This building is the front end of the process, where reagents for the process are prepared and transported to the processing units.
- **AP Area** – This area is the location of the primary chemical processing (Aqueous Polishing).
- **MP Area** – This area contains the manufacturing unit for the production of fuel assemblies (MOX Process).

Each of these facilities has control requirements that are incorporated into the overall design of the control system for process safety control. The control system will be designed to be available and reliable.

Reagents are stored and chemical mixtures are prepared in the Reagent Processing Building and in the reagent storage area of the AP Area. The AP facility is broken down into process functional units, which are functionally made up of one or more subunits performing elementary unit operations. The breakdown into functional units allows each unit to be operated relatively independently of other functional units.

Process storage and operation conditions are controlled to prevent unintended exothermic and potential autocatalytic reactions in the Reagent Processing Building and AP Area. Autocatalytic and exothermic reactions of chemicals are prevented through control of the process parameters (e.g., reactant concentration, temperature, catalyst concentration in solution, and pressure) that affect the reactions.

Significant chemical-related risks and associated design bases information are discussed in the following sections.

8.5.1.1 Hazards Associated with Hydrogen Gas

This section discusses the hazards associated with hydrogen as used or produced in the various processes within the MFFF. The following text discusses the flammable and explosive nature of hydrogen and provides the basis for the limits to be applied in the design of the processes using or producing hydrogen to assure the risks associated with hydrogen hazards satisfy the performance requirements of 10 CFR §70.61. The subsections that follow this section discuss the specific hazards identified in Section 5.5 associated with hydrogen (i.e., hazards associated with hydrogen-argon mixture in sintering furnace, radiolysis, and electrolysis).

Flammability Phenomena

Hydrogen is flammable over a wide range of concentrations in air. The values typically quoted are for concentrations of hydrogen in air at standard atmospheric temperatures and pressures (i.e., 4% through 74% by volume of hydrogen). The leanest mixture that burns completely is 9%; however, hydrogen flames will propagate in the upward direction at concentrations as low as 4% because of the high diffusivity of hydrogen. The flammability limits of hydrogen have been found to be consistent for gas pressures below 1 atm up to 100 atm.

The flammability limits are affected by temperature and by various concentrations of inert diluents, see Figure 8.5.1.1-1 for gas mixtures containing argon. Increasing the temperature tends to lower the lower flammability limit (LFL) and raise the upper flammability limit (UFL) for hydrogen in air, until the spontaneous ignition temperature is reached. At that point any amount of hydrogen coming into contact with oxygen burns with a slow flame (less than 1 m/s at less than 8% H_2 in air). Increasing the temperature of a mixture of pure hydrogen in air will cause the LFL to decrease from 9 to 5.4%, and the UFL to increase from 74 to 88%. This effect is different when hydrogen is diluted with an inert gas such as argon.

As shown in Figure 8.5.1.1-1, flammable mixtures of hydrogen in air can be made nonflammable by the addition of enough inert gas, such as argon, provided sufficient controls are placed on the environment in which the mixed gas is used. Different diluents have different levels of inerting efficiency which must be accounted for in evaluating the potential risks for creating explosive mixtures.

Explosion Phenomena

Hydrogen gas mixtures can become explosive if a sufficient amount of fuel and oxidant is distributed throughout the mixture while the mixture is not exposed to an ignition source or it is below the spontaneous ignition temperature. Even if the mixture is exposed to an ignition source or raised to high enough temperature, the mixture will only ignite and explode under certain conditions. The explosiveness of the mixture depends on the gas concentration, temperature, pressure (i.e., the flammability limits), the container surface conditions and the container size. Gas concentrations below or above the LFL and UFL are nonexplosive. Because the flammability limits vary with temperature and gas composition, these variables are considered when choosing the applicable lower and upper explosive limits (the LEL and UEL).

Outside of the sintering furnace in the BMP and BAP, the MFFF intends to control combustible gas concentrations to levels below 50% of the LFL to ensure that the LEL is not exceeded and to prevent explosions in the BMP and BAP. Inside of the sintering furnace, the MFFF intends to control the combustible gas concentrations to levels above the UFL at high temperatures, prevent or limit the introduction of air or other oxygen sources into the furnace, and to provide enhanced administrative controls during startup and shutdown of the furnace to ensure that the supply of combustible gas is stopped or the furnace is purged of combustible gases whenever the furnace is offline and prior to energizing the resistor heaters.

Explosions due to lean hydrogen concentrations below 8% in air will result in a peak pressure rise slightly above 1 bar (14.5 psi) because the low H_2 concentration does not allow downward propagation of the flame. At slightly higher concentrations of 9 to 10% H_2 (i.e., above the downward lower flammability limit) the peak pressures may be close to 3 to 4 bar (44 to 58 psi). The hydrogen concentration and temperature also play strong roles in determining whether the mixtures burn or explode. Thus, physical structures that mitigate or contain potential explosions are designed with these limits in mind.

Besides increasing the temperature of a combustible hydrogen mixture to above its spontaneous ignition temperature, the mixture can be ignited by a weak spark, such as one caused by the discharge of static electricity from a human body; open flames; hot surfaces or matches. Ignition of a gas mixture can result in the generation of a variety of different combustion regimes ranging from slow flames to detonations. Under certain conditions after ignition, slow flame fronts may be accelerated and transformed into detonations by the phenomenon of flame acceleration (FA) and deflagration to detonation transition (DDT). The conditions necessary to accelerate a flame to detonation are specific to the properties of the burned and unburned gas mixture and the physical layout and dimensions of the containment structure. Explosions may be prevented by controlling critical dimensions in the containment structure or by preventing the conditions necessary to sustain combustion or initiate ignition. Because of the complexity of the internal structures of the sintering furnace, the MFFF intends to prevent these types of explosions by controlling the conditions necessary to support combustion or initiate ignition.

Hydrogen Formation by High Temperature Reactions

Hydrogen can be formed at high temperatures by reactions with burning metals in which the oxygen atoms in the water are stripped off by unoxidized metal, thus releasing free hydrogen atoms. Hydrogen explosions in furnaces processing certain reactive metals (especially titanium) have been reported as a result of this reaction. The sintering furnace only processes a mixture of oxidized forms of uranium and plutonium. Therefore, any water that could come into contact with these oxides from excessive humidity in the process gas will only form steam and is not expected to become dissociated into free hydrogen. Explosions caused by increasing the hydrogen content of the process gas by this mechanism are thus precluded. Chapter 5.5.2.4.6.2 discusses the hazards involved with steam overpressure events.

8.5.1.1.1 Argon-Hydrogen Mixture in Sintering Furnace and Hydrogen Storage

A mixture of argon and hydrogen gas is used in the sintering furnace to provide the required atmosphere for pellet sintering. The gases are mixed outside of the MFFF building in the proper proportion and transferred to the pellet sintering areas via facility piping. Inherent with the use of hydrogen are the associated hazards of fire and explosion. These hazards are present at the gas storage/mixing area, sintering furnace area, furnace gloveboxes and airlocks, sintering furnace exhaust and associated HVAC system, and the sintering furnace itself. Control of the hazards associated with hydrogen in these areas is discussed in the following paragraphs.

Fire and explosion events are prevented in the sintering furnace area, furnace gloveboxes and airlocks, sintering furnace exhaust, and associated HVAC system by the process safety control subsystem. The process safety control subsystem prevents the formation of flammable mixtures of hydrogen. The design basis for this control is fifty percent of the lower flammability limit (LFL) of hydrogen in air. Fifty percent of the LFL will not be exceeded during normal or off-normal conditions. The LFL is considered the safety limit, while twenty five percent of the LFL is the expected setpoint at which necessary control actions are initiated during normal operations. Actual setpoints will be determined as part of final design.

Fire and explosion events are prevented in the sintering furnace by the use of design features and procedures (administrative controls) that prevent the formation of flammable mixture of hydrogen in air. The basis for these engineered and administrative controls is NFPA 86C, *Industrial Furnaces Using a Special Processing Atmosphere*. As stated in Chapter 7.0, Fire Protection, fire safety for the sintering furnace is in accordance with the applicable requirements of NFPA 86C-1995.

The design bases of PSSCs associated with fire and explosion at the facility gas storage area (external events) are discussed in Section 11.1.7.

8.5.1.1.2 Hydrogen Production due to Radiolysis

Radiolysis is the process of hydrogen gas production by radiolytic dissociation of hydrogenous materials. Within the MFFF process, the hazards associated with radiolysis are present in some AP processes and in some waste drums. The potential for hydrogen production in the MOX process is low due to the negligible quantity of hydrogenous materials.

The design bases associated with the control of the hazards associated with hydrogen gas is in accordance with standard NFPA practices. The lower flammable limit (LFL) is considered the safety limit. This is the value at which an event may occur because the hydrogen concentration may be flammable. Fifty percent of the LFL is the design basis value. This is the value that will not be exceeded during normal or off-normal conditions. Twenty-five percent of the LFL is the projected setpoint. This is the value used to design the process and as necessary, is used to initiate control actions during normal operations.

In the AP processes, the risk associated with radiolysis is mitigated by maintaining adequate dilution airflow and ensuring an exhaust path exists. Calculations will be performed as part of detailed design to determine appropriate air flow rates and summarized in the ISA. Should normal airflow be lost to an AP process vessel, emergency scavenging air will be provided as described in Section 11.9. These airflow rates will ensure that 50 percent of the LFL is not exceeded during normal or off-normal conditions.

Hydrogen production and accumulation may occur in the waste and byproducts, such as contaminated organic waste or organic-additive-bearing waste containing significant amounts of plutonium, scraps in transuranic (TRU) waste containers, and other liquid waste. Where this may become a hazard, the containers are equipped with a filtered vent system that limits hydrogen accumulation by providing an exhaust flow path while maintaining confinement of radioactive materials.

8.5.1.1.3 Hydrogen Production by Electrolysis

The dissolution unit and the dechlorination and dissolution unit utilize a catholyte loop in which nitric acid is used to dissolve plutonium oxide. This electrolytic dissolution process introduces the risk of generating hydrogen gas.

The design bases associated with the control of the hazards associated with hydrogen gas is in accordance with standard NFPA practices. The LFL is considered the safety limit, the value at which an event may occur because the hydrogen concentration may be flammable. Fifty percent of the LFL is the design basis value. This is the value that will not be exceeded during normal or off-normal conditions. Twenty-five percent of the LFL is the target setpoint. This is the value used to design the process and as necessary is used to initiate control actions during normal operations. Specific setpoints will be developed in accordance with the codes and standards described in Section 11.6.7 to ensure the design basis value is not exceeded.

The production of hydrogen during electrolysis is a function of the nitric acid normality. As described in Section 5.5.2.4, the normality of the nitric acid will be maintained sufficiently high to ensure that the off-gas is not flammable. Calculations will be performed as part of detailed design and summarized in the ISA to determine the appropriate nitric acid limits. These limits will ensure that 50 percent of the LFL is not exceeded during normal or off-normal conditions.

8.5.1.2 Solvent Related Hazards

Some units within the AP process are fed with solvent. The potential for solvent related fires and explosions exists due the possible attainment of a flammable/explosive mixture in the gaseous phase due to excessive heating.

As described in section 5.5.2, a combination of IROFS will be in place to ensure that explosive conditions associated with solvent vapors are prevented from occurring. These IROFS will include controlling the temperature of solutions containing solvents, minimizing the potential ignition sources, and providing an exhaust path for dilution of vapors.

8.5.1.3 Hydroxylamine Nitrate (HAN) and Hydrazine (N_2H_4) in Nitric Media

The Aqueous Polishing (AP) process uses a mixture of hydroxylamine nitrate (HAN) and nitric acid (HNO_3) during the extraction step of the plutonium purification unit (KPA) to strip plutonium from the solvent after removal of americium and gallium. HAN has a number of advantages as a plutonium reductant. It is nonmetallic, it is readily decomposed to innocuous products by heating, the gaseous reaction products – nitrogen (N_2), nitrous oxide (N_2O), and water (H_2O) – contribute to minimization of the volume of solid wastes produced, and it possesses the proper Pu (IV) to Pu (III) reduction attributes. However, due to the potential for HAN to undergo an autocatalytic reaction with nitrous acid under certain conditions, the use of HAN in the AP Process introduces an explosion/overpressure hazard.

Experience and insights gained from previous accidents involving HAN and experimental data from the Hanford and Savannah River sites are utilized in conjunction with La Hague Plant experience to assist in the determination of safe operating conditions for the storage and the handling of HAN, hydrazine and nitric acid.

The HAN-nitric acid system is a complex multi-parametric system involving the interdependence of the following four parameters:

- Chemical concentration of each reactant
- Molar ratio of nitric acid to HAN
- Temperature of the mixture
- Concentration of metal ion catalysts.

A general feature that has characterized many of the previous accidents with HAN mixtures without hydrazine is the inadvertent increase of solution temperature and/or concentration of or an inadvertent acid addition to these solutions. Experimental results indicate that high nitric acid concentrations or the presence of impurities (such as metal ions) increase the likelihood of the initiation of an autocatalytic reaction. Furthermore, for systems without metal catalyst, a trend of decreasing the autocatalytic reaction temperature threshold when increasing the nitric acid to HAN ratio has been found. Maintaining low nitrous acid concentrations has been indicated as important to storage and use of HAN, with respect to autocatalytic reactions. Previous attempts to characterize the stability of a system have examined both experimental and accident conditions in which the concentrations of nitric acid and HAN have increased. In these systems the energy liberated as a result of an autocatalytic reaction also increases as a function of the original energy content of the solution and the initial concentrations of HAN.

To understand the behavior of systems comprised of HAN, hydrazine, plutonium and metal ions with nitric acid, the various associated reactions are modeled. In this manner the kinetic rates for reactions governing production and consumption of nitrous acid are used to describe the stability of the system under normal, abnormal, and accident conditions. The chemical reactions that govern the solutions that may contain HAN include:

- Plutonium (IV) reduction by HAN
- Plutonium (IV) reduction by Hydrazine
- Plutonium (III) Re-oxidation
- HAN reaction with nitrous acid
- Hydrazine reaction with nitrous acid
- Catalyzed Nitrous Reactions with Metal Ions

Additional discussion of the safety strategies and specific controls associated with control of these reactions is found in Section 5.5.

8.5.1.4 Hydrogen Peroxide

A 35 wt % hydrogen peroxide solution is received and diluted to 10 wt % for use in the Dissolution Unit. Explosive vapors can be produced if the concentration of the hydrogen peroxide solution exceeding 75 wt % is boiled. As described in Section 5.5.2.4, chemical safety controls have been identified as the principal SSC to ensure that the explosive concentration of hydrogen peroxide does not occur at the MFFF. This principal SSC verifies through sampling that the specification and dilution of the reagent hydrogen peroxide concentration before use in the process is below the explosion limit. There are no processes in the MFFF that can increase the hydrogen peroxide solution concentration.

8.5.1.5 TBP – Nitrate (Red Oil)

8.5.1.5.1 Background

The degradation of TBP and subsequent oxidation of the associated by-products by nitric acid introduces the risk of a runaway reaction and associated over-pressurization event due to the exothermic property of the reactions and the off-gases produced. This risk exists in process units within the AP Process that may contain these constituents and simultaneously is subject to high temperatures (i.e., Acid Recovery Unit, Oxalic Mother Liquor Recovery Unit, Purification Unit, and Solvent Recovery Unit).

The term "red oil" has been used since two incidents occurred in 1953, one at Hanford and another at Savannah River, involving rapid chemical decomposition reactions that over-pressurized semi-works or pilot-plant evaporators. In a broad sense, red oil is any unstable organic-based material that forms or accumulates during an operation at high temperature and progresses, as the temperature increases, to a decomposition reaction yielding gaseous products and heat. The material may be degraded organic reaction products (such as nitrated or oxidized diluent or compounds consisting of butyl groups from TBP) or an organic-nitrate complex (such as a plutonium adduct). Examination of the residue remaining after the incidents identified a red-colored organic phase containing uranium, TBP, nitrate, and organic material derived from the diluent. The red color probably resulted from the nitration of relatively unstable constituents in the diluent, and it is believed these diluent degradation products may have also contributed to the event sequence. Once decomposition started and the temperature increased, however, the major reactants are thought to have been adducts, TBP, and associated by-products from the hydrolysis reaction.

8.5.1.5.2 Chemical Reactions

The degradation of TBP may proceed by the following mechanisms:

- **Acid Catalyzed Hydrolysis**

  TBP, being an ester of phosphoric acid (H_3PO_4)), is likely to undergo ready hydrolysis. The reaction produces both butyl alcohol and dibutyl phosphate (DBP) as given by equation 8.5-1:

$$(C_4H_9O)_3PO + H_2O \rightarrow (C_4H_9O)_2POOH + C_4H_9OH \tag{8.5-1}$$

Further hydrolysis leads to the formation of monobutyl phosphate (MBP) and, ultimately, phosphoric acid as given by equations 8.5-2 and 8.5-3:

$$(C_4H_9O)_2POOH + H_2O \rightarrow C_4H_9OPO(OH)_2 + C_4H_9OH \tag{8.5-2}$$

$$C_4H_9OPO(OH)_2 + H_2O \rightarrow H_3PO_4 + C_4H_9OH \tag{8.5-3}$$

- **Dealkylation**

TBP may also undergo dealkylation with nitric acid as given by equation 8.5-4:

$$(C_4H_9O)_3PO + HNO_3 \rightarrow (C_4H_9O)_2POOH + C_4H_9ONO_2 \tag{8.5-4}$$

- **Pyrolysis**

When no water is present and the temperature goes above 150°C, TBP can undergo a pyrolysis reaction producing phosphoric acid and three molecules of butene, which is highly volatile and flammable, as presented in equation 8.5-5:

$$(C_4H_9O)_3PO \xrightarrow{\Delta} H_3PO_4 + 3C_4H_8 \tag{8.5-5}$$

As noted above in the hydrolysis and dealkylation reactions, the degradation of TBP may form butanol and butyl nitrate. The butanol formed via the hydrolysis of TBP, DBP, and MBP may subsequently undergo nitration to form butyl nitrate. Subsequent oxidation of butyl nitrate by nitric acid leads afterwards to the formation of butyric acid, propionic acid, and acetic acid. Each of these respective degradation mechanisms is identified in Figure 8.5-2, and the degradation products are defined in Table 8-8.

In addition to the chemical degradation of TBP, radiolysis also creates a mechanism by which degradation products of TBP are produced. Within the AP Process, radiolysis of TBP predominately occurs in the organic phase due to the low solubility of TBP within the aqueous solution. Furthermore, within the organic phase, the predominant mechanism by which radiolysis occurs is attributed to the presence of plutonium. Thus, the mechanism of concern is alpha-induced radiolysis. Therefore, essentially all of the decay energy is deposited in the solution. Radiolysis rates generally depend on a large number of factors, such as radiation type (alpha, beta, or gamma radiation), dose rate, the concentrations of water, nitric acid and plutonium, the phase in which radiolysis occurs (aqueous or organic), the isotopic composition of plutonium, the presence or absence of air, the concentrations of radiolysis products, etc. Bombardment of solutions of TBP by alpha ionizing radiation generates fragments (radicals and ions) of water and chemicals in solutions. Radiolysis of a TBP/n-dodecane solution in the presence of nitric acid could produce butanol and butyl nitrate, along with other organic nitrates ($RONO_2$), organic nitro compounds (RNO_2), and organic nitrites (RONO). These are formed by the capture of hydrocarbon radicals (C_nH_{2n+1}, n = 1 - 4) by nitrogen dioxide. Analysis has shown, in fact, that the rate of radiolysis-induced TBP degradation is approximately equal to that of the chemical degradation at 30°C under conditions present in the AP Process.

8.5.1.5.3 Reaction Kinetics

The reactions governing the chemical degradation of TBP are presented in Figure 8.5-2. In order to understand the dynamics of the system, the heat generation rate, and the quantity of degradation products in the system at a given time, the rate coefficients governing each step in the degradation process must be determined.

Kinetic studies have shown that TBP degrades much faster in aqueous solutions than it does in organic solutions. However, in mixed aqueous-organic systems, the concentration of TBP in the aqueous system is so low compared to that in the organic phase that the effect of aqueous phase hydrolysis is expected to be negligible (the solubility of TBP is 0.3g/L of nitric acid and the volume ratio of organic to aqueous is 1:5). Therefore, the concern is with the degradation of organic in the organic phase.

There have been numerous investigations of the reaction rate of TBP in the organic phase. Experimental results have concluded that the hydrolysis of TBP was the rate-limiting step in the overall TBP degradation process. Furthermore, the hydrolysis reaction was determined to be first order in TBP and zeroth order in nitric acid.

An Arrhenius fit to the rate data has been obtained:

$$k_{HNO_3.2TBP} = 4.3*10^{10}*\exp(-\frac{112}{RT}) \qquad (8.5\text{-}6)$$

where $k_{HNO_3.2TBP}$ is the rate constant for the hydrolysis of TBP. The units for the activation energy are kJ/g-mol and temperature (T) is in Kelvin, and the gas constant (R) is equal to $8.314*10^{-3}$ J/(g-mol K).

As indicated in Figure 8.5-2, TBP hydrolysis yields DBP. DBP may also undergo hydrolysis, which will result in the formation of MBP. MBP also undergoes hydrolysis and produces the same byproducts. It has been found that the first order rate constants for the hydrolysis reaction decrease in the order TBP>DBP>MBP. Thus, all hydrolysis may be conservatively given by the TBP hydrolysis rate for the purpose of quantifying reaction energetics.

8.5.1.5.4 Reaction Energetics

Energetic reactions may involve TBP, nitric acid, plutonium nitrate/TBP adduct, and TBP degradation products due to both chemical reactions (nitration/oxidation/hydrolysis) and radiolysis (the exclusion of cyclic chain hydrocarbons eliminates the diluent as a contributor to the reaction energetics). However, it is assumed in the following discussions of reaction energies that the reactions of nitrate and TBP and associated by-products adequately describe the behavior of the TBP-nitrate systems. It is further assumed that diluent and reactive products of diluent nitration are absent. From thermodynamic data, the total heat generated by the complete oxidation of TBP to carbon dioxide, phosphoric acid, and water by nitric acid has been calculated to be approximately 1689 kcal/mole. However, only approximately 20% of the energy content can be liberated due to the limited quantity of oxidizer present within the organic phase. The energetics are further reduced in an open system because the oxidation does not go to completion. Intermediate products such as CO, NO, and butyric acid remain and a portion of the oxidizer is evaporated from the system. Differential scanning calorimetry measurements indicate a reaction energy of approximately 67 kcal/mol in comparison to the theoretical value of 368 kcal/mole in the case of a 1:3 TBP to HNO_3 ratio. Explanation for this diminished energy release is attributed to both the evaporation of the oxidizer and some of the TBP degradation products. Thus, the experimentally measured energetic content of red oil is much smaller than typical explosive nitrated aromatic compounds such as TNT (4564 J/g) because of both the poor oxidant to fuel ratio in the TBP adduct and the evaporation of the oxidizer and by-products of degradation. Nevertheless, the energy available via TBP decomposition is substantial. Consequently, it is important to understand the means by which these reactions are limited to ensure that the energy generated via these reactions does not exceed the rate at which energy is removed from the system.

8.5.1.5.5 AP Process Operating Conditions

The reaction mechanisms for the degradation of TBP due to both chemical attack and radiolysis yield sufficiently energetic reactions that may proceed at appreciable rates under certain conditions such that over-pressurization and/or explosive conditions could arise. Ultimately, a runaway condition could occur if the rate of energy generation exceeds the rate at which heat is removed from the system. Therefore, mechanisms that ensure that the heat transfer and mass transfer of the reactants are adequate to control the system must be addressed.

Design bases to preclude a runaway condition must be viewed in aggregate. Principal SSCs and corresponding design bases synergistically provide reasonable assurance that runaway reactions will not occur (i.e., the combination of the control of the energy generation and heat transfer ensures that a runaway reaction is precluded).

Once a quantity of TBP and nitrate is heated to the point that it begins to react at an appreciable rate, subsequent reactions are determined by the heat removal processes available, and include:

- evaporation of water and other materials;
- heat transfer by conduction or convection to an aqueous phase;
- heat transfer to the vessel walls; and
- convective cooling by the gas in the head space.

In an unstirred closed vessel, geometric aspects influence the available heat transfer mechanisms. Chemical heating may occur in an organic phase overlying an aqueous phase. The floating organic phase is in the form of a disc, with its radius potentially much greater than its thickness in a cylindrical tank or vessel. Because organic solutions are generally poor conductors of heat, only a small region of the organic phase can be affected by cooling the vessel walls, and geometry inhibits establishment of large-scale convection processes with the organic phase. With the top of the aqueous phase being heated (producing a less dense top layer), there are no gravitational forces producing convection in this phase. Downward heat transfer between the phases, therefore, involves conduction, rather than convection, and heat removal is consequently lower. This description represents the limiting system from the perspective of selecting a minimum initiation temperature for a runaway reaction.

DCS has selected a design basis temperature of 135°C to limit the heat generation rate. This design basis temperature is based on the experimentally determined minimum initiation temperature for a ***closed*** system and is derived from isothermal experimental conditions. Furthermore, selection of this design basis temperature ensures that the selected diluent (discussed below) will not undergo degradation and lower the minimum initiation temperature of a runaway reaction.

Based on experimental evidence, the exclusion of cyclic chain hydrocarbons in diluents indicates that temperatures far in excess of 135°C are necessary to initiate runaway reactions in *open* systems containing nitric acid. Experimental evidence also suggests that diluents containing a large fraction of cyclic hydrocarbons (i.e., ~20—30% naphthenes) undergo significant nitration at temperatures lower than corresponding systems composed of both TBP and diluent. Therefore, the nature of the diluent is relevant in establishing the temperature at which systems composed of TBP/diluent begin to "run -away." The use of C_{10}-C_{13} branched chain hydrocarbons (aliphatic diluent HPT) in the AP process optimizes both the plutonium decontamination factor and the nitration resistance to ensure an adequate safety margin associated with the operation of the process. Consequently, DCS has identified the properties of the diluent as a principal SSC. The design basis for the diluent is to utilize a diluent containing no cyclic chain hydrocarbons.

