8.0 CHEMICAL AND PROCESS SAFETY

8.1 CONDUCT OF REVIEW

This chapter of the revised Draft Safety Evaluation Report (revised DSER) contains the staff's review of chemical and process safety described by the applicant in Chapter 8 of the revised Construction Authorization Request (revised CAR) (Reference 8.3.19), with supporting process safety information from Chapters 5 and 11 of the revised CAR. The objective of this review is to determine whether the chemical process safety principal structures, systems, and components (PSSCs) and their design bases identified by the applicant provide reasonable assurance of protection against the consequences of potential accidents. The staff evaluated the information provided by the applicant for chemical process safety by reviewing the revised CAR, supplementary information provided by the applicant, and relevant documents available at the applicant's offices but not submitted by the applicant. The staff also reviewed technical literature as necessary to understand the process and safety requirements. The review of aqueous polishing (AP) and mixed oxide process (MP) safety design bases and strategies was closely coordinated with the review of the radiation and chemical safety aspects of accident sequences described in the Safety Assessment of the Design Bases (see Chapter 5.0 of this revised DSER), the review of fire safety aspects (see Chapter 7.0 of this revised DSER), and the review of plant systems (see Chapter 11.0 of this revised DSER).

The staff reviewed the chemical process and safety information in the revised CAR and supporting documents against the following regulations:

- Section 70.23(b) of 10 CFR states, as a prerequisite to construction authorization, that the design bases of the PSSCs and the quality assurance program be found to provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

- Section 70.64 of 10 CFR requires that baseline design criteria (BDC) and defense-in-depth practices be incorporated into the design of new facilities. With respect to chemical protection, 10 CFR 70.64(a)(5) requires that the Mixed Oxide Fuel Fabrication Facility (MFFF or the facility) design provide for adequate protection against chemical risks produced from licensed material, facility conditions which affect the safety of licensed material, and hazardous chemicals produced from licensed material. Related to chemical protection, 10 CFR 70.64(a)(3) requires that the facility design provide for adequate protection against fires and explosions, such as those that could be initiated by or involve chemicals at the proposed facility.

The review for this construction authorization focused on the design bases of chemical process safety systems, and components. For each chemical process safety system, the staff reviewed information provided by the applicant for the safety function, system description, and safety analysis. The review also encompassed proposed design basis considerations such as redundancy, independence, reliability, and quality. The staff used NUREG-1718, Chapter 8.0 of the "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility" (Reference 8.3.28) as guidance in performing the review. As stated on page 8.0-2 of NUREG-1718, "information contained in the application should be of sufficient quality and detail to allow for an independent review, assessment, and verification by the NRC reviewers."

8.1.1 Background

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

The NRC staff reviewed the revised CAR submitted by the applicant (Reference 8.3.19) for the following areas applicable to process safety at the construction authorization stage.

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

Additional documentation from the applicant and the literature was reviewed as necessary to understand the process and safety requirements. Duke, Cogema Stone & Webster (DCS) states that the BDC of 10 CFR 70.64(a) are incorporated into the facility design and that applicable sections of the revised CAR are intended to demonstrate compliance with these BDCs (revised CAR, page 5.5-67).

In performing its review of the revised CAR and supporting documents, the staff used the applicable guidance of Section 8.4 of NUREG-1718 for determining acceptance with 10 CFR Part 70, consistent with a construction authorization stage and the level of the design. The evaluation is summarized in the sections that follow.

8.1.2 Areas of Review and Evaluation Findings

8.1.2.1 Chemical Processes

The plutonium feedstock to the facility requires purification before it can be used in nuclear fuel. This purification process is termed Aqueous Polishing (AP). A solvent extraction process is used in the AP process to separate plutonium from gallium, americium, uranium, and other minor impurities. The solvent extraction process is similar to the PUREX process used domestically and worldwide in nuclear fuel processing (Reference 8.3.3). The resulting purified plutonium, sometimes referred to as polished plutonium, is converted into plutonium dioxide (PuO_2). Subsequently, powder processing operations combine the polished PuO_2 with uranium dioxide (UO_2) to form the nuclear fuel. This is often referred to as the MOX Process (MP). Chemical processes occur as part of the AP and MP operations, supported by reagent preparation in the Reagent Processing Building.

The MOX Fuel Fabrication Building and the Reagent Processing Building form the core group of buildings for plutonium polishing (i.e., AP process) and MOX fuel fabrication (i.e., MP process). These are described in Section 1.1.1.1.2.

The Reagent Processing Building would be located adjacent to the main MFFF building. The applicant does not intend to store, process, or commingle radioactive materials or radiochemicals in this building. Most of the initial reagent dilution and mixing operations would occur here. The design has a below-grade collection tank room that would receive waste chemicals from the Reagent and AP buildings. The AP waste chemicals could be slightly radioactive. In addition, the Liquid Solvent Area will be located on the Northwest side of the building for the collection and transfer of liquid waste solvent from the AP process. The waste solvent would be slightly radioactive. The Reagent Processing Building will be divided into discrete rooms/areas to segregate chemicals and the associated equipment and vessels to prevent inadvertent chemical interactions. Most reagents (e.g., nitric acid, hydrogen peroxide, hydroxylamine nitrate [HAN], hydrazine, oxalic acid, sodium carbonate, diluent [C10-C13 isoalkanes, HTP - hydrogenated tetrapropylene, or TPH - tetrapropylene hydrogenate], and tributyl phosphate [TBP]) are stored and solutions would be prepared in the Reagent Processing Building for use in the AP Area. Sodium hydroxide and nitrates of silver and manganese are stored and prepared in the AP Area. Liquid chemical containers would be 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.

In addition, there would be a separate, secure warehouse building (SWB) that also stores depleted uranium dioxide, as a fine powder, in steel drums. The powder is used to form the matrix for the MOX fuel pellets and as an isotopic diluent for enriched uranium in the process. The building would have a metal panel on frame design, without reinforcement, with standard features required by the building codes. The building would not have filters or other special features for radioactive materials.

The staff review identified the need for additional information regarding mass, energy, and radioactivity balances relative to what was provided in the revised CAR. The applicant has provided supplemental information in specific correspondence (References 8.3.14 and 8.3.5). Mass balances have been found to generally agree to within 5-10 percent. The staff notes that these values may change as the design progresses. The staff concludes that the additional information provided on the major balances and overall process meets the Standard Review Plan (SRP) acceptance criteria and is adequate and acceptable for construction authorization.

Fluid transport system (FTS) categories and their applicable codes and standards are discussed further in Section 11.8 of this revised DSER. FTS categories 1 and 2 represent PSSCs, with FTS-1 representing a higher qualification level due to higher anticipated quantities and concentrations of radionuclides. No quantitative criteria are provided. Based upon the qualitative descriptions, the staff anticipates that the majority of the AP equipment would have a PSSC and an FTS-1 or 2 designation. Specific PSSC and design basis findings for chemical safety are discussed later in this chapter and in Sections 11.2 and 11.3 of this revised DSER.

8.1.2.1.1 AP Process

The AP process can be segmented into the following four operational areas (Unit symbols are provided in parentheses):

- Plutonium purification process - Includes the Decanning Unit (KDA), Dissolution Unit (KDB), Dechlorination and Dissolution Unit (KDD), Purification Cycle (KPA), Oxalic Precipitation and Oxidation Unit (KCA), Homogenization Unit (KCB), Milling Unit (KDM), Canning Unit (KCC), Recanning Unit (KDR), and Uranium Oxide Dissolution Unit (KDC).

- Recovery processes - Includes the Solvent Recovery Cycle (KPB), Oxalic Mother Liquor Recovery Unit (KCD), and Acid Recovery Unit (KPC). The design no longer includes a Silver Recovery Unit.

- Waste storage - Includes the Liquid Waste Reception Unit (KWD).

- Offgas treatment - Includes the Offgas Treatment Unit (KWG).

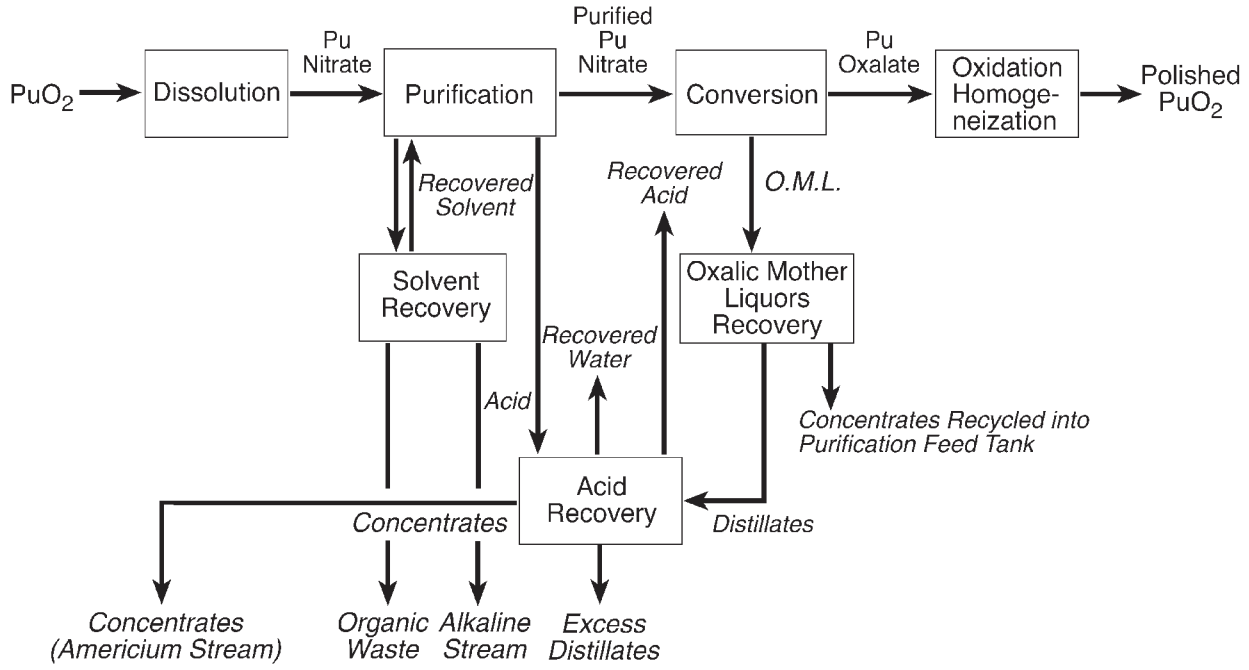

Figure 8-1 AP Process Overview

A sampling system also exists for providing materials for radiochemical analyses.

Overviews of these operational areas are discussed in revised DSER Section 1.1. Figure 8-1 provides a process overview. Section 11.2 provides a more detailed description and evaluation of the AP process.

8.1.2.1.2 MP Process

The MP process involves dry subprocesses (i.e., blending of uranium and plutonium dioxide powders, poreformer and lubricant additions, pelletizing, sintering, and rod and assembly processing). The MP process is reviewed in detail in Section 11.3.

8.1.2.1.3 Laboratory

Chemical and physical analyses of samples from the MP and AP areas will be conducted in the laboratory. The MFFF laboratory operations would also include laboratory liquid and solid waste management, temporary storage of scrap materials from the laboratory, MP process adjustment in a test line, calibration and document storage.

As shown in revised CAR Appendix 5A, the applicant's safety assessment identified that laboratory operations involve hazards associated with the major event types described in revised CAR Section 5.4.1.2.1. These events include loss of confinement/dispersal, fire, explosions, criticality, natural phenomena, external man-made events, external exposure and chemical release. For this reason, the applicant stated that the following list of PSSCs are relied upon to reduce risks to the facility worker, site worker, public and the environment from potential hazards in the laboratory:

- C3/C4 Confinement Systems
- Chemical Safety Controls
- Laboratory Material Controls
- Combustible Loading Controls
- Criticality Controls
- Fire Barriers
- Fire Detection and Suppression
- Fluid Transfer Systems
- Gloveboxes
- Glovebox Pressure Controls
- Material Handling Controls
- Material Handling Equipment
- Material Maintenance and Surveillance Programs
- Process Control Safety Subsystem
- Facility Worker Action

As discussed in Section 5.6.2.7 of the revised CAR, Laboratory Material Controls consist of administrative procedures that would be used to control the quantity of radiological and chemical materials in the laboratory. The safety function is to limit the extent of any potential explosion by limiting the quantity of hazardous chemicals that may be involved in any explosion and to limit the quantity of radiological/chemical material available for dispersion following a potential explosion. The applicant intends to develop procedures to establish limits on sample size, the number of samples that may be stored and used in the laboratory overall and in any one location, and the quantity of chemicals, reagents, or other hazardous materials that may be stored or used in a laboratory. The applicant will also develop procedures to ensure laboratory operations are performed in accordance with safe laboratory operating practices. Procedures will be developed by the applicant and reviewed by the NRC staff as part of the possession and use license application.

As discussed in revised DSER Section 5, the staff independently evaluated the consequences of the controlling events within each event group for the laboratory. The staff's analysis confirms the applicant's assessment that the PSSCs listed above would be adequate to reduce the risk to all receptors to acceptable levels. Section 11.11 and Tables 11.3-34, 11.11-1, and

11.11-2 of the revised CAR provides information on the laboratory and the samples. The proposed safety strategies are similar to practices at many radiochemical facilities. The staff finds this approach acceptable for the construction authorization stage.

8.1.2.1.4 Chemical Reagents

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 would be stored in the AP Area or the MP Area. The main chemicals potentially stored in these areas have been identified by the applicant as the following:

- Solids
  - Reagent Processing Building - oxalic acid and sodium carbonate.
  - AP Area - silver nitrate and manganese nitrate.
  - MP Area - azodicarbamide and zinc stearate.

- Liquids
  - Reagent Processing Building - hydrazine hydrate, HAN, nitric acid, TBP, solvent/diluent, and hydrogen peroxide.
  - AP Area - fresh and recovered nitric acid, and sodium hydroxide.

- Gases
  - Reagent Processing Building - nitrogen tetraoxide (N_2O_4).
  - Site - nitrogen, oxygen, hydrogen, argon, and P10 (10%methane+ 90%argon).

Storage facilities in the Reagent Processing Building would contain the following:

- Drums of the following reagents: 13.6N HNO_3, TBP, diluent (dodecane), HAN, and $N_2H_4.H_2O$.

- Cylinders of N_2O_4.

- Bottles of hydrogen peroxide (10 wt percent and 35 wt percent).

- Storage of material for dissolving solid reagents, such as oxalic acid, Na_2CO_3, $AgNO_3$, and $Mn(NO_3)_2$.

A list of process chemicals can be found in Tables 8-1a to 1e and 8-2a to 2c of the revised CAR.

Chemicals and chemical mixtures in the process are usually used at lower concentrations than the reagent-grade chemicals potentially stored in the Reagent Processing Building or AP Area. The more dilute reagents usually pose reduced hazards.

The applicant provided information about the delivery of chemicals to the proposed facility and the potential impacts from spills and explosions. The applicant concluded that potential releases from the delivery of chemicals would not affect the site worker and members of the public. The applicant states that the Emergency Control Room Air Conditioning System is designated as a PSSC to ensure habitable conditions for all potential workers in the emergency control rooms. Based upon completion of the chemical consequence analyses, measures will

be provided, if necessary, to ensure that emergency control room workers are protected from potential chemical releases. The applicant states that no chemical delivery scenarios have been identified that exceed the performance criteria of 10 CFR 70.61. Habitability is discussed further in revised DSER Section 8.1.2.6. The applicant has identified an administrative PSSC entitled "Hazardous Material Delivery Controls" which has the safety function of ensuring that the quantity of delivered hazardous material and its proximity to the MOX Fuel Fabrication Building structure, the Emergency Generator Building structure, and the waste transfer line are controlled to within the bounds shown in the safety analysis to produce acceptable results. Currently, this is expressed qualitatively because the designs are still evolving and numeric values may change. The staff finds this qualitative approach acceptable for the construction authorization stage.

NRC staff finds the overall process description adequate and acceptable for the construction authorization stage, recognizing that some of the information provided by the revised CAR represents a snapshot in time as the design has continued to evolve.

8.1.2.1.5 Chemical Process Inventories

The applicant has provided chemical inventory information (revised CAR Sections 8.1, 8.2, 11.2, and 11.3). Common hazardous materials (e.g., vehicle fuel) and commonly used small quantities of solvents or gases are also used onsite, and the applicant states specific inventories will be identified in the detailed design.

The staff has reviewed the list of chemicals and their inventories. For construction, the chemical listing appears sufficiently complete and the quantities appear appropriate for preliminary safety assessments. The staff finds this information is adequate and acceptable for the proposed activities and the construction authorization stage.

8.1.2.2 Hazardous Chemicals and Potential Interactions

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

8.1.2.2.1 Chemicals

Plutonium would be received as impure PuO_2 in the AP Area and will be transformed into various compounds in different solutions at various stages of the process to remove the impurities (e.g., gallium, americium, uranium). Purified plutonium will be converted back into PuO_2 (now purified) before being transported to the MP PuO_2 buffer storage unit. During some AP operations, new chemical compounds would be produced. Table 8-1 in this revised DSER identifies chemicals potentially produced in hazardous quantities under off normal conditions.

Nitrogen and helium gases at appropriate pressures would be used in the MP process. Azodicarbamide (a pore former) and zinc stearate are used in powder form in the pelletizing process. Other chemicals (liquids, solids, and gases) used in the MP Area are present mainly in the laboratory for inspection and analysis purposes. Chemicals that are potentially stored and used in the MFFF laboratory in small quantities. In the revised CAR, the applicant stated laboratory chemicals will be identified in the license application for possession and use of special nuclear material (SNM). The applicant provided a preliminary list of anticipated

chemicals and quantities in the laboratory area (revised CAR Table 8-2c). Typical quantities are less than 10 kg of each reagent.

Table 8-1, Potentially Hazardous Chemicals Produced in Aqueous Polishing under Off-Normal Conditions

Chemical	Formula	Revised CAR Comment
Hydrazoic Acid	HN_3	Interaction of hydrazine nitrate and nitrous acid could initiate, under certain conditions, the formation of hydrazoic acid. However, any accumulation of HN_3, which occurs in the AP process, is ten times lower than the explosive limits. In the gaseous phase, HN_3 may decompose to N_2 and H_2. (see revised DSER Section 8.1.2.5.3.2)
Hydrazoic Salts (i.e., azides)	NaN_3 AgN_3	Interaction of hydrazine nitrate and nitrous acid could initiate, under certain conditions, the formation of hydrazoic salts (i.e., azides). However, since the solubility limits of these azides are not exceeded, precipitation and the potential for an explosion are prevented. (see revised DSER Section 8.1.2.5.3.3)
Red Oil	(Various)	Red oil is an organic mixture, consisting of tri-butyl phosphate and its complexes with plutonium nitrate and nitric acid, degradation products of TBP (e.g., dibutyl phosphate), and possibly various nitrated hydrocarbons. These are compounds that could react exothermically at temperatures higher than 135°C. Process unit design prevents the process fluid temperature from exceeding 135°C by providing adequate margin between the maximum operating temperature and 135°C. (see revised DSER Section 8.1.2.5.5)

Table 8-2. Process Chemical Hazardous Characteristics and Incompatibilities (Revised CAR 2002)

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, Nirtic 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					x	Aluminum, Acids, Hydrogen Peroxide
	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	x	Combustible Materials, Strong Reducing Agents, Metals
Gas	Dinitrogen Tetroxide/Nitrogen Dioxide	x		x	x	x	Reducing Agents, Organics, Metals
	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

8.1.2.2.2 Chemical Interactions

Human error or equipment malfunction may result in inadvertent chemical interactions and initiate hazardous reactions. Hazardous chemical characteristics and incompatibilities with the associated materials/process conditions have been identified by the applicant and are summarized in Table 8-2. The staff concluded that this list was derived from standard guidelines. The applicant intends to conduct hazard and operability analyses (HAZOPs) as part of the Integrated Safety Analysis (ISA) during detailed design and submit a complete chemical interaction matrix as part of the possession and use license application. As stated in the revised CAR, the applicant intends to control chemical preparation in accordance with operating procedures by trained personnel to minimize the potential for unexpected interactions. To minimize the risk to PSSCs associated with inadvertent chemical interactions, the applicant intends to prepare most chemical reagents for the AP process in the Reagent Processing Building (a non-radiological building), with subsequent distribution to the AP Area.

Sections 8.4.3.2 (B) and (C) of the Standard Review Plan (SRP) list the acceptance criteria for potential chemical interactions, with the understanding that some generalities are acceptable at the construction authorization stage. The staff notes that the applicant has identified general precautions and several specific hazards associated with the interaction of chemicals and also has considered radiolysis effects. Specific hazards include: red oil (solvent), HAN/hydrazine, azides, plutonium (VI) oxalate, hydrogen, and pyrophoric effects from certain metals and oxides. Thus, the staff finds the overall process description itself is generally adequate and acceptable for the construction authorization stage. Significant chemical-related risks are discussed further in revised DSER Sections 8.1.2.5, 11.2, and 11.3.

8.1.2.2.3 Unusual and Unexpected Reactions

New chemical compounds are produced in some AP operations. The applicant states the behavior of these mixtures is well understood from experience at the La Hague facility in France and is included in the preliminary chemical process safety evaluation.

In general, for vapor and gaseous species, AP chemical interactions produce NO_x, CO_2, CO, and H_2, as well as possible plutonium, americium, and uranium mixtures entrained in nitric acid vapors. These chemicals would be generated in tanks and equipment and would be collected by the offgas treatment system. Solvent-diluent vapors would also be collected in a separate stream and treated by the offgas system before being released to the stack.

The staff review notes that the list of chemicals produced in the process, as identified by the applicant, is reasonably comprehensive but that additional reactions and compounds may be added as the design progresses. The overall approach is reasonable for the construction authorization stage. Revised DSER Section 8.1.2.5 discusses process safety information and specific concerns in more detail and revised DSER Sections 11.2 and 11.3 discuss specific chemical concerns by unit. Staff findings are presented in those sections.

8.1.2.3 Chemical Accident Sequences

The applicant has provided information on chemical-related events in Sections 5.5 and 8 of the revised CAR. The applicant provided supplementary information in public meetings (References 8.3.64-66), correspondence on the docket (Reference 8.3.61), and in-office reviews of the preliminary hazards analysis (PHA), preliminary accident analysis (PAA), and

chemical accident modeling reports (References 8.3.32 and 8.3.63). This section presents the staff's assessment of accident sequence bases, unmitigated sequences, estimated concentrations, and concentration limits for chemical safety.

This section also provides the methodology and results for the evaluation of chemical consequences that may be associated with a release of radiochemical materials.

As reflected in 10 CFR 70.64(a)(5), the design must provide for adequate protection against risks produced from:

(1) chemical risks produced from licensed radioactive material,

(2) facility conditions which affect the safety of licensed material, and

(3) hazardous chemicals produced from licensed materials.

Staff evaluations and conclusions are presented in subsequent sections.

8.1.2.3.1 Chemical Consequence Limits

This section evaluates the chemical risks to workers and members of the public from events that release chemicals and radionuclides. The chemical consequences are based on bounding analyses.

The applicant has based the chemical consequence limits for accident categories on Temporary Emergency Exposure Limits (TEELs) Revision 18. The proposed limits are listed in Tables 8-3 and 8-4. 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.

The proposed chemical consequence values would be:

Low Consequence	TEEL-1
Intermediate Consequence	TEEL-2
High Consequence	TEEL-3

TEELs were developed by the U.S. Department of Energy (DOE), Subcommittee on Consequence Assessment and Protective Action (SCAPA) (Reference 8.3.38), to serve as temporary guidance until the American Industrial Hygiene Association (AIHA) publishes Emergency Response Planning Guideline (ERPG) concentrations. The TEEL values are used by DOE, the Department of Defense and other government agencies as ERPG approximations until peer-reviewed ERPGs become available. However, TEELs are not a regulatory based and revised document and NRC regulations and guidance do not invoke TEELs, TEEL methodology, or values derived from TEELs.

The TEEL definitions are similar to the ERGP definitions except for the 1-hour term. This is because concentration-dependent chemical limits are based on a 15-minute exposure time and dose dependent chemicals are based on a 1-hour exposure time. The concentrations are than adjusted to the same exposure time frame by a formula.

ERPGs were developed by the AIHA ERPG committee (Reference 8.3.52) as planning guidelines to anticipate adverse health effects from the exposure to toxic chemicals. The ERPGs do not contain safety factors that are usually incorporated into exposure guidelines and are not a standard for public protection.

The staff has found that the TEEL limits are subject to change over time. TEEL limits are revised if new or additional toxicity data are found or new concentration limits are issued. For example, within the last two years, the TEEL-3 limits for nitric acid, hydrazine hydrate and nitrogen tetraoxide, three important chemicals used in bulk quantities in the AP system, varied by more than 50 percent.

The NRC does not promulgate its own chemical consequence limits, but relies on values from other government agencies and organizations that have a clear toxicological and regulatory basis. The staff notes that there are multiple limits available for assessing the impacts from potential chemical releases. The EPA is developing Acute Exposure Guideline Levels (AEGLs) as a government standard for emergency response. The AEGLs are defined as:

- AEGL-1 is the airborne concentration (expressed as ppm or mg/m^3) of a substance at or above which it is predicted that the general population, including “susceptible” but excluding “hyper-susceptible” individuals, could experience notable discomfort. Airborne concentrations below AEGL-1 represent exposure levels that could produce mild odor, taste, or other sensory irritations.

- AEGL-2 is the airborne concentration (expressed as ppm or mg/m^3) of a substance at or above which it is predicted that the general population, including “susceptible” but excluding “hyper-susceptible” individuals, could experience irreversible or other serious long-lasting effects or impaired ability to escape. Airborne levels below AEGL-2 but above AEGL-1 represent exposure levels which may cause notable discomfort.

- AEGL-3 is the airborne concentration (expressed as ppm or mg/m^3) of a substance at or above which it is predicted that the general population, including “susceptible” but excluding “hyper-susceptible” individuals, could experience life-threatening effects or death. Airborne levels below AEGL-3 but at or above

AEGL-2 represent exposure levels that may cause irreversible or other serious, long-lasting effects or impaired ability to escape.

Currently, AEGLs have been established for only four chemicals. Interim AEGLs are available for additional chemicals, including chlorine, hydrazine, nitric acid, and nitrogen dioxide, which are chemicals of concern in the AP process. The staff notes that the definition of AEGL-2 overlaps the TEEL-3 definition and AEGL-1 overlaps the TEEL-2 definition. However, the High Consequence Level values proposed by the applicant, which come from TEEL Revision 18 are generally higher than the AEGL values.

Staff comparison of the applicant's proposed values for selected chemicals to the limits contained in the National Institute for Occupational Safety and Health (NIOSH) Immediately Dangerous to Life and Health (IDLH) values (References 8.3.54-58) (of which 10% is sometimes used for members of the public to accommodate a wider range of population groups) and the Short-Term limits, to be non-conservative.

The staff has also reviewed the chemical literature found other sources of limits. Those sources included Military Air Guidelines (MAGs) for short term chemical exposure to deployed military personnel, Short-term Public Emergency Guideline Levels (SPEGLs - a minimum effects level)Ceiling Limit Values (also a minimum effects level), and EPA Toxic Endpoints as part of its risk management program (Reference 8.3.67). Many of the published values were more conservative then those proposed by the applicant. As a result of that review, the staff has concluded that no single source of chemical hazard limits may contain all of the chemicals likely to be encountered at the proposed facility and address all of the potential release situations (e.g., worker and public, and high, intermediate and low consequence events).

The values proposed by the applicant are temporary limits are not from a regulatory based and revised document, not based on a peer-review process, and have high numerical values as compared to other standards. Thus, they do not provide adequate margin and conservatism for assessing chemical risks and identifying PSSCs to meet the performance requirements of 10 CFR 70.61. Therefore, the NRC does not find the applicants proposed values in Table 8-11 acceptable. These concerns about consequence levels are identified as part of Open Item CS-5b.

Table 8-3, Chemical Consequence Limits Proposed By the Applicant for the MFFF (mg / m^3)

Name	Low Consequence Level (TEEL-1 Value)	Intermediate Consequence Level (TEEL-2 Value)	High Consequence Level (TEEL-3 Value)
Aluminum Nitrate	15	15	500
Azodicarbonamide	125	500	500
Chlorine	3	7.5	60
Chromic (III) Acid	1	2.5	25
Diluent (C10-C13 Isoalkanes)	5	35	200
Ferrous sulfate (Lab)	7.5	12.5	350
Fluorine (Lab)	0.75	7.5	30
Hydrazine Monohydrate	0.0075	0.06	50
Hydrazine Nitrate	3	5	5
Hyrofluoric 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

Table 8-3, Chemical Consequence Limits Proposed By the Applicant for the MFFF (cont.) (mg / m^3)

Name	Low Consequence Level (TEEL-1 Value)	Intermediate Consequence Level (TEEL-2 Value)	High Consequence Level (TEEL-3 Value)
Sodium Nitrite	0.125	1	60
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 8-4, Applicant's Use of Chemical Limits for 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

8.1.2.3.2 Chemical Accident Assumptions

The applicant considered a range of initial conditions, as well as the failure modes of storage containers and associated systems. The following release scenarios are stated in the revised CAR:

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

The applicant modeled releases using the total material at risk from the largest single tank or container. No credit was taken for process equipment installed to scrub and remove gases and vapors (i.e., installed for normal operations; assumed not to function during an accident involving a release). The applicant states more detailed accident sequences will be developed as necessary as part of the ISA during final design.

The distance of the possible receptors was also considered. A 100 meter distance was used for calculations involving the site worker. The public receptor was assumed to be approximately 8 km (5 miles) from the point of release.

The applicant used the largest evaporation rate calculated from two models, as discussed in revised CAR Section 8.3.3, as input to the dispersion models for gases and vapors. The applicant used the dispersion coefficient derived from the ARCON96 model (see revised DSER Section 9) for estimating concentrations for the site worker (100 meter receptor). Concentrations for the public (8 km [5 mile] receptor) were estimated using the evaporation rate as input to the Areal Locations of Hazardous Atmospheres (ALOHA) code. For chemicals that do not have appreciable vapor pressures and are released as fine particles (dust), the applicant used the five factor formula for the release rate with dispersion coefficients calculated by the ARCON96 model for the site worker and the MACCS2 model for the public (see Section 9).

The staff notes the ARCON96 and MACCS2 codes have been found acceptable (see Section 9). The ALOHA code is developed and maintained by the U.S. EPA for releases of chemicals. The staff finds its use acceptable.

The analyses used the following input parameters and assumptions:

- Release duration of 1 hour.
- Pool depth of 1 cm.
- F atmospheric stability, with a 2.2 m/sec wind speed, based on 95 percent of 5 year averages (References 8.3.44 and 8.3.46).
- Largest single process vessel without consideration of common mode failures of adjacent vessels; this becomes 126 gallons (each) for nitric acid, dodecane, TBP, and hydrazine hydrate; 180 gallons for hydroxylamine nitrate; and 240 gallons for nitrogen tetraoxide.
- For depleted uranium dioxide storage, 200 drums containing 187.5 kg DuO_2 per drum in 30 gallon drums
- Gas storage area gases will not reduce oxygen in personnel areas.
- A temperature of 25°C and 50% relative humidity
- A ground level release
- No mechanical or buoyancy plume rise
- A rural - flat terrain - topography
- Neutrally buoyant gas model

Section 5.5.2.10 of the revised CAR also indicates that direct chemical consequences with no direct radiological effects are not regulated by 10 CFR Part 70 because they do not impact or directly involve radiological material. In the case of a chemical release that has the potential to impact a facility worker and prevent the performance of a safety function, Section 5.5.2.10.6.1 of the revised CAR states the worker would only perform a monitoring role from the emergency control room during emergency conditions. Consequently, the Emergency Control Room Air Conditioning System is designated as a PSSC with the safety function of ensuring habitable conditions are maintained in the emergency control room. The staff's evaluation of this issue is described in Section 8.1.2.6 below.

Section 12.1 of the revised CAR states the control of the facility would rely to a great extent on automated systems to ensure facility safety. It also mentions that the operations staff would be expected to monitor and confirm the status of confinement systems, fluid systems, and other facility systems; and to recover from off-normal conditions. The applicant expects few personnel actions would be relied upon for safety. At the present time, the applicant has identified the closing of dampers and the valving in of emergency scavenging air as two operator actions required outside of the Emergency Control Room as part of a longer term response, and the applicant expected the effects of a chemical release would have dissipated by the time these operator actions might become necessary (Reference 8.3.63). The applicant stated that no safety-related operator or worker actions are necessary outside of the emergency control room that affect radiological safety, during or after a chemical release. As regards PSSCs that are administrative controls, the applicant indicates in the revised CAR (Section 5.5.2.10.6.1) these are either permissive in nature (e.g., no action until a sample is analyzed) or fail safe (i.e., crane stops).

8.1.2.3.3 Chemical Modeling Approach

The applicant has estimated hazardous chemical concentrations using techniques and models that are generally consistent with industry practice and generally follow the guidance on atmospheric and consequence modeling found in NUREG/CR-6410, "Nuclear Fuel Cycle Accident Analysis Handbook" (Reference 8.3.44)

The staff has reviewed the chemical modeling approach and finds the basic models and approaches acceptable. However, the staff is concerned that the input selected may not be sufficiently conservative to provide adequate assurances of safety. For example:

- The inventories used in the calculations are based upon single tanks and this may be too specific considering the level of design at the construction authorization stage. Common mode failures that could impact several adjacent tanks or an area are not considered.

- The temperature of 25EC does not adequately represent anticipated high temperatures in the Summer. NRC has approved a temperature of 41EC (106EF) for safety-related calculations for a licensed facility located near the proposed facility (Reference 8.3.60).

- Concentration controls are applied to hydrazine and peroxide deliveries. Concentration controls are not applied to the other reagents and the delivery and storage of higher concentration reagents is a credible event. This is primarily a concern with nitric acid. An increase from 13.6 N (about 63 percent) to 80-90 percent due to a delivery mistake

would increase the vapor pressure by a factor of 5-10 for nitric acid. This is discussed in Section 8.1.2.5.

- The applicant has reduced air flow velocities (to 0.1 and 0.01 m/sec) used to determine evaporations rates in some areas of the facility well below the wind speed used in the dispersion analyses (2.2 m/sec). Use of the 2.2 m/sec wind would result in nitric acid concentrations exceeding levels of concern. No PSSCs are identified. This is discussed in Section 8.1.2.4.1.

- The UO_2 powder comes from a fuel manufacturer and is likely to have a small particle size. The respirable fractions are likely to be higher than those used in the analyses by the applicant. However, the applicant has already identified PSSCs to address uranium dioxide toxicity effects from a warehouse fire.

The applicant stated in revised CAR Section 8.4.1 that for events involving the release of uranium, the unmitigated consequences are estimated to be low and PSSCs are not applied.

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

The staff applied several modeling approaches and assumptions and found that the levels of concern (10 mg/m^3 for high and 1 mg/m^3 for intermediate) could be exceeded for the site worker. The applicant provided supplemental information (Reference 8.3.64) that included PSSCs to address this event. Combustible loading controls were applied as the administrative PSSC to protect the site worker, and facility worker action was applied to protect the facility worker. The staff review concludes these PSSCs would adequately mitigate potential fire events affecting uranium dioxide at the warehouse. Thus, the staff finds the applicant's approach for addressing a warehouse fire involving uranium dioxide to be acceptable for the construction authorization stage.

8.1.2.4 Chemical Accident Consequences

This section presents the staff's assessment of accident consequences for chemical safety.

8.1.2.4.1 Analysis

The applicant evaluated potential chemical consequences for a member of the public at the nearest point of the Savannah River Site (SRS) boundary (approximately 8 km away; this is equivalent to the controlled area boundary identified by the applicant in the revised CAR). The applicant's results of the analyses show that the unmitigated chemical consequences are low to the public, and thus, the applicant concluded that no principal SSCs are required for public protection (Reference 8.3.19, Section 8.4).

For the site worker and facility worker, the applicant estimated the chemical consequences to be low. PSSCs have been defined for radiological events, and the applicant believes these PSSCs may be applicable to process units where chemicals mix with radiological material. The applicant has further stated that the chemical consequence analyses for the site worker bound the consequences for the facility worker. As stated in Section 11.2 of the DSER, the staff concurs with the applicant's qualitative distance analysis that, from the point of an in-cell release to a worker would be 100 meters. This closes a portion of AP-13. However, for a 100-200 gallon leak of radioactive nitrate solution, site worker limits could be exceeded for several

hundred meters, and the performance requirements of 10 CFR 70.61(b)(4) and 10 CFR 70.61 (c)(4) might not be met. The staff identifies this as Open Item CS-05.

The staff evaluation notes that the Emergency Control Room Air Conditioning System is identified for chemical safety (protecting operators from chemical releases that could impact the safe handling of radioactive materials). No other PSSCs are currently identified (see revised CAR, Section 5.5.2.10.6.1). As discussed in Section 8.1.2.6, the applicant must provide design basis values for habitability in the Emergency Control Room.

The applicant has identified events involving the release of hazardous chemicals (primarily chlorine) produced from radioactive materials, from the Dechlorination and Dissolution Unit equipment and associated areas that can affect the potential facility worker. The applicant has identified a mitigation strategy. The PSSCs are process entry controls for leaks occurring in cells, the C4 confinement system for leaks occurring in gloveboxes, and facility worker action for leaks occurring in C3 ventilated areas. The staff finds the applicant's approach for addressing these chemical effects to be acceptable for the construction authorization stage. As discussed in revised DSER Section 8.1.2.3.1, the applicant must identify chemical consequence limits that are acceptable to the staff (Open Item CS-5b).

The applicant has identified an event involving the release of hazardous chemicals and radioactive material. This scenario involves the flow of NO_2/N_2O_4 at an abnormally high rate through the oxidation column (i.e., for plutonium, in the Purification Unit). This has the potential for excessive chemical consequences for the site worker. The applicant has identified a safety strategy based upon mitigation. The PSSC is the process safety control subsystem. The safety function is to ensure the flow of NO_2/N_2O_4 is limited to under 44 kg/hr (e.g., by active flow controls) to the oxidation column such that chemical consequences to the site worker are acceptable. The staff finds the applicant's fundamental approach of flow limitation for addressing these chemical effects to be acceptable for the construction authorization stage. As discussed in revised DSER Section 8.1.2.3.1, the applicant must identify chemical consequence limits that are acceptable to the staff (Open Item CS-5b) and this may affect the design basis value for the flow limit.

The staff has identified a concern with the air speed and phenomenological model used to estimate evaporation rates from spills within the facility. Section 8.3.3 of the revised CAR identifies an air speed of 0.1 m/sec, based upon the maximum volumetric air flow through the room in which the pool or puddle is located. Section 8.4.1 of the revised CAR identifies an indoor air speed of 0.01 m/sec for nitric acid spills or leaks in the AP area, with spill temperatures modeled up to the boiling point of nitric acid. The applicant has used these air speeds as input into the evaporation models, which provide a release rate or source term. The staff notes this use of low air velocities results in a significant reduction of the estimated consequences by factors of between 20 and 200, because the evaporation rate model used by the applicant is approximately linearly dependent with air velocity. Using these air speeds for evaporation and source term estimation, combined with the 2.2 m/sec wind speed for dispersion, the applicant concluded that the consequences would be low for the potential site worker and members of the public. The staff concerns and conclusions are as follows:

- The approach of using different air speeds for evaporation and dispersion is an uncommon practice.
- Use of the 2.2 m/sec wind speed would likely result in exceeding the high consequence level for nitric acid, currently identified by the applicant as 200

mg/m3 (for comparison, the IDLH value often used by the NRC in control room evaluations is 25 ppm [64 mg/m3]). The applicant states that the principal parameters which result in low consequences for all indoor releases are the spill/room size and the low indoor wind speed. The applicant does not consider these input parameters to be design basis values (Reference 8.3.61). Thus, a safety effect is credited without identification of PSSCs and design bases.

- Experience has shown that air flow velocities are usually uneven in cells, with higher velocities as the air exhaust inlets are approached. Most facility designs include exhaust inlets near the floor, where spills could likely occur. These real effects would likely result in much higher velocities near spills than the 0.01-0.1 m/sec calculated on an average basis. The applicant's analysis does not account for these facts.
- There is inadequate conservatism and margin in the assumed air velocities of 0.01-0.1 m/sec.
- The selected models may no longer be suitable (e.g., laminar versus turbulent flow) or may not be supported by experimental data for the low velocities assumed by the applicant.
- Other phenomena may need to be considered and modeled. These could include flashing and bulk convection effects. These would likely exceed the straight wind velocity effects upon evaporation.

The applicant should address these concerns and identify PSSCs, or justify the low air speed approach. Consequently, the staff identifies this as an open item. This is identified as part of Open Item CS-05b.

8.1.2.4.2 Uncertainty

Estimates of risks are often accompanied by uncertainty because of the complexity of the postulated scenarios, the physical models used to describe them, and the design itself (particularly if it's preliminary). At this stage of the design, the applicant believes conservative modeling has been utilized for the chemical releases and this bounds any uncertainty. The applicant intends to perform more detailed consequence analyses in the ISA and evaluate uncertainties and these will be described in the license application for possession and use of SNM. The staff expects the applicant to provide justification of conservatism or adequate margin for addressing uncertainties in meeting the assumed wind speeds and air velocity used to calculate chemical release concentrations and consequences as discussed in the open items in Section 8.1.2.4.1 (above).

8.1.2.5 Process Safety Controls

The applicant provides process safety information in Section 8.5 of the revised CAR. Additional information has also been obtained from the applicant in correspondence on the docket, in-office reviews of documentation, and public meetings (References 8.3.61, 63-66). This is reviewed and evaluated in the sections that follow.

Each of the MFFF facilities would have control requirements that would be incorporated into the overall design of the control system for process safety control. More information on the control system is available in revised DSER Section 11.6.

Reagents are stored and chemical mixtures are prepared in the Reagent Processing Building and the reagent storage area of the AP Area. The AP facility is broken down into process functional units, which are made up of one or more subassemblies performing consistent and elementary tasks. The applicant states the breakdown into control functional units allows each entity to be operated relatively independently in the given operating mode.
The applicant intends to control process storage and operation conditions in order to prevent exothermic and potential autocatalytic reactions in the Reagent Processing Building and the AP Area. Autocatalytic and exothermic reactions of chemicals would be prevented through control of the process parameters (e.g., reactant concentration, temperature, catalyst concentration in solution, and pressure) that affect the reactions.

The applicant states that there is reasonable assurance that the PSSCs will be sufficiently reliable and available, and this will be provided through the use of standard nuclear industry engineering practices. These practices are incorporated into the facility general design philosophy, design bases, system design, and commitments to applicable management measures. These practices ensure that applicable industry codes and standards are utilized, adequate safety margins are provided, engineering features are utilized to the extent practicable, the defense-in-depth philosophy is incorporated into the design, and PSSCs will be appropriately maintained. Significant chemical-related risks and associated process safety information are discussed in the following sections.

8.1.2.5.1 Explosion Due to Hydrogen

The staff notes that flammable liquids and gases would be delivered to and used in the proposed MOX facility. In Section 8.5.1.1.1, the revised CAR states that the hydrogen design basis is 50% of the lower flammability limit (LFL) of hydrogen in air (the LFL of hydrogen is normally 4% in an air atmosphere under ambient conditions). This value will not be exceeded during normal and off-normal conditions. The LFL is considered the safety limit, while 25% of the LFL is considered the expected setpoint at which necessary control actions are initiated during normal operations. The criterion for applying the emergency scavenging air is based upon those systems and vessels that could achieve the LFL within 7 days after a loss of ventilation would have emergency scavenging air applied to maintain the hydrogen concentrations below 25% of the LFL at all times. The staff notes that the application of scavenging air is based upon the limit at which the event (flammability) can occur; there is no margin.

The applicant did not identify any other situations or flammable gases and vapors. Therefore, the design basis for flammable gases and vapors has not been adequately resolved and is considered an open item. The applicant needs to provide additional PSSC and design basis information for flammable gases and vapors or provide sufficient justification that none are necessary (Open Item AP-2).

The staff notes that a design basis value of 25% of the LFL is endorsed by standards (e.g., National Fire Protection Association [NFPA] 801 (Reference 8.3.24)), prior NRC activities (References 8.3.62), and DOE practices. The NRC inspects existing fuel cycle facilities using this criterion.

8.1.2.5.1.1 Argon-Hydrogen Mixture in Sintering Furnace and Hydrogen Storage

The sintering furnaces and the hydrogen storage unit/mixing station are two places associated with the use of an argon-hydrogen mixture (see revised DSER Section 11.3). The nominal mixture is nonexplosive argon (95 percent) and hydrogen (5 percent). The intended control range has a maximum concentration of 9% hydrogen. Mixtures of argon and hydrogen containing more than about 5.8% hydrogen are flammable in air (Reference 8.3.14 and Reference 8.3.5). The applicant intends to minimize explosion risk by the following preventive measures:

- Storage tanks containing argon and hydrogen and the mixing station are located approximately 60 meters outside the MFFF Building,.
- The argon-hydrogen mixture is prepared in the vicinity of the storage tanks located outside the MFFF Building.
- The composition of the argon-hydrogen mixture is monitored and controlled.
- Welded supply tanks and feed lines are designed in accordance with the guidelines of the Compressed Gas Association (CGA).
- Ignition sources (e.g., electricity, fire, lightning) are either eliminated or precluded by design for the area containing the hydrogen storage system.

The staff has requested the applicant to describe its comprehensive strategy regarding potential explosions associated with the sintering furnace (References 8.3.15, 8.3.17, 8.3.22, 8.2.23, 8.3.33, 8.3.64, and 8.3.65). This is an open item as discussed in revised DSER Section 11.3.1.2.4 and carried as Open Item AP-02 .

8.1.2.5.1.2 Radiolytic Hydrogen Production

Hydrogen production by radiolytic dissociation of hydrogenous molecules occurs due to the presence of radioactive material in solution. The applicant intends to preclude radiolytic-hydrogen explosion hazards by preventing the accumulation of hydrogen.

Hydrogen generation will occur in the AP process. For the air-hydrogen system under ambient conditions, the lower flammability limit (LFL) is 4% hydrogen. The applicant states in the revised CAR that hydrogen concentration in the free volume of AP equipment would be maintained below 1 vol. percent (i.e., less than 25 percent of the LFL) during normal operation by maintaining an adequate dilution airflow and ensuring an exhaust path exists. The applicant considers this the setpoint. Air for dilution would be provided by the Scavenging Air System. The design basis is 50% of the LFL which will not be exceeded during offnormal situations.

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. The applicant intends to use container filters to limit hydrogen accumulation while maintaining confinement of radioactive materials.

The staff has performed preliminary calculations on hydrogen production by radiolysis. For 1.9 kg (2.41E14 Bq) of americium in a tank and a G value of 1.6 per 100 eV, the hydrogen production rate can be around one cm^3 per second. The applicant has not provided a clear explanation of the design basis for controlling hydrogen from plutonium, americium, and other radioactive materials. As discussed further in revised DSER Section 11.2.3, this is identified as Open Item AP-02.

8.1.2.5.1.3 Hydrogen Generated by Electrolysis

The applicant has identified limits for hydrogen generated in the electrolyzers. This is discussed in revised DSER Section 11.2. In an efficient process and with relatively low voltages, hydrogen production by electrolysis is usually 5-10% of the passed current. At higher voltages, the cathode may "blow" hydrogen, and the majority of the current is involved with hydrogen generation. Using the applicant's stated electrical conditions, the rate could approach 10 cc/sec or more, which can be an order of magnitude or more larger than that generated by radiolysis. The applicant has stated nitric acid normality and voltage limits may be used to prevent hydrogen generation and keep the hydrogen concentration below the design basis of 50% of the LFL (References 8.3.19 and 8.3.64). The applicant has also indicated that acid concentration controls may be used. The staff anticipates that additional limits (e.g., air concentrations, acid concentrations, and/or voltage) may be necessary. As discussed further in revised DSER Section 11.2. (Open Item AP-02)

8.1.2.5.2 Solvents

The Purification Cycle and the Solvent Recovery Cycle are two units where solvent and diluent are used in processing. The Purification Cycle uses the solvent-diluent mixture for the extraction of plutonium. The Solvent Recovery Cycle regenerates the solvent-diluent mixture by removing the degradation products and adjusting the tributyl-phosphate content, and stores the treated solvent at a slightly acidic condition to prevent degradation by hydrolysis. The aqueous stream is washed with the diluent to remove traces of entrained solvent. The solvent-diluent utilized in these processes is flammable and could be involved in a fire. Combustible characteristics of these chemicals are presented in revised DSER Table 8-5.

Table 8-5: Combustible Characteristics of Chemicals in the AP Area

Combustible	Location	Flashpoint, C
Solvent: Diluent only	Pulsed column, Diluent Washing, and Storage	> 57
Solvent: TBP only	Storage tanks and solvent recovery	> 120
Solvent: Diluent and TBP mixture	Purification Cycle and Solvent Recovery	> 55
Solvent: Diluent, TBP, and aqueous	Purification Cycle and Solvent Recovery	> 66

The PSSCs and design bases associated with fire and explosion hazards in the solvent recovery area are addressed in Chapters 5.0 and 7.0 of this revised DSER, respectively.

With respect to potential explosions, the staff review notes that the applicant identifies a preventive strategy. The PSSCs are:

- Process Safety Control Subsystem, with the function to ensure the temperature of the solutions containing solvents do not exceed the temperature at which the resulting gas phase becomes flammable.

- Process Cell Fire Prevention Features, with the function to ensure that fires in process cells are highly unlikely.

- Offgas Treatment System, with the function of providing an exhaust path for the removal of gases and vapors so that an explosive accumulation does not occur.

The staff finds that the general approach is reasonable but has identified concerns with some of the functions and implied design basis values. For example, the staff believes the temperature value corresponding to the temperature at which the event occurs is inadequate. A temperature margin is needed because the uncertainties and experimental errors in the original flammability and flashpoint measurements and spatial versus bulk temperature differences in a real system may exceed 5° C. The applicant also identified flashpoints of greater than 120°C for TBP and greater than 57°C for dodecane. The applicant cites French experience that indicates a flashpoint greater than 66°C once the solvent/TBP mixture is exposed to water, as it is during the aqueous/organic extraction/purification step. In addition, the applicant states the dodecane planned for use in the facility is actually a petroleum fraction (a distillation cut) and is not a pure compound. It consists of a range of hydrocarbons containing from ten to thirteen carbon atoms per molecule. The staff postulates that additional butyl compounds (e.g., butanol and butene) may be present in the solvent mixture from the degradation of TBP. These compounds have lower flashpoints than pure dodecane and may be responsible for the lower flashpoint of the mixture. The staff notes that a temperature with sufficient safety margin is not identified for the solvent system. The applicant should identify a reasonably conservative, design basis temperature for the solvent, which considers potential spatial variations in temperature measurements, or provide adequate justification why this information is not necessary. (Open Item CS-09).

8.1.2.5.3 Hydroxylamine Nitrate (HAN) and Hydrazine (N_2H_4) in Nitrate Media

The AP process uses a mixture of HAN and nitric acid (HNO_3) to strip (i.e., recover in the aqueous phase) plutonium from the solvent after removal of americium and gallium at the extraction step. HAN reduces the plutonium (IV) to the plutonium (III) state. HAN possesses the proper Pu (IV) to Pu (III) reduction potentials and produces volatile reaction products: nitrogen (N_2), nitrous oxide (N_2O), and water (H_2O). These products do not contribute to the wastes generated by the process.

Hydrazine (N_2H_4) is used in conjunction with HAN to impede the HAN reaction on nitrous acid (HNO_2 is always present in nitric acid solutions) and, thus, increase HAN availability for plutonium reduction. However, interaction of hydrazine nitrate and nitrous acid could initiate, under certain conditions, the formation of hydrazoic acid (HN_3) or azides (hydrazoic salts), which are hazardous compounds.

Besides limiting the plutonium losses in the process, hydrazine can enhance safety by keeping the nitrous acid concentration at a very low level. Nitrous acid is the main intermediate chemical that can lead to the formation of unstable compounds and conditions in the solvent extraction process.

The use of HAN and hydrazine in nitric acid is a complex, multi-parameter chemical system. This system involves the interrelationship of the chemical concentrations of each material, molar ratios (particularly for HAN and nitric acid), temperature, and the concentration of metals (i.e., potential catalytic effect). These systems generally present three main hazards - HAN autocatalytic decomposition, hydrazoic acid, and azides - which correspond to over-pressurization and explosion events.

8.1.2.5.3.1 Hydroxylamine Nitrate (HAN) Decomposition

The applicant has characterized potential HAN decompositions that could lead to explosions into three categories (revised CAR Section 5.5.2.4.6.4):

Category I: Process vessels containing HAN and hydrazine nitrate without NO_x addition
Category II: Process vessels containing HAN and no hydrazine nitrate
Category III: Process vessels containing HAN and hydrazine nitrate with NO_x addition

Category I: Process vessels containing HAN and hydrazine nitrate without NO_x addition

The applicant has proposed a preventive safety strategy to reduce the risk to the worker, site worker, the public, and the environment. The PSSCs are:

- Process Safety Control Subsystem: this has the safety function of maintaining temperatures of these solutions to within safety limits.

- Chemical Safety Control: this has the safety function of ensuring the concentrations of nitric acid, metal impurities, and HAN introduced into the process are within safety limits.

In the revised CAR, the applicant notes that the presence of hydrazine (as hydrazine nitrate in nitric acid solutions) can be effective in limiting the quantity of nitrous acid in the system and, consequently, limits the HAN autocatalytic reaction.

Category II: Process vessels containing HAN and no hydrazine nitrate

The applicant has proposed a preventive safety strategy to reduce the risk to the worker, site worker, the public, and the environment from explosion and over-pressurization events for vessels in the AP Building that feed the AP process and could impact vessels containing radiological materials. One potential example is the 1.9 M HAN buffer tank in the HAN system. The PSSCs are:

- Process Safety Control Subsystem: this has the safety function of maintaining temperatures of these solutions to within safety limits.

- Chemical Safety Control: this has two safety functions: ensure the concentrations of nitric acid, metal impurities, and HAN introduced into the process are within safety limits, and ensure the concentrations of HAN and nitric acid are maintained within their safety limits.

The revised CAR indicates the Chemical Safety Control is added as a PSSC because no hydrazine is present and there is the potential for concentration by evaporation.

Category III: Process vessels containing HAN and hydrazine nitrate with NO_x Addition

The AP purification cycle includes vessels designed to receive NO_x gases for the destruction of hydrazine, HAN, and hydrazoic acid; examples include the oxidation column and the recycling tank. These vessels are designed to destroy hydrazine, HAN, and hydrazoic acid by the reaction with an excess of nitrous acid produced by dissolved NO_x. The reactions result in temperature and pressure increases in the vessels.

The applicant has proposed a preventive safety strategy to reduce the risk to the worker, site worker, the public, and the environment from explosion and over-pressurization events for these vessels in the AP Building. The staff notes these vessels usually include dissolved plutonium. The PSSCs are:

- Chemical Safety Control: this has the safety function to ensure the concentrations of HAN, hydrazine, and hydrazoic acid introduced in the system are within safety limits.

- Offgas Treatment System: this has the safety function to provide an exhaust path for the removal of offgases generated during the decomposition reactions, which provides a means for heat transfer and pressure relief for these vessels.

- Process Safety Control Subsystem: this has the safety function of controlling the liquid flow rate into the oxidation column, thereby regulating the quantity of HAN, hydrazine, and hydrazoic available for reaction and the potential temperature and pressure increases do not exceed the design capabilities of the process vessel.

The staff finds that the applicant did not identify clear design bases for these PSSCs, such as concentration, pressure, and temperature values or ranges of values. The staff notes that additional design bases and PSSCs may be needed to control potential HAN/hydrazine events.

The staff notes that energetic hydroxylamine-nitric acid reactions can occur under the right conditions, as evidenced by DOE investigation of an accident at Hanford (References 8.3.10, 8.3.11, and 8.3.12). As a result of this explosion, DOE investigated the situation and concluded the HAN phenomena involved the interdependence between at least the following five parameters:

- Chemical concentration of each reactant.
- Molar ratio of nitric acid to HAN.
- Temperature of the mixture.
- Concentration of metal ions (as catalysts).
- Pressure of the system (appears to influence the severity of the reactions but not the initial autocatalytic initiation).

DOE derived an instability index and a graph to link these parameters and “generally” account for the behavior of the system. DOE also identifies other precautions, such as frequent monitoring of HAN solutions and mentions that only dilute nitric acid should be added to HAN, and the addition should be performed slowly and in a well-ventilated tank. Dilute nitric acid was not specified further.

The Material Safety Data Sheet (MSDS) for hydroxylamine (which may be mixed with nitric acid to make HAN) also lists safety precautions that include temperature limits, venting/volume increase concerns, crystallization concerns, and hazardous reactions with oxidants, such as nitrates. The MSDS documentation identifies large volume increases (up to 2,000 times the initial volume of the solution) during modest heating and violent decomposition at temperatures above 167°F (75°C), with the liberation of ammonia, nitrogen, and nitric oxide. Metallic impurities and surfaces, such as iron, can accelerate the reactions.

The applicant indicated that the strategy for addressing these HAN issues was undergoing re-evaluation (Reference 8.3.64). The applicant is considering an approach based upon hydrazine scavenging that is different from the DOE guidance. The applicant has indicated additional written information in the form of a report will be submitted to the NRC at a future time.

The applicant has also indicated that the tank in the reagent building would be inerted but has not determined whether the tank in the MOX building would be inerted. Inerting was intended for process control and not for safety purposes. The applicant did not anticipate either of these becoming PSSCs but planned HAZOPS at a later time to further investigate the hydrazine and HAN areas.

The staff concludes that, for addressing HAN/hydrazine mixtures in nitric acid mixtures, the applicant should identify their safety strategy and all applicable PSSCs, safety functions, and design bases. The staff considers this to be an open item identified as Open Item CS-02. In responding to this open item, temperatures and minimum vent requirements should be considered. The staff notes that the DOE reports have items that may provide guidance for appropriate controls, such as a maximum surface temperature, addition of dilute acids, pressure, hydrazine/nitrous acid concentration, and maximum HAN concentrations.

Finally, the applicant intends to use hydrazine as a scavenger for nitrous acid and as a means to improve the efficacy of the plutonium stripping. Hydrazine can also react strongly with oxidants such as nitric acid and peroxide. In the revised CAR, the applicant proposed the use of administrative controls to control hydrazine concentrations within safety limits. The applicant provided additional information indicating the hydrazine would be received as hydrazine hydrate, at a certified concentration of 35% (22% as N_2H_4). The applicant stated solutions below 40% hydrazine (60% as the hydrate) possess no flash or fire point and are thus nonflammable. The applicant stated that the concentration would be confirmed by independent testing not to exceed 35% hydrazine (Reference 8.3.14). The applicant summarized the approach as follows:

- A certified or lot analysis by the manufacturer under a facility approved quality assurance plan.
- An analysis upon receipt at the facility.
- An analysis after mixing/diluting for facility use.

The staff evaluation concludes that the applicant's proposed approach using multiple independent administrative controls at different times to control hydrazine concentrations provides reasonable assurance that the additions do not exceed 35% as hydrazine. The staff finds this acceptable for the construction authorization stage.

8.1.2.5.3.2 Hydrazine and Hydrazoic Acid

Hydrazoic acid (HN3) is also called hydrogen azide. It is formed when hydrazine reacts with the relatively small quantities of nitrous acid present in nitric acid solutions:

$$N_2H_5NO_3 + HNO_2 \Rightarrow HN_3 + 2\ H_2O + HNO_3$$

Hydrazoic acid can undergo further oxidation to yield gases and water:

$$HN_3 + HNO_2 \Rightarrow N_2O + N_2 + H_2O$$

The first reaction generally proceeds faster than the second reaction under most of the conditions in the AP process. Thus, there is a net accumulation of hydrazoic acid and, over time, an equilibrium concentration can be established. Hydrazoic acid exists in the aqueous phase and organic phases that have contacted the aqueous solutions. Thus, the process is designed to destroy aqueous hydrazoic acid in the oxidation column (with nitrous/NO_x fumes) and to remove the organic hydrazoic acid in the solvent recovery unit (as sodium azide, in the aqueous alkaline waste stream). The sodium azide is subsequently destroyed by sodium nitrite in the Liquid Waste Reception Unit.

Hydrazoic acid is a colorless liquid and extremely soluble in water. The multiple nitrogen bonds produce a molecule containing significant energy that can be released by decomposition reactions as follows:

$$2HN_3 \Rightarrow 3\ N_2 + H_2 + 526KJ.$$

Energetic decomposition of hydrazoic acid can occur if sufficient concentrations form in either the liquid or gaseous phases. The applicant has identified the following two type of hazards associated with hyrazoic acid:

- an explosion related to a mixture of hydrazoic acid in air, (the applicant intends to relate this to the liquid phase concentration via Henry's Law correlation), and
- an explosion related to the distillation and condensation of hydrazoic solutions

The applicant has adopted a preventive safety strategy to protect the worker, site worker, public, and the environment. The PSSCs are as follows:

- <u>Chemical Safety Control:</u>
  The first safety function is to assure the proper concentration of hydrazine nitrate is introduced into the system, thus limiting the quantity of hydrazoic acid produced. The applicant has identified the design bases as a maximum hydrazine concentration of 0.14 moles/liter and a hydrazine yield of 39.3% or less.

  The second safety function is to ensure that hydrazoic acid does not accumulate or propagate into the acid recovery and oxalic mother liquor recovery units. This is accomplished by neutralization in the Solvent Recovery Unit. The applicant intends to demonstrate the effectiveness of hydrazoic acid neutralization as part of the ISA at the time of the possession and use license application (Reference 8.3.64). Sampling

controls have been identified as a PSSC to confirm the destruction of the hydrazoic acid (revised CAR Section 8.5.1.8. page 8-33).

- Process Safety Control Subsystem:
  The safety function is to limit the temperature of the solution, thereby limiting the vapor pressure and evaporation of hydrazoic acid. The applicant has identified a design basis temperature of not exceeding 60E C.

The applicant has not provided the staff with an adequate justification of the design basis values. (Open Item CS-03)

8.1.2.5.3.3 Hydrazine and Azides

Hydrazoic acid forms metal azides with cations in near-neutral and alkaline solutions. These are slightly soluble or insoluble, depending on the cation. Some metal azides can become unstable under certain conditions and present a potential explosion hazard.

The applicant has adopted a preventive safety strategy to protect the worker, site worker, public, and the environment. The PSSCs are as follows:

Chemical Safety Control:

- The first safety function is to assure that azides are not added to high temperature process equipment (e.g., the calciner). The applicant has identified the design basis as no addition of azides to high temperature process equipment.

- The second safety function is to ensure that azides have been destroyed prior to acidification of the alkaline wastes to the high alpha waste of the Liquid Waste Reception Unit. Sodium nitrite is added as the scavenging agent for the azides. Sampling controls have been identified as a PSSC to confirm the destruction of the azides (revised CAR Section 8.5.1.9. page 8-33) prior to acidification.

- The third safety function is to ensure that tanks potentially containing azides are not left dry (revised CAR Section 8.5.1.9, page 8-32).

Process Safety Control Subsystem:

- The first safety function is to ensure that metal azides are not exposed to temperatures that would supply sufficient energy to initiate energetic azide decomposition. The temperature design basis has been identified as not exceeding 140E C.

- The second safety function is to limit and control conditions under which dryout can occur.

Silver azide can also form upstream in the process according to the reaction:

$$HN_3 + AgNO_3 \Rightarrow AgN_3 + HNO_3.$$

However, the process separates silver from hydrazoic acid containing vessels and does not recycle hydrazoic acid. In addition, silver concentrations are estimated to be very low in vessels

containing hydrazoic acid. Finally, the temperature design basis of 140°C is below the decomposition temperature of silver azide.

The staff review has found the applicant has identified the potential hazards of metal azides, the process includes steps to reduce these hazards, and PSSCs and design bases have been proposed to reduce potential hazards and risks even further. Consequently, the staff concludes the approach provides adequate assurances of safety.

8.1.2.5.4 Hydrogen Peroxide

A 35 weight percent hydrogen peroxide solution is received and diluted to 10 wt percent for use in the Dissolution Units and the Oxalic Mother Liquor Recovery Unit. Explosive vapors can be produced if a concentration of hydrogen peroxide solution exceeding 75 wt percent is boiled. The applicant has stated that administrative controls would be used to specify and dilute the hydrogen peroxide concentration before use in the process in order to prevent explosions.
The applicant provided supplemental information (Reference 8.3.5) stating that the peroxide would be received as 35% solution, and diluted to form a 10% solution. The applicant summarized the approach as follows:

- A certified or lot analysis by the manufacturer under a facility approved quality assurance plan.
- An analysis upon receipt at the facility.
- An analysis after mixing/diluting for facility use.

The staff evaluation concludes that the applicant's proposal to use administrative controls to control hydrogen peroxide concentrations is acceptable.

8.1.2.5.5 TBP - Nitrate (Red Oil)

Tributyl-phosphate (TBP) is a phosphate ester containing three butyl groups which is added to the solvent phase as the extractant for uranium and plutonium nitrate complexes. A TBP-solvent mixture preferentially moves uranium and plutonium from the aqueous (acid) phase to the organic phase, leaving most of the impurities in the acid stream. In a separate, stripping column, the solvent-TBP-uranium-plutonium mixture is contacted with nitric acid containing a reductant (HAN). HAN changes the oxidation state of the plutonium to a form that is only soluble in the nitric acid, thus allowing its recovery and separation from uranium. The organic phase containing the uranium is contacted with dilute nitric acid in a separate step that reverses the equilibria and the uranium nitrate moves back into the aqueous phase. In the absence of TBP, no uranium and plutonium would be removed from the aqueous phase and purification could not be accomplished.

In the presence of a nitrate of heavy metals or in nitric acid solutions, the TBP will form nitrate complex compounds that could react exothermically. Exothermic TBP-nitrate reactions are frequently referred to as red oil reactions because of the reddish color that has been observed in nitrated TBP/diluent mixtures and residues found during experiments and after the incidents. Red oil is an organic mixture, consisting of TBP and its complexes with plutonium nitrate and nitric acid, degradation products of TBP (e.g., DBP), and possibly various nitrated

hydrocarbons. The applicant has analyzed the risk associated with red oil in units where the aqueous phase is likely to contain traces of these products at above ambient temperatures or with heating sources (e.g., Acid Recovery Unit, Oxalic Mother Liquor Recovery Unit).

8.1.2.5.5.1 Applicant's Proposed Approach for Red Oil

The applicant has adopted a preventive safety strategy to protect the worker, site worker, public, and the environment (revised CAR, Section 5.5.2.4.6.7 and References 8.3.64 and 66). The PSSCs are as follows:
Process Safety Control Subsystem:

- The first safety function is to ensure that temperatures in process vessels are limited to control the rates of reaction and the associated enthalpy effects. The temperature design basis is identified as 135° C (see the revised CAR, Section 8.5.1.5.5). The applicant has subsequently modified this to limiting the steam temperature (used for heating) to 133° C.

- The second safety function is to control the residence time of organic compounds in the presence of oxidizers (e.g., nitric acid) and radiation fields. This controls the quantity of degraded organic compounds in the system (revised CAR, Section 5.5.2.4.6.7). A design basis is not identified.

Chemical Safety Control:

- The first safety function is to limit the quantities of organic compounds entering vessels with oxidizing agents and high temperatures. The applicant has not identified the design basis. Section 8.5.1.5.5 of the revised CAR indicates the applicant is currently evaluating this safety function.

- The second safety function is to ensure that a solvent extraction diluent is used that is not very susceptible to either nitration or radiolysis. The applicant has identified the use of no cyclic hydrocarbons in the diluent as the design bases..

Offgas Treatment System

The safety function is to provide an exhaust path for the removal of gases in process vessels. This allows some reactants (e.g., TBP, HNO_3, NO_x) and products (e.g., butyl nitrate) to leave and evaporative cooling to occur (i.e., from the liquid species evaporating). It also reduces the pressure of the ullage space. In a boiling system, adequate venting usually corresponds to relatively constant temperatures of the mixture. A design basis for venting is not identified in the revised CAR. Subsequent information from the applicant identified a Process Vent System as the PSSC. For closed systems, a second safety function is to provide adequate evaporative cooling to prevent a runaway reaction. The design basis is to provide evaporative cooling capability of 120 % of the combined heat input plus heat generation rates.

The staff notes that subsequent information from the applicant (References 8.3.64 and 8.3.66) makes a greater distinction about open and closed systems than shown in the revised CAR. The applicant initially identified open systems as at atmospheric pressure while closed systems could be pressurized. In the subsequent information, the applicant is basing the definitions on the system's ability to accommodate solvent; an open system can be 100% solvent and use a

non-pressurization correlation for the design basis of the safety function, whereas a closed system cannot be 100% solvent and must use an evaporative cooling correlation.

8.1.2.5.5.2 NRC Review of Red Oil

The staff has reviewed the proposed use of evaporators for waste processing and reagent recovery at the planned facility. The contact between TBP with aqueous solutions of nitric acid and acidic solutions of metal nitrates is intrinsic to the PUREX and similar solvent extraction processes, and evaporator treatment of PUREX streams has been performed safely since the 1950s. However, several destructive events have occurred even in the presence of safety controls and at relatively low temperatures. Extended contact between heated mixtures of TBP and nitric acid, nitrates, and/or heavy metal nitrate salts can form degradation products and intermediates (including nitrated esters and adducts) that may lead to violent exothermic reactions of potentially explosive force under certain conditions (References 8.3.18, 8.3.31, 8.3.36, 8.3.39, and 8.3.41-8.3.43).

Several explosive incidents have occurred in the United States (Savannah River in 1953 and 1975; Hanford in 1953) (Reference 8.3.31, 8.3.42, and 8.3.43), and the former Soviet Union (Tomsk-7 in 1993) (Reference 8.3.9, 8.3.20 and 8.3.35). The Hanford and first Savannah River event involved evaporators undergoing heating with low pressure steam; temperature control was not precise but ranged from 135$^{\beta}$ to 140$^{\beta}$ C. The second Savannah River incident involved a denitrator operating at greater than 150$^{\beta}$ C. It should be noted that the pretreatment step for the denitrator is an evaporator operated with controls and a design basis temperature not exceeding 135$^{\beta}$ C. Thus, the TBP and solvent mixture safely traveled through the evaporator prior to the event in the denitrator. The incident at Tomsk did not involve heated equipment; the reactions started in a tank at a nominal temperature of 50$^{\beta}$ C with an (unknown at the time) organic layer estimated to be at around 90$^{\beta}$ C. Other, less serious incidents have occurred. The resulting safety trend as a result of those events is towards more conservative controls and operating conditions.

The staff notes from its review that these events occurred because of the unanticipated presence (either carryover or accumulation) of the TBP, solvent, and degradation products. The applicant has indicated solvent carryover can be considered as an anticipated event in the facility.

References 8.3.42 and 8.3.43 summarize much of the experimental information that is available to understand the phenomena and establish reasonable controls. Experimental work has replicated portions of the observed phenomena. The important specific reactions are summarized as follows:

- Hydrolysis Reactions (occur slowly - rates increase with temperatures)
- Dealkylation and Nitration Reactions (occur slowly - rates increase with temperature)
- Pyrolysis (becomes significant at about 150$^{\beta}$ C with little or no water present)
- Butyl Alcohol and Butyl Nitrate Nitration/Oxidation Reactions (become significant at 90$^{\beta}$-100$^{\beta}$ C)
- TBP Nitration/Oxidation (becomes significant around 135$^{\beta}$ C)
- Uranium and Plutonium Adduct Reactions (become significant at 150$^{\beta}$-175$^{\beta}$ C):

These reactions evolve large quantities of gases, including the reddish-brown NO_x fumes observed in several red oil events. The chemical reactions are outlined in revised CAR Section

8.5.1.5.2, the degradation mechanisms in Figure 8.5-2, and the degradation products in Table 8-8.

In general, these reactions can occur in aqueous or organic phases. Organic compounds have a greater affinity for and tend to concentrate in the organic phase, if it is present. Organic phases also tend to have poorer heat transfer characteristics than aqueous phases. Radiolysis also produces similar reactions and products, albeit at slower rates. Finally, the staff review found there are three basic routes to the red oil phenomena. If volatile species do not evaporate, the reactions become significant with heating at 90ᴮ-100ᴮ C and reaction runaway at 135ᴮ C. Pyrolysis dominates at higher temperatures if little water is present.

8.1.2.5.5.3 NRC Review of Controls, Limits, and Safety Design Bases Proposed in the Literature:

After a review of the Tomsk accident and additional experimental studies in the early 1990s, DOE researchers have recommended conditions for controlling red oil effects and preventing related explosions at DOE facilities. Paddleford and Fauske (Reference 8.3.41) mentioned the following preventive measures:

- Prevent accumulation of significant masses of TBP.
- Prevent significant interaction with strong nitric acid.
- Stirring (mixing) during additions and sampling.
- Maintaining low temperatures.
- Maintaining cooling system effectiveness.
- Keep TBP/HNO_3 mixed with or thermally coupled to aqueous layers.
- Practical vent sizing (0.005 in2/kg of TBP in HNO_3).

The DOE team recommendations included the following (Reference 8.3.9):

- Adequate venting and relief disks on vessels.
- Adequate mixing.
- Vessel containment.
- Controls with interlocks and independent verification.
- Minimize organic compound accumulations in vessels containing high concentrations of nitric acid.
- Have alarms on temperature and pressure controls.
- Controls and limits on strong oxidants and reductants.

The Tomsk engineers mentioned the following lessons learned (Reference 8.3.9):

- Using tanks capable of withstanding high pressures (20 atm).
- Limit the concentration of added nitric acid (e.g., for pH adjustments) to 6 M or less.
- Limit the total nitric acid concentration to 3 M or less.
- Perform continual air sparging (for mixing).
- Maintain a temperature rise of no more than 13ºF (7ºC) in any organic layers.
- Keep the tank contents below 158ºF (70ºC).
- Provide adequate relief valves and rupture disks.

Hyder (Reference 8.3.42) mentioned the following lessons learned from the incidents and the experimental studies:

- Natural processes provide adequate cooling at temperatures below 176°F (80°C).
- Above this, temperature care should be taken to ensure that adequate cooling is available for the amount of TBP present.
- In well ventilated systems, n-butanol evaporation and convective cooling are sufficient to control the reactions up to about 248°F (120°C) and the decomposition reactions become very rapid in the 266-302°F (130-150°C) range.
- Confined systems and circumstances that can give rise to confined systems should be avoided.
- Limits on TBP mass, concentration, or mass per unit surface area (SRS currently uses a concentration limit of 0.5 percent in the agitated (total) feed to an evaporator).

Hyder (Reference 8.3.43) further elaborated upon potential limits:

- Tanks in which TBP-nitrate complexes are or may be present should be adequately vented. A value of 0.032 cm^2/kg (0.005 in^2/kg) of TBP is mentioned.
- Chemically degraded TBP, or TBP that has sat a long time in the presence of acids or radiation, should be purified before use in solvent extraction.
- Evaporators in which TBP might be introduced should be operated at a controlled temperature and their TBP content should be limited. Local high temperatures should be avoided. No portion or surface of the evaporator should exceed 130°C and operating temperatures substantially lower than this are desirable. If evaporators or heating units must operate at higher temperatures, the means for preventing the introduction of TBP must be correspondingly rigorous.
- Evaporator bottoms and other solutions that may contain TBP should be cooled under conditions that ensure heat removal. Sparging and agitation may also be appropriate.
- Process design and operations should consider the potential for red oil reactions, particularly for nonroutine operations and situations.

The SRS currently operates evaporators in H Canyon (Reference 8.3.69). These evaporators are subjected to DOE Safety Class (i.e., for the public) and Safety Significant (for the workers) controls to prevent a potential red oil runaway reaction and explosion (i.e., frequency under 1E-6/yr). The controls are generally divided into two categories - those that prevent excessive amounts of TBP entering the evaporators and those to prevent overheating. Significantly, the latter include a 120° C temperature limit, a high steam coil pressure interlock, and an alarm for the operator to manually check that the steam flow has been terminated. The staff notes that the 120° C temperature limit corresponds to the normal boiling point of the water-nitric acid azeotroph (Reference 8.3.70).

NFPA 801 (Reference 8.3.24) , under 5-3.2.5.3, states: “In order to ensure the safe operation of process evaporators, such as Plutonium Uranium Reduction and Extraction (PUREX), means shall be provided to prevent entry of excess quantities of water-soluble solvents into the evaporators.” The associated appendix note states: “Experience and experiments have confirmed that using nitric acid during scrap (fuel and PUREX) recovery can result in exothermic reactions of distinctive violence between tributylphosphate and uranyl nitrate, between tributylphosphate and nitric acid, or both.”

Several NRC fuel cycle licensees utilize PUREX processes for uranium recovery and recycle, and waste treatment. These licensees use evaporators as part of their processing. The licensees have internal administrative requirements on temperature (usually less than 194°F (90°C)), steam pressure control (if steam is used for heating), organic content, single phase (i.e., no organic layer), and nitric acid content. Both administrative controls and equipment

(e.g., extra decanters, steam pressure control) are typically used, and formalized in procedures. These usually apply to evaporator and solvent extraction systems, including tankage. These facilities process uranium which presents a lower hazard than MOX. More operator verification (e.g., looking in a tank) is possible with uranium systems due to uranium's lower radiotoxicity as compared to plutonium.

The NRC staff notes that these controls proposed in the literature are more restrictive than those proposed by the applicant.

8.1.2.5.5.4 NRC Staff Conclusions and Findings on Red Oil

The staff review has found that the TBP-nitrate runaway reactions (e.g., red-oil) are similar to many other chemical runaway reactions that occur in the chemical process industry. The red-oil reactions liberate large amounts of thermal energy and non-condensable gases that, if not properly controlled, can rupture process equipment and injure plant personnel. The applicant has proposed an approach based on first principles that involve:

- Use of a non-cyclic hydrocarbon diluent that will not contribute significantly to the formation of degradation products through radiolysis or chemical breakdown.

- Diluent properties related to foaming will be considered to limit possible effects on the vent system used to assure adequate evaporative cooling.

- Control of the amount of TBP degradation products created through radiolysis or hydrolysis by limiting the residence time of organics in process vessels containing oxidizing agents and potentially exposed to high temperatures and in radiation fields.

- Solutions containing organics will be restricted to temperatures within safety limits to control the energy generation rate.

- An adequately sized exhaust path will be provided for aqueous phase evaporative cooling. For closed systems, the vent size will accommodate sufficient mass transfer to prevent initiation of a runaway reaction. A safety margin of 120% of the combined heat input plus heat generation was proposed (Reference 8.3.66).

- Evaporator steam temperature limits of 133EC.

The applicant has also committed to conducting confirmatory experiments to verify or determine the key safety characteristics of several process variables, including: (1) reaction kinetics to determine heat generation rates, (2) diluent foaming - vent size, (3) metal ion effects on the runaway reaction initiation temperature, and (4) allowable residence time to identify the degraded product concentration limits for heat generation (Reference 8.3.66).

The staff notes that the applicant's approach envelopes many, but not all of the published DOE practices. Specifically, DOE facilities control evaporator steam temperatures to 120EC while the applicant is proposing 133EC, which is close to the 135EC initiation temperature (Reference 8.3.64). The applicant is relying adequate evaporative cooling to limit the temperature of the evaporator liquids.
Staff review of the literature found two fundamental contributors to the known red-oil events. The first involved the unexpected presence of TBP and/or degraded products, often accumulated over an extended period of time (months). The applicant has indicated that most

process vessels would be sized to accommodate being filled 100% with TBP and associated degradation products (limited by residence time). However, limits are yet to be established for the evaporators. The second contributor involved either the lack of, or an inadequate process hazard analysis. This issue will be addressed as part of the Integrated Safety Assessment required to support the licensing phase.

The remaining staff concerns focus on four principle areas:

- The evaporator steam temperature design basis of 133EC is close to the runaway reaction initiation temperature of 135EC, presenting a limited margin. Additionally, system impurities can lower the reaction initiation temperature by an undefined amount.

- An adequate safety margin has not been demonstrated for the complete, integrated approach, including temperature and heat removal capacity, and adequate consideration of uncertainties.

- The applicant has stated that the design bases to preclude a runaway reaction must be viewed in the aggregate (Section 8.5.1.5.5 of the revised CAR). However, the significance of the relative contributions of each safety control towards meeting the preventative safety strategy for the "highly unlikely" performance requirements of 10 CFR 70.61, particularly as they apply to open and closed systems, have not been identified.

- Since the applicant has indicated that solvent carryover is an anticipated event, the potential for common mode failure mechanisms that could challenge the venting and heat transfer controls (i.e., impact from organics through foaming, two-phase flow, pressurization, etc.) has to be considered when determining the "highly unlikely" performance requirements of 10 CFR 70.61.

In addition to the above, the staff notes that the applicant is continuing design activities in this area and has identified several action items which apply to the red oil phenomena (References 8.3.32, 8.3.36, and 8.3.66). Consequently, the staff identifies the red oil phenomena as an open item requiring resolution. The applicant should provide additional PSSCs and design bases for addressing the red oil concerns in the evaporators and associated vessels, equipment and piping, and provide adequate margin, or provide adequate justification why the proposed safety strategy, PSSCs, and design bases are acceptable. The red oil phenomena is identified as Open Item CS-01.

8.1.2.5.6 Plutonium (VI) Oxalate

Plutonium can exist in several different oxidation states in aqueous solutions. The most common are the +3, +4, and +6 states. The applicant intends to precipitate plutonium (IV) oxalate and calcine it to the plutonium dioxide powder for subsequent MOX fuel manufacture. Plutonium (VI) forms slowly in nitric acid solutions and may also be present if the valence adjustments are not performed correctly. Upon heating, plutonium (VI) oxalate [$PuO_2C_2O_4$] exhibits an endothermic peak around 142^{8} C due to dehydration (it is usually present as the trihydrate) and a subsequent rapid exothermic peak at circa 219^{8} C associated with oxidation of the oxalate. Section 8.5.1.7 of the revised CAR mentions a potential explosive hazard with plutonium (VI) oxalate introduction into the calcining furnace and its subsequent rapid decomposition. As described in revised CAR Section 5.5.2.4.6.12, the safety strategy is prevention using the PSSC of chemical safety control. The safety function is to perform a measurement of the valency of the plutonium prior to adding oxalic acid to it in the oxalic

precipitation and oxidation unit. If plutonium (VI) is detected, feed would be terminated. The revised CAR also indicates the design basis is to prevent the introduction of plutonium(VI) oxalate into heated equipment where temperatures in excess of 219ß C are credible. In addition, controls will be in place to ensure that temperatures do not exceed 219ß C where plutonium(VI) oxalate might be present (e.g., the oxalic mother liquor recovery unit and the oxalic precipitation and oxidation unit).
The applicant intends to develop a measurement system for plutonium (VI) as part of the final design process. Analytical methods under consideration include ultraviolet-visible spectrum and alpha spectrum spectroscopy, with detection/resolution limits of 1E-5 and 1E-9 M for plutonium (VI), respectively. (References 8.3.64 and 8.3.66)

The applicant also provided information on the design basis for the calciner (References 8.3.64 and 8.3.66). Per Section 11.8 of the revised CAR, the design basis pressure criteria for storage tanks, process columns, and exchangers are the greater of maximum pressure acting at the top of the vessel in normal operating conditions or the maximum pressure acting at the top of the vessel during transient or accident conditions, plus 10%. The applicant commits to the same design basis criteria for the calciner furnace.

The staff notes the detection limits of plutonium(VI) are very low regardless of the method used and effectively prevent significant quantities from entering the calciner (i.e., the safety strategy of prevention). In addition, the design basis of the calciner (the maximum pressure plus 10%) assures that pressure increases from the rapid decomposition of any plutonium(VI) oxalate that remains after detection will not challenge the vessel's integrity. The staff review also found that the highest temperature in any piece of AP equipment other than the calciner is 135E C - this provides a significant margin vis-a-vis the exotherm temperature of around 219 C. The staff finds the approach acceptable for the construction authorization stage.

8.1.2.6 Habitability Issues

The purpose of this section is to review the criterion used by the applicant to ensure the habitability of the facility during routine operations and during an accident or event.

8.1.2.6.1 Design Approach

The applicant proposed standards that would be used as design information for the chemical processes that involve chemicals which could displace oxygen, thus decreasing its concentration in the air.

For operating procedures to avoid asphyxiating atmospheres, the applicant specifies that the high ventilation rates preclude the creation of an asphyxiating atmosphere (Reference 8.3.14). The applicant references the publication P-14 of the Compressed Gas Association (CGA), *"Accident Prevention in Oxygen Rich and Oxygen-Deficient Atmosphere*s,"- as guidance (Reference 8.3.7).

The applicant proposes two standards to assure the quality of breathable air:

- Compressed Gas Association (CGA) G-7.1, Commodity Specification for Air (Reference 8.3.6) and
- American National Standards Institute (ANSI) Z88.2-92, American National Standard for Respiratory Protection (Reference 8.3.2)

The CGA G-7.1 standard states, “The breathing air design will use the ANSI Z88.2-92 standard for respiratory protection as guidance.” It is not clear if the ANSI Z88.2-92 is used as design guidance for the respiratory equipment or for the breathing air system.

The description of the emergency control room air-conditioning system is depicted in Section 11.4.2.7 of the revised CAR. The following functions are attributed to that system:

- Maintain a habitable environment in each of the two emergency control rooms for the facility personnel.

- Provide cooling to the emergency electrical rooms.

The system will include two, 100% capacity air filter trains, one for each emergency control room. Each unit consists of a filtration unit and a booster fan for each intake. Each filter housing contains a hazardous gas removal cartridge and/or an organic vapor cartridge, and high efficiency particulate air (HEPA) filter cartridges. Design bases were not identified by the applicant.

The control strategy is provided as follows:

- Each emergency control room intake is continuously monitored for hazardous chemicals.
- Upon detection of a hazardous chemical above allowable limits, the intake is automatically isolated and switched to the recirculation mode using a filtration unit with HEPA filtration and hazardous gas removal elements.
- An alarm sounds if hazardous chemical concentrations are detected at both intakes.
- The alarm alerts operators to don emergency self-contained breathing apparatuses (SCBAs).

The applicant stated that monitoring would be performed for those chemicals whose unmitigated release could result in control room concentrations exceeding the TEEL-3 limits in revised CAR Table 8-5. The emergency actions (i.e., the control concept, above) would be initiated when the chemical concentrations are at or below the TEEL-3 limit. Specific setpoints would be determined during final design. Initial calculations by the applicant have identified releases of hydrazine or nitrogen tetraoxide as having the potential for resulting in concentrations at or above the TEEL-3 limit. Calculations would be made during final design to verify the list of chemicals monitored.

If a TEEL-3 value is higher than the IDLH value for a given chemical, the applicant intends to provide confirmation in the ISA that the TEEL-3 value provides sufficient time to allow the control room operator to take protective action, or use the IDLH value. The applicant plans on identifying an alternate value (such as TEEL-2) for the limit where no IDLH value exists and the ISA evaluation cannot confirm that the TEEL-3 value provides sufficient time to take protective action.

8.1.2.6.2 Asphyxiating and Hazardous Atmospheres

The excess or lack of oxygen may become the initiators of additional accidents; for example, “non-flammable” materials can become flammable with more oxygen present while operating personnel can suffer anoxia and experience difficulties controlling the plant with less oxygen

present. If the atmospheric concentration of oxygen exceeds 23 percent, it is called an oxygen-rich atmosphere (Reference 8.3.7, see CGA P-14, Section 2.1). An oxygen-deficient atmosphere is one that contains less than 19.5 percent of oxygen (Reference 8.3.7, see CGA P-14, Section 2.2). An atmosphere containing less than 19.5 percent oxygen can cause problems in the cognitive abilities and impair the operational capacity of personnel. Moreover, the exposure to insufficient concentrations of oxygen for a prolonged time may cause convulsions, unconsciousness, and death. It is important to consider that the exposure effects may vary depending on the individual (References 8.3.7 and 8.3.8) .

In terms of the design of rooms and areas, the applicant does not specify design bases for asphyxiating or hazardous atmospheres in the revised CAR Section 11.4.11.16 or in References 8.3.14 and 8.3.5. The applicant only stipulates the following in the RAI response: "During detailed design, individual rooms and areas will be addressed on the case by case basis as necessary to establish if air monitors with alarms are required in some rooms/areas."

As regards exposure limits for chemicals that can cause a hazardous atmosphere, the applicant intends to use the values of TEELs: an updated list of TEELs is provided in the revised CAR and reprinted in this revised DSER (Table 8.6). The staff notes that TEELs were developed for emergency response personnel and situations, and are based upon an exposure period of approximately 1 hour, whereas NRC guidance for control room habitability is based upon a 2 minute exposure (Reference 8.3.29). Staff concerns regarding the values associated with the updated TEELs are discussed in Section 8.1.2.3 of this revised DSER. However, for longer exposure periods such as those in the emergency control room, operator areas, and designated safe havens, different values may be more appropriate (e.g., see References 8.3.21 and 8.3.34).

8.1.2.6.3 Habitability Standards

Regulatory guidance on control room habitability and ventilation systems is summarized as follows:

- <u>Regulatory Guide 1.78: Assumptions in Evaluating the Habitability of a Nuclear Power Plant Control Room During Postulated Hazardous Release (Reference 8.3.29)</u>

  This regulatory guide provides as general guidance for the evaluation of the control room habitability. This document has information about hazardous chemicals and the toxic limits of some components. Although the information included in this document is more qualitative than quantitative, this depicts some information that could be used as the design basis. For example, the approach is based upon detection of hazardous chemical levels exceeding IDLH values. If this occurs, the control room would be isolated and operators would don SCBAs. The document concludes a chemical exposure period not exceeding two minutes at the IDLH value provides sufficient margin (i.e., as compared to the maximum 30 minute exposure assumed in the derivation of IDLH values).

- <u>ANSI/ASHRAE 62-1989: Ventilation for Acceptable Indoor Air Quality (Reference 8.3.1)</u>

  This standard includes tables with information about outdoor air requirements in order to achieve the stipulated indoor air quality. These requirements only apply to some parts of the facility as offices, lobbies, reception areas, cafeterias, conference rooms, restrooms, lockers and dressing rooms, elevators, etc.

Appendix C includes some standards and dose limits that can be used as basis for air pollutants (CO, NO_2, particulate, etc.). The dose limits are depicted in terms of short term exposure limit (STEL), threshold limit value (TLV), and weighted average concentration (TWA). Although this information could be used for the air ventilation design its important to remember that the document specifies that these tables "are not part of the standard," they are "included in the standard only for information purposes."

- *Prehospital Emergency Care & Crisis Intervention* (Reference 8.3.25):

  This document provides guidance for constituents in air considered dangerous for human beings, based upon a 30 minute or longer exposure.

Most of the limits shown in ANSI/ASHRAE 62-1989 are included in 29 CFR 1910.1000, "Air Contaminants," (Reference 8.3.4).

8.1.2.6.4 Staff Conclusions on Habitability

The staff notes that the applicant used values based upon the TEEL-3s submitted in the revised CAR. As noted in Section 8.1.2.3, the staff has concerns about these values. In addition, NRC guidance for control room habitability is based upon a maximum exposure of 2 minutes to the chemicals using IDLH values, as contrasted to the applicant's approach of one-hour exposure standards using values equivalent to TEEL-3s. The staff notes the applicant values are higher for certain hazardous chemicals such as hydrazine, nitric acid, and chlorine. The staff concludes that the applicant has not provided suitable habitability design bases (for oxygen levels, impurities, and hazardous materials) that are consistent with their proposed approach and provide sufficient margin. The staff identifies this as an open item (CS-10).

8.1.2.7 Baseline Design Criteria

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

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

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

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

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

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

8.1.3 Chemical Process Safety Interfaces

It is the applicant's intent to make controls established for chemical safety consistent with those established for radiological safety and criticality safety, along with the associated management measures. Accordingly, the chemical safety program will be conducted under the same elements of programmatic infrastructure described in Chapters 4, 12, and 14 of the revised CAR, and interfaces with the management measures discussed in Chapter 15 of the revised CAR.

8.2 EVALUATION FINDINGS

In revised CAR Chapters 5, 8 and 11, DCS provided design basis information for chemical process safety PSSCs identified for the proposed facility. Based on the staff's review of these revised CAR chapters and supporting information provided by the applicant relevant to chemical process safety, the staff finds that, due to the open items discussed above and listed below, DCS has not met the BDC set forth in 10 CFR 70.64(a)(3) and (a)(5). Further, until the open items are closed, the staff cannot conclude, pursuant to 10 CFR 70.23(b), that the design bases of the PSSCs identified by the applicant will provide reasonable assurance of protection against natural phenomena and the consequences of potential accidents.

The open items are identified as follows:

- The staff concludes that the red oil phenomenon analysis in Chapter 5.5 of the revised CAR is not complete and that the applicant should provide additional PSSCs and design bases for addressing the red oil concerns for all potentially affected units and components or provide adequate justification why the proposed design basis and PSSC are acceptable. At a minimum, this applies to the following areas: purification, solvent recovery, calciner, oxalic mother liquor, acid recovery, and offgas. (Section 8..1.2.5.2.5) (CS-01)

- The staff concludes that the HAN/hydrazine analysis in Chapter 5.5 of the revised CAR is not complete and that the applicant should provide additional PSSCs and design bases for preventing HAN/hydrazine explosions for all potentially affected units and components or provide adequate justification why the proposed design basis and PSSC are acceptable. At a minimum this applies to the following areas: purification, solvent, recovery, offgas. (Section 8.1.2.5.2.3) (CS-02)

- The staff concludes that the HAN/hydrazine analysis in Chapter 5.5 of the revised CAR is not complete and that additional PSSCs and their design bases for preventing hydrazoic acid formation and potential explosions are necessary for all potentially affected units and components. (Section 8.1.2.5.2.3) (CS-03)

- The applicant should provide chemical consequence levels that provide a clear toxicological basis, and provide adequate margin and conservatism (Section 8.1.2.3.1) (CS-05b).

- There are two findings that are related to chemical consequence modeling. The applicant has not justified the use of air speeds significantly below the wind speed in the evaporation calculations and the applicability of the models in the low air velocity region (Section 8.1.2.3) (CS-05b).

- The applicant has not provided a solvent temperature design basis with adequate margin. (Section 8.1.2.5.2.2) (CS-9)

- A suitable design basis for habitability in the Emergency Control Room has not been identified. (Section 8.1.2.6.1)(CS-10)

The following open items in the April 30, 2002, draft Safety Evaluation Report, have been closed: CS-04, CS-05a, CS-06,CS-07, and CS-08. See Appendix B.

The applicant provided information on open item CS-01. Because the information was recently received, the staff has not completed its review.

8.3 REFERENCES

8.3.1 American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE). 62-1989, "Ventilation for Acceptable Indoor Air Quality." ASHRAE: Atlanta, Georgia. 1990.

8.3.2 American National Standards Institute (ANSI). Z88.2-92, "American National Standard for Respiratory Protection." ANSI: New York, New York. 1992.

8.3.3 Bennedict, Pigford, and Levi, *Nuclear Chemical Engineering*. New York, New York: McGraw Hill. 1983.

8.3.4 Code of Federal Regulations, *Title 29, Labor,* Part 1910, "Air Contaminants."

8.3.5 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Requests for Additional Information, Clarifications, and Open Item Mapping into the Construction Authorization Request Revision, November 22, 2002.

8.3.6 Compress Gas Association, Inc. (CGA). G-7.1, Commodity Specification for Air. 1992." CGA: Arlington, Virginia. 1992.

8.3.7 _____. P-14, "Accident Prevention in Oxygen Rich and Oxygen-Deficient Atmospheres." CGA: Arlington, Virginia. 1992.

8.3.8 _____. SB-2-2001, "Oxygen-Deficient Atmospheres." CGA: Chantilly, Virginia 2001.

8.3.9 Department of Energy (U.S.)(DOE). DOE-DP-0120 "Trip Report: Moscow and Tomsk, Russia, June 19-29, 1993." DOE: Washington, D.C. September 1993.

8.3.10 _____. DOE/EH-0555, "Technical Report on Hydroxyloamine Nitrates." DOE: Washington, D.C.

8.3.11 _____. DOE/RL-97-6, "Summary Report - Accident Investigation Board Report on the May 14, 1997 Chemical Explosion at the Plutonium Reclamation Facility, Hanford, Washington." DOE: Washington, D.C. July 26, 1997.

8.3.12 _____. DOE/RL-97-59, "Final Report - Accident Investigation Board Report on the May 14, 1997 Chemical Explosion at the Plutonium Reclamation Facility, Hanford, Washington." DOE: Washington, D.C. July 26, 1997.

8.3.13 _____. DOE Std 1128-98, "Guide of Good /Practices for Occupational Radiological Protection in Plutonium Facilities." DOE: Washington, D.C. June 1, 1998.

8.3.14 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Response to Request for Additional Information, August 31, 2001.

8.3.15 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, January 7, 2002.

8.3.16 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission RE Clarification of Responses to NRC Request for Additional Information, DCS-NRC-000083, February 11, 2002

8.3.17 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, March 8, 2002.

8.3.18 Hou, Y., E.K. Barefield, D.W. Tedder, and S.I. Abdel-Khalik, "Thermal Decomposition of Nitrated Tributyl Nitrate." *Nuclear Technology*. Vol 113, pp. 304-315. March 31, 1996.

8.3.19 Ihde, R, Duke Cogema Stone & Webster, letter to W. Kane, U.S. Nuclear Regulatory Commission, RE. Mixed Oxide Fuel Fabrication Facility—Construction Authorization Request, February 28, 2001.

8.3.20 International Atomic Energy Agency (IAEA). "The Radiological Accident in the Reprocessing Plant at Tomsk." IAEA: Vienna, Austria. 1998.

8.3.21 Malachowski, M.J. *Health Effects of Toxic Substances*. 2nd Edition. Rockville, Maryland: Government Institutes a Division of ABS Group, Inc. 1999.

8.3.22 National Fire Protection Association (NFPA). 50A "Gaseous Hydrogen Systems at Consumer Sites." NFPA: 2000.

8.3.23 _____. 86C, "Industrial Furnaces Using a Special Processing Atmosphere." NFPA: 2000.

8.3.24 _____. 801, "Standard for Fire Protection for Facilities Handling Radioactive Materials. NFPA: 1998.

8.3.25 National Ski Patrol, "Components and Hazardous Atmospheres (Prehospital Emergency Care & Crisis Intervention." 4th Edition. page 349. Brady Morton Series. 1992. <http://www.patrol.org/resource/petri/airgas.html>.

8.3.26 Nuclear Regulatory Commission (U.S.), Washington, D.C. Information Notice 92-14, "Uranium Oxide Fires at Fuel Cycle Facilities." NRC: Washington, D.C. February 21, 1992.

8.3.27 _____. "Memorandum of Understanding between the Nuclear Regulatory Commission and the Occupational Safety and Health Administration: Worker Protection at NRC-licensed Facilities." *Federal Register:* Vol. 53, No. 210, pp. 43950-43951. October 31, 1998.

8.3.28 _____. NUREG-1718, "Standard Review Plan for the Review of an Application for a Mixed Oxide (MOX) Fuel Fabrication Facility." NRC: Washington, D.C. August 2000.

8.3.29 _____. Regulatory Guide 1.78, " Assumptions in Evaluating the Habitability of a Nuclear Power Plant Control Room During Postulated Hazardous Release." NRC: Washington, D.C. 2001.

8.3.30 _____. Draft Regulatory Guide 1114, "Control Room Habitability at Nuclear Power Reactors." NRC: Washington, D.C. 2001.

8.3.31 Oak Ridge National Laboratory (ORNL). ORNL/TM-10798, " The Red Oil Problem and Its Impact on Purex Safety." ORNL: Tennessee. June 16, 1988.

8.3.32 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to E.J. Leeds, NRC, RE 11/27-29/01 In-Office Review Summary of DCS Construction Authorization Request Supporting Documents for the MFFF, December 18, 2001.

8.3.33 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to E.J. Leeds, NRC, RE 2/22/02 Phone Call Summary: DCS Construction Authorization Request Supporting Documents for the MFFF, February 28, 2002.

8.3.34 Proceedings at the American Conference of Governmental Industrial Hygienists. "Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices." 1994.

8.3.35 Proceedings at a Topical Meeting on Safety of the Nuclear Fuel. "Tomsk-7 Nuclear Event: Causes, Consequences, and Lessons Learned." Organization for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA), Cadarache, September 20-21, 1994. OECD/NEA:

8.3.36 Savannah River Site (SRS). DP-1418, "Behavior of Tributyl Phosphate in A-Line Processes." SRS: Savannah River Laboratory. August 1976.

8.3.37 Sitting, Marshall. *World-wide Limits for Toxic and Hazardous Chemicals in Air, Water, and Soil*. New Jersey: Noyes Publications. 1994.

8.3.38 Westinghouse Safety Management Solutions (WSMS). WSMS-SAE-00-0266, “ERPGs and TEELs for Chemicals of Concern: Rev. 17.” WSMS: Aiken, South Carolina. August 20, 2000.

8.3.39 Westinghouse Savannah River Company (WSRC). WSRC-MS-94-0649, “Safe Venting of “Red Oil” Runaway Reactions.” WSRC: Aiken, South Carolina. December 1994.

8.3.40 _____. WSRC-MS-98-00899, “Inventory or Consequence-Based Evaluation of Hazardous Chemicals: Recommendations for DOE Facility Safety Analysis.” WSRC: Aiken, South Carolina.

8.3.41 _____. WSRC-RP-95-259, “Thermal Decomposition of Nitrated Tributyl Phosphate.” WSRC: Aiken, South Carolina. January 1995.

8.3.42 _____. WSRC-TR-94-059, “Safe Conditions for Contacting Nitric Acid or Nitrates with Tri-n-Butyl Phosphate (TBP).” WSRC: Aiken, South Carolina. January 1994.

8.3.43 _____. WSRC-TR-94-0372, “Safe Handling of TBP and Nitrates in the Nuclear Process Industry.” WSRC: Aiken, South Carolina. July 1994.

8.3.44 Nuclear Regulatory Commission (U.S.), Washington, D.C. NUREG/CR-6410, “Nuclear Fuel Cycle Facility Accident Analysis Handbook.” Washington, D.C. March 1998.

8.3.45 Environmental Protection Agency, "ALOHA: Areal Locations of Hazardous Atmospheres, User's Manual," EPA: Washington, DC. January 1999.

8.3.46 Brown, D., U.S. Nuclear Regulatory Commission (NRC), memorandum to E.J. Leeds, NRC, RE 2/21-22/02 In-Office Review Summary of DCS Construction Authorization Request Supporting Documents for the MFFF, March 11, 2001.

8.3.47 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Clarification of Responses to NRC Request for Additional Information, April 23, 2002.

8.3.48 www.epa.gov

8.3.49 American Society of Mechanical Engineers, "ASME Code for Pressure Piping," B31.

8.3.50 American Society of Mechanical Engineers, "Boiler and Pressure Vessel Code, Section VIII, Division 1, Rules for Construction of Pressure Vessels."

8.3.51 www.bnl.gov/scapa/

8.3.52 www.aiha.org

8.3.53 MAGs Reference: USACPPM TG 230A, “Short-Term Chemical Exposure Guideline for Deployed Military Personnel,” Technical Guide, May 1999 Version.

8.3.54 NIOSH Reference: NIOSH Pocket Guide to Chemical Hazards, U.S. Department of Health and Human Services, National Institute foe Occupational Safety and Health, June 1994.

8.3.55 www.cdc.gov/niosh/

8.3.56 Casarett and Douyll's TOXICOLOGY: The Basic Science of Poisons, Second Edition, New York.

8.3.57 Genium's Handbook of Safety, Health, and Environmental Data for Common Hazardous Substances, McGraw-Hill, New York, 1999.

8.3.58 R.J. Lewis, Sr., Sax's Dangerous Properties of Industrial Materials, Ninth Edition, Van Nostrand Reinhold, New York 1996.

8.3.59 D.K. Stumpf, TITAN II: A History of a Cold War Missile Program, The University of Arkansas Press, Fayetteville, 2000.

8.3.60 Vogtle Energy Generation Plant, FSAR-2, Section 2-3-2.

8.3.61 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Responses to Financial Qualification, Fire Safety, Chemical Safety, Aqueous Processing, Material Processing and Ventilation Open Items/Additional NRC Questions on Construction Authorization Request (CAR) Revision, February 18, 2003.

8.3.62 R.C. Pierson, U.S. Nuclear Regulatory Commission (NRC), memorandum to D. Clark Gibbs, U.S. Department of Energy (DOE), RE Estimates of Hydrogen Generation From Wastes at the Proposed, TWRS-P Facility, April 21, 1999.

8.3.63 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to M.N. Leach, NRC, RE August 28-30, 2002 In-Office Review Summary of DCS Construction Authorization Request Supporting Documents for the MFFF, December 31, 2002.

8.3.64 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to M.N. Leach, NRC, RE December 10-12 Meeting Summary: Meeting with DCS to Discuss Mixed Oxide Fuel Fabrication Facility Revised Construction Authorization Report, January 31, 2003.

8.3.65 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to M.N. Leach, NRC, RE January 15-16 Meeting Summary: Meeting with DCS to Discuss Mixed Oxide Fuel Fabrication Facility Revised Construction Authorization Report, March 5, 2003.

8.3.66 Persinko, A., U.S. Nuclear Regulatory Commission (NRC), memorandum to M.N. Leach, NRC, RE February 6-7 Meeting Summary: Meeting with DCS to Discuss Mixed Oxide Fuel Fabrication Facility Revised Construction Authorization Report, March 5, 2003.

8.3.67 40 CFR 68, "Chemical Accident Prevention Provisions," Appendix A.

8.3.68 Y. Nomura, R. Leicht, and P. Ashton, “Fault Tree Analysis of System Anomaly Leading to Red Oil Explosion in Plutonium Evaporator,” Journal of Nuclear Science and Technology, 31 (8), pp 850-860 (August 1994).

8.3.69 R.P. Jones, "A Potential Inadequacy Related to Operator Response Time Potentially Inadequate t Effectively Respond to an Analyzed Condition," U.S. Department of Energy, Occurrence Report Number SR-WSRC-HCAN-2003-0006, March 21, 2003.

8.3.70 Lange’s Handbook of Chemistry, 15th Edition, McGraw-Hill, 1999.

8.3.71 Hastings, P., Duke Cogema Stone & Webster, letter to U.S. Nuclear Regulatory Commission, RE Construction Authorization Request Change Pages, April 10, 2003.

This page intentionally left blank