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6.0 CHEMICAL PROCESS SAFETY

This chapter describes the AREVA Enrichment Services (AES) plan for managing chemical process safety and demonstrating that chemical process safety controls meet the requirements of 10 CFR 70 (CFR, 2008a) thereby providing reasonable assurance that the health and safety of the public and facility employees are protected. The chapter describes the chemical classification process, the hazards of chemicals of concern, process interactions with chemicals affecting licensed material and/or hazardous chemicals produced from licensed material, the methodology for evaluating the consequences of hazardous chemical release, and the chemical safety assurance features.

The Eagle Rock Enrichment Facility (EREF) chemical process safety program meets the acceptance criteria in Chapter 6 of NUREG-1520 (NRC, 2002) and complies with 10 CFR 70.61 (CFR, 2008b), 70.62 (CFR, 2008c) and 70.64 (CFR, 2008d).

The chemical process safety program for the Eagle Rock Enrichment Facility (EREF) is similar to attributes for chemical safety which were submitted for Nuclear Regulatory Commission (NRC) review in the LES license application for the National Enrichment Facility (LES, 2003). The NRC staff evaluated these prior attributes and concluded in NUREG-1827 (NRC, 2005) that the applicant's plan for managing chemical-process safety and chemical-process-safety controls meets the requirements of 10 CFR Parts 30, 40, and 70 (CFR, 2008j; CFR, 2008k; CFR, 2008a), and provides reasonable assurance that the public health and safety, and the environment, will be protected.

There are no substantive differences between the EREF chemical process safety program and measures prescribed for the National Enrichment Facility (NEF). The NEF and EREF differ due to site characteristics including property boundary, facility layout, variations in building and area names, more exterior cylinder storage pads, different building construction types due to differing building code requirements and natural phenomenon hazard (NPH) parameters, as well as minor differences in UF_6 operations and process layout.

The differences in this Chapter are as follows:

- Tables 6.1-1 through 6.1-6 are grouped differently reflecting the changes in site layout and additional exterior cylinder storage locations. Modifications were also made to provide inventories by floor rather than by room in some cases and to aggregate small quantities of hydrocarbon solvents and oil sludges. EREF also did not list waste streams that did not have hazardous classification as they have no potential process safety impact.
- Unlike NEF, the EREF does not have a PFPE oil recovery system (referred to as Fomblin oil recovery for NEF).
- Unlike NEF, the EREF does not have a Chilled Water System. Halocarbon refrigerants will be used for most air cooling. Where water is a heat rejection medium, it is from the Process Water System.
- There are variations in the values used for assessing the severity of UF_6 release to receptors at the controlled area boundary. NEF converted published AEGLs for UF_6 into AEGLs for soluble U to account for the impact that solubility has on chemical toxicity. EREF uses published soluble uranium dose values to account for U toxicity. Both methods are predictive of the health effects expected from low dose soluble uranium uptake. For the postulated accidents, UF_6 will have reacted to form HF and uranyl fluoride and will not exist as UF_6 at the boundary.

- EREF uses the 10-minute AEGL values for assessing worker exposure for all lesser duration worker releases. These values are conservative compared to initial NEF values.

The information provided in this chapter, the corresponding regulatory requirement and the section of NUREG-1520 (NRC, 2002) Chapter 6 in which the NRC acceptance criteria are presented are summarized below:

Information Category and Requirement	10 CFR 70 Citation	NUREG-1520 Chapter 6 Reference
Section 6.1 Chemical Information		
• Properties and Hazards	70.62(c)(1)(ii)	6.4.3.1
Section 6.2 Chemical Process Information		
• General Information	70.65(b)(3)	6.4.3.1
• Design Basis, Materials, Parameters	70.62(b)	6.4.3.1
• Process Chemistry, Chemical Interaction		6.4.3.2
Section 6.3 Chemical Hazards Analysis		
• Methodology, Scenarios, Evaluation	70.65(b)(3)	6.4.3.2
Section 6.4 Chemical Safety Assurance		
• Management, Configuration Control, Design, BDC, Maintenance, Training, Procedures, Audits, Emergency Planning, Incident Investigation	70.65(b)(4)	6.4.3.2 6.4.3.3

6.1 CHEMICAL INFORMATION

This section addresses the criteria utilized to classify all site chemicals based on their potential for harm and as defined by regulatory requirements. It also presents information on the properties of those chemicals.