DCS has also identified venting of vessels/equipment that may potentially contain TBP and its associated by-products as a principal SSC to provide additional heat transfer capability and to provide adequate safety margin. Venting provides the following benefits:

- limits pressurization of the system
- permits evaporation of dissolved water and/or nitric acid from the organic phase in an open system, which allows for additional heat transfer capability and, in the case of nitric acid, reduces the available energy by limiting reactants (this mode of heat transfer is much more efficient than the heat transfer provided by a closed system; experimental evidence suggests that this can dominate the energy balance at lower temperatures, causing a net cooling and slowing the chemical reaction);
- maintains a constant temperature in a boiling system (in an evaporator, for example, in which the entire contents are heated, the resultant turbulent mixing should keep the organic and aqueous phases at the same temperature, so that the overall temperature is controlled by the boiling aqueous phase);
- permits evaporation of a fraction of the degradation products (butanol and butyl nitrate) from the system thereby reducing the energy content of the system; and
- allows escape of NO_x, the decomposition product of alkyl nitrates reacting to alcohol. NO_x, in equilibrium with HNO_2, may also play the role of catalyst for this decomposition reaction.

Also, historical evidence suggests that there is no violent reaction in a system with appreciable venting. Minimum vent sizes will be determined during final design.

The use of venting implies control of the bulk quantity of organics added to a given vessel. DCS has implemented the following features to preclude the transfer of bulk quantities of organic to heated equipment:

- A diluent washing pulsed column for washing the extracted plutonium aqueous stream
- A diluent washing pulsed column for washing the extraction process unloaded feeding solution ("raffinates stream")
- A diluent washing mixer-settler for washing the extracted uranium aqueous stream
- A diluent washing mixer-settler for washing the aqueous phase containing TBP degradation products from solvent recovery.

DCS is currently evaluating the principal SSCs that will be required to prevent bulk quantities of organic from entering process equipment that could exceed the associated minimum vent-size-to–organic-mass ratio. In the event that a quantity of organic material, sufficient to exceed the design basis vent size to organic mass ratio for a given vent dimension, could occupy a vessel/tank, controls to preclude the quantity of organic from being placed into the corresponding vessel will be identified in the ISA.

In addition, because gases are released during the chemical reactions, foaming may be possible. Foaming in the organic phase occurs as self-heating accelerates due to the gases generated. Significant amounts of foam could limit the effectiveness of the vent. In addition, foam can be thermally isolated from the rest of the system because of its insulating qualities. A foaming mass that is undergoing an exothermic reaction may therefore attain a higher temperature than a liquid in contact with a heat sink, such as water. When a cyclic diluent was utilized in past red oil incidents, foaming is believed to have occurred prior to a runaway condition. Again, the selection of a diluent containing no cyclic hydrocarbons and limitations on the temperature are implemented as principal SSCs to limit foaming and provide reasonable assurance that the vents remain effective.

8.5.1.5.6 Impact of Tomsk-7 Event

On April 6, 1993, at the Tomsk-7 nuclear fuel processing facility located in Siberia, Russia, there purportedly were two sequential explosions that caused physical damage to the facility and contaminated the facility and the surrounding area. The explosions appear to be due to the "red oil" phenomenon associated with nitric acid, TBP, and the hydrocarbon diluent used by the Russians, and was initiated by actions that constituted violations to operating procedures and operating conditions unlikely to occur at the MFFF. Inadequate venting was also a likely contributor in the explosion.

The Tomsk-7 event identified a new mechanism to the TBP degradation/red oil formation phenomenon. This arose from the apparent initiation of an energetic runaway reaction in the vicinity of 90°C, far below the previously observed minimum temperature for a runaway TBP hydrolysis-limited reaction. Several investigators postulated that the accumulation of two degradation products, butanol and butyl nitrate, may have been responsible for the lower initiation temperature. Experimental results have verified that these two degradation products of TBP can, in the presence of concentrated nitric acid, release significant energy at temperatures far less than 135°C. Significant buildup of degraded organics is not expected at the MFFF (i.e., solvent is routinely used and regenerated as part of normal operations, and most degraded organics are destroyed during normal operation). Nonetheless, such a buildup is conservatively postulated.

Butanol, a TBP degradation product, is rapidly and completely converted to butyl nitrate at temperatures of 110°C to 120°C, and is oxidized further to butyric acid, propionic acid, and acetic acid when contacted with moderate to strong (6M to 15.8M) nitric acid. Butyl nitrate oxidation begins as solutions with 10M to 15.8M nitric acid are heated to between 52°C and 85°C, and these reactions are strongly exothermic. The heat of reaction for butanol oxidation has been determined to be -466 cal/g (-1948 J/g) of butanol based on a 1:1 butanol to nitric acid ratio. The negative heat of reaction favors the formation of butyl nitrate in this reaction equilibrium. Additional experimental results indicate that even at a fairly low concentration of nitric acid (0.8M), butanol is converted to butyl nitrate at about 100°C.

Thus, in order to determine whether the accumulation of TBP degradation products butanol and butyl nitrate can provide the initial energy release via oxidation to raise the organic phase temperature to above 135°C, a determination of the quantity of each species in solution must be obtained (unlike the pre-Tomsk-7 operating assumption that, in the formulation of a model to describe TBP degradation at elevated temperatures, the oxidation reactions proceeded much more rapidly than the hydrolysis reaction and consequently degradation products did not build up).

To determine the quantity of degraded organics necessary to raise the temperature of the bulk organic to 135°C, the minimum initiation temperature for a runaway reaction, the total quantity of organic necessary support a runaway reaction in an open system is calculated utilizing the vent-to-organic-mass ratio described above. A heat balance is then utilized to calculate the quantity degraded organic necessary to elevate the bulk organic temperature to 135°C.

Preliminary analyses have indicated that the organic mass in a vessel or tank must be limited to on the order of 30 kg of organic material. Based on conditions that could be encountered during unlikely extended shutdowns, the mass of degraded organics necessary to elevate the bulk organic temperature to the 135°C is a few kilograms. The total degraded organic/TBP mass is given by the production rates from both radiolysis and hydrolysis minus the amount of degraded organic lost to the system from evaporation and oxidation via the nitric acid. These preliminary analyses indicate the degraded mass is reached in on the order of years. Consequently, the principal SSCs are established to provide reasonable assurance that significant quantities of butanol and/or butyl nitrate do not build up in the process. The design basis for these controls is limiting the residence time of organics in the presence of oxidizers such as nitric acid (i.e., in process vessels containing oxidizing agents and potentially exposed to high temperatures), and radiation fields, to limit the quantity of degraded organics that may buildup in the system either through hydrolysis and/or radiolysis.

8.5.1.6 Pyrophoricity of Uranium and Plutonium

Both plutonium and uranium metals are pyrophoric and readily ignitable when existing in a finely divided form. When these metals are present in large or massive forms they do not present a significant fire risk. When these metals exist in the dioxide form (e.g., PuO_2 and UO_2) they are relatively stable and not considered pyrophoric. The MFFF only handles these materials in the dioxide form.

While the fire risk associated with the dioxide forms of U and Pu is low, hazards associated with handling of these materials do exist. Uranium dioxide can undergo further oxidation to higher oxides resulting in spontaneous heating. Sub-stoichiometric plutonium oxides formed by incomplete or partial oxidation of plutonium metal can be pyrophoric. These hazards are described below.

8.5.1.6.1 UO_2

At elevated temperatures, finely divided UO_2 can undergo further oxidation to higher uranium oxides, specifically U_3O_8. This reaction results in spontaneous heating of the oxide and is typically referred to as "burnback." In the past, this phenomenon has been associated with fires at fuel fabrication facilities handling UO_2. In these events, the oxidizing uranium powder was believed to be heated by some mechanical failure (i.e., friction) which initiated the burnback reaction and released heat. Combustible materials such as transfer hoses and boots then provided the fuel to support a fire.

In addressing this hazard, the SA has identified UO_2 spontaneous heating as a cause for fire in a glovebox. Also, the heat generated by the burnback phenomenon has been considered in the thermal analysis of facility gloveboxes as described in Section 5.5.2.1.6.9. The specific power of UO_2 oxidation is taken into account using the following design basis values:

- If $T < 74°C$ (165.2°F) then $P_{ox} = 0$ W/kg (0 W/lb) of UO_2,
- If 74°C (165.2°F)$< T < 340°C$ (644°F) then $P_{ox} = 1.1$ W/kg (0.499 W/lb) of UO_2,
- If $T > 340°C$ (644°F) then $P_{ox} = 4.63$ W/kg (2.1 W/lb) of UO_2

where T is the powder temperature.

Although not identified as principal SSCs to address this specific hazard, the following features of the UO_2 storage/handling processes provide additional protection:

- UO_2 delivered to the MFFF site and stored in steel drums, double bagged under a N_2 atmosphere
- UO_2 maintained in a N_2 atmosphere throughout the process
- Fire detection and suppression systems provided for gloveboxes (CO_2 injection) and process rooms (clean agent)
- Use of noncombustible or nonflammable materials for process equipment construction and furnishing

- Control of combustible materials.

These additional protection features incorporate selected recommendations of NRC Information Notice 92-14, *Uranium Oxide Fires at Fuel Cycle Facilities.* Consideration of recommended administrative controls (operator training, process unit operator attendance, etc.) will be addressed in facility procedures.

8.5.1.6.2 PuO_2

Although PuO_2 is unreactive in air, sub-stoichiometric compounds of plutonium can be formed as a result of partial oxidation of plutonium metal. These compounds can be pyrophoric and when exposed to an oxidizing atmosphere could rapidly form PuO_2 while releasing heat. To control this hazard the MFFF will ensure that a stable PuO_2 form is introduced to the MFFF.

Plutonium feed material is received at the MFFF from the Pit Disassembly and Conversion Facility (PDCF). A small quantity of feed material (alternate feed stock) will initially be supplied from alternate sources until the PDCF is operational. To ensure stability of the MFFF Pu feed material, both of these sources will supply PuO_2 satisfying the requirements of DOE-STD-3013-2000, *Stabilization, Packaging, and Storage of Plutonium-Bearing Materials.* Specifically, the requirement that oxide material be placed in a continuously oxidizing atmosphere at a material temperature of at least 950° C for a minimum of two hours ensures a stable product. Not only does this requirement eliminate sub-stoichiometric plutonium oxides and finely divided metal, it also achieves the following additional stabilization objectives:

- Elimination of organic materials
- Reduction of water content to less than 0.5 wt% and reduction of quantities of species that may produce water
- Minimization of potential for water readsorption above the 0.5% threshold
- Stabilization of any other potential gas-producing constituents

DOE-STD-3013-2000 accepts two methods of verification that materials have been adequately stabilized. These methods are 1) testing of every container loading or 2) use of a "qualified process" for stabilization and packaging that would reduce the requirements for materials testing. Details of the method to verify the receipt of stabilized material will be addressed in the ISA.

The formation of sub-stoichiometric oxides is associated with the conversion of plutonium metal to oxide. The conversion process step associated with MFFF aqueous polishing converts plutonium oxalate to plutonium dioxide. The formation of sub-stoichiometric oxides during this conversion process is not a concern as reduction of the Pu (IV) oxalate does not occur.

It should also be noted that the thermal power generated by the decay of plutonium has been taken into account in the design. The design basis values are as follows:

- Unpolished Pu: 2.9 W/kg of unpolished PuO_2 powder
- Polished Pu: 2.2 W/kg of polished PuO_2 powder

See section 5.5.2.1.6.9 for additional details regarding the effects of decay heat.

8.5.1.7 Plutonium (VI) Oxalate

Plutonium oxalate is produced in the VI valence state in the plutonium dissolution unit and dechlorination unit, where it is reduced utilizing H_2O_2 to Pu (IV) prior to entering the purification unit. In addition, Pu (VI) is produced within the oxalic mother liquor recovery unit. This material is then re-introduced into the purification unit. Within the purification unit, Pu(VI) is reduced by the hydroxylamine and oxidized to Pu(IV). Within the oxalic precipitation and oxidation unit, the plutonium oxalate is precipitated via the addition of oxalic acid. In the event of a failure to oxidize Pu (IV) within the purification unit following HAN reduction and subsequent oxidation, Pu (VI) oxalate could be produced within the oxalic precipitation and oxidation unit. The Pu (VI) oxalate could then be introduced into the calcining furnace, which would create a hazard as discussed below.

Experimental evidence performed using differential thermal analysis (DTA) has evaluated the activation energy and order of the reaction for the thermal decomposition of $PuO_2C_2O_4{:}3H_20$ in air. The DTA curve for Pu (VI) oxalate shows a broad endothermic peak (due to dehydration) with a maximum at 142°C and a sharp exothermic peak (oxidation of the oxalate) with a maximum at 219°C. The dehydration enthalpy was determined to be 13 kcal/mole and the exothermic reaction was found to be -25 kcal/mole. Although not particularly exothermic, the decomposition is rapid and can be explosive. (Plutonium (VI) is likely to be reduced to Pu (III) as an intermediate oxidation state in this reaction, but, as with Pu(IV) oxalate, the final product will be PuO_2.) Therefore, DCS has implemented a preventative safety strategy to satisfy the performance requirements of 10 CFR §70.61.

The design basis to control this hazard is to preclude the introduction of Pu(VI) oxalate into heated equipment where temperatures in excess of 219°C are credible. In addition, controls will be in place to ensure that temperatures do not exceed 219°C were plutonium (VI) oxalate may be present (e.g., in the oxalic mother liquor recovery unit and in the oxalic precipitation and oxidation unit). The specific temperature setpoints will be determined during final design.

8.5.1.8 Hydrazoic Acid

Hydrazoic acid, also known as hydrogen azide (HN_3), is formed when hydrazine (N_2H_4 or $N_2H_5^+$) is oxidized by nitrous acid (equation 8.5-7). Further oxidation leads to the formation of nitrous oxide and nitrogen gases (Equation 8.5-8).

$$N_2H_5^+ + HNO_2 \rightarrow HN_3 + 2H_2O + H^+ \tag{8.5-7}$$

$$HN_3 + HNO_2 \rightarrow N_2O + N_2 + H_2O \tag{8.5-8}$$

The competitive nature of the hydrazoic acid formation reaction (equation 8.5-7) and its scavenging reaction (equation 8.5-8) initially establishes preferable generation of hydrazoic acid due to the faster reaction kinetics associated with nitrous acid and hydrazine (equation 8.5-7).

However, due to the scavenging properties of hydrazoic acid, an equilibrium concentration of hydrazoic acid will be reached within a solution containing hydrazine and nitrous acid. The maximum equilibrium concentration of hydrazoic acid is set by the hydrazine concentration, whereas the equilibrium concentration in the process is based on the quantity of nitrous acid available for reaction.

Hydrazoic acid is a colorless liquid that is very soluble in water. It is a relatively weak acid with the approximate strength of acetic acid (pKa = 4.77). Hydrazoic acid is an unstable compound, especially in the pure chemical form when heated or shocked. Its relatively low boiling point (T = 35.7°C under atmospheric pressure) makes it volatile at room temperature. The activation energy has been determined to be 147 kJ/mole. In the presence of metal ions, hydrazoic acid can transform into a metal azide. More details of these azide reactions are covered in Section 8.5.1.9.

Energetic decomposition of hydrazoic acid can occur both in an aqueous liquid phase, when the threshold concentration of 4.7 mol/L is reached (i.e., the lower explosive concentration limit, LECL for the pure chemical form) and also in a gaseous phase as given by equation 8.5-9. The threshold partial pressure moving hydrazoic acid into an explosive regime has been experimentally determined to be 25 to 68 Torr (0.09 atm) and theoretically established to be 19 Torr (0.025 atm).

$$2HN_{3(g)} \rightarrow 3N_2 + H_2 + 526kJ \qquad (8.5\text{-}9)$$

For the AP processes, the specific hydrazoic acid risk in the gaseous phase is related to its phase transfer from the liquid phase (aqueous or organic) to the gaseous phase, per equations 8.5-10 and 8.5-11.

$$HN_{3(aq)} \rightarrow HN_{3(g)} \qquad (8.5\text{-}10)$$

$$TBP \cdot HN_{3(org)} \rightarrow HN_{3(g)} + TBP \qquad (8.5\text{-}11)$$

The partial pressure of hydrazoic acid in the gaseous phase, P_{HN_3}, is related to hydrazoic acid concentration in the aqueous phase or to the hydrazoic acid—TBP complex ($TBP \cdot HN_3$) concentration in the organic phase, by the Henry coefficient (H):

$$H(atm \cdot L/mol) = P_{HN_3}/[HN_3] \qquad (8.5\text{-}12)$$

Utilizing Henry's Law and the more conservative theoretical partial pressure, the limiting hydrazoic acid explosive concentration is determined for both the aqueous and organic phase as follows:

- **For hydrazoic acid in aqueous phase that could subsequently be transferred to the gaseous phase and result in an explosion risk:**

  Explosive decomposition of hydrazoic acid could occur in the aqueous phase when the threshold concentration of 4.7 mol/L is reached. The kinetic study of hydrazoic acid desorption from an aqueous phase to the gaseous phase has shown that the Henry coefficient for HN_3 may be expressed by the following formula for temperatures varying from 25 to 60°C:

  $$H(\mathrm{atm \cdot L/mol}) = C\exp(-E_a/RT) = 75{,}475\exp(-4{,}001.9/T) \qquad (8.5\text{-}13)$$

  where T is the temperature in Kelvin. This formula accounts for a desorption activation energy of 8 kcal/mol (33.4 kJ/mol).

  Utilizing equations 8.5-12 and 8.5-13 and the theoretically determined partial pressure threshold of 19 Torr (0.09 atm) for the gaseous phase, the minimum hydrazoic acid concentration in 0.1 to 1 M nitric acid for solutions to reach the explosive concentration in the gaseous phase has been determined to be 0.055 mol/L at 60 °C. This concentration and its associated temperature can be used to preclude the explosion risk in the gaseous phase from the aqueous phase of solutions found in various AP pieces of equipment that may contain hydrazine.

- **For hydrazoic acid in organic phase, that could subsequently be transferred to the gaseous phase and result in an explosion risk:**

  Hydrazoic acid is soluble in the organic phase composed of TBP 30%, HTP 70%. The kinetic study of hydrazoic acid desorption from an organic phase to a gaseous phase has shown that the desorption activation energy is 16 kcal/mol (66.8 kJ/mol). The theoretically determined partial pressure of 19 Torr corresponds to a concentration of 1.4 mol/L at 25°C in the organic phase. The Henry coefficient (H) as a function of temperature can thus be expressed by the following formula:

  $$H(\mathrm{atm \cdot L/mol}) = C\exp(-E_a/RT) = 9.5\times10^9\exp(-8038/T) \qquad (8.5\text{-}14)$$

  where T is the temperature in Kelvin. Accounting for a maximum process temperature of 60°C, the minimum hydrazoic acid concentration to reach the explosive concentration in the gaseous phase has been determined to be 0.08 mol/L. This concentration and its associated temperature can be used to preclude the explosion risk in the gaseous phase from the organic phase of solutions found in various AP pieces of equipment that may contain hydrazine.

When utilizing the theoretical value as the limiting concentration for the hydrazoic acid, the yield of hydrazoic acid derived from the reaction between nitrous acid and hydrazine becomes an important parameter that limits the quantity of hydrazoic acid in the system. The yield of hydrazoic acid from the reaction between hydrazine and nitrous acid is determined predominately by both the relative reaction rates of the nitrous acid reaction with hydrazine and hydrazoic acid, and the concentration of hydrazine present in the system, which is added to the Purification Cycle at 0.14 mol/L. A yield of 39.3% or less is necessary (0.055/0.14) to ensure limiting conditions are not present in the AP processes.

Thus, the design basis to control the risk related to hydrazoic acid explosions is as follows: ensure the hydrazoic acid yield is 39.3% or lower, ensure a maximum hydrazine concentration of 0.14 moles per liter is used, and ensure a maximum temperature of 60°C where these chemicals are used in the AP process. DCS will perform analysis in the ISA to establish a bounding hydrazoic acid yield and implement any necessary controls to ensure that the hydrazoic yield is below 39.3%, which ensures that the critical concentration of 0.055 mol/L of hydrazoic acid is not exceeded.

It should be noted that that the corresponding limitations on the hydrazoic acid yield assume adiabatic conditions. DCS is currently investigating more realistic heat transfer that may be utilized in the ISA to justify the use of a larger threshold partial pressure (i.e., greater than 19 Torr, which is the theoretically calculated partial pressure of hydrazoic acid).

In addition to the previously identified design basis, sampling controls are also implemented to ensure that the process of transforming the hydrazoic acid to sodium azide within the Solvent Recovery Unit is effective to ensure that hydrazoic acid does not accumulate in the process to a limiting concentration due to the continuous injection of hydrazine into the Purification Cycle. This sampling control also ensures that azides are not formed within the extraction and diluent washing pulse columns of the Purification Cycle (i.e., PULS2000 and PULS2200) due to the potential presence of metal impurities within these columns.

An additional case involves the evaporation of hydrazoic acid in solution at low temperatures (e.g., approximately 20°C) and subsequent condensation of the hydrazoic acid in the ventilation system. In this case, it is theoretically possible to reach a limiting for the hydrazoic acid concentration to reach the explosive threshold in the condensing aqueous solution of 0.055 mol/L (limiting value based on theoretical threshold partial pressure). At higher temperatures (i.e., greater than approximately 20°C), the gaseous phase contains sufficient water vapor to ensure that if any vapor is condensed, limiting concentrations of hydrazoic acid cannot be obtained. The partial pressure of hydrazoic acid will be dramatically reduced, however due to the dilution in the ventilation system; further unrealistically low temperatures would need to be present in the ventilation system in order for hydrazoic acid condensation to occur. Consequently, DCS will perform additional analyses during the ISA to determine if any additional controls are necessary to preclude the condensation of hydrazoic acid inside the ventilation system.

8.5.1.9 Metal Azides

The azide anion, N_3 forms adducts with metallic cations. Metal azides, formed in basic media from metallic cations and hydrazoic acid interaction, are slightly soluble to non-soluble (e.g., Ag or Zr) in aqueous media. Characteristics of the bond between the anion and the cation, which form the azide salt, can cause these compounds to become unstable under specific conditions. The most unstable azide salts are the heavy metallic salts that form covalent bonds with N_3^-.

Most azides in pure chemical form decompose when heated. Azide salts are thus not stable when placed in dry conditions at temperatures far above 135°C. With the exception of the calcining furnace, this is the limiting temperature within the AP Process.

With the exception of hydrazoic acid, the AP process precludes any significant production of azides. This is accomplished by the removal of a significant fraction of the impurities in the plutonium feedstock introduced into the front end of the Purification Cycle (i.e., into the extraction pulse column, PULS2000) and by the absence of hydrazoic acid from the columns and tanks that may contain these impurities. The absence of hydrazoic acid from the front end of the Purification Cycle is assured due to sampling controls whose function is to detect hydrazoic acid prior to reintroducing solutions into the front end of the Purification Cycle (e.g., TK1000 or PULS2000).

In the plutonium stripping pulsed column (PULS3000) and equipment downstream of this column, hydrazoic acid is present due to the introduction of hydrazine into the plutonium barrier mixer-settler (MIXS4000) which feeds PULS3000 and subsequent downstream equipment. In the event that metal azides are formed within this Purification Cycle equipment, the azides will reside in the aqueous phase which is introduced into the oxidation column (CLMN6000) within the Purification Cycle prior to transfer to a downstream unit. Within the oxidation column, the azides will be destroyed due to the presence of nitrous acid which reacts with the azide to produce a nitrogen gas.

Finally, prior to being introduced into the calcining furnace, the solution is sampled to further ensure that azides are not introduced into the furnace whose temperature may exceed 140°C. This sampling measurement which ensures that azides are not present is identified as a principal SSC. In addition, the Process Safety Control Subsystem is also identified as a principal SSC to ensure that equipment potentially containing azides are not exposed or raised to temperatures that could exceed 135°C.

As discussed previously, azides in a dry environment are also unstable with respect to shocks due to the weak intermolecular force holding the azide together. Consequently, to ensure that conditions do not exist to create this potential hazard, administrative controls have been identified as the principal SSC to ensure that tanks potentially containing azides are not left dry. Previously identified process controls and the sampling controls to limit the presence of hydrazoic acid in process vessels are also used to preclude this potential explosion event.

Additional details on specific azides that could potentially be formed within the AP Process are provided below.

Plutonium and Uranium Azides

The azide anion can form soluble weakly bonded azido complexes with uranium and plutonium at molar ratios of HN_3/Pu and HN_3/U less than one. Considering the bounding hydrazoic acid (HN_3) concentration developed in the previous section is 0.055 mol/L, the plutonium/uranium concentration in process vessels in which this condition could exist must be very low. Furthermore, the formation of solid uranium or plutonium azides in alkaline solutions may be safely excluded because hydroxide or carbonate complexes are preferentially formed, and therefore the production of uranium and plutonium azides is expected to be much less than 0.055 mol/L.

Silver Azide (AgN_3)

Contact of hydrazoic acid with silver nitrate in the process can form silver azide salts in accordance with the following:

$$HN_3 + AgNO_3 \rightarrow AgN_3 + HNO_3 \qquad (8.5\text{-}15)$$

The initial silver concentration upstream of the Purification Cycle is approximately 0.011 mol/L. TBP liquid/liquid extraction operates with a decontamination factor for silver of approximately 2 x 10^5. No silver has ever been detected downstream of the extraction step in operating installations at the Cogema UP3 facility, based on mass spectrometry detection threshold for silver of 9.3 x 10^{-9} mol/L. The silver nitrate concentration reaching the "Pu stripping" (PULS3000) and "Pu barrier" (MIXS4000) purification steps can therefore be assumed to be less than 5.5 x 10^{-8} mol/L (0.011/2 x 10^5) under anticipated conditions.

The credited principal SSC required to meet the performance requirements of 10 CFR §70.61 is the Process Safety Control Subsystem, which ensures the temperatures in process vessels that may potentially contain hydrazoic acid are maintained below 140°C, which is below the thermal decomposition temperature of silver azide.

As described above, the presence of silver azide is limited to equipment within the Purification Cycle downstream of the plutonium stripping pulse column (PULS3000). This limitation on the location of the silver azide is attributed to a process that destroys azides and hydrazoic acid that may have formed in the Purification Cycle and Solvent Recovery unit. As previously stated, sampling controls which have been identified as a principal SSC confirm the effectiveness of the destruction of both azides and hydrazoic acid prior to transfers of solutions for processing by downstream units.

Sodium Azide (NaN_3)

Sodium azide results from the reaction between sodium cations and azide anions as follows:

$$2HN_3 + Na_2CO_3 \rightarrow 2NaN_3 + H_2CO_3 \qquad (8.5\text{-}16)$$

$$HN_3 + NaOH \rightarrow NaN_3 + H_2O \qquad (8.5\text{-}17)$$

In the Solvent Recovery unit, sodium (in the form of sodium carbonate and sodium hydroxide) is added to the solvent washing mixer-settler (MIXS1000). This sodium reacts with the hydrazoic acid formed in the Purification Cycle producing sodium azide. The maximum concentration of azide in the system is 0.058 M Thus, as in nitric acid media, the solubility of sodium azide is approximately 6.3 M at 25°C, the minimum concentration of sodium needed for sodium azide to precipitate would be 684 M ($[Na^+][N_3^-] = 6.3^2$), i.e., 342 M of Na_2CO_3. Such value cannot be reached as the solubility of Na_2CO_3 in water at 25°C is equal to 4 M, so that the concentration of sodium azide formed as a result of the neutralization reactions is limited within safety requirements. Consequently, no additional safety controls are required.

To limit the propagation of the sodium azide within the AP process, DCS will incorporate a process to destroy the sodium azide. This process relies on the addition of sodium nitrite followed by acidification.

As previously discussed, the sampling principal SSC will ensure the effectiveness of the process to destroy sodium azide. This destruction is necessary prior to the introduction of the waste stream containing the sodium azide into acidified solutions due to the possible liberation of hydrazoic acid from the solution which is possible if the normality of the solution is in excess of 0.426 M nitric acid.

8.5.1.10 Nitrogen Dioxide/Dinitrogen Tetroxide

Dinitrogen tetroxide is stored in cylinders in the Reagents Processing Building in liquefied form. Instrument air is injected into the cylinder to transfer the liquid into an electric boiler, also located in the Reagents Processing Building, where it is vaporized to gaseous nitrogen dioxide and other NOx gases prior to entry into the aqueous polishing area.

Under normal operations, the vaporized gases are reacted with the hydrazine, HAN, and hydrazoic acid that are present with plutonium nitrate in the oxidation column (CLMN6000) of the purification cycle of the Aqueous Polishing process. If these gases or the unreacted nitrogen dioxide/dinitrogen tetroxide gases are released from the stack the consequences to all potential receptors are acceptable (no offgas treatment is required).

However, if the process fails (e.g., the flow of plutonium nitrate with hydrazine, HAN, and hydrazoic acid is deterministically assumed to be abnormally terminated to the oxidation column) and/or the nitrogen dioxide/dinitrogen tetroxide supplied to the oxidation column flows at an abnormally high rate, then there is the potential for chemical consequences associated with the release of these gases that may have come into contact with licensed materials to be unacceptable to the site worker. As described in section 5.5.2.10, the flow of nitrogen dioxide/dinitrogen tetroxide is limited to the oxidation column such that chemical consequences to the site worker are acceptable. The design basis value is the TEEL-2 limit for nitrogen dioxide/dinitrogen tetroxide listed in Table 8-5. This is the value that will not be exceeded during normal and off-normal conditions. To exceed this value, preliminary calculations indicate a flow rate in excess of approximately 44 kg/hr is necessary. The normal flow rate is approximately 1.3 kg/hr. Calculations will be performed as part of detailed design (and summarized in the ISA) to determine the appropriate means to assure the TEEL-2 limit is not exceeded.

8.5.2 Design Bases During Normal Operations

Chemical process and control system descriptions and their associated design bases are provided in Sections 11.3, 11.6, and 11.8.

8.5.3 Chemical Process Safety Design Features

Principal SSCs related to chemical process safety are discussed in Section 5.5 and the design basis associated with these features are provided in Section 8.5.1. Specific setpoint ranges will be identified as part of detailed design and provided as part of the ISA Summary submitted with the license application for possession and use of SNM.

8.5.4 Principal SSCs

Principal SSCs are discussed in Section 5.5.

8.5.5 Graded Approach to Safety

The application of graded controls on principal SSCs and IROFS according to their safety function and significance is described in Section 15.1.

8.5.6 Management Measures

Management measures are described in Chapter 15.

8.6 CHEMICAL PROCESS SAFETY INTERFACES

Chemical safety related to storage, handling, and processing of licensed material (and hazardous chemicals produced from license material) is provided through integration of chemical safety analyses with the ISA (see Chapter 5). Controls established for chemical safety are consistent with those established for radiological safety and criticality safety, as are the associated management measures. Accordingly, the chemical safety program is conducted under the same elements of programmatic infrastructure described in Chapters 4, 12, and 14, and interfaces with the management measures discussed in Chapter 15.

8.6.1 Organizational Structure

The Duke Cogema Stone & Webster (DCS) MFFF organization structure is described in Chapter 4, including designation of positions within the DCS organization responsible for principal SSCs. Principal SSCs are established for radiological, chemical, and criticality control in accordance with 10 CFR §70.61. Thus, the positions responsible for principal SSCs, as indicated in Chapter 4, also are responsible for chemical safety. Chapter 5 also indicates positions responsible for the conduct of the ISA. Since the ISA includes evaluation of chemical hazards, these positions also are responsible for the conduct of chemical safety analysis.

As indicated in Chapter 4, DCS will maintain continuity of control over principal SSCs during and following the transition from design and construction to operations. This control will also extend to chemical safety as an integrated component of the ISA process.

8.6.2 Human Factors

Human factors engineering for personnel activities relied on for safety is discussed in Chapter 12. The MFFF is a highly automated facility based in large part on existing facilities. Criteria for human factors engineering are applied to the design of principal SSCs with associated personnel activities for operation or maintenance. These operations will include those associated with chemical processes, both inherently (i.e., the AP and MP processes are intrinsically chemical processes) and explicitly (i.e., the scope of human factors engineering is associated with control of principal SSCs whose function is protection against radiological, chemical, and criticality hazards).

8.6.3 Emergency Management

An emergency plan is not expected to be required to be submitted for approval (see Chapter 14). However, the MFFF emergency management program will be integrated with the SRS and F-Area emergency preparedness programs, which include appropriate consideration of chemical-related accidents.

8.6.4 Quality Assurance

The quality assurance program provides confidence that principal SSCs provide adequate protection against potential radiological, chemical, and criticality hazards. SSCs and personnel actions relied on for chemical safety are controlled under the same program as those established for radiological and criticality hazards. The DCS MOX Project Quality Assurance Plan (MPQAP) is described in Section 15.1.

8.6.5 Configuration Management

The configuration management program will provide oversight and control of design bases and modifications (both temporary and permanent) to SSCs and management measures relied on for safety, including those associated with chemical safety. The MFFF configuration management program is described in Section 15.2.

8.6.6 Maintenance

The MFFF maintenance program is described in Section 15.3. Surveillance, preventative and corrective maintenance, and post-maintenance testing are applied to principal SSCs as appropriate to help ensure their reliability and availability. Chemical safety SSCs are included as part of this maintenance program.

8.6.7 Training and Qualification

Qualification of personnel and training to conduct IROFS activities are applicable to those functions that involve principal SSCs for protecting against radiological, chemical, and criticality hazards. Personnel responsible for performing activities involving chemical safety will be qualified and trained in accordance with the MFFF training program, as described in Section 15.4.

8.6.8 Plant Procedures

Activities associated with principal SSCs are conducted in accordance with appropriate procedures. In the operating MFFF, plant procedures govern operations, maintenance, emergency response, and administrative actions and ensure that principal SSCs are operated in a manner consistent with the ISA. Plant procedures associated with SSCs relied on for chemical safety will take into account chemical hazards, as well as radiological and criticality hazards, as appropriate for the activity. MFFF plant procedures are described in Section 15.5.

8.6.9 Audits and Assessments

Audits and assessments will be used to determine the effectiveness of management measures, including those associated with chemical safety. Audit and assessment attributes (including independence of auditors from personnel responsible for the chemical safety activities being audited, reports to management, and so forth) are consistent with those for other principal SSCs. The MFFF audits and assessments program is described in Section 15.6.

8.6.10 Incident Investigations

Incident investigation activities will identify corrective actions for and root causes of incidents that affect principal SSCs for chemical safety, as appropriate. As necessary, such investigations will identify actions to preclude recurrence of the incident. These incident investigations will be conducted in accordance with an incident investigation program used for all principal SSCs, described in Section 15.7.

8.6.11 Records Management

Chemical safety records are controlled in accordance with the configuration management system, the requirements of the MPQAP, and the records management program described in Section 15.8. Chemical safety records are processed and retained in the same manner as records associated with other principal SSCs and related programs.

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Tables

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Table 8-1a. Process Chemicals in the Reagent Processing Building (BRP)

CHEMICAL			
Name	Formula	CAS Number (Note 3)	STATE
Diluent (C10-C13 Isoalkanes)	C10-C13 Isoalkanes	68551-17-7	Liquid
Hydrazine Monohydrate	$N_2H_4.H_2O$	7803-57-8	Liquid
Hydrazine Nitrate (Note 1)	N_2H_4-HNO_3	13464-97-6	Liquid
Hydrogen Peroxide	H_2O_2	7722-84-1	Liquid
Hydroxylamine Nitrate	NH_2OH-HNO_3	13465-08-2	Liquid
Nitric Acid	HNO_3	7697-37-2	Liquid
Nitrogen Dioxide (Note 2)	NO_2	10102-44-0	Gas
Nitrogen Tetroxide	N_2O_4	10544-72-6	Liquid/ Gas
Oxalic Acid	$H_2C_2O_4$	144-62-7	Solid/ Liquid
Sodium Carbonate	Na_2CO_3	497-19-8	Solid/ Liquid
Sodium Hydroxide	NaOH	1310-73-2	Liquid
Tributyl Phosphate	$(C_4H_9)_3PO_4$	126-73-8	Liquid

Table 8-1a Notes:

1. Hydrazine nitrate is made up in the BRP from hydrazine hydrate and nitric acid.
2. Nitrogen dioxide is the coexisting dimer of nitrogen tetroxide in gas form.
3. CAS Number refers to Chemical Abstract Services Registry Number.

Table 8-1b. Process Chemicals in the Aqueous Polishing Building (BAP)

CHEMICAL			
Name	**Formula**	**CAS Number**	**STATE**
Aluminum Nitrate	$Al(NO_3)_3*9H_2O$	13473-90-0	Liquid
Chlorine (Note 1)	Cl_2	7782-50-5	Gas
Diluent (C10-C13 Isoalkanes)	C10-C13 Isoalkanes	68551-17-7	Liquid
Hydrazine Nitrate	N_2H_4-H NO_3	13464-97-6	Liquid
Hydrogen Peroxide	H_2O_2	7722-84-1	Liquid
Hydroxylamine Nitrate	NH_2OH-HNO_3	13465-08-2	Liquid
Manganese Nitrate	$Mn(NO_3)_2$	10377-66-9	Solid/ Liquid
Nitric Acid	HNO_3	7697-37-2	Liquid
Nitric Oxide (Note 1)	NO	10102-43-9	Gas
Nitrogen Dioxide	NO_2	10102-44-0	Gas
Nitrogen Oxides (Note 1)	NO_x	N/A	Gas
Oxalic Acid	$H_2C_2O_4$	144-62-7	Solid/ Liquid
Plutonium Dioxide	PuO_2	N/A	Solid
Plutonium Oxalate (Note 2)	$Pu(C_2O_4)_2$	N/A	Solid/Liquid
Plutonium Nitrate (Note 2)	$Pu(NO_3)_3$, $Pu(NO_3)_4$, $PuO_2(NO_3)_2$	N/A	Liquid
Silver Nitrate	$AgNO_3$	7761-88-8	Solid/ Liquid
Sodium Carbonate	Na_2CO_3	497-19-8	Solid/ Liquid
Sodium Hydroxide	NaOH	1310-73-2	Liquid
Tributyl Phosphate	$(C_4H_9)_3PO_4$	126-73-8	Liquid
Uranium Dioxide	UO_2	1344-59-8	Solid
Uranyl Nitrate (Note 2)	$UO_2(NO_3)_2$	36478-76-9	Liquid
Zirconium Nitrate	$Zr(NO_3)_2*5H_2O$	13746-89-9	Liquid

Table 8-1b Notes:

1. Chlorine and nitrogen oxides are by-products of AP processing.
2. Plutonium oxalate, plutonium nitrate, and uranyl nitrate are intermediate products of AP processing.

Table 8-1c. Process Chemicals in the MOX Processing Building (BMP)

CHEMICAL			
Name	Formula	CAS Number	STATE
Azodicarbonamide	$H_2NCONNCONH_2$	123-77-3	Solid
Isopropanol	C_3H_7OH	67-63-0	Liquid
Zinc Stearate	$Zn(C_{18}H_{35}O_2)_2$	557-05-1	Solid

Table 8-1d. Process Chemicals in the Laboratories

CHEMICAL			
Name	Formula	CAS Number	STATE
Aluminum Nitrate	$Al(NO_3)_3*9H_2O$	13473-90-0	Liquid
Argon-Hydrogen	95% Ar; 5% H_2	N/A	Gas
Chromic (III) Acid	CrO_3	7738-94-5	Liquid
Ferrous sulfate	$FeSO_4$	7720-78-7	Liquid
Fluorine	F	7782-41-4	Liquid
Hydrofluoric Acid	HF	7664-39-3	Liquid
Hydrochloric Acid	HCl	7647-01-0	Liquid
Iron	Fe	7439-89-6	Liquid
Manganous Sulfate	$MnSO_4$	7785-87-7	Liquid
Potassium Permanganate	$KMnO_4$	7722-64-7	Liquid
Silver Oxide	AgO	20667-12-3	Liquid
Sodium	Na	7440-23-5	Liquid
Sodium Nitrite	$NaNO_2$	7632-00-0	Liquid
Sulfuric Acid	H_2SO_4	7664-93-9	Liquid
Sulfamic Acid	HSO_3NH_2	5329-14-6	Liquid
Thenoyl TrifluoroAcetone	$C_8H_5F_3O_2S$	326-91-0	Liquid
Xylene	$C_6H_4(CH_3)_2$	1330-20-7	Liquid

Table 8-1e. Process Gases in the Gas Storage Area (GSA)

CHEMICAL			
Name	**Formula**	**CAS Number**	**STATE**
Argon	Ar	7440-37-1	Liquid/ Gas
Argon-Hydrogen	95% Ar; 5% H_2	N/A	Gas
Argon-Methane (P10)	90% Ar; 10% CH_4	N/A	Gas
Helium	He	7440-59-7	Gas
Hydrogen	H_2	N/A	Gas
Nitrogen	N_2	7727-37-9	Gas
Oxygen	O_2	N/A	Gas

Tables 8-2a and 8-2b removed under 10 CFR 2.390.

Table 8-2c. Anticipated Chemical Inventory in the Laboratories

Chemical	Total Quantity Anticipated in Laboratories
Aluminum Nitrate	Less than 10 kilograms
Argon-Hydrogen (95% Ar 5% H)	No more than one cylinder (300 cu ft) per lab
Argon-Methane (P10)	(Piped into laboratories)
Chromic (III) Acid	Less than 10 kilograms
Ferrous sulfate	Less than 10 kilograms
Fluorine	Less than 10 kilograms
Hydrofluoric Acid	Less than 10 kilograms
Hydrochloric Acid	Less than 10 kilograms
Iron	Less than 10 kilograms
Manganous Sulfate	Less than 10 kilograms
Potassium Permanganate	Less than 10 kilograms
Silver Oxide	Less than 10 kilograms
Sodium	Less than 10 kilograms
Sodium Nitrite	Less than 1 kilogram
Sulfuric Acid	Less than 10 kilograms
Sulfamic Acid	Less than 10 kilograms
Thenoyl TrifluoroAcetone	Less than 10 kilograms
Xylene (Lab)	Less than 10 kilograms

Table 8-2d. Anticipated Gas Storage Area Inventory

Chemical	Anticipated Gas Storage Area Inventory
Argon	Two (2) 3,000 gallon liquefied gas storage tanks
Argon-Hydrogen	One tube trailer - 56,000 scf
Argon-Methane (P10)	One tube trailer - 45,000 scf
Helium	One large tube trailer – 140,494 scf
Hydrogen	Two (2) tube trailers – 43,000 scf each
Nitrogen	Two (2) buffer tanks – 1209 and 11 cu ft Liquid nitrogen storage tank – 9000 gallons
Oxygen	Two (2) cylinders – 6250 scf each

Table 8-3. Reaction Products of the Aqueous Polishing Process (Normal Operations)

Chemical	Formula	Comment
Alkaline Wastes (including dibutyl phosphate and monobutyl phosphate)	Various	Alkaline wastes are generated in the Solvent Recovery Unit as a result of washing solvent with sodium carbonate and sodium hydroxide solutions (Note 3)
Carbon Dioxide	CO_2	Reaction product when plutonium oxalate is transformed into PuO_2 in the Oxalic Precipitation and Oxidation Unit (Note 3)
Carbon Monoxide	CO	Reaction product when plutonium oxalate is transformed into PuO_2 in the Oxalic Precipitation and Oxidation Unit (trace quantities only) (Note 3)
Chlorine	Cl_2	Reaction product from dissolution of AFS material in the Dechlorination Dissolution Unit (subsequently treated in the dechlorination scrubbing column) (Note 2)
Hydrogen	H_2	Produced from radiolysis and electrolysis reaction (Note 4)
Nitrogen Oxides	NO_x	Reaction product of UO_2 dissolution in the UO_2 Dissolution Unit (subsequently scrubbed in the NO_x scrubbing columns of the UO_2 Dissolution Unit and Offgas Treatment Unit) (Note 2)
Nitrogen	N_2	Reaction product of several reactions in the Purification Cycle oxidation column; reaction product in dechlorination scrubbing column of the Dechlorination Dissolution Unit (Note 3)
Nitric Acid	HNO_3	Reformed in NO_x scrubbing columns (UO_2 Dissolution Unit and Offgas Treatment Unit) (Note 1)
Nitrous Acid	HNO_2	Always present in nitric acid solutions (Note 3)

Table 8-3. Reaction Products of the Aqueous Polishing Process (continued) (Normal Operations)

Chemical	Formula	Comment
Nitrous Oxide	N_2O	Reaction product of several reactions in the Purification Cycle oxidation column (Note 2)
Oxygen	O_2	Reaction product of hydrogen peroxide decomposition during PuO_2 dissolution in the Dissolution Unit (Note 3)
Plutonium Dioxide	PuO_2	Reformed in the calcining furnace of the Oxalic Precipitation and Oxidation Unit from the plutonium oxalate feed (Note 1)
Plutonium Oxalate	$Pu(C_2O_4)_2$	Precipitated in the Oxalic Precipitation and Oxidation Unit from the reaction of plutonium nitrate with oxalic acid (Note 1)
Plutonium (III, IV, VI) Nitrate	$Pu(NO_3)_3$, $Pu(NO_3)_4$, $PuO_2(NO_3)_2$	Plutonium (VI) Nitrate - formed from the dissolution of plutonium dioxide in the Dissolution Unit and in the evaporator of the Oxalic Mother Liquor Recovery Unit (Note 1) Plutonium (IV) Nitrate – formed from the addition of hydrogen peroxide to the plutonium (VI) nitrate solution in the Dissolution Unit (Note 1) Plutonium (III) Nitrate – formed from the reduction of plutonium (IV) nitrate solution with HAN in the Purification Unit (Note 1)
Sodium Chloride	NaCl	Reaction product in the dechlorination scrubbing column of the Dechlorination Dissolution Unit (Note 3)
Uranyl Nitrate	$UO_2(NO_3)_2$	Formed from the dissolution of uranium dioxide in nitric acid (Note 1)

Table 8-3. Reaction Products of the Aqueous Polishing Process (continued) (Normal Operations)

Chemical	Formula	Comment
Water	H_2O	Reaction product of several reactions in the Purification Cycle oxidation column; reaction product of hydrogen peroxide decomposition during PuO_2 dissolution in the Dissolution Unit; Reaction product of UO_2 dissolution reaction in the UO_2 Dissolution Unit (Note 3)

Table 8-3 Notes:

1. Chemical consequence analyses have been performed for nitric acid, uranyl nitrate and the plutonium compounds. Inventories are identified in Table 8-2a.
2. Chemical consequence analyses have been performed for chlorine and nitrogen oxides.
3. Because of low rate of production and/or lack of toxicity, inventories are not quantified for the purposes of calculating chemical consequences to the site worker or the public from spills or releases.
4. The generation of hydrogen is considered in the design of the scavenging air system.

Table 8-4. Process Chemical Hazardous Characteristics and Incompatibilities

Form	Chemical	Corrosive	Flammable	Explosive	Chemical Burn	Toxic	Incompatibilities
Liquid	Nitric Acid (13.6N)	x			x	x	Organics, Hydrogen Peroxide, Hydroxylamine Nitrate, Hydrazine Monohydrate, Sodium Carbonate, Sodium Hydroxide
	Hydrogen Peroxide			x	x	x	Organics, Nitric Acid, Manganese (metal), Hydrazine, Sodium Carbonate, Metallic Salts
	Tributyl Phosphate (solvent)		x	x	x	x	Ammonia, Nitric Acid, Oxidizing Agents, Strong Bases
	Diluent (C10-C13 isoalkane)		x	x		x	Oxidizing Agents, Oxygen
	Sodium Carbonate (also present as a solid)					x	Aluminum, Acids, Hydrogen Peroxide
	Demineralized Water						
	Hydroxylamine Nitrate (HAN)	x		x	x	x	Bichromate and Permanganate of Potassium, Copper Sulfate, Zinc, Strong Oxiders, Strong Reducing Agents, Nitric Acid, Combustible Materials
	Hydrazine Monohydrate	x		x	x	x	Oxidizing Agents (Nitric Acid), Metals, Asbestos
	Sodium Hydroxide	x			x	x	Acids, Aluminum and other metals, Organic Halogens (especially Trichlorethylene), Sugars
	Aluminum Nitrate	x			x	x	Combustible Materials, Strong Reducing Agents, Metals, Water
	Hydrazine Nitrate	x			x	x	Acids, Strong Oxidizers, Metal Salts
	Isopropanol		x			x	Oxidizing Agents
	Zirconium Nitrate	x			x	x	Combustible Materials, Strong Reducing Agents, Metals
Gas	Dinitrogen Tetroxide/Nitrogen Dioxide	x		x	x	x	Reducing Agents, Organics, Metals
	Helium						
	Argon						
	Hydrogen		x	x			
	Oxygen					x	Organics
Solid	Silver Nitrate (also present as liquid)	x		x	x	x	Ammonia, Carbonates, Chlorides
	Manganese Nitrate (also present as liquid)	x		x	x	x	Strong Reducing Agents, Combustible Materials
	Oxalic Acid (also present as liquid)				x	x	Silver, Sodium Chloride, Sodium Hypochlorite
	Azodicarbonamide						Strong Oxidizing Agents
	Zinc Stearate		x			x	Strong Oxidizing Agents, Acids

Table 8-5. TEELs Used as Chemical Limits for Chemicals at the MFFF (Note 1)
(mg/m^3)

Name	TEEL-1	TEEL-2	TEEL-3
Aluminum Nitrate	15	15	500
Azodicarbonamide	125	500	500
Chromic (III) Acid	1	2.5	25
Chlorine	3	7.5	60
Diluent (C10-C13 Isoalkanes)	5	35	200
Ferrous sulfate	7.5	12.5	350
Fluorine	0.75	7.5	30
Hydrazine Monohydrate	0.0075	0.06	50
Hydrazine Nitrate	3	5	5
Hydrofluoric Acid	1.5	15	40
Hydrochloric Acid	4	30	200
Hydrogen Peroxide	12.5	60	125
Hydroxylamine Nitrate	15	26	125
Iron	30	50	500
Isopropanol	1000	1000	5000
Manganese Nitrate	10	15	500
Manganous Sulfate	7.5	12.5	500
Nitric Acid	2.5	15	200
Nitric Oxide	30	30	125
Nitrogen Dioxide	7.5	7.5	35
Nitrogen Tetroxide	15	15	75
Oxalic Acid	2	5	500
Potassium Permanganate	7.5	15	125
Silver Nitrate	0.03	0.05	10
Silver Oxide	30	50	75
Sodium	0.5	5	50
Sodium Carbonate	30	50	500
Sodium Hydroxide	0.5	5	50
Sodium Nitrite	0.125	1	60

Table 8-5. TEELs Used as Chemical Limits for Chemicals at the MFFF (Note 1) (continued)
(mg/m^3)

Name	TEEL-1	TEEL-2	TEEL-3
Sulfuric Acid	2	10	30
Sulfamic Acid	40	250	500
Thenoyl TrifluoroAcetone	3.5	25	125
Tributyl Phosphate	6	10	300
Uranium Dioxide	0.6	1	10
Uranyl Nitrate	1	1	10
Xylene	600	750	4000
Zinc Stearate	30	50	400
Zirconium nitrate	35	35	50

Table 8-5 Notes:

1. Temporary Emergency Exposure Limits (TEELs), Revision 18, are derived from approved methodologies developed by Department of Energy Subcommittee on Consequence Assessment & Protective Actions (SCAPA) and are identified in WSMS-SAE-02-0001.

Table 8-6. Application of Chemical Limits to Qualitative Chemical Consequence Categories

Consequence Category	Worker	Public
High	Concentration ≥ TEEL-3	Concentration ≥ TEEL-2
Intermediate	TEEL-3 > Concentration ≥ TEEL-2	TEEL-2 > Concentration ≥ TEEL-1
Low	TEEL-2 > Concentration	TEEL-1 > Concentration

Table 8-7. Combustible Characteristics of Chemicals in the AP Area

Combustible	Location	Flash Point (°C)
Solvent + Diluent (30/70)%	Purification Cycle and Solvent Recovery Cycle	> 55
Solvent (TBP)	Storage Tanks and Solvent Recovery	146
Diluent	Pulsed Column, Diluent Washing and Storage	>55
Oil & Hydraulic Fluid	Building	>100

Table 8-8. Nomenclature of Chemical Species

Name	Abbrev.	Formula
Tri-n-butyl phosphate	TBP	$(C_4H_9O)_3PO$
Dibutyl phosphate	DBP	$(C_4H_9O)_2PO(OH)$
Monobutyl phosphate	MBP	$(C_4H_9O)PO(OH)_2$
Butyl alcohol or Butanol	BuOH	C_4H_9OH
Butyl nitrate	$BuNO_3$	$C_4H_9NO_3$
Butyric acid		C_3H_7COOH
Propionic acid		C_2H_5COOH
Acetic acid		CH_3COOH
Phosphoric acid		H_3PO_4
Butene		C_4H_8

Figures

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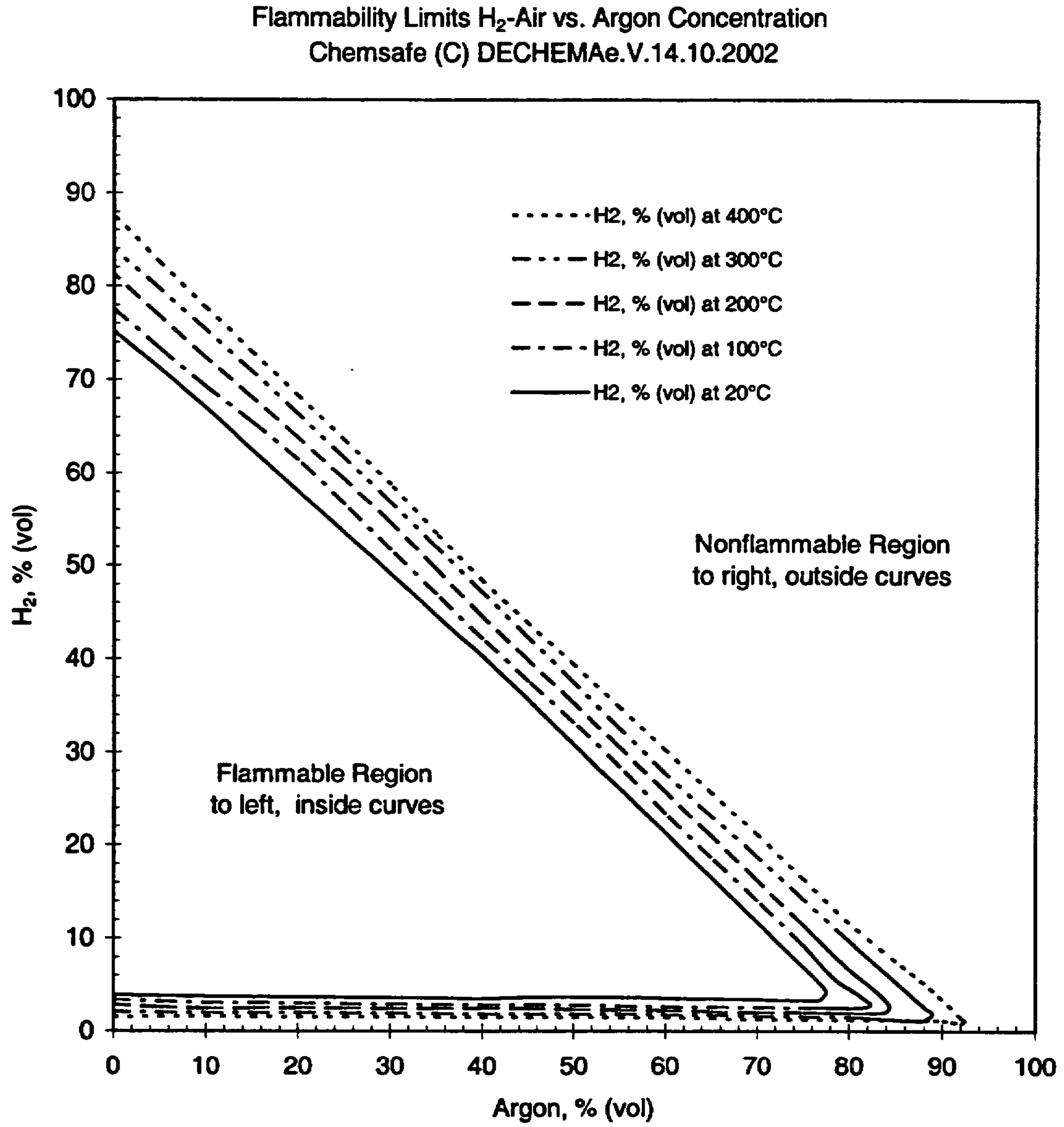

Figure 8.5-1. Flammability Limits H_2-Air vs Argon Concentration

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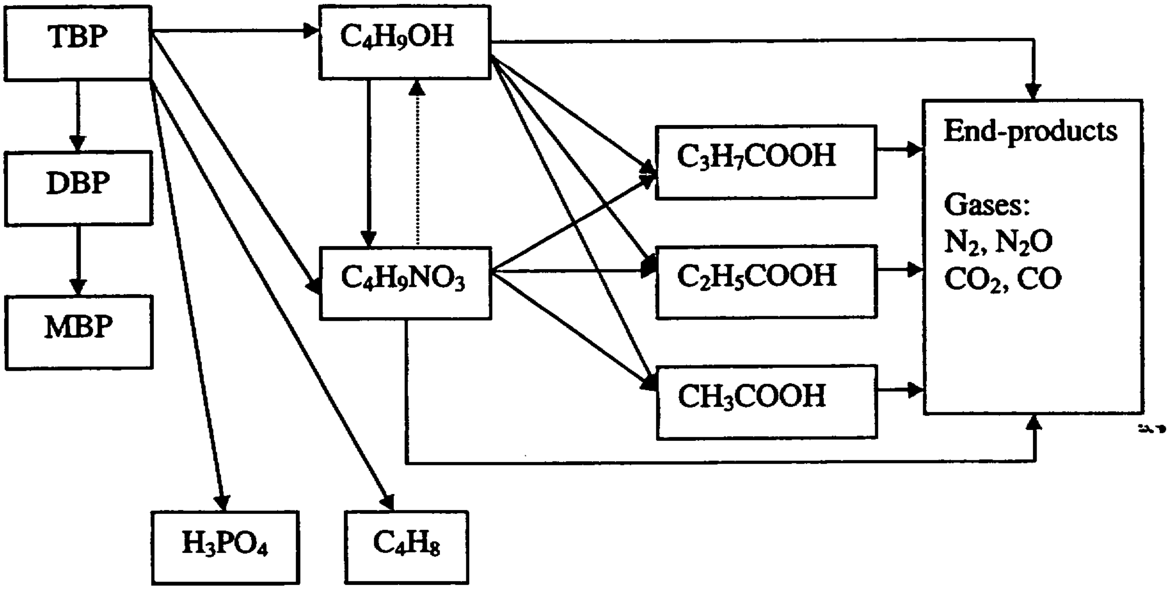

Figure 8.5-2. Oxidative Reaction Scheme of TBP Degradation in Contact with Nitric Acid

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9. RADIATION SAFETY

This chapter addresses the radiological health and safety of workers during normal operations and anticipated events. The requirements for radiation safety are found in 10 CFR Part 20, *Standards for Protection Against Radiation,* and 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material.* This chapter focuses primarily on occupational exposure during normal and anticipated abnormal events. Public and environmental protection is discussed in Chapter 10, and design basis accidents are discussed in Chapter 5.

The potential for occupational exposure at the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) exists primarily as a result of the processing of plutonium (i.e., potential internal exposure from inhalation) and also as a result of handling other radioisotopes (i.e., direct external exposure). The primary design features that limit exposure in accordance with ALARA (as low as reasonably achievable) goals are confinement systems (e.g., gloveboxes, process cells, ventilation), monitoring, alarms, and radiation shielding. Confinement systems are described in detail in Section 11.4.

The design of the facility ensures that the total effective dose equivalent (TEDE) to individual members of the public from the MFFF will not exceed 100 mrem in a year from normal operations and anticipated operational occurrences. The design also ensures that annual occupational doses are maintained below a TEDE of 5 rem and 50 rem to any extremity.

The TEDE design goal for individual workers will be ALARA and less than 500 mrem/yr to most of the operating team members, with an extremity exposure goal of less than 10 rem/yr.

The annual occupational exposure limits from 10 CFR Part 20 are as follows:

• Total (CEDE + DDE) = TEDE	5 rem (0.05 Sv)
• Lens of Eye (LDE)	15 rem (0.15 Sv)
• Other Organs (CDE + DDE)	50 rem (0.5 Sv)
• Skin or Extremity (SDE)	50 rem (0.5 Sv).

Note: CEDE is committed effective dose equivalent; DDE is deep dose equivalent; LDE is lens of the eye dose equivalent; CDE is committed dose equivalent; and SDE is shallow dose equivalent. The extremities are considered to be the hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

Potential occupational radiation exposure from exposure to external radiation sources is evaluated and minimized throughout the facility design process using three techniques: (1) general radiation zoning criteria, (2) the ABAQUES Method, and (3) design ALARA evaluations. The application of these criteria is sequential. The general radiation zoning criteria are established at the outset of the facility design. The ABAQUES Method is performed during the facility design, and the design ALARA evaluation is performed after the preliminary design. The design will be reviewed for ALARA concerns in accordance with 10 CFR Part 20 to ensure that exposures to workers are within the limits specified therein.

This chapter describes the design features of the MFFF and programmatic elements that together minimize occupational exposure.

9.1 RADIATION SAFETY DESIGN FEATURES

The MFFF design objectives ensure that operation of the MFFF is in accordance with 10 CFR Part 20 and the ALARA policy. Engineering features and controls are implemented during the facility design and operations to ensure that occupational doses are ALARA. The MFFF design objectives include, as a minimum, the following criteria:

- Integrating ALARA features based on experience from operating facilities into facility design and operating procedures with technological, economic, and social factors taken into consideration
- Maintaining radiation zoning criteria and design goals through access restrictions, and shielding
- Estimating individual and collective doses to ensure the design provides for exposures to be ALARA
- Conducting periodic training and exercises for management, engineers, and designers in radiation protection principles and procedures, individual and group protective measures, specific facility procedures, and emergency response
- Integrating appropriate radiation protection controls into work activities.

9.1.1 ALARA Design Considerations

The purpose of this section is to summarize the elements showing that the design for construction and operation of the facility is adequate to protect the radiological health and safety of MFFF workers. The protection of members of the public and the control of effluent releases are discussed in Chapter 10.

The MFFF design reflects consideration of ALARA principles. Specific ALARA considerations in the MFFF design include the following:

- Control of plutonium particulate to prevent inhalation by confining radioactive materials in process equipment and in gloveboxes
- Multiple-zone ventilation system design
- Continuous remote monitoring of airborne conditions in the access areas
- Use of automated and remotely operated equipment to minimize personnel exposure
- Removal of radioactive sources before most maintenance operations
- Placement of radiation shields between radioactive sources and the operators according to the intensity, nature, and penetrating power of the radiation
- Design of structures, systems, and components (SSCs) that require a minimum of maintenance or repair to minimize personnel stay times in radiation areas

- Placement of administrative, security, and radiation protection activities away from radiation areas
- Use of area radiation monitoring with local and remote readouts and alarms to inform personnel of changing conditions.

9.1.1.1 Organizational Relationships and Responsibilities for ALARA Design

The MFFF Engineering Manager is responsible for the implementation of radiation protection design criteria. The MFFF Facility Design function includes responsibility for the integrated design of the facility and reports to the MFFF Engineering Manager.

The design organization employs personnel qualified in radiation protection design and ALARA concepts, including personnel experienced in radiation protection, radiation shielding, and general radiation safety. Design personnel are trained to recognize potential radiation hazards and to minimize the effects of these hazards on operations.

The primary radiation analyses performed in support of the radiation protection design are radiation shielding calculations and occupational radiation dose assessments.

9.1.1.2 Design-Stage Collective Dose Estimates

The design process includes an estimate of the occupational dose assessment for the facility. ALARA evaluations are performed and documented to determine cost-effective design enhancements to reduce exposures. Dose assessments are performed using Regulatory Guide 8.19, *Occupational Radiation Dose Assessment in Light-Water Reactor Power Plants, Design Stage Man-Rem Estimates*, and Regulatory Guide 8.34, *Monitoring Criteria and Methods to Calculate Occupational Radiation Doses.*

For the license application for possession and use of special nuclear material (SNM), the dose assessments will take into account both direct and internal dose. The direct dose assessment is determined by dose rate analyses and the ABAQUES Method described in Section 9.1.2.3.2. The internal dose assessment is determined based on the MFFF design and review of MELOX experience (Section 9.1.2.4). The internal dose will be added to the direct dose. This sum is compared to the 500-mrem/yr goal to maintain exposures ALARA.

Cumulative doses are estimated at this stage in Section 9.1.2.4, based on the comparison of MELOX and MFFF source terms and MELOX operating experience.

9.1.1.3 Design Review Process

Competent personnel are responsible for the review of, and concurrence on, preliminary and final designs. The design reviews incorporate the experience from MELOX and La Hague. The project design reviews include ALARA evaluations of designs that may lead to high occupational exposures. The design team tracks the recommendations included in the evaluations to completion.

Continuing radiation safety (ALARA) design reviews for facility or process modifications will be conducted during construction and operations. An appropriately qualified organization will be responsible for reviewing facility or process modifications for the express purpose of maintaining exposures ALARA.

9.1.1.4 Past Experience

The MFFF design incorporates applicable experience from MELOX and La Hague for radiation protection, such as the following:

- Descriptions of process unit operations
- Personnel access times
- Source configurations
- Radiation dosimetry
- Radiation exposure problem areas
- ALARA design features and performance
- Contamination estimates
- Radiation monitoring design and operations
- Process unit shielding design.

Much of the MFFF facility design is the same as that used at the MELOX facility. Therefore, the occupational exposures should be similar with adjustment for the difference in the radiation source terms.

9.1.1.5 Other Design Considerations

The design reduces the time spent in radiation areas by incorporating design features of the MELOX and La Hague facilities. The zone classification of the facilities provides information to the designers for minimizing occupational radiation exposure through access control and shielding design to meet exposure criteria.

The design provides for the accessibility of components requiring routine maintenance or in-service inspection by using gloveboxes as described in Section 9.1.4.2.

The design minimizes the distribution and retention of radioactive materials throughout plant systems by:

- Designing the process equipment containing the radioactive materials so as to confine them to the maximum extent practical and reduce glovebox contamination

- Designing the gloveboxes to prevent accumulation of contamination and allow easy access for cleaning

- Using a vacuum system in gloveboxes as necessary so that airborne dust is collected in dust pots in the concerned gloveboxes and the material is recycled.

The project conducts ongoing training for designers and engineers in ALARA design objectives. Designers and engineers are aware of ALARA design objectives. This awareness ensures that

ALARA features are incorporated into the design as it is being developed, before radiation protection engineers review the design for the express purpose of ensuring that it meets ALARA design objectives.

As described in Section 9.1.1.4, experience from the MELOX and La Hague facilities is incorporated into the design to ensure that the total exposure from the MFFF is maintained ALARA. Airborne contamination and loose surface contamination are prevented during normal operations by the glovebox and ventilation system design to maintain inhalation dose ALARA.

Radiation protection design improvements that have been made at the MELOX and La Hague facilities are incorporated into the MFFF facility design. For example, the Grinding Unit vacuum system minimizes loose contamination in the glovebox. Project team members have direct experience with those facilities, and design documentation is available to the design team for this project to consider and incorporate to the maximum extent practical.

9.1.2 Facility Design Features

This section describes the primary design features and equipment that directly or indirectly reduce radiation exposure for facility workers and provide monitoring capability.

9.1.2.1 Equipment and Facility Design Features

The greatest potential for occupational radiation exposure is from plutonium inhalation. Therefore, the design incorporates multiple systems and barriers to prevent releases to personnel access areas. Depending on the stage in the process, confinement of radioactive materials and worker protection are obtained by process vessels in cells (aqueous polishing [AP]), gloveboxes (Powder Area and Pellet Process Area), or sealed envelopes (rods, containers) (see Section 11.4). Sealed gloveboxes are used to prevent personnel contamination. The gloveboxes are kept at a negative pressure with respect to the area occupied by personnel to ensure that contamination would be contained in the event of a breach. A second ventilation system in the cell forces air down from the ceiling to the floor to minimize the potential for inhalation in the event of a glovebox breach. Airborne contamination and pressure are monitored to detect changes in the containment barriers.

A second source of potential occupational radiation exposure is from direct exposure to radiation sources within the gloveboxes. Although exposure rates are low, various design features have been implemented to attenuate ionizing radiation and to further limit operator exposures, including (1) limiting exposure times through automation and remote control of production workstations, and (2) placing shielding between radiation sources and operators according to the radiation intensity.

For the AP Area, the primary feature is the remote operations capability (see Section 11.3). Few operations are performed in the radiation area. System sampling and inspections are designed to be performed from access areas outside of the high radiation areas. Sources of radiation are removed from the work area prior to extensive work being performed. For process cells, routine access is precluded and radiation shielding is made up by the cells' concrete walls.

For process rooms containing gloveboxes, few operations are performed in the process rooms themselves, so free access is not necessary. The areas around the process rooms are protected against direct radiation by the rooms' concrete walls. Radiation shielding is implemented on the gloveboxes as necessary, and the facility is designed so that sources of radiation can generally be removed from the work area prior to extensive work being performed.

MOX Processing (MP) Area work is primarily performed from the process rooms, so these rooms are accessed routinely. Radiation and pressure monitoring are performed to detect changes in the confinement barriers. Shielding is designed so dose rates in radiation work areas are low to accommodate the required access. Existing data from the MELOX and La Hague facilities are used to estimate the access requirements for the facility. Dose rates based on MFFF source terms are used to show the low occupational doses expected for this facility. Where gloveboxes are present for radioactive material confinement, radiation shielding for both neutron and gamma sources is designed permanently into the glovebox system (inside the glovebox for large radiation sources when this does not impair operation, and outside the glovebox whenever practical). Shielding is separate from the confinement barrier to allow for changes, if needed, without the potential for contamination spread. The radiation shielding concepts in the MFFF include the following:

- **AP cells** – thick concrete walls constitute the primary shielding
- **AP gloveboxes** –shielding on the gloveboxes as needed; locked doors to the cells
- **MP gloveboxes** – internal shielding inside the gloveboxes whenever practical; external shielding outside the gloveboxes in general
- **MP areas** – separate cells for each process unit shielded by concrete and sealed to prevent the spread of contamination.

The glovebox design incorporates the use of shielding to protect workers from direct radiation. Interior shields are provided to ensure that radiation from specific sources is minimized. Glovebox walls incorporate appropriate shield materials to reduce worker exposures. Regular glovebox maintenance is scheduled to minimize radiation exposures to the maintenance personnel and to limit the potential for a release of airborne radioactive material.

9.1.2.2 Design Features to Reduce Contamination and Waste Production

Many of the design features addressed in the previous section perform contamination control functions. In addition, the design reduces the distribution and retention of radioactive materials throughout plant systems by using a vacuum system in gloveboxes as required. Airborne dust is collected in dust pots in gloveboxes, as necessary, and the material is recycled.

Design features will control contamination so that secondary waste production is minimized. The design features ensure that contamination is isolated to specific areas and that contamination is minimized at the time the plant license is terminated. The design incorporates extensive recycling for the materials exiting the main process (i.e., secondary waste streams of the AP process, scraps not meeting specifications in the MP process). The recycling process is designed to minimize the quantity of plutonium in the final waste by using systems that process the radioactive materials and send them back to previous steps of the main process, as described in Sections 11.2 and 11.3.

9.1.2.3 Facility Design Goals

The general design requirements established for the various radiological attributes addressed below include those that maintain exposures ALARA during normal operations of the facility and minimize exposures during off-normal conditions.

Potential occupational radiation exposure from exposure to external radiation sources is evaluated and minimized throughout the facility design process using general radiation zoning criteria, the ABAQUES Method, and design ALARA evaluations.

9.1.2.3.1 Radiation Zoning

Preliminary radiation zoning is developed based on estimates of the access required for each zone and radiation dose limits for personnel from 10 CFR Part 20. Shielding for the process units and access areas is designed to satisfy these preliminary radiation zoning criteria. The final dose assessment verifies that the facility can be operated within the occupational exposure limits of 10 CFR Part 20 and ALARA principles.

The design criteria for occupational exposures inside the MFFF are supported by the radiation zone limits presented in Table 9-1.

In zones Z1 and Z2, residence time is not restricted. The design basis maximum area radiation dose rates shown on Figure 9-1 allow continuous occupancy. The design basis maximum area radiation dose rate limit is the only shielding design criterion. Residence time is restricted in zones Z3, Z4, and Z5 of the AP Area, and access is permitted only for maintenance or intervention.

Access to Z3 process rooms in the MP process areas is necessary for normal operations and routine maintenance. The annual dose equivalent for workers is evaluated by the ABAQUES Method (see Section 9.1.2.3.2) using reasonable assumptions (in the form of time-motion studies). Access to zones Z4 and Z5 is restricted for nonroutine maintenance or intervention.

Radiation zones are shown in Figures 9-1 through 9-9. The blue zone, Z1, is a continuous occupancy area for staff and visitors. The green zone, Z2, is a continuous occupancy area for trained workers. The yellow zone, Z3, is a limited occupancy area in which routine maintenance may be performed by trained workers. The orange zone, Z4, and red zone, Z5, are conservatively estimated and are expected to be high radiation and very high radiation areas, respectively. Detailed shielding analyses will be conducted in the final design phase of the project with the results provided in the license application for possession and use of SNM.

9.1.2.3.2 The ABAQUES Method

The facility design and resultant occupational dose are evaluated using the ABAQUES Method, which is similar to that provided in Regulatory Guides 8.19 and 8.34. Radiation shielding is selected to minimize personnel occupational exposures based on facility occupancy for normal operations and facility maintenance. Personnel exposures are estimated based on facility experience for access requirements, and standard shielding methods are used to estimate radiation fields. The method is iterated to minimize the number of personnel that have the potential of receiving **more than** 500 mrem/yr. The general equation that is used to satisfy this prerequisite is as follows:

$$\frac{\sum_i \mathrm{f}_i \times t_i \times DER_i}{\sum_i \mathrm{f}_i \times t_i} \le \frac{500\, mrem/yr \text{ (design objective for individual doses)}}{\mathrm{T}} \qquad (9\text{-}1)$$

where:

f_i = the frequency of each task associated with a given process unit or group of process units

t_i = the time of exposure for the task

DER_i = the dose equivalent rate for the task

T = the average estimated annual working time in radiation zones

$\sum_i \mathrm{f}_i \times t_i$ = the total yearly duration of all of the tasks performed by the same work group associated with the process unit or group of process units.

The *DER*s are adjusted by varying the shielding thickness, and/or the operating conditions (operation duration and frequency) are changed to reduce the exposures to below the 500-mrem/yr goal. The *T* is an estimate of the average time an individual spends in the radiation area per year based on industry operating experience.

9.1.2.3.3 ALARA Evaluations

This process includes a preliminary estimate of the occupational exposure, an ALARA evaluation of the activities that produce exposures, and recommendations for design enhancements to reduce occupational exposures. Lessons learned from facility operations and industry guidance are used to evaluate potential design enhancements. ALARA cost-benefit analyses are performed to support design enhancements using NUREG/CR-0446, *Determining Effectiveness of ALARA Design and Operational Features.*

Preliminary occupational exposure data based on data from MELOX are estimated. These data are used during the preliminary design phase to evaluate occupational radiation exposures and to recommend potential enhancements to the design to effectively reduce doses. Final design shielding calculations are performed to estimate dose rates and doses using the ABAQUES Method.

9.1.2.4 Predicted Occupational Doses

Occupational exposures will be estimated for the MFFF facility in order to perform ALARA evaluations as described in Section 9.1.2.3.3. Dose rates from shielding analyses are combined with access requirements and/or time-motion information from MELOX and La Hague. These results are evaluated to determine if design enhancements are needed to further reduce exposures ALARA. This work will be summarized in the license application for possession and use of SNM.

9.1.2.4.1 Dose Assessment Estimate

A preliminary estimate of the facility occupational exposures is made based on MELOX experience with adjustments for source term differences, but assuming consistent shielding. At the MELOX facility, photon and neutron radiation accounts for approximately 40% and 60%, respectively, of the total radiation dose. (Internal exposure represents only a fraction of total dose.)

As discussed in Section 9.1.3.3, the ratio of the MELOX photon dose to the MFFF photon dose is approximately 20:1, and the neutron dose ratio is approximately 11:1. Using these ratio data, the occupational exposures at the MFFF can be estimated. This estimate assumes that the same equipment is used with the same shielding and that similar personnel access is required.

Inhalation dose contributes less than 4.5 person-rem per year (assuming the full 50-year dose commitment in the year of exposure). The direct dose estimate is expected to be approximately 12 person-rem per year, while the total dose is estimated to be below 20 person-rem per year.

The final dose assessment will incorporate input from the shielding analysis and personnel access requirements based on existing facility experience and the MFFF design. This information will provide the data necessary for performing ALARA evaluations during the final design phase.

9.1.2.4.2 Contribution from Internal Exposure

There are two primary sources of radiation risk to the MFFF worker: plutonium inhalation and direct radiation exposure. Plutonium inhalation is the most significant potential hazard at the facility. Design engineers are instructed on the risks and the methods of controlling plutonium contamination. The Powder Area and Pellet Process Area have the greatest potential for generating respirable particulate, releasing contamination, and causing worker inhalation exposure. These process areas provide radiation protection through multiple system barriers and controls:

- The operations for the units are controlled remotely and are automated to minimize access to the work area.
- The plutonium is contained in a sealed glovebox. This internal environment is kept under negative pressure relative to the worker environment. Any leakage in the glovebox would be from the work area into the glovebox, thus preventing the release of contamination.
- Pressure within the glovebox is monitored, and a lighted signal indicates system operability.
- Glove ports are provided for maintenance access to the process equipment.

- Dedicated preventative maintenance is performed in the absence of process material to the extent practical to further reduce the hazard to the worker.
- Radiation monitoring of the air environment is provided at the work location with alarms at low setpoints to cause evacuation from the work location if contamination is detected.

Potential loss-of-confinement events are analyzed so that systems can be designed to minimize the likelihood and consequences of such events. The confinement systems are protected against damage from internal and external events to minimize the possibility of failure. The structure is designed to withstand the effects of natural phenomena hazards. Internal events that could compromise the integrity of the confinement system are prevented by the design.

Events that are expected to occur over the lifetime of the facility and their consequences are estimated and added to occupational exposure estimates. Total exposures are designed to be within the limits of 10 CFR Part 20.

Review of MELOX operating history indicates that, in eight years, there have been 12 reportable instances. These events were not significant (i.e., none at level 2 or greater on the International Nuclear Event Scale [INES]). Design and management measures at MELOX are similar to MFFF; thus, the normal internal exposure received at MELOX, which is a fraction of the total dose, is assumed to represent a reasonable estimate for the MFFF.

The INES uses an eight-level system to rate events: 0 to 7, with 0 being the least severe and 7 being the most severe. The events at the MELOX facility and their corresponding INES ratings are provided in Table 9-2. Based on the INES rating system, level 0 events are those events classified as being without safety significance (i.e., low consequence to the worker). Level 1 events are classified as anomalies. Level 2 events are classified as events resulting in worker exposure over the occupational limits set by 10 CFR Part 20. There have been no level 2 (or greater) events at the MELOX facility during its operation.

In conclusion, although events that result in loss of confinement may occur during the operating life of the MFFF facility, as evidenced by the MELOX model, such events are expected to be infrequent and result in low consequences to the worker based on system design. The cumulative dose potential is insignificant compared to the direct dose contribution.

9.1.2.5 Facility and Process Drawings

Chapter 11 includes facility and process drawings and descriptions. Further information will be provided with the license application for possession and use of SNM. Drawings, process descriptions, and other plant documentation to be maintained at the MFFF include the following:

- Scaled drawings
- Features relied upon to reduce doses to meet the requirements of 10 CFR Part 20 during routine and non-routine operations (including anticipated events)
- Locations of detectors and alarm systems
- Locations of permanent shielding (e.g., penetrations, labyrinths, shield doors)

- Provisions for installation/removal of temporary shielding
- Locations and access control points for radiation areas
- The controlled area, including the means to limit access to the controlled area as necessary
- The restricted area (coincident with the protected area shown on Figure 1.1-2)
- Change rooms, showers, and locker rooms
- Contamination control and waste minimization design features.

9.1.2.6 Self-Assessment

Self-assessment of the facility design, shielding, traffic patterns, expected maintenance, and sources to determine that both collective and individual doses are within the limits of 10 CFR Part 20 will be addressed in the license application for possession and use of SNM. The self-assessment will address these items against the facility design goals for routine and non-routine operations, including anticipated events.

9.1.2.7 Worker Access Controls

Worker access controls for high and very high radiation areas that will meet 10 CFR §20.1601 and §20.1602, respectively, will be discussed in the license application for possession and use of SNM. Change rooms are provided as addressed in Section 9.1.2.10.

9.1.2.8 Health Physics Counting Equipment

MFFF Health Physics equipment comprises a broad spectrum of analytical instruments used to determine the presence of radioactive material and to quantify the amount of contamination. The instrumentation ranges from gross measurements to specific isotopic analytical analyzers that can determine the constituents and quantity of each isotope. The instrumentation also includes installed personnel monitors and hand-held survey equipment.

9.1.2.8.1 Alpha/Beta Counters

Due to the nature of the radioactive material at the MFFF, the ability to detect minute quantities of plutonium requires the use of sensitive equipment. The MFFF radiation protection equipment will be capable of detecting extremely low levels of alpha contamination in a relatively short counting time cycle. The selection process centered on instruments with a high sensitivity toward alpha particles while still being capable of detecting beta contamination for the incoming radioactive material.

Each Health Physics laboratory (MP and AP) will be equipped with at least two alpha/beta counters to enable the processing of swipes and airborne contamination surveys on a continuous basis without interruption. Additional counters are located within the MP Area to support incoming radioactive material and shipments of waste, fuel, and excess materials.

9.1.2.8.2 Isotopic Analytical Equipment

Each laboratory will be equipped with instrumentation capable of quantifying the radioactive material on swipes, air samples, and any other sample configuration. The detector portions of the instrumentation will be installed in counting shields to reduce any background effects and minimize background counts.

9.1.2.9 Personnel Monitoring Equipment

9.1.2.9.1 Hand and Foot Monitors

Each transition between confinement zones, as defined by the ventilation system areas in Chapter 11, requires personnel to monitor for contamination. To provide for this transition, airlocks are installed between confinement zones, as well as in areas where there is a potential for the spread of contamination. Each airlock is provided with personnel monitoring equipment to ensure that contamination is controlled as close to the source as physically possible.

9.1.2.9.2 Installed Survey Instruments

Each airlock and glovebox has an installed survey meter to ensure that personnel perform a thorough survey before exiting the work area and the confinement zone. The survey meters, commonly named "friskers," are counters with a high efficiency for alpha detection. Placement of the friskers is based on providing personnel with an instrument as close to the work area as possible. By placing detectors on the gloveboxes, personnel are able to survey their hands as soon as they remove them from the glove ports. This capability enables the control of potential contamination as close to the source as possible.

The hand and foot monitors and friskers are equipped with alarm circuits to provide indication of personnel contamination in the Health Physics offices. If an individual alarms either of the instruments during a survey, Health Physics personnel are dispatched to the location to minimize the spread of contamination and to decontaminate the individual and the area.

9.1.2.9.3 Personnel Contamination Monitors

Prior to exiting the production areas of the MFFF, personnel are required to be surveyed to ensure that no contamination leaves the facilities. Personnel contamination monitors (PCMs) are installed at the access control point so that personnel have to be surveyed prior to leaving the airlock. The monitors consist of multi-detector instruments that allow an individual to be monitored over their entire body in a relatively short time period.

9.1.2.10 Health Physics Working Spaces

9.1.2.10.1 MOX Fuel Fabrication Building

The Health Physics working spaces in the MOX Fuel Fabrication Building are shown on the general arrangement drawings and consist of two radiation protection laboratories, which will contain instruments and areas where technicians may prepare their survey results and store hand-held instruments. These laboratories will contain multi-sample alpha/beta counters, as well as hand-held survey instruments and portable air samplers. One laboratory will contain an isotopic analyzer. The space will allow personnel to perform surveys, count the samples, perform isotopic analyses, and record results.

9.1.2.10.2 Aqueous Polishing Area

The radiation protection working spaces in the AP Area are shown on the general arrangement drawings and consist of two rooms (i.e., radiation protection laboratory and radioprotection storage room) assigned for the placement of instruments and areas where technicians may prepare their survey results and store hand-held instruments.

The radiation protection laboratory will contain multi-sample alpha/beta counters, as well as the isotopic analyzer. The space will allow personnel to count samples and to perform an isotopic analysis of the samples as necessary.

The radioprotection storage room will contain survey and sampling equipment, as well as necessary Health Physics support equipment, consisting of the equipment necessary to support maintenance activities in the AP Area.

9.1.2.10.3 Shipping and Receiving Area

The Shipping and Receiving Area contains the access control point, which serves as the egress point for both the MP and AP Areas. This area has the PCMs and the Decontamination Area / Contaminated First Aid Room. The Decontamination Area / Contaminated First Aid Room contains a shower and sinks to perform minor decontamination of individuals and treat minor injuries.

The readout and alarm monitors located in the Polishing Utilities Control Room and the Respirator Maintenance/Health Physics Room present the alarms and radiation levels for the radiation monitoring equipment. These visual displays provide for the identification of specific alarms and the locations of the monitors in the workplace for the area radiation monitors (ARMs), continuous air monitors (CAMs), criticality monitors, friskers, hand and foot monitors, and PCMs.

The monitoring system uses trending software to identify increasing direct radiation levels over a period of time. The system provides the initial warning of increasing radioactivity in gloveboxes and production rooms and releases to the environment.

9.1.2.10.4 Technical Support Building

The Technical Support Building has three rooms dedicated to Health Physics activities:

- **Respirator Maintenance and Health Physics Room** – This room is designed to house the respirator equipment and issue area for the MFFF. This room provides for the minor repair of respirators and storage of spare equipment and emergency supplies.
- **Clean Anti-Contamination Storage Room** – This room provides for the storage of anti-contamination clothing for use during maintenance activities.

- **Technical Support Building Locker Rooms and Change Areas** – These areas contain storage racks for respirators and dosimetry devices. Personnel are able to obtain their respirator and alarming dosimeter, and log in on the appropriate Radiation Work Permit (RWP) prior to transiting to the MFFF. Space is provided for an increase in staff during maintenance outages.

Maintenance activities are performed in local enclosures, and personnel change into appropriate protective clothing at these locations. Used clothing is deposited in containers at the local enclosures, and personnel check themselves for contamination prior to exiting the area. Personnel assigned to maintenance activities obtain their protective clothing in the locker room but don the clothing at the local work control point.

The Technical Support Building Break/Lunchroom also serves as the assembly area during emergency conditions. This area allows for the staffing of personnel for response teams. Space is provided to support assembly, briefings, and preparation for entry of multiple teams into the MFFF.

9.1.2.11 Savannah River Site Facilities

The MFFF may rely upon SRS for instrument calibration, medical support, and dosimetry issue.

9.1.2.12 Radiation Monitoring and Alarms

The radiation monitoring system is designed to monitor MFFF workspaces, through the use of general ARMs and airborne radiation monitors, to protect the health and safety of personnel. This design is accomplished by identifying occupancy requirements and their respective environments (i.e., considering the potential for elevated airborne radioactivity or changes to workspace radiation levels).

The MFFF radiation monitoring system consists of a number of different types of monitors: general ARMs (neutron and gamma) and airborne alpha contamination monitors. This combined monitoring system allows for the detection of the possible radiation that a worker may be exposed to during normal and abnormal operations. The system also provides trending information so that increasing radiation levels may be determined to facilitate removing the sources of radiation exposure or limiting the time that a worker might be in the general area.

In addition to individual monitoring devices carried by the workers, the digital radiation monitoring system monitors and tracks, for trending purposes, area background radiation levels. The CAMs, along with individual monitoring devices, take representative and timely measurements of radioactivity concentrations in air at workstations and general work areas to maintain worker exposures ALARA.

9.1.2.13 Area Radiation Monitoring

General area ARMs are provided to monitor the neutron or gamma radiation levels in rooms containing gloveboxes, production units, and the laboratory. ARMs are also placed where radiation workers are likely to be stationed or perform routine operations. These monitors detect and warn workers of an unexpected increase in the radiation level of the general area. Either a neutron or gamma area monitor is provided, dependent on the primary source of radiation, to detect increases in radiation environments caused by significant variations in quantities of radioactive materials, including radiation from nearby gloveboxes and conveyors, loss or failure of shielding, or an unexpected source of direct radiation.

ARMs inform Health Physics and control room personnel of radiation levels in excess of the limit designated for an area (i.e., radiation zone limit) and/or a limit determined to be ALARA. Also, direct personnel monitoring may be performed through the use of worker alarming dosimeters.

Gamma and/or neutron ARMs are used, as deemed necessary, to monitor the intensity of radiation in areas where significant quantities of plutonium are stored and/or handled. Selected monitors have pre-selectable trip settings with audible annunciation, provide electronic signals for remote alarms, and/or are equipped with digital readout.

9.1.2.14 Airborne Radiation Monitoring

A person working in a glovebox (i.e., hands/arms extended into glovebox gloves) is required to have an airborne contamination monitoring device (i.e., CAM) located in close proximity to the breathing air zone. To ensure coverage at all glovebox workstations, the CAM sample heads are movable. These moveable heads contain the filter, detector, and electronics, connected to a combination wire and vacuum hose for communications and proper airflow for particulate collection. In addition to the CAMs provided for the numerous workstations, CAMs are also strategically placed in the routinely occupied areas surrounding the gloveboxes.

Most CAMs operate on the central vacuum system that provides a constant controlled airflow across the filter paper. The monitors draw a sample of the air from the vicinity of the worker onto a sample paper filter. An installed detector analyzes the filter paper and provides a signal to the local readout, and, readout and alarm monitors located in the Polishing Utilities Control Room and the Respirator Maintenance/Health Physics Room. The system also provides an alarm in the glovebox room, and in the airlocks for the glovebox room if the airborne contamination exceeds preset limits. Portable CAMs, with vacuum pumps, are available for use during maintenance and provide additional coverage as necessary.

To ensure that workers are provided adequate monitoring, there may be more than one CAM in a room. The actual number of CAMs is determined based on the anticipated number of operations and the potential for an uptake. Where there is a potential for airborne contamination, a monitor is installed so that the workers are provided coverage. The initial number and location of monitors are based on the MELOX and La Hague designs. Further evaluations will be conducted to determine the best locations for the MFFF CAMs. During maintenance activities, portable monitors will be installed as necessary, to provide additional monitoring of the task.

Airborne contamination monitors are installed to detect barrier failures. These monitors are placed in each room where personnel access is allowed and that contains the first confinement barrier. In rooms with no routine personnel access, airborne contamination monitors obtain air samples taken from the ventilation exhaust ducts exiting rooms (cells) as appropriate.

Alarm setpoints are provided at two distinct levels to enable the worker to take appropriate action if a release should occur. The lower (first) setpoint provides a warning of increasing airborne contamination so that the worker can exit the room or don appropriate respiratory equipment. This alarm also warns other workers outside the room that there is an increase in airborne contamination and that they should not enter the room without respiratory equipment. The alarm is provided with remote readouts in the Polishing Utilities Control Room and the Respirator Maintenance/Health Physics Room so that the process can be terminated and corrective actions can be initiated to stop the release.

The higher (second) alarm setpoint provides worker and remote readouts, indicating that personnel are in danger and that immediate actions are required to provide protective measures to the workers. These setpoints are less than the 10 CFR Part 20 Appendix B limits but above the warning level. In addition to local alarms, remote readouts and alarms are provided in the Polishing Utilities Control Room and the Respirator Maintenance/Health Physics Room.

During maintenance activities when a glovebox or a system boundary is opened, portable air samplers are used to monitor personnel inside contamination control enclosures. The use of portable monitors allows for closer supervision of the airborne activity in the area of the work. The portable units are provided with local and remote alarm capabilities to warn Health Physics and supervisory personnel, as well as the workers and personnel in the surrounding area.

A foot pedal is another design safety feature that further reduces the likelihood of airborne radioactivity uptake to the glovebox worker or others in the area. This device can be used by the glovebox worker to alert others of the need for help in case of a torn glove in the glovebox or other incident at the workstation. The foot pedal, placed near the glovebox operator, allows the operator to sound an audible and visual alarm in the Respirator Maintenance/Health Physics Room. The operator is trained to stay at the glovebox station, tell others in the area to stay clear, and wait for Health Physics support. Health Physics personnel immediately notify other workers in the general area and respond to support the glovebox worker.

9.1.3 Source Identification

9.1.3.1 Sources of Radiation and Contamination

Five primary radiation sources are used for radiation protection design: non-polished plutonium, polished plutonium, raffinates, master blend, and final blend. Non-polished plutonium, as received at the MFFF, contains daughter products from the original product that has decayed for about 40 years. As the facility nears the end of life, the original product received will have decayed about 70 years. These daughter products decay by beta and alpha emissions that are higher in abundance and energy than the original product material. Neutrons are produced by spontaneous fission and through alpha-neutron reactions. Impurities associated with input materials (see Chapter 11) are incorporated into the (α,n) reaction for the unpolished source.

Impurities from feed material originating from sources other than the PDCF have been analyzed to determine the impact on shielding design and estimated occupational doses. Impurities such as sodium and beryllium have an impact on the neutron intensities for feed material at the front end of the AP process. This will have little impact on facility occupational doses since the operations in these cells are performed remotely.

Polished plutonium contains much less of the daughter products (or impurities from feed material originating from sources other than the PDCF), such that the radiation levels are lower. The master blend is a maximum of 20% PuO_2 with the balance being depleted UO_2. The final blend will be in the range of 2% to 6%. The conservative estimate for the long-term average for personnel exposure is assumed to be 5% PuO_2 + 95% depleted UO_2. Table 9-3 shows the non-polished plutonium source at 0 year decay, 40 year decay, and 70 year decay. Table 9-4 shows polished plutonium from AP, master blend, and final blend sources. Table 9-5 shows the AP raffinate sources.

The Radiological Isotopic Composition (RIC) is back-calculated using the decay schemes for the affected isotopes from Today's Isotopic Composition (TIC), which is based on 40 years of decay since the plutonium was first refined. The Final Isotopic Composition (FIC) is the decay of the TIC to a total of 70 years since the plutonium was first refined. The Raffinates Isotopic Composition (RAIC) corresponds to all of the mass of ^{241}Am obtained at the entrance of the AP Area; all of the daughters (except neptunium and thorium) produced by the decay of plutonium during 70 years; and a small amount of plutonium and uranium corresponding to the repartition of plutonium and uranium in the AP process. These notations are used in Tables 9-3 and 9-5.

Multiple sources are identified to maximize photon and neutron source terms. The 0-year decay sources represent the initial isotopic composition of the product material. The 40-year decay sources represent the expected isotopic compositions at the start of facility operations. The 70-year decay sources are the isotopic compositions at the maximum decay time expected at the facility. Non-routine and accident sources will be addressed in the license application for possession and use of SNM, as will additional details concerning shielding analyses (i.e., model and geometries).

A residual source of contamination is conservatively estimated for loss-of-confinement analysis and extremity dose analysis based on MELOX operating experience.

The occupational dose is assessed during the design phase. Significant occupational doses are evaluated for design enhancements to reduce the potential doses. ALARA evaluations are documented and summarized in the license application.

9.1.3.2 Source Pertinent Information

The sources identified in Section 9.1.3.1 are used to:

- Evaluate consequences in the safety assessment of the design basis
- Provide input to shielding codes used in the design
- Establish design features
- Develop plans and procedures
- Assess occupational dose.

9.1.3.3 MELOX and MFFF Source Term Comparison

The source term comparison in Table 9-6 is made to assist in extrapolating existing MELOX radiation exposure data to that for the MP Area. No source comparison is used for the AP process since the expected occupational exposure is small. In the absence of radiation dose rate and activity data at this time, existing MELOX data are extrapolated for the MFFF to estimate the expected occupational dose. These data provide a focus for design evaluations.

The specific activities associated with these sources are used in shielding calculations to determine the ratio of the dose rates for MELOX and the MFFF. In this way, the sources can be compared to extrapolate expected dose rates in the MFFF. Tables 9-7 and 9-8, along with Figures 9-10 and 9-11, provide comparisons of photon and neutron spectra, respectively.

The ratio of the MELOX photon dose to the MFFF photon dose is 20:1. This ratio is based on a calculated dose comparison for a specific geometry of the MELOX fuel (8.5%) to the final blend MFFF fuel (5%).

The ratio of the MELOX neutron dose to the MFFF neutron dose is 11:1. This ratio is based on the ratio of the intensities and on a comparison of the calculated dose rates for specific geometries from each facility.

9.1.4 Ventilation Systems and Glovebox Design

The design and operation of the ventilation system and gloveboxes are to protect workers from airborne radioactive material such that the limits of 10 CFR Part 20 are not exceeded during routine and non-routine operations and anticipated events.

The design objectives for the ventilation systems and gloveboxes ensure that during routine and non-routine operations and anticipated events, the airborne concentration in occupied operating areas will remain well below the limits of 10 CFR Part 20, Appendix B. Engineering controls are preferred over the use of respirators.

Uninterruptible power supplies (UPSs) ensure air monitoring and warning systems associated with the ventilation system and gloveboxes will function during a loss of power unless they can tolerate a temporary loss of function without loss of data. The air monitoring and warning systems are designed with a standby power supply.

Chapter 11 provides details of the system design for the ventilation system and gloveboxes.

9.1.4.1 Ventilation System Design

The ventilation system is designed to incorporate features that ensure workers are protected, to the greatest extent practical, from airborne radioactive material during normal and accident conditions. Many of the ventilation system design features described in this section also promote reduced airborne effluent releases and minimize exposures to site workers and members of the public.

The heating, ventilation, and air conditioning (HVAC) systems are designed to maintain negative pressure gradients between the building confinement zones and between the building and the outdoors to ensure that the airflow is from zones of lesser contamination potential to zones of greater contamination potential. The confinement systems are bounded by "confinement system boundaries," across which well-defined pressure gradients are maintained to ensure that any air exchange, and consequently airborne contaminants, through breaches is also from zones of lesser contamination potential to zones of greater contamination potential.

The system design provides for a progressively inward flow so that air flows from clean areas (C1 or C2 zones) to the most contaminated areas (C4 zones) (e.g., gloveboxes) and eventually exhausts via high-efficiency particulate air (HEPA) filters. C4 zones are the primary confinement zones containing process equipment and the associated cells and enclosures. C3 zones are broken down into two levels depending on the contamination hazard: C3a zones have a low occasional hazard, while C3b zones have a moderate hazard. C2 zones have a very low occasional contamination hazard, and C1 zones have no potential for contamination. Confinement zone maps are presented in Chapter 11.

Airlocks are provided at the access between zones of different depressurization levels and limited access areas where airflow must be maintained in one direction, from the lower to the higher potential contamination. The cascading air from the clean area through the airlock and into the potentially contaminated area minimizes the potential for airborne contaminant migration to the clean areas from the potentially contaminated areas during personnel access.

The very high depressurization exhaust system is designed to prevent any backflow due to "breaches" in static barriers to prevent the escape of airborne contaminants. To ensure that airflow is always away from workers and to ensure that radioactive materials remain inside the glovebox, a minimum of 125 linear feet per minute of airflow into the glovebox is maintained.

Monitors and alarms are provided to indicate changes in confinement pressures to warn personnel so that appropriate actions can be taken. The instrumentation for a glovebox or enclosure ventilation system includes devices to indicate the differential pressure between the glovebox or enclosure and the surrounding work area, the filter resistance, and the exhaust flow rate from the glovebox or enclosure. When glovebox or enclosure operations are not attended full time, a sensor is provided to monitor abnormal pressure and to alarm at a point where operations personnel are stationed.

The dynamic confinement systems are designed to operate continuously to protect personnel from exposure to airborne and transferable contamination. Redundancy ensures continuous operation of an HVAC system in the event of the failure of an active component (e.g., a fan or a damper) during normal or accident conditions.

Room airflow is designed to reduce the possibility of airborne radioactive materials being released in the vicinity of the worker's breathing zone during abnormal conditions. Air is supplied above the worker and exhausted as close to floor level as possible. This design provides for a "wash" across the worker, resulting in the air around the worker being maintained free of contaminants.

These design features minimize the potential that workers are exposed to airborne radioactive material during normal operations, maintenance, or accidents.

Airborne radioactivity monitoring and warning systems provided for worker protection and safety are powered by a reliable offsite power source. In the event offsite power is lost, the monitoring and warning systems are powered by standby power and UPS units. The monitoring and warning systems are connected to a data network, providing numerous communication links and readout capabilities. Alarms and instrument readouts are provided in the respective process area control rooms, the AP control room, and the Respirator Maintenance and Health Physics Room, which is used as the Operations Support Center during postulated events. The instrument readouts are also available in the Emergency Operations Center.

9.1.4.2 Glovebox System Design

The primary function of the glovebox is to protect workers from radioactive materials. The gloveboxes are considered the primary confinement and are designed to meet ALARA objectives for both direct and internal radiation sources and to ensure worker safety (see Chapter 11 for additional details concerning the glovebox design).

The glovebox design incorporates design techniques to minimize pockets and sharp corners. Smooth surfaces and rounded corners provide for ease of cleaning and recovery of material. This design reduces the localized collection of radioactive material and thereby reduces worker radiation exposures. Maintenance procedures address periodic cleaning inside the gloveboxes to remove dust and eliminate "hot spots" and contamination.

The gloveboxes are designed to withstand accidental conditions as defined by the safety assessment of the design basis (e.g., the design basis earthquake, over- or under-pressure). This design ensures that, in an accident condition, personnel are provided appropriate protection from a release of radioactive material. The glovebox design is based on providing adequate airflow and sealing surfaces to preclude releases from the glovebox. Glovebox penetrations are designed with glove ports that are sealed to prevent release of contamination.

9.1.5 Shielding Evaluations

MELOX operating experience is utilized throughout the MFFF design process to minimize occupational and public radiation exposures. Actual operating experience that defines the occupancy for each of the process units is used to estimate the occupational exposures for each glovebox. Radiation sources are determined for the MFFF. The redesign of some process units for process reasons and/or to optimize radiation protection will be taken into account in the analysis. These sources are used to calculate the dose rates and thus establish the radiation shielding requirements. Process units that result in higher occupational exposure are reviewed to maximize productivity, minimize maintenance, and thus minimize radiation exposures. The types of MELOX data used for the MFFF design are as follows:

- Personnel access requirements:
  - Description of activities
  - Proximity to radiation sources

  - Definition of radiation sources
  - Duration of activities
  - Duration of time that hands are in the gloveboxes.

- Radiation exposure data:
  - Total facility doses
  - Doses for each process zone (i.e., powder, pellets, rods, and assemblies)
  - Doses from routine operations
  - Gamma versus neutron dose rates.

Permanent shielding is designed in the facility to lower dose rates to comply with 10 CFR Part 20 during routine and non-routine operations and anticipated events. DCS has developed radiation zone drawings that contain higher radiation zones within decreasing lower radiation zones (see Section 9.1.2.3.1). The design will identify and describe areas in which temporary shielding will be required for non-routine maintenance. Provisions will be incorporated into the design to minimize the time required to install temporary shielding by designing the type of temporary shielding anticipated and by designing temporary shielding storage locations.

Design goals for internal and direct doses will be based on fractions of 10 CFR Part 20 limits. These are developed in the design by making use of the design features and experience of the MELOX and La Hague facilities. The use of actual exposure data and the difference in the source terms between MELOX and MFFF material facilitate setting these design goals. The permanent and temporary shielding developed as part of this design meets these design goals. The design goals are set based on this dose estimate.

The TEDE design goal (i.e., ALARA and minimize the number of operators with occupational doses greater than 500 mrem/yr) is established early in the design process for individual workers and is also intended to be applied to the facility operations.

Detailed design drawings and descriptions of the shielding for high and very high radiation areas are developed to clearly identify the penetrations, shield doors, and labyrinths incorporated to meet the design shielding criteria. Radiation shielding analyses are used to verify the shielding for each process room including the dose rates for each position workers are required to take to perform routine and non-routine maintenance. This design is based on experience and the design features of the MELOX facility. Details of the shielding design and the dose estimate will be provided in the Integrated Safety Assessment (ISA) Summary with the license application for possession and use of SNM.

A Radiation Shielding Test Program will verify the efficacy of the installed shielding materials in meeting the radiation shielding design goals and the regulatory direct dose requirements of 10 CFR Part 20.

Several standard industry computer codes are used in the shielding calculations (e.g., Monte Carlo N-Particle [MCNP], SCALE, Perceval, SN1D, Microshield). The computer codes are discussed in Section 9.1.5.4.

The shielding design complies with 10 CFR §20.1406 requirements for the minimization of contamination and uses the MELOX facility design experience for guidance. The MFFF facilitates waste minimization of shielding materials. The design includes permanent shielding in the process rooms. Temporary shielding that could add to radioactive waste volumes will be minimized based on the uses described previously in this section.

The Project Quality Assurance Program applies to the shielding design. This program will be used as appropriate in shielding design, procurement, installation, maintenance, and operation.

9.1.5.1 Shielding Information for Each Radiation Source

Shielding information for each radiation source will be provided in the license application for possession and use of SNM.

9.1.5.2 Criteria for Penetrations

Penetrations in shielding for high radiation sources are minimized in the design. For lower dose rate sources, the impacts are analyzed in shielding analyses. Penetration analyses will be discussed further in the license application for possession and use of SNM.

9.1.5.3 Shielding Materials

Standard shielding materials are used to attenuate the radiation intensity at the worker. Materials such as leaded glass, leaded polymers, borated concrete, borated polymers, borated plasters, and ordinary concrete are utilized. ANSI/ANS-6.4.2-1985, R1997 is used as the reference for shielding material properties for performing calculations.

9.1.5.4 Computer Codes

The MCNP computer code is used to estimate photon and neutron transport. Source configurations (e.g., jars of powder, vessels of liquids, trays of pellets, rods, and assemblies) are modeled in the computer software to estimate direct and scattered radiation.

The MicroShield computer code is used to check the photon shielding analyses of gloveboxes.

The SCALE computer code was designed by the Radiation Shielding Information Computational Center at Oak Ridge National Laboratory for the NRC. It is comprised of several control modules that perform specific analysis tasks. The control module SAS1 is used for a one-dimensional neutron dose rate analysis for this project. SAS1 uses functional modules BONAMI, NITAWL-II, and XSDRNPM to process cross sections, XSDRNPM to perform the shielding calculation, and XSDOSE to calculate dose rates.

The Perceval and SN1D codes are used by Cogema in France. Perceval is a nuclear radiation protection software program that calculates the gamma dose equivalent rate or the radiation shielding thickness for a given gamma dose equivalent rate. SN1D is a discrete ordinates code. The SN1D calculation system is used for solving the Boltzmann neutral neutron and gamma particles transport equation. The one-dimensional computer code accepts plane, spherical, and cylindrical geometries. The multigroup approach allows the calculation of a particle flow within each energy group; the possible boundary conditions are the vacuum, reflection, and albedo conditions. It can handle the scattering and external source anisotropy, making a direct or subsidiary calculation. The reaction rates and dose rates are assessed from the flows.

Neutron sources are adjusted for subcritical multiplication and alpha-neutron reactions. Photon sources include daughter products of plutonium decay that contribute to the photon source term over the facility's lifetime.

Each source of radiation within the facility is identified and included in the shielding analysis to estimate radiation dose rate fields throughout the facility. Shielding materials are selected for the source term to effectively reduce dose rates to meet ALARA goals. Borated polymers are used for neutron attenuation, and leaded plastic and glass are used for photon shielding in the glovebox units. AP areas contain stainless steel vessels with concrete shielding between equipment. Dose collection points (or tallies or detector points) are set at locations of expected occupancy. Multiple dose collection points are chosen to represent the position of the whole body and the extremities. ANSI 6.1.1-1977 flux-to-dose conversion factors are used to estimate dose rates.

9.1.5.5 Special Protective Features

Special features to ensure that normally occupied areas are ALARA (as applicable) will be defined during final design and summarized with the license application for possession and use of SNM.

9.1.6 Integrated Safety Analysis

Chapter 5 describes the programmatic and analytical details of radiation safety associated with design basis events (i.e., the safety assessment of the design bases of principal SSCs). The ISA Summary will be completed and submitted with the license application for possession and use of SNM.

9.2 RADIATION PROTECTION PROGRAM

The Radiation Protection Program specifically implements the requirements of 10 CFR Part 20, *Standards for Protection Against Radiation*, and the appropriate sections of 10 CFR Part 19, *Notices, Instructions and Reports to Workers: Inspection and Investigations*, and 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*. The Radiation Protection Program implements the necessary programmatic requirements to ensure that radiological work activities are performed in a manner that protects the health and safety of workers.

9.2.1 Radiation Protection Program Description

The Radiation Protection Program ensures the following:

- The individual worker's exposure to radiological hazards is ALARA.
- Personnel responsible for performing radiological work are appropriately trained.

- Personnel responsible for implementing and overseeing the Radiation Protection Program are technically competent.
- The ALARA process is incorporated into the facility design, modifications, and work processes.
- Line management is involved and accountable for radiological performance.
- Radiological measurements, analyses, worker monitoring results, and estimates of public exposures are accurately and appropriately conducted.
- Radiological operations are conducted in a manner that controls the spread of radioactive materials and reduces exposure to the workforce and the general public, and a process is utilized that maintains exposure levels ALARA.

Radiological facilities and areas will be operated in such a manner to meet radiological dose limits and to meet the goals of the ALARA Program and Regulatory Guide 8.10, *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable*. Radiological work activities performed under this materials license, including those performed by subcontractors, will meet the requirements of the Radiation Protection Program.

Operating plans and procedures will be developed in consideration of ALARA principles. The following considerations will be included for operations:

- Training is provided to operations personnel to minimize the potential for plutonium inhalation.
- Preventive maintenance is performed during times when no sources are being processed, or alternatively, maintenance is performed on equipment outside radiation areas.
- Dry runs are performed during startup testing to determine probable radiation exposures, and results are factored into operating procedures.
- Pre-operational and continuing training on procedures, including dry runs, is conducted for operations personnel to minimize radiation exposures.
- Contingency procedures are developed for off-normal occurrences and accidents, including recovery operations.

9.2.2 Radiation Protection Program Functional Elements

9.2.2.1 ALARA Program

9.2.2.1.1 ALARA Program Description

The ALARA policy is to keep radiation exposures within regulatory limits and to ensure that radiation exposure is ALARA. Line management and the workforce are committed to this policy. The ALARA Program is composed of the following:

- ALARA Program description and procedures
- ALARA Committee

- ALARA Chairman
- ALARA Program Coordinator – A member of the Radiological Protection staff will be appointed as the ALARA Program Coordinator, who will assist the ALARA Chairman in implementing the ALARA Program.

9.2.2.1.2 Management Commitment

The responsibility for complying with radiological protection requirements and for maintaining radiation exposures ALARA starts with the individual worker and broadens as it progresses upward through the organization. Line managers are fully responsible for radiological performance among their personnel and take necessary actions to ensure that personnel are properly trained and that performance to the requirements is monitored and corrected as necessary. As part of the commitment to the Radiation Protection Program, senior management ensures that the ALARA Program is implemented and that line management is held accountable.

9.2.2.1.3 ALARA Committee

The ALARA Committee provides the focus and direction for improving the Radiation Protection Program. The ALARA Committee includes the ALARA Chairman (who is a member of line management and nominated by senior management); the ALARA Program Coordinator; the Radiological Protection Manager; and personnel from line management, operations, and the technical support organizations. Radiological protection personnel act as advisors to the committee.

9.2.2.1.4 Administrative Control Levels and Dose Limits

The objective of minimizing radiation exposure is to maintain individual radiation doses ALARA, but in all cases below regulatory limits. To accomplish this objective, administrative control levels are established below the regulatory limits to control individual and collective radiation dose. The administrative control levels are multi-tiered with increasing levels of authority required to exceed higher administrative control levels. Unless otherwise indicated, administrative control levels and dose limits are stated in terms of the total effective dose equivalent (TEDE).

9.2.2.1.5 Internal Audits and Assessments

Internal self-assessments by radiation protection and plant operating/maintenance personnel are routinely performed to provide continuous evaluation of the Radiation Protection Program for needed procedural and implementation improvements. Formal independent audits performed by the quality assurance organization will also be scheduled and performed such that over a 12-month period, functional elements of the Radiation Protection Program are evaluated for program compliance and implementation. These audit results provide valuable feedback to line managers on those areas that need more management attention.

9.2.2.2 Organization and Administration

9.2.2.2.1 Radiological Protection Organization

During operations, the radiological protection organization is independent of the operations and maintenance organizations. The radiological protection organization provides relevant support to facility operations. The radiological protection organization develops policies and procedures to ensure compliance with 10 CFR Part 20. Written procedures are developed and implemented as necessary to ensure compliance with 10 CFR §20.1101(b).

Individuals responsible for developing and implementing measures necessary for ensuring compliance with the requirements of 10 CFR Part 20 have the appropriate education, training, and skills to discharge these responsibilities. The radiological protection organization, working with facility management, ensures adherence to the Radiation Protection Program in operations and provides the required radiological support to the facility organization.

9.2.2.2.2 Radiological Protection Manager

The Radiological Protection Manager is responsible for setting radiological protection policy and has direct access to senior-level management for implementation of this policy. In addition, the Radiological Protection Manager has the responsibility for planning, administering, and maintaining the Radiation Protection Program with support from line management at all levels. The Radiological Protection Manager will ensure that the Radiation Protection Program elements are appropriately implemented and maintained through radiological policies, procedures, and documents. The Radiological Protection Manager, or his designee, will approve radiological protection policies and procedures.

9.2.2.3 Radiation Safety Procedures and Radiation Work Permits

The primary methods used to control workplace exposure are operating procedures and facility and equipment design features. These controls are augmented with the use of area entry/exit requirements to control access to and from radiological areas and RWPs to control radiological work. Proposed maintenance and modification plans are reviewed to identify and incorporate radiological protection requirements.

Employees have the authority and responsibility to stop radiological work activities suspected of being unsafe.

9.2.2.3.1 Radiological Work Planning

Performance of work planning is the responsibility of line management, with support from the radiological protection organization. Radiological surveys are used to develop the radiological protection requirements and are documented on the RWP. Specific radiological controls based on the surveys, and from any formal ALARA reviews that were performed because established planning thresholds were exceeded, are incorporated into the work documents. Line management ensures that safety requirements supplement each other and do not conflict for the overall safety of the worker.

9.2.2.3.2 Entry and Exit Control

Specific requirements for entering and exiting radiological areas are established. Radiation safety training commensurate with the hazards and required controls is required before unescorted access to radiological areas is permitted. The primary control for entry into radiological areas is the RWP, which is augmented by signs and barricades. For access to high and very high radiation areas, the process meets the requirements of 10 CFR §20.1601 and §20.1602 and employs one or more control devices, which include conspicuous visual and/or audible alarms, locked entrances, and/or administrative controls.

9.2.2.3.3 Radiological Work Controls

Positive control of personnel is established through RWPs, and the dose and training status of each employee entering radiological controlled areas are confirmed prior to entry. Only trained and qualified personnel, who have the information available to understand and respond to the radiological conditions that they will encounter during the work activity, are allowed to enter the restricted area unescorted. In some circumstances, specialists may be granted escorted access to perform specific tasks with permission of the Radiological Protection Manager.

The RWP is the administrative mechanism used to establish radiological controls for intended work activities. The RWP informs employees of area radiological conditions and entry requirements and provides a mechanism to relate employee exposure to specific work activities.

9.2.2.3.4 Posting and Labeling

Posting and labeling of radiation areas and radiologically contaminated areas, equipment, and material are used to alert personnel about the radiological status of the item or area and to prevent any inadvertent dose to the worker. This program includes the use of the standard radiological posting and labeling and meets the requirements of 10 CFR Part 20 Subpart J. The program also controls posting of signs so they are clearly and conspicuously posted.

9.2.2.3.5 Release of Materials and Equipment

Material and equipment that are contaminated or potentially contaminated are considered contaminated until they are surveyed and released. This program is implemented to ensure that no contaminated material or equipment is released from the control of the program. The program controls the movement of material and equipment from contamination areas and between controlled areas. The program also controls the release of material and equipment from controlled areas and from the site.

9.2.2.3.6 Sealed Radioactive Source Accountability and Control Program

The purpose of this program is to control radioactive sealed sources and to prevent the loss or unintentional exposure of the worker to these sources. The program sets the accountability requirements for sources and monitoring requirements.

9.2.2.3.7 Receipt of Packages Containing Radioactive Material

The Transportation Program controls the receipt of packages containing radioactive materials. The purpose of this program is to ensure that appropriate controls are implemented for these packages from the time of receipt to its final destination. This program will prevent any unauthorized access to the packages and ensure that any subsequent radiation dose will be maintained ALARA.

9.2.2.4 Radiation Safety Training

Radiation safety training is commensurate with the employee's duties. Standardized core courses are utilized, to the extent practicable, and are supplemented by facility-specific information. Depending on their work activities, employees will take General Employee Training or Radiological Worker Training (see Section 1.1.2.1).

9.2.2.5 Air Sampling

The Airborne Radioactivity Monitoring Program uses air samplers and/or CAMs, and usage is based on the working conditions. The program is designed to minimize the internal exposure to the radiation workers and is part of the overall ALARA Program. The estimation of internal dose will be based upon airborne radioactivity concentrations. In the event of high exposures, the internal dose will be verified by also using bioassay data.

9.2.2.6 Contamination Monitoring and Control Program

The Contamination Monitoring and Control Program is designed to prevent the movement of radioactive contamination from controlled areas to uncontrolled areas and to monitor personnel and equipment leaving contamination areas. Radioactive contamination is controlled by using engineering controls, by containing contamination at the source, by monitoring, and by promptly decontaminating areas that become unintentionally contaminated.

The program requires surveying of contamination areas to determine the current levels of contamination. The survey results are also used to determine if postings are correct and if additional controls are required and to determine the appropriate personnel protective equipment.

9.2.2.7 Direct Exposure Control Program

The Direct Exposure Control Program provides the following:

- Exposure monitoring
- Dosimeters and their processing
- Dose determinations
- Dose record maintenance
- Dose reporting
- Records maintenance.

Dosimetry will be processed and evaluated by a processor accredited by the National Voluntary Laboratory Accreditation Program. The purpose of the Direct Exposure Control Program is to ensure that radiation workers' doses do not exceed dose limits. The program is composed of the following:

- The measurement of the direct radiation dose received by workers using a dosimeter
- Control, as practicable, of personnel that have received radiopharmaceuticals
- Planned special exposures
- Exposure limit for minors and the general public
- Radiological protection for the embryo/fetus.

9.2.2.8 Internal Exposure Control Program

The Internal Exposure Control Program identifies both the discretionary and non-discretionary bioassay sampling requirements and is designed to monitor internal uptakes and to determine the quantity of the uptake. The program is composed of the following:

- The non-discretionary measurement of the internal radiation dose received by workers who are likely to receive a committed effective dose equivalent (CEDE) to the whole body of greater than 500 mrem in a year

- The discretionary measurement of workers to determine the effectiveness of the Respiratory Protection Program.

9.2.2.9 Summing of Internal and Direct Exposure

Doses will be summed using the guidance provided in Regulatory Guide 8.7, *Instructions for Recording and Reporting Occupational Radiation Exposure Data*; Regulatory Guide 8.34, *Monitoring Criteria and Methods to Calculate Occupational Radiation Doses*; and Regulatory Guide 8.36, *Radiation Dose to the Embryo/Fetus*.

The maximum doses allowed for occupationally exposed workers are contained in 10 CFR §20.1201. These limits apply to all radiation workers 18 years of age or older. These limits are expressed in units of dose equivalent (DE) in rem and Sv. Internal dose to a specific organ is given as committed dose equivalent (CDE), while the internal dose relative to a whole-body exposure is given as CEDE. Direct dose is expressed as deep dose equivalent (DDE), shallow dose equivalent (SDE), and lens of the eye dose equivalent (LDE).

The annual occupational exposure limits from 10 CFR Part 20 are as follows:

• Total (CEDE + DDE) = TEDE	5 rem (0.05 Sv)
• Lens of Eye (LDE)	15 rem (0.15 Sv)
• Other Organs (CDE + DDE)	50 rem (0.5 Sv)
• Skin or Extremity (SDE)	50 rem (0.5 Sv).

Note: The extremities are considered to be the hand, elbow, arm below the elbow, foot, knee, and leg below the knee.

9.2.2.10 Respiratory Program

Using ALARA concepts, the use of respiratory protection is minimized and will be determined to ensure that the TEDE dose is optimized for the work activity. Specialized training and a medical evaluation are required for individuals required to wear respirators. The Respiratory Program will follow the guidance of ANSI-Z88.2-1992, *Practices for Respiratory Protection*, ANSI-Z88.6-1984, *Physical Qualifications for Respirator Use*, and NUREG-0041, *Manual of Respiratory Protection Against Airborne Radioactive Materials.*

9.2.2.11 Instrument Calibration and Maintenance Program

The Instrument Calibration and Maintenance Program ensures that the fixed and portable radiological protection instrumentation used for the Radiation Protection Program are appropriately calibrated and maintained in accordance with ANSI 323. This program ensures that the instruments used in the Radiation Protection Program produce accurate and reproducible results.

9.2.2.12 Area Monitoring and Control

In general, the workplace is monitored to:

- Document radiological conditions in the workplace
- Detect changes in radiological conditions
- Detect the gradual buildup of radioactive material in the workplace
- Verify the effectiveness of engineering and process controls in containing radioactive material and in reducing radiation exposure
- Determine the level of posting that is required
- Determine the appropriate dosimetry, personnel protective clothing, and respiratory requirements on the RWP
- Demonstrate compliance with the requirements of the Radiation Protection Program.

9.2.2.13 Records

Complete and accurate radiation protection records of the facilities, including the records of individuals who work in or visit them, are maintained in accordance with 10 CFR Part 20 Subpart L. Reports are formatted in accordance with 10 CFR §20.2110. These records are used to document the radiation exposures of individuals and are available as prescribed by the Privacy Act of 1974. These records are also used for (1) evaluation of the effectiveness of the Radiation Protection Program, (2) demonstration of compliance with regulations and requirements, and (3) personnel records. These dose records are sufficient to evaluate compliance with applicable dose limits and monitoring and reporting requirements.

9.2.2.14 Reports to Individuals

As a minimum, exposure reports are provided to individuals under the following conditions:

- Upon request from an individual terminating employment, records of exposure are provided to that individual when the data become available.
- If requested, a written estimate of radiation dose, based on available information at the time of termination, is provided.
- Annual radiation dose reports are provided to individuals monitored during the year.
- If requested, detailed exposure information is provided.
- Reports are provided to individuals when required to report to the NRC pursuant to occurrence reporting and processing, or planned special exposures.

9.3 DESIGN BASIS FOR RADIATION PROTECTION

This section discusses the design bases requirements applicable to systems, equipment, and design features associated with radiation protection. Principal SSC concepts are described in Chapter 5. The systems, equipment, and other radiation protection design features discussed below are not principal SSCs.

The MFFF basis of design for radiation protection is to ensure that SSCs necessary to maintain the safety and health of the workforce are in compliance with the requirements of 10 CFR Part 70 and 10 CFR Part 20. The MFFF is designed to provide radiation protection for workers in conformance with applicable regulatory criteria so that occupational radiation exposures are maintained ALARA. Guidance provided by NRC Regulatory Guides, DOE Program Implementation Guides and Standards, and various industry codes and standards is used.

The ARMs, CAMs, PCMs, other radiation monitoring equipment, and temporary and permanent radiation protection features are designed to monitor direct radiation and potential airborne or surface radioactive contaminants, for the purpose of protecting the health and safety of workforce personnel.

The systems, equipment, and radiation protection design features are designed using the following documents:

- 10 CFR Part 20, *Standards for Protection Against Radiation*
- 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*, including proposed draft rule text dated July 30, 1999
- Regulatory Guide 8.8 (1978), *Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable*
- Regulatory Guide 8.10 (1977), *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable*
- Regulatory Guide 8.25 (1992), *Air Sampling in the Workplace*
- ANSI/ANS-6.1-1-1977, *Neutron and Gamma-Ray Flux-to-Dose Rate Factors*

- ANSI/ANS-6.4-1977, *Guidelines on the Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants*
- ANSI/ANS-6.4.2 (1985, R1997), *Specification for Radiation Shielding Materials*
- ANSI-N13.1-1969, *Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities* [Reaffirmed 1993]
- NUREG/CR-0446, *Determining Effectiveness of ALARA Design and Operational Features*, April 1979
- DOE-STD-1128-98, *Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities.*

The MFFF design reflects consideration of ALARA principles given in NRC Regulatory Guide 8.8. Specific ALARA considerations in the MFFF design include the following:

- Multiple confinement barriers to prevent contamination spread
- Remotely operated equipment and remote readout of instrumentation to minimize personnel access to radiation areas
- Use of permanent shielding designed to minimize personnel exposure
- Use of moveable radiation shielding to minimize radiation streaming
- Access restrictions for radiation areas featuring a minimum of access points to easily control personnel ingress.

To minimize the potential for internal occupational exposures, a secondary confinement system comprises at least one confinement barrier and is provided where the potential for breach exists in primary confinement during normal operations or in an incident or accident situation.

The design of the facility ensures that the TEDE to individual members of the public from the MFFF will not exceed 100 mrem in a year from normal operations and anticipated operational occurrences. The design also ensures that annual occupational doses are maintained below a TEDE of 5 rem and 50 rem to any extremity.

The TEDE design goal for individual workers will be ALARA and less than 500 mrem/yr to most of the operating team members, with an extremity exposure goal of less than 10 rem/yr.

Worker training is provided that identifies potential loss of confinement events. Instructions on the quick identification of the event and worker response are provided.

To detect and warn workers of unexpected increases in direct radiation and airborne radioactivity concentrations, ARMs and CAMs are placed in general workspaces. As necessary, gamma and/or neutron ARMs are used to monitor the intensity of radiation in areas where significant quantities of plutonium are stored and/or handled. CAMs are installed where personnel without respiratory protection could receive an annual intake of 2% or more of the specified annual limit on intake (ALI) values (i.e., 40 Derived Air Concentration [DAC] hours). To detect a barrier failure as close to the source of leakage as possible and minimize the potential for undetected uptake of airborne radioactivity, CAMs are placed at specified glovebox workstations based on risk.

The MFFF CAMs, including sample points and sample lines, are designed to reach the lowest detection level possible (i.e., approaching less than or equal to 4 DAC-hr concentrations of ^{238}Pu). Additionally, sample lines are eliminated when practical, and when not practical, are designed with short lines, proper sampling rate, and smooth bends.

Airborne radioactivity in the AP cells will be monitored by taking representative samples of the exhaust air in the ventilation duct. This same approach will be used to monitor the air from selected high-risk MFFF processing areas.

PCMs are permanently installed at the exit of the AP and MP process areas to ensure that workers are not contaminated when they leave the radiation areas. ARMs, CAMs, and PCMs receive normal electrical power from a reliable source and, following the loss of offsite power, the monitors are powered by UPS and standby diesel power sources. Hand survey instruments and laboratory equipment are provided and strategically located to perform routine and non-routine radiation surveys of direct radiation, airborne radioactivity, and surface contamination in the AP and MP Areas and general MFFF spaces.

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Tables

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Table 9-1. MFFF Radiation Zoning Criteria

Radiation Zone	Design Basis Maximum Area Radiation Dose Rate (mrem/hr)
1 - High access, Non-radiation area	<0.05
2 - Intermediate access, Radiation area	<0.25
3 - Low access, Radiation area	<5.0
4 - Very low access, High radiation area	<100
5 - No access, Very high radiation area	>100

Table 9-2. MELOX Event INES Ratings

Event Date	Unit	INES Rating
03/16/95	Powder	Level 0
06/25/96	Powder	Level 0
08/17/96	Pellet	Level 0
08/07/97	All Ventilation	Level 1
01/09/98	Pellet	Level 0
09/26/98	Pellet	Level 0
02/08/99	UO_2 Powder	Level 0
06/29/99	Laboratory	Level 0
11/03/99	UO_2 Powder	Level 0
11/14/00	Pellet	Level 1
12/09/01	Pellet	Level 0
01/14/02	Pellet	Level 0

INES – International Nuclear Event Scale
Data are current as of August 2002

Table 9-3. Non-Polished Plutonium Sources

Non-Polished Plutonium Sources			
Isotope	Concentration (gm/gm Pu+Am)		
	0 yr RIC	40 yr TIC	70 yr FIC
He-4		2.52E-05	5.27E-05
Tl-207		1.59E-21	5.11E-20
Tl-208		1.87E-17	1.40E-17
Tl-209			1.05E-24
Pb-206		1.06E-15	1.47E-14
Pb-207		1.28E-15	4.65E-14
Pb-208		2.76E-10	4.37E-10
Pb-209			4.38E-21
Pb-210		4.18E-15	3.21E-14
Pb-211		1.23E-20	3.95E-19
Pb-212		1.10E-14	8.26E-15
Pb-214		3.89E-20	1.97E-19
Bi-209			5.76E-17
Bi-210		2.57E-18	1.97E-17
Bi-211		7.24E-22	2.33E-20
Bi-212		1.05E-15	7.83E-16
Bi-213			1.03E-21
Bi-214		2.89E-20	1.46E-19
Po-210		7.11E-17	5.45E-16
Po-211		8.88E-27	2.86E-25
Po-212		5.53E-26	4.14E-26
Po-213			1.54E-30
Po-214		3.98E-27	2.01E-26
Po-215		1.03E-26	3.31E-25
Po-216		4.40E-20	3.30E-20
Po-218		4.51E-21	2.28E-20
At-217			1.24E-26
Rn-219		2.33E-23	7.50E-22
Rn-220		1.66E-17	1.24E-17
Rn-222		8.30E-18	4.19E-17
Fr-221			1.12E-22
Fr-223		1.08E-22	3.48E-21
Ra-223		5.92E-18	1.90E-16
Ra-224		9.61E-14	7.20E-14
Ra-225			5.07E-19
Ra-226		1.29E-12	6.52E-12
Ra-228		4.43E-20	1.64E-19
Ac-225			3.43E-19
Ac-227		4.19E-15	1.35E-13
Ac-228		4.63E-24	1.71E-23
Th-227		9.72E-18	3.13E-16
Th-228		1.87E-11	1.40E-11
Th-229			9.35E-14
Th-230		1.07E-08	3.05E-08

Table 9-3. Non-Polished Plutonium Sources (continued)

Non-Polished Plutonium Sources			
Isotope	Concentration (gm/gm Pu+Am)		
	0 yr RIC	40 yr TIC	70 yr FIC
Th-231		4.24E-15	7.74E-14
Th-232		1.50E-10	4.58E-10
Th-234		1.02E-18	1.83E-14
Pa-231		2.02E-11	5.62E-10
Pa-233			1.84E-11
Pa-234m		3.45E-23	6.16E-19
Pa-234		1.54E-23	2.75E-19
U-232		6.96E-10	5.22E-10
U-233			2.33E-09
U-234		1.83E-04	2.86E-04
U-235		1.83E-02	1.90E-02
U-236		2.57E-04	4.49E-04
U-237			7.31E-11
U-238		1.26E-03	1.26E-03
Np-237			5.42E-04
Pu-236	1.00E-09	5.98E-14	4.06E-17
Pu-238	6.86E-04	5.00E-04	3.95E-04
Pu-239	9.21E-01	9.20E-01	9.19E-01
Pu-240	6.18E-02	6.15E-02	6.13E-02
Pu-241	1.00E-02	1.00E-02	1.00E-02
Pu-242	1.00E-03	1.00E-03	1.00E-03
Am-241		7.00E-03	7.92E-03

RIC – Radiological Isotopic Composition

TIC – Today's Isotopic Composition

FIC – Final Isotopic Composition

Table 9-4. Polished Plutonium Sources

Isotope	Concentration at t=70 yrs		
	Polished Pu From AP (gm/gm Pu + U+Np+Th)	Master Blend (20%) (gm/gm Pu+U+Np+Th)	Final Blend (5%) (gm/gm Pu+U+Np +Th)
Th-227	3.13E-17	6.31E-18	1.58E-18
Th-228	1.40E-12	2.82E-13	7.06E-14
Th-229	9.35E-15	1.89E-15	4.71E-16
Th-230	3.05E-09	6.15E-10	1.54E-10
Th-231	7.74E-15	1.56E-15	3.90E-16
Th-232	4.58E-11	9.23E-12	2.31E-12
Th-234	1.83E-15	3.69E-16	9.21E-17
U-235		2.00E-03	2.38E-03
U-238		7.98E-01	9.48E-01
Np-237	1.09E-04	2.19E-05	5.47E-06
Pu-236	4.06E-17	8.19E-18	2.05E-18
Pu-238	3.95E-04	7.95E-05	1.99E-05
Pu-239	9.19E-01	1.85E-01	4.63E-02
Pu-240	6.13E-02	1.24E-02	3.09E-03
Pu-241	1.00E-02	2.02E-03	5.04E-04
Pu-242	1.00E-03	2.02E-04	5.04E-05

Table 9-5. AP Raffinate Sources

Raffinate Source Constituents	
Isotope	Concentration (gm/gm Pu + Am) RAIC at 70 yr
He-4	5.27E-05
Tl-207	5.11E-20
Tl-208	1.40E-17
Tl-209	1.05E-24
Pb-206	1.47E-14
Pb-207	4.65E-14
Pb-208	4.37E-10
Pb-209	4.38E-21
Pb-210	3.21E-14
Pb-211	3.95E-19
Pb-212	8.26E-15
Pb-214	1.97E-19
Bi-209	5.76E-17
Bi-210	1.97E-17
Bi-211	2.33E-20
Bi-212	7.83E-16
Bi-213	1.03E-21
Bi-214	1.46E-19
Po-210	5.45E-16
Po-211	2.86E-25
Po-212	4.14E-26
Po-213	1.54E-30
Po-214	2.01E-26
Po-215	3.31E-25
Po-216	3.30E-20
Po-218	2.28E-20
At-217	1.24E-26
Rn-219	7.50E-22
Rn-220	1.24E-17
Rn-222	4.19E-17
Fr-221	1.12E-22
Fr-223	3.48E-21
Ra-223	1.90E-16
Ra-224	7.20E-14
Ra-225	5.07E-19
Ra-226	6.52E-12
Ra-228	1.64E-19
Ac-225	3.43E-19
Ac-227	1.35E-13
Ac-228	1.71E-23
Pa-231	5.62E-10
Pa-233	1.84E-11
Pa-234m	6.16E-19
Pa-234	2.75E-19
U-232	7.97E-13

Table 9-5. AP Raffinate Sources (continued)

Raffinate Source Constituents	
Isotope	**Concentration (gm/gm Pu + Am) RAIC at 70 yr**
U-233	3.55E-12
U-234	4.38E-07
U-235	2.91E-05
U-236	6.86E-07
U-237	1.12E-13
U-238	1.92E-06
Pu-236	1.32E-21
Pu-238	1.28E-08
Pu-239	2.98E-05
Pu-240	1.99E-06
Pu-241	3.24E-07
Pu-242	3.24E-08
Am-241	7.92E-03

RAIC – Raffinates Isotopic Composition

Table 9-6. Radionuclide Inventory Comparison

Isotope	MELOX (% per gram of metal)		MFFF (% per gram of metal)	
	30% PuO_2	8.5% PuO_2	20% PuO_2	5% PuO_2
Ru-106	6.24E-10	2.58E-10		
Rh-106	5.81E-16	2.41E-16		
Tl-208	2.17E-14	7.61E-15		
Bi-212	1.21E-12	4.26E-13		
Th-227			6.31E-16	1.58E-16
Th-228			2.82E-11	7.06E-12
Th-229			1.89E-13	4.71E-14
Th-230			6.15E-08	1.54E-08
Th-231			1.56E-13	3.90E-14
Th-232			9.23E-10	2.31E-10
Th-234			3.69E-14	9.21E-15
Np-237			2.19E-03	5.47E-04
U-232	1.15E-06	3.86E-07		
U-233	9.26E-08	1.21E-07		
U-234	3.41E-02	2.35E-02		
U-235	6.63E-01	8.64E-01	2.00E-01	2.38E-01
U-236	2.89E-01	3.71E-01		
U-237	7.38E-08	2.09E-08		
U-238	6.08E+1	7.94E+01	7.98E+01	9.48E+01
Pu-236	3.48E-07	9.86E-08	8.19E-16	2.05E-16
Pu-238	4.56E-01	1.29E-01	7.95E-03	1.99E-03
Pu-239	1.54E+01	4.37E+00	1.85E+01	4.63E+00
Pu-240	6.01E+00	1.71E+00	1.24E+00	3.09E-01
Pu-241	2.43E+00	6.89E-01	2.02E-01	5.04E-02
Pu-242	1.33E+00	3.77E-01	2.02E-02	5.04E-03
Am-241	7.91E-01	2.24E-01	0.00E+00	0.00E+00

Table 9-7. Comparison of Photon Spectra

(per gram of oxide)

Photon Energy (MeV)	MELOX (gammas/sec)	
	30% PuO_2	8.5% PuO_2
0.014	7.50E+07	2.13E+07
0.021	7.83E-01	3.24E-01
0.028	3.13E+07	8.86E+06
0.060	4.06E+08	1.15E+08
0.077	2.83E+04	8.28E+03
0.101	9.36E+05	2.66E+05
0.118	3.24E+03	9.33E+02
0.147	3.79E+05	1.08E+05
0.210	5.86E+05	1.67E+05
0.333	4.86E+04	1.38E+04
0.389	2.90E+04	8.23E+03
0.560	5.12E+03	1.69E+03
0.664	5.51E+03	1.56E+03
0.770	7.73E+03	2.26E+03
0.980	2.99E+02	9.45E+01
1.598	1.45E+02	5.11E+01
1.915	1.41E+01	5.09E+00
2.615	2.67E+03	9.39E+02
	5.14E+08	1.46E+08

Photon Energy (MeV)	MFFF (gammas/sec)	
	20% PuO_2	5% PuO_2
0.015	4.79E+07	1.20E+07
0.025	7.03E+01	1.76E+01
0.038	4.94E+04	1.23E+04
0.058	1.27E+05	3.17E+04
0.085	1.36E+04	3.40E+03
0.125	4.21E+04	1.06E+04
0.225	5.93E+03	1.57E+03
0.375	2.72E+04	6.80E+03
0.575	1.02E+03	2.55E+02
0.850	1.39E+02	3.47E+01
1.250	1.25E+01	3.13E+00
1.750	5.67E+00	1.42E+00
2.250	3.24E+00	8.14E-01
2.750	1.86E+00	4.67E-01
3.500	1.65E+00	4.13E-01
5.000	6.94E-01	1.74E-01
7.000	7.84E-02	1.97E-02
9.500	8.91E-03	2.24E-03
	4.82E+07	1.20E+07

Table 9-8. Comparison of Neutron Intensities

(per gram of oxide)

	MELOX (neutrons/sec)		MFFF (neutrons/sec)	
	30% PuO_2	8.5% PuO_2	20% PuO_2	5% PuO_2
Spontaneous fission	100.14	28.39	11.8	2.96
Reaction emission (α,n)	149.34	42.32	12.0	3.00
Total	249.48	70.71	23.8	5.96

Figures

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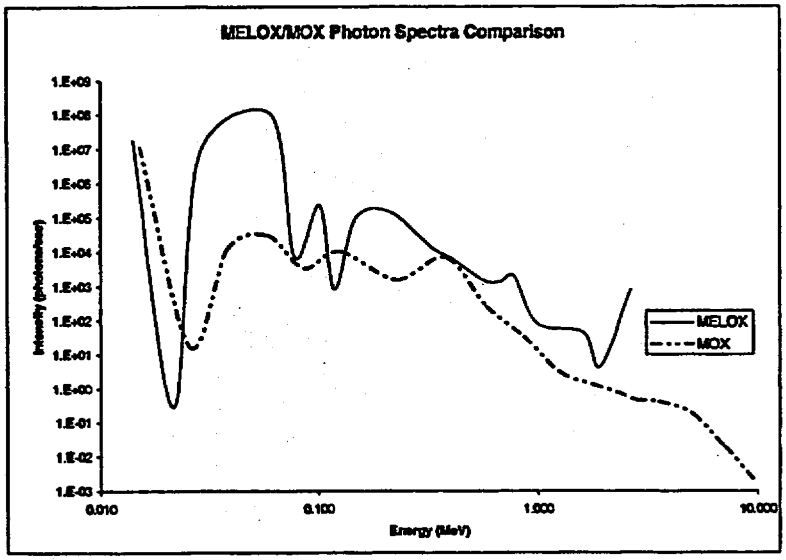

Figure 9-10. MELOX/MFFF Photon Spectra Comparison

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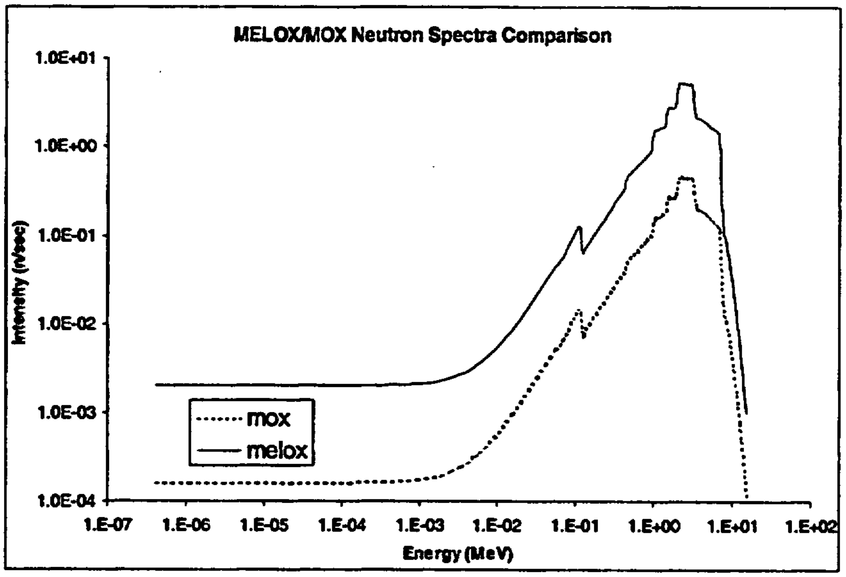

Figure 9-11. MELOX/MFFF Neutron Spectra Comparison

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10. ENVIRONMENTAL PROTECTION

The components of the Mixed Oxide (MOX) Fuel Fabrication Facility (MFFF) Environmental Protection Program include the following:

- The Radiation Safety Program, which is established to control and assess the level of radioactive releases to the environment during normal and anticipated off-normal operations, minimize facility contamination, and minimize waste generation
- The Effluent Monitoring Program, which is established to measure and monitor the radioactive effluents released from the facility
- The Environmental Monitoring Program, which is established to monitor potential environmental impacts from operations.

10.1 RADIATION SAFETY PROGRAM

The Radiation Safety Program is described in Chapter 9. That portion of the Radiation Safety Program related to protection of the environment is given herein.

10.1.1 ALARA Goals for Effluent Control

Effluent control begins with the facility design by limiting the material capable of becoming a radioactive effluent. The MFFF processes generate minimal airborne radioactive effluents, and no radioactive liquid effluents are released directly to the environment.

The as-low-as-reasonably-achievable (ALARA) goal for airborne radioactive effluents released from the MFFF is 20% of the effluent concentrations from 10 CFR Part 20, Appendix B, Table 2, Column 1. Additionally, the goal for total effective dose equivalent to the individual member of the public likely to receive the highest dose from the facility, based on estimates for normal operations, is less than 10 mrem/yr. Normal operating release values are calculated at the restricted area boundary (RAB). The dispersion model calculates the X/Q for the 50 % annual average for a receptor at the closest point to the stack (170.6 ft [52 m]). The X/Q value is 2.5E-4 sec/m^3. The maximum dose contribution is from Pu-239 and the concentration is 7.25E-16 Ci/ml, which is less than the ALARA goal and the constraint on air emissions of 10 CFR §20.1101(d). Procedures will be established to report exceedances of the constraint level in accordance with 10 CFR §20.2203 and to take prompt corrective action to prevent recurrence.

An ALARA goal for radioactive liquid effluents is not provided since the facility design precludes the release of radioactive liquid effluents to the environment.

10.1.2 Effluent Controls to Maintain Public Doses ALARA

As previously indicated, the MFFF does not discharge any radioactive liquid directly to the environment. The only nonradioactive liquid effluent is from storm drains. The sanitary drains are not in radiation areas.

Radioactive airborne effluents from the MOX processing (MP) and aqueous polishing (AP) process areas are filtered and released through the stack located on the roof of the MOX Fuel

Fabrication Building. Design features that support reduced airborne effluent releases to maintain public doses ALARA include the placement and use of filter banks containing a minimum of two stages of high-efficiency particulate air (HEPA) filters. These filters minimize environmental releases by removing particulates present in ventilation exhaust. Spaces with the greatest potential for generating airborne contaminants in the effluent (i.e., gloveboxes) are exhausted through these filters prior to discharge to the environment. Design features of the AP ventilation system also take into account potentially corrosive materials.

Specific decontamination factors have not been established for all filters but are expected to be more than adequate to reduce the total radioactivity to acceptable levels. The experience at the MELOX and La Hague facilities is that the concentrations of airborne effluents are less than the minimum detectability of continuous air monitors (CAMs) and samples evaluated in the laboratory.

The combined MP and AP airborne effluents are monitored with two monitoring systems, including two CAMs and two fixed air samplers, with each unit provided air representative of that present in the stack. A representative sample of the particulate effluent from the stack is collected continuously for determination of quantities and average concentrations of radionuclides released. The sampling is conducted regardless of the concentration of radioactive material in the effluent, which is expected to be negligible under normal operating conditions.

Trending of results from effluent monitors, samplers, and other MFFF airborne monitoring equipment provides early indications of elevated radiation environments. Procedures will be developed to identify evaluations and actions to be taken when the concentrations of airborne radioactivity exceed prescribed limits.

To investigate elevated stack releases and/or anomalies, sample connections are installed at key locations in the MP and AP process area ventilation ducts. The placement and use of sample connections are based on the risk to facility workers, site personnel, and members of the public. The potential for leakage from process systems, equipment, and confinements is also considered. The evaluation focuses on the equipment and spaces with the higher potential for leakage or airborne contaminants (e.g., AP process cells, and AP and MP gloveboxes) as determined by experience at the MELOX and La Hague facilities. During MFFF operations, elevated readings from CAMs and/or fixed air samplers will be used to identify the need to perform maintenance or to take other action to reduce effluent releases. Following a loss of offsite power, the CAMs and fixed air samplers obtain power from the uninterruptible power supply (UPS) and emergency diesel power sources.

10.1.3 ALARA Reviews

ALARA reviews and reports to management include the development of trending charts so that analytical results and effluent monitor readings can be trended against the goals. Abnormal increases in the trending of either the monitor readings or the analytical results are reported to MFFF management as soon as practical. To ensure that releases are maintained ALARA, management is informed of the trends measured against the goals on a quarterly basis. Annually, the goals are reevaluated and new goals are established for the upcoming year.

10.1.4 Waste Minimization and Waste Management

The Waste Minimization Program begins with the process design and continues into operations. During the process design, recycling and reuse are implemented for waste minimization purposes. For operations, waste minimization procedures will provide for separation and segregation of solid and liquid wastes and the removal of packing and shipping materials prior to entry into contaminated areas. Worker training will also be developed.

Many of the design features addressed in the MP and AP process descriptions (Sections 11.2 and 11.3, respectively) perform contamination control and associated waste minimization functions. In addition to the confinement system, the process design reduces the distribution and retention of radioactive materials throughout plant systems by using vacuum systems in the gloveboxes. Airborne dust is collected in dust pots in dedusting systems installed in selected gloveboxes, and the material is recycled. These design features control contamination to ensure that secondary waste production is minimized during plant operation and to ensure that only a minimal amount of contamination is generated. The design incorporates extensive recycling for the materials exiting the main process (e.g., secondary waste streams of the AP process and scraps not meeting specifications in the MP process). The recycling process is designed to minimize the quantity of plutonium in the final waste by using systems that return the radioactive materials to previous steps of the main process.

The following features of the AP process are specifically designed to minimize waste by maximizing recycling or recovery:

- **Acid recovery** – Nitric acid is recovered from the bottom of the rectification column and reused as reagent feedstock in the aqueous polishing units. The distillates from the rectification column are also collected and redistributed to the aqueous polishing process.
- **Solvent regeneration** – Following purification of the plutonium solution in pulsed columns by solvent extraction, the extracted raffinate stream is washed with diluent and routed to the Acid Recovery Unit. The regenerated solvent is adjusted with the addition of pure tributyl phosphate and reused in the Purification Cycle.

The design includes systems that provide separation and segregation of streams to minimize the amounts and types of contaminated materials. There are separate collection tanks for laboratory rinse waters and sanitary washings. There are also features to concentrate streams through evaporation. The acid recovery evaporator produces distillates that are relatively free of radioactivity and can be reintroduced into the process, while its concentrates contain wastes that are prepared for disposal.

MFFF waste management is guided by the principles of ALARA, waste minimization, and pollution prevention. Liquid and solid wastes produced in the MFFF will be transferred to the Savannah River Site (SRS) for processing and disposal. DCS has worked closely with SRS during the MFFF 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 MFFF low-level waste streams meet the SRS WAC except for the chloride stream. Based on evaluation of the characterization information by SRS, 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 prepared, but the interface between DCS and SRS will ensure that the WSB is designed to manage the MFFF high alpha waste stream and the depleted uranium stream.

The expected and maximum waste volumes and concentrations of the main chemicals and radioisotopes have been computed for the liquid waste streams. The tanks, pumps and transfer lines have been designed on this basis as well as the planned waste transfer frequencies.

The various streams from the MP process are extensively treated to recover feedstock and plutonium to the maximum extent practical, resulting in a very small amount of generated waste that is transferred to SRS. The various waste streams and their disposition are discussed in the following sections.

10.1.4.1 Liquid Waste Management

The quantity of radioactive liquid waste is small because the AP process uses recycling to the extent feasible; all liquid wastes are transferred to SRS. Figure 10-1 depicts the streams from the AP process.

10.1.4.1.1 High-Alpha-Activity and Stripped Uranium Streams

Two liquid streams from the AP process are classified as high-alpha-activity streams: the americium stream and the alkaline wash stream. The excess acid stream, from acid recovery, is also managed as a high-alpha-activity stream because of the stream properties. These three streams are combined and the merged stream is managed as the high-alpha-activity stream. The stripped uranium stream contains less than 1% uranium 235 following isotopic dilution. The stream is managed at the SRS WSB.

The high-alpha-activity and stripped uranium streams are separately pumped to the SRS WSB in dedicated double-walled stainless steel pipes provided with leak detection. The leak detection system provides early warning of any leaks in lines used for transfer of radioactive liquid streams from the MFFF to the WSB so that remedial action may be initiated. The high alpha and stripped uranium liquid transfer lines are designed to withstand the effects of the design basis earthquake and other applicable events as described in Chapter 5.

The waste transfer lines are buried underground and are unlikely to be impacted by load handling activities. The waste transfer lines will be designed to accommodate external loads, including dead loads (soil pressure) and live loads (wheel loads).

Liquid Americium Stream

The raffinate from the Polishing Process contains americium, gallium and traces of plutonium extracted from the plutonium oxide feed and silver from the dissolution unit. This stream is termed the liquid americium stream and is a high-alpha-activity stream. The americium stream, along with the alkaline and excess acid streams, are transferred to the batch constitution tank where they are mixed, analyzed for pH, and then transferred to a high alpha storage tank. The

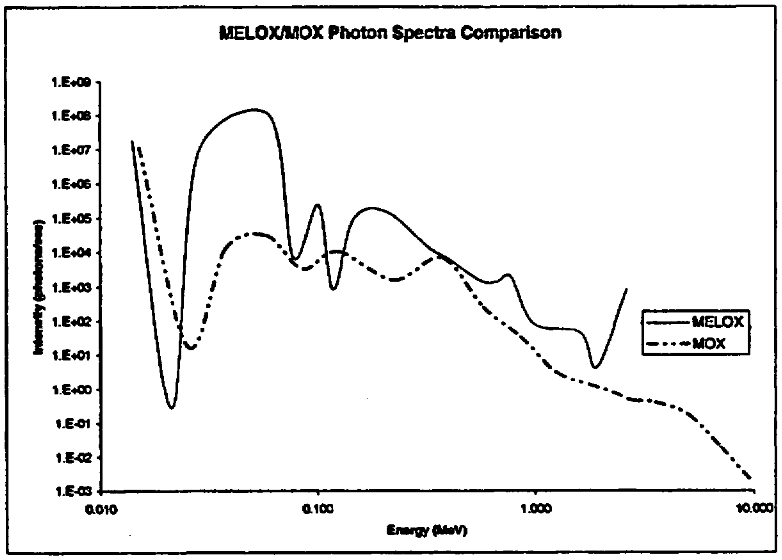

Figure 9-10. MELOX/MFFF Photon Spectra Comparison

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high alpha storage tank along with the high alpha buffer storage tank are a holding point for the high alpha streams and provide 90 days of storage. The contents of the high alpha buffer storage tank are sampled and analyzed to ensure compliance with the SRS WAC before being pumped to the WSB through dedicated double-walled stainless steel pipes provided with leak detection.

Excess Acid Stream

The acid recovery process produces a condensate stream and excess acid. The acid recovery condensate stream is transferred for AP recycled water solution feeding. The excess recycled water is collected in a buffer storage tank, analyzed for activity and transferred to the liquid waste reception unit. The recovered excess acid is expected to be a liquid high-alpha-activity stream and is managed with the high-alpha- activity stream. The excess recovered acid is transferred to a buffer tank and then to the batch constitution tank, where it is mixed with the other high alpha liquid streams and managed as described previously.

Alkaline Wash Stream

The alkaline treatment process generates an alkaline wash stream. After these washings, the alkaline wash stream is transferred to the alkaline waste tank. The alkaline wash stream is then transferred to the batch constitution tank where it is mixed with other high alpha liquid streams and managed as described previously.

Waste Solvent Stream

The alkaline treatment process generates a small quantity of slightly contaminated excess solvent. The slightly contaminated excess solvent is a low-level waste (LLW). Waste solvent is pumped from the solvent recovery tank to an intermediate holding tank where it is sampled to assure compliance with the SRS WAC. The intermediate tank is fitted with mixing and sampling capabilities. The batch is transferred through a dedicated pipe to a 300-gallon carboy or other suitable container located in an enclosure outside the Reagents Process Building.

The carboy transfer operations from MFFF to SRS will be controlled under the radiation protection program as described in Chapter 9. The waste container will be transferred to an SRS vehicle for transport from MFFF. HP technicians will accompany the movement of the vehicle from the loading area, to the Restricted Area boundary (RAB). SRS will take possession of the waste prior to reaching the RAB and is responsible for the safe movement and disposition of the waste.

Stripped Uranium Stream

After the uranium-stripping process, the highly enriched uranium undergoes isotopic dilution and is collected in the stripped uranium reception tank. The uranium stream also contains a small amount of plutonium. The uranium stream is sampled and analyzed to ensure that it complies with the WAC. The stripped uranium stream is transferred to the stripped uranium buffer tank for neutralization and acidification before transfer to the stripped uranium transfer tank. The stripped uranium transfer tank is the final holding and sample point for the stripped uranium stream. After verification that the stream complies with the SRS WAC, the stream is transferred to the SRS WSB through dedicated double walled construction piping provided with leak detection.

10.1.4.1.2 Chloride Stream

A dechlorination step is necessary for product quality before dissolution for chlorinated feeds (e.g., AFS). The extracted chlorine is filtered and washed in a scrubbing column. The chlorinated liquid stream is transferred from the dechlorination/dissolution unit to a reception tank in the Waste Reception area. The chloride stream is diluted using chloride free streams destined for the Effluent Treatment Facility (ETF). This dilution step will reduce the chloride concentration to a value acceptable to the ETF without increasing the total volume of waste being generated. The combined stream will be sampled and analyzed to verify compatibility with SRS site requirements and will be then pumped to the SRS ETF.

10.1.4.1.3 Potentially Contaminated Water

Potentially contaminated wastewater is collected in the MFFF. This wastewater consists of laboratory rinse water, mop water from washing, MFFF building floor drains, and condensate from room air conditioners. These waters are collected, sampled, and analyzed. After analysis, the water is transferred to the SRS ETF.

Potentially contaminated liquid containment features include the following engineered systems:

- Tanks containing contaminated liquids are located in containment basins.
- Stainless steel-lined floors and portions of walls creating containment basins are used in tank rooms of the AP building.
- Double-wall pipe and leak detection are used on transfer lines to SRS.

10.1.4.1.4 Nonhazardous Liquid Waste

Nonhazardous liquid waste includes rinse water and the sanitary waste from sinks, showers, urinals, and water closets. Nonhazardous wastewater, exclusive of the potentially radioactive LLW rinse water, will be discharged to the SRS sanitary sewer system.

10.1.4.2 Solid Waste Management

Solid waste is classified as solid transuranic (TRU) waste, solid mixed TRU waste, solid LLW, solid mixed LLW, hazardous solid waste, and nonhazardous solid waste. Wastes are processed through the waste storage unit prior to transfer to SRS. Solid wastes (with the exception of nonhazardous solid wastes) are transferred to SRS. These solid waste types are discussed in the following sections.

10.1.4.2.1 Solid Transuranic Waste

Solid TRU waste generation is related to the normal process operations, maintenance operations, and replacement of equipment.

Several types of waste originate from glovebox operations. These include cleaning materials, such as cotton, wool, and cellulose fabrics used for cleaning inside the gloveboxes; maintenance wastes, including parts and equipment removed from service; and removed gloves.

Convenience cans are a waste stream originating in the decanning glovebox. Molybdenum boats are a source of waste from the sintering of pellets. Zirconium clads and laboratory wastes (glass) are mainly generated by control operations on samples at each production batch. Balls from the ball mills and welding samples are other metallic wastes.

HEPA filters used in the gloveboxes are another source of waste. Decloggable filters will be used in the grinding gloveboxes, thus reducing the number of HEPA filters disposed and providing an opportunity to recover plutonium.

Plastic wastes include latex, neoprene, and polyurethane gloves, as well as polyvinyl chloride, polyethylene, or polyurethane. Other wastes include grinding wheels and ceramic wastes from maintenance and repair of the sintering furnaces, staff clothing, and other maintenance-related wastes.

Solid TRU waste streams are separated at the source of generation and packaged in standard waste containers. Waste drums are marked at the point of generation, uniquely labeled, and tracked through storage and shipping.

10.1.4.2.2 Solid Mixed Transuranic Waste

Mixed TRU waste contains both a hazardous component and a TRU radioactive component. Solid mixed TRU waste produced at the MFFF may include lead-lined gloves, if they are used in the gloveboxes. The gloves, if they are used, are considered mixed TRU waste because they meet the criterion for TRU waste and the criterion for the toxicity characteristic for lead. Mixed TRU waste is handled as discussed above for solid TRU waste.

10.1.4.2.3 Solid Low-Level Waste

LLW will be generated as a result of normal MFFF process operations and maintenance activities and includes alpha-emitting TRU radionuclides with half-lives greater than 20 years but in concentrations less than 100 nCi/g of the waste matrix without regard to source or form. LLW is expected from normal process operations and from routine and nonroutine maintenance activities. Solid LLW will include the following material: cleaning materials (e.g., cotton, wool, and cellulose fabrics used for cleaning gloveboxes), parts and equipment, plastic wastes, inner cans, room filters, uranium area waste, wipes, packaging foils, protective clothing, and maintenance-related wastes.

All waste that is potentially contaminated with plutonium is treated in the same fashion, with steel drums used as the standard waste containers. However, the waste category is not determined until the waste containers are counted and categorized by waste type. They are then separated and stored as TRU waste, mixed TRU waste, LLW, and mixed LLW.

10.1.4.2.4 Solid Mixed Low-Level Waste

Mixed LLW is LLW determined to contain both a hazardous component subject to the Resource Conservation and Recovery Act (RCRA) and source, special nuclear, or byproduct material. Mixed LLW includes hazardous materials contaminated with plutonium and scintillation vials from the analytical laboratory.

Mixed LLW is packaged and transferred to SRS in a manner consistent with the SRS requirements. To the extent practical, commingling of waste from streams requiring different treatment technologies will be prevented.

Containers of hazardous waste known or suspected to be contaminated with radioactive material are uniquely labeled and tracked through storage and shipping. The mixed LLW is then transferred to SRS.

10.1.4.2.5 Hazardous Solid Waste

Hazardous solid waste is waste that is, or contains, a listed hazardous waste or that exhibits one of the four U.S. Environmental Protection Agency (EPA) hazardous waste characteristics (i.e., ignitability, corrosivity, reactivity, and toxicity). Hazardous waste includes some wastes from the analytical laboratory that are not contaminated with radioactive material. MFFF hazardous waste is transferred to SRS.

10.1.4.2.6 Nonhazardous Solid Waste

Nonhazardous waste is waste that is not or does not contain listed hazardous waste, that does not exhibit one of the four EPA hazardous waste characteristics, and that does not contain radioactive material. Nonhazardous solid waste includes office trash and other industrial wastes from utility and maintenance operations. Nonhazardous solid waste is packaged in conformance with standard industrial practice. Recyclable solid wastes (e.g., office paper, metal cans, and plastic and glass bottles) are sent offsite for recycling. The remaining solid sanitary waste is sent to a solid waste landfill.

10.1.4.3 Laboratory Waste

The laboratory is treated separately because it is a discrete source of waste and may produce various types of radioactive and hazardous wastes. The laboratory receives samples from the MP process as powder and pellets and as vials of liquid intermediates from the AP process. Laboratory waste solutions containing plutonium are collected and recycled back to the AP process according to solution composition.

Chemical reagents contaminated with radioactivity may be solidified in the laboratory and disposed of as solid mixed LLW. Hazardous chemical waste is collected and packaged for transfer to SRS.

10.2 EFFLUENT MONITORING PROGRAM

10.2.1 Airborne Effluent Monitoring and Sampling

Airborne emissions from the MFFF are controlled by the building and glovebox ventilation systems, the process ventilation offgas system, and MFFF stack HEPA filters.

10.2.1.1 HEPA Filter Testing

HEPA final filter banks contain provisions for dioctyl phthalate (DOP) testing. Following maintenance on the final filter banks, such HEPA filters are DOP-tested prior to being placed in service.

10.2.1.2 Radionuclides in Airborne Effluents

Estimated annual airborne effluent releases from the MFFF stack are based on experience at the MELOX and La Hague facilities. Extensive experience at these facilities has shown that the concentrations of airborne effluents are less than the minimum detectability of CAMs and samples evaluated in the laboratory. Due to the content of incoming feedstock and MFFF processes, radioactive airborne releases contain isotopes of plutonium, uranium, americium, and other minor dose contributors. The maximum concentrations of radioactive airborne effluents, averaged over a calendar year, are expected to be much less than 20% of the values in 10 CFR Part 20, Appendix B, Table 2. These airborne effluent values are approximately 9 wt % uranium and 4 wt % plutonium. Almost all of the uranium generated by MP process area activities is expected to be ^{238}U.

10.2.1.3 Physical and Chemical Characteristics of Radionuclides

Duke Cogema Stone & Webster (DCS) will demonstrate compliance with the annual dose limit in 10 CFR §20.1301 as provided for in 10 CFR §20.1302(b). Therefore, DCS does not need to take into account the actual physical and chemical characteristics of the effluents (e.g., aerosol size distribution, solubility, density, radioactive decay equilibrium, and chemical form).

10.2.1.4 Discharge Locations and Monitoring

The MFFF stack represents the only facility location that has the potential for discharging airborne radionuclides. The various process exhausts are mixed and filtered through at least two HEPA filter stages before being released through the MFFF stack.

Two redundant CAMs and two fixed airborne particulate samplers monitor the MFFF stack. Gaseous grab samples are collected periodically during operation. Output from the CAMs alerts personnel in the Polishing Utilities Control Room (located in the Shipping and Receiving Building) and the Respirator Maintenance/Health Physics Office (located in the Technical Support Building), by way of audible and visual alarms, if the airborne radioactive effluent exceeds a prescribed limit.

Continuous sampling of the main stack effluent addresses the combined source of radioactive airborne contaminants from the MP and AP processes during normal and anticipated off-normal operations. To quantify the contribution from each source, two additional CAMs are included to sample the discharged air from the MP and AP process areas. Effluents from areas not used for processing special nuclear material (e.g., laboratories, storage areas, and fuel element assembly areas) are also sampled continuously.

Upstream or local area CAMs are also installed to identify elevated releases resulting from off-normal operations. Data collected from these monitors will support control room operators in locating the source of increases in airborne radioactivity. CAMs are installed to obtain the lowest minimum detectable concentration for monitoring airborne effluents.

Information concerning the following elements associated with airborne effluents will be submitted with the license application for possession and use of special nuclear material:

- A description of the sampling, collection, and analysis procedures, including the minimum detectable concentration of radionuclides, equipment, calibration information, and laboratory quality control procedures
- A description of the proposed action levels and actions to be taken when action levels are exceeded
- The identification of the pathway analysis methods to estimate public doses, including a demonstration of compliance with 10 CFR §20.1301, through a calculation of the total effective dose equivalent to the maximally exposed offsite individual
- A description of the recording and reporting procedures, including event notification for airborne releases.

10.2.2 Liquid Effluent Monitoring

Since there are no radioactive liquid effluents, liquid effluent monitoring is not necessary.

10.3 ENVIRONMENTAL MONITORING PROGRAM

The Environmental Monitoring Program assesses the environmental impact of licensed activities and will include preoperational and operational environmental monitoring.

The objectives of the Preoperational Environmental Monitoring Program are as follows:

- Establish a baseline of existing radiological and biological conditions in the area of the MFFF site
- Determine the presence of any contaminants that could be a safety concern for personnel
- Evaluate procedures, equipment, and techniques used in the collection and analysis of environmental data, and train personnel in their use.

The objective of the Operational Environmental Monitoring Program is to determine whether or not there are adverse impacts from operations that result in radiological and biological effects to the MFFF site and environs.

Radiological impacts to the environment from operation of the MFFF are expected to be minimal. Since the MFFF does not discharge any radioactive liquid directly to the environment, the Environmental Monitoring Program will focus on the environmental media impacted by the airborne pathway for the anticipated types and quantities of radionuclides released from the facility.

The Operational Environmental Monitoring Program is being developed with SRS and will be integrated with existing and future environmental monitoring programs, as appropriate. Preconstruction environmental monitoring measurements for the entire Plutonium Disposition Program at SRS have been recently completed and are contained in "Plutonium Disposition Program (PDP) Preconstruction Environmental Monitoring Report", dated June 26, 2002.

Details of the Environmental Monitoring Program will be submitted with the license application for possession and use of special nuclear material. At a minimum, the preoperational assessment will contain the following elements:

- A characterization of the existing environmental conditions that could be affected by the operations of the facility
- The establishment of background levels of radioactivity
- The characterization of pertinent environmental parameters
- The identification of potential pathways for human exposure and environmental impact.

The MFFF preoperational assessment will establish or confirm the applicability of an MFFF Operational Environmental Monitoring Program that determines radioactivity levels of environmental media (e.g., air, surface water, groundwater, soil, sediments, and vegetation), as appropriate, with analyses for uranium, plutonium, and other radionuclides of interest.

10.4 ENVIRONMENTAL PERMITS, LICENSES, AND APPROVALS

Tables 10-1 and 10-2 list the environmental permits and plans that are required prior to construction and prior to operation of the MFFF, respectively. The permits and plans that are required prior to MFFF construction activities are under preparation, and several discussions associated with permitting strategies with the South Carolina Department of Health and Environmental Control (SCDHEC) have taken place.

Several Site Utilization Permits are being prepared for the SRS Environmental Protection and Site Utilities Departments since approval of these permits is driven by procedures internal to SRS and is outside of the purview of SCDHEC.

10.5 DESIGN BASES

This section discusses the design bases requirements applicable to the design of the stack effluent monitoring system and the programs and systems in place to manage radioactive, mixed, hazardous, and non-hazardous wastes. The MFFF will be designed to provide appropriate waste management systems and to monitor releases.

The safety assessment of the design bases and concepts for principal structures, systems, and components (SSCs) are described in Chapter 5. The stack effluent monitoring system (including the CAMs and air samplers) and waste management systems, with the exception of the high alpha liquid transfer line, are not principal SSCs because they are not relied upon to prevent or mitigate design basis accidents.

10.5.1 Design Basis for Non-PSSCs

10.5.1.1 Effluent Monitoring

Redundant CAMs and air samplers, two each, are designed to provide indications and early warnings of radioactive effluents released to the environment. The airborne effluent CAMs (in conjunction with the air samplers, laboratory testing, and calculations) are capable of ensuring that the annual average concentrations of radioactive gaseous effluents do not exceed the concentrations presented in 10 CFR Part 20, Appendix B, Table 2, Column 1.

The effluent CAMs and air samplers (i.e., stack monitors) will be connected to a reliable source of normal power. In the event normal offsite power is lost, the CAMs and air samplers are powered from UPS units and emergency power.

Although they are not principal SSCs credited with prevention or mitigation of design basis events, the redundant CAMs and air samplers and their respective electrical and mechanical features will be separated to prevent common mode failures.

The stack effluent monitors and air samplers will provide information to comply with 10 CFR §70.59 (effluent monitoring reporting requirements). The stack effluent monitors and air samplers are designed in accordance with 10 CFR Part 20 and using the following documents as guidance:

- Regulatory Guide 3.12, *General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants*, August 1973
- Regulatory Guide 4.1, *Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants*
- Regulatory Guide 4.15, *Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment*
- Regulatory Guide 4.16, *Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants*, December 1985
- Regulatory Guide 4.20, *Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other than Power Reactors*
- Regulatory Guide 8.37, *ALARA Levels for Effluents from Materials Facilities*
- ANSI-N13.1-1999, *Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities*
- ANSI-N42.18-1980, *On-Site Instrumentation for Continuously Monitoring Radioactivity in Effluents*
- ANSI-N317-1980, *Performance Criteria for Instrumentation Used for In-Plant Plutonium Monitoring Instrumentation.*

The minimum detectability of stack effluent radioactivity concentration is expected to be less than 5% of the concentration limits listed in 10 CFR Part 20, Appendix B, Table 2, Column 1.

The MFFF does not discharge radioactive liquid directly to the environment. The nonradioactive liquid effluent is limited to storm drains.

10.5.1.2 Waste Management

Uranium-235 in the stripped uranium transfer tank is established by upstream units at not greater than 1% of the total uranium which ensures that the waste is inherently safe with respect to criticality. (See section 6.3.4 for a description of the uranium content and controls).

10 CFR Part 20 sets requirements for the identification of radionuclides and the quantification of the nuclides in all solid waste containers. The MFFF will be designed to quantify the activity in solid waste containers and to ensure that the waste shipments meet the receiving facility's waste acceptance criteria. In addition to 10 CFR Part 20, the following documents provide guidance for the design of waste and operational systems for fuel fabrication facilities:

- Regulatory Guide 3.7, *Monitoring of Combustible Gases and Vapors in Plutonium Processing and Fuel Fabrication Plants*
- Regulatory Guide 3.10, *Liquid Waste Treatment System Design Guide for Plutonium Processing and Fuel Fabrication Plants*
- Regulatory Guide 3.12, *General Design Guide for Ventilation Systems of Plutonium Processing and Fuel Fabrication Plants*, August 1973
- Regulatory Guide 4.16, *Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants*, December 1985
- Regulatory Guide 4.20, *Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees Other than Power Reactors*
- NRC Information Notice 94-23, *Guidance to Hazardous, Radioactive and Mixed Waste Generators on the Elements of a Waste Minimization Program*
- ANSI/ANS 16.1-1986, *Measurement of the Leachability of Solidified Low-Level Radioactive Wastes by a Short-Term Test Procedure*
- ANSI/ANS 40.35-1991, *Volume Reduction of Low Level Radioactive Waste*
- ANSI/ANS 40.37-1993, *Mobile Radioactive Waste Processing Systems*
- ANSI N13.10-1974, *Specification and Performance of Onsite Instrumentation for Continuously Monitoring Radioactivity in Effluent*
- ANSI N15.10-1987, *Unirradiated Plutonium Scrap - Classification*
- ANSI N15.22-1987, *Nuclear Materials - Plutonium-Bearing Solids - Calibration Techniques for Calorimetric Assay*

- ANSI N317-1980 (1991), *Performance Requirements for Instrumentation Used for Inplant Plutonium Monitoring*
- ASME B31.3, *Process Piping*
- ISO 11932:1996, *Activity Measurements of Solid Materials Considered for Recycling, Re-use or Disposal as Non-radioactive Waste*
- DOE/WIPP-069, *Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, Rev. 7, November 1999.

10 CFR §20.1406 requires waste minimization. Guidance for achieving waste minimization goals is provided in NRC Information Notice 94-23.

The primary function of the Waste Minimization Program is to reduce the quantity of waste generated and the associated hazard of the waste. The program is intended to reduce worker and public exposure to radiation and radioactive and hazardous materials. The program also reduces the requirements for waste management facilities, including storage, handling, and disposal and the associated analysis. Waste minimization is (1) a preemptive activity that utilizes the design to reduce the potential for creation of waste, and (2) an operations philosophy that minimizes the introduction of excess materials that can become contaminated. Fundamental design features (e.g., confinement systems) minimize contamination. The MFFF design also incorporates surface coatings (e.g., paint and stainless steel drip pans) to reduce the potential for contaminating surfaces. Liquid waste tanks are designed to accommodate the maximum expected volume of liquids to reduce the potential for overflow and further contamination. These design features minimize the production of wastes and their impact on the environment.

10.5.2 Design Basis for PSSCs

The high-alpha activity and stripped uranium streams are pumped to the SRS WSB. The waste transfer lines are PSSCs. They are double walled stainless steel pipes seismically designed with leak detection. They are buried underground and unlikely to be impacted by load handling activities. The waste transfer lines will not be routed through yard storage areas where load handling activities are likely to occur. Load handling activities are not expected to occur outside of designated storage areas. The waste transfer lines will be designed to accommodate external loads including dead loads (soil pressure) and live loads (wheel loads). The transfer lines are designed to withstand the effects of the design basis earthquake and other applicable events as described in Chapter 5.

- ASME B31.3, *Process Piping*

Tables

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Table 10-1. Environmental Permits and Plans Needed Prior to Construction

AIR QUALITY PROTECTION

- Bureau of Air Quality (BAQ) Construction Permit (MFFF stack, diesel fuel tanks, diesel generators, concrete batch plant)
- Construction Emissions Control Plan (CECP)

SURFACE WATER PROTECTION

- Construction National Pollutant Discharge Elimination System (NPDES) General Permit
- No Discharge NPDES Permit (Concrete Batch Plant)
- SCDHEC Sanitary Wastewater Construction Permit
- Notice of Intent (NOI) for stormwater pollution prevention
- Stormwater Pollution Prevention Plan (SWPPP)
- Grading Permits

GROUNDWATER PROTECTION

- Domestic Water Distribution Construction Permit *
- Backflow Preventer Test Form
- Underground Storage Tank (UST) Construction Permit

SITE UTILIZATION*

- Site Utilization Permit
- Site Clearance Permit
- Underground Piping Permit
- Work Clearance Permit
- Power Services Utilization Permit (PSUP): Parts A and B

* Permits that will be acquired from the appropriate SRS department and that do not involve federal, state, or local agencies.

Table 10-2. Environmental Permits and Plans Needed Prior to Operation

AIR QUALITY PROTECTION

- Title V Operating Permit

SURFACE WATER PROTECTION

- SCDHEC Sanitary Wastewater Operations Permit
- Industrial NPDES General Permit
- Spill Prevention Control and Countermeasures Plan

GROUNDWATER PROTECTION

- Domestic Water Distribution Operation Permit*
- UST Operating Permit
- RCRA Generator Notification Number

SITE UTILIZATION

- Power Services Utilization Permit (PSUP): Part C*

* Permits that will be acquired from the appropriate SRS department and that do not involve federal, state, or local agencies.

Figures

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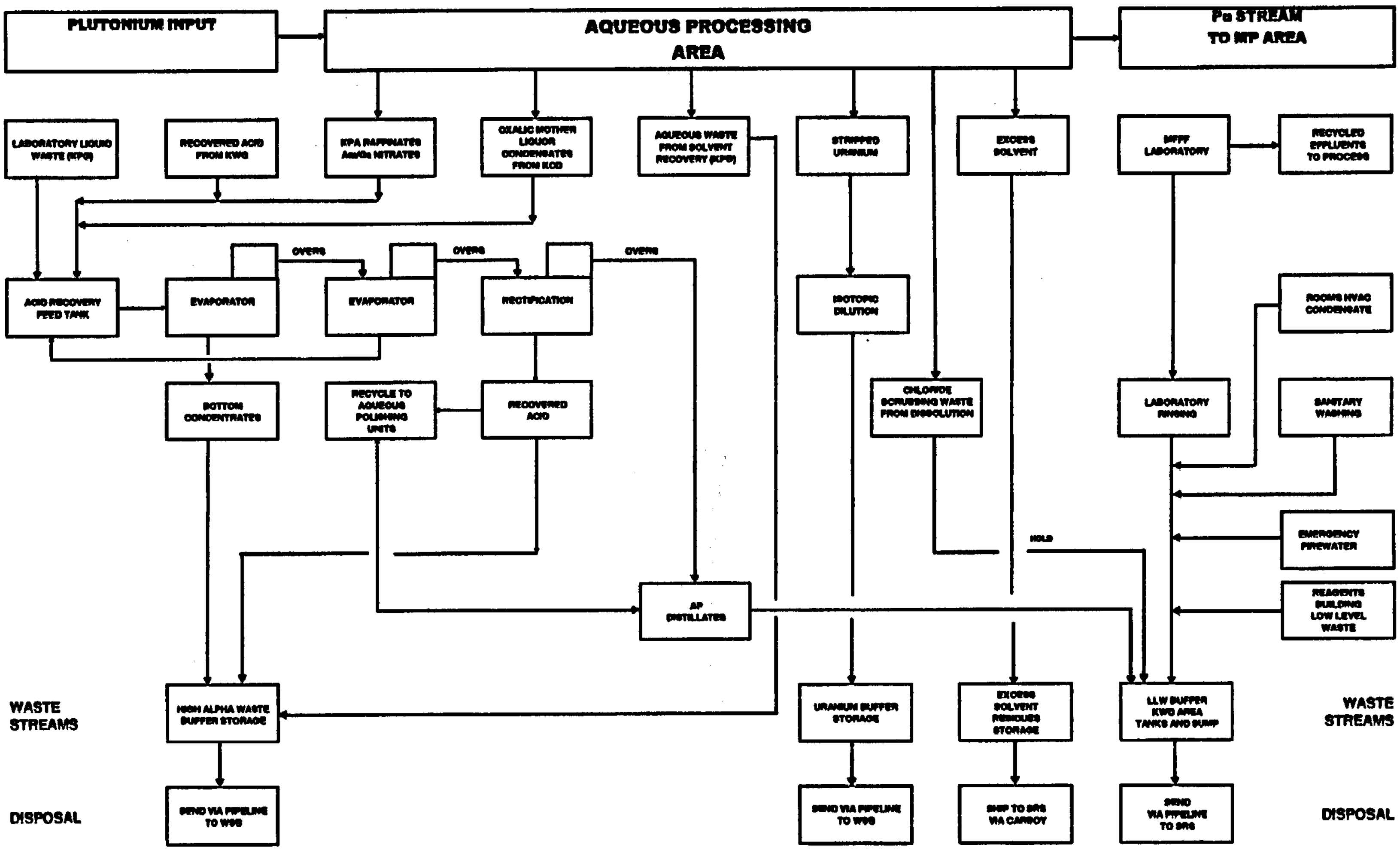

Figure 10-1. Aqueous Polishing Waste Streams

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