6.1.1 Chemical Screening and Classification

Table 6.1-1, Chemical Hazard Classification, provides the listing of chemicals that are expected to be in use at the EREF in quantities where they require stored inventory. Chemical formulas in this Chapter utilize subscripting per standard convention. The hazardous classification of each chemical is presented as it is defined in the International Fire Code (IFC), 2006 edition (ICC, 2006). Although not expressly identified as a hazardous classification in the IFC, a column has also been provided to identify chemicals that are radioactive.

Each chemical has been classified into one of three categories (EREF Classes): Chemicals of Concern (Class 1), Interaction Chemicals (Class 2), or Incidental Chemicals (Class 3).

The definition of each classification is provided below.

Tables 6.1-2 through 6.1-6 are the basic chemical inventories for the enrichment-related process structures and support areas at the facility. Each of these tables lists a major facility structure or area and the associated inventory of significant chemicals stored or used for each area. These tables do not include the listing of all incidental effluents, sludges, wastes and waste streams, and other incidental chemicals characterized as Class 3 materials that may be present. These chemicals are not a process safety concern as they have no ability to impact licensed material systems in a manner affecting 10 CFR 70.61 (CFR, 2008b) performance requirements. Inventories of solid wastes, gaseous and liquid effluents, sludges, and other chemical containing waste streams that will be processed and/or discharged are detailed in Chapter 2 of the Environmental Report.

6.1.1.1 Chemicals of Concern (Class 1)

Chemicals of Concern (EREF Class 1) are determined based on one or more characteristics of the chemical and/or the quantity in storage/use at the facility. For licensed material or hazardous chemicals produced from licensed materials, chemicals of concern are those that, in the event of release have the potential to exceed any of the concentrations defined in 10 CFR 70 (CFR, 2008a) as listed below.

<u>High Risk Chemicals of Concern</u>

1. An acute worker dose of 1 Sv (100 rem) or greater total effective dose equivalent.
2. An acute dose of 0.25 Sv (25 rem) or greater total effective dose equivalent to any individual located outside the controlled area.
3. An intake of 30 mg or greater of uranium in soluble form by any individual located outside the controlled area.
4. An acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that:
   - (i) Could endanger the life of a worker, or
   - (ii) Could lead to irreversible or other serious, long-lasting health effects to any individual located outside the controlled area.

Intermediate Risk Chemicals of Concern

1. An acute worker dose of 0.25 Sv (25 rem) or greater total effective dose equivalent.
2. An acute dose of 0.05 Sv (5 rem) or greater total effective dose equivalent to any individual located outside the controlled area.
3. A 24-hour averaged release of radioactive material outside the restricted area in concentrations exceeding 5000 times the values in Table 2 of Appendix B to 10 CFR 20 (CFR, 2008e).
4. An acute chemical exposure to an individual from licensed material or hazardous chemicals produced from licensed material that:
   - (i) Could lead to irreversible or other serious, long-lasting health effects to a worker, or
   - (ii) Could cause mild transient health effects to any individual located outside the controlled area.

Non-Licensed Chemicals of Concern

For those chemicals that are not related to licensed materials, chemicals of concern are those that are listed and handled above threshold quantities of either of the following standards:

1. 29 CFR 1910.119 (CFR, 2008f) – OSHA Process Safety Management
2. 40 CFR 68 (CFR, 2008g) – EPA Risk Management Program.

These chemicals represent, based on their inherent toxic, reactive, or flammable properties, a potential for large, airborne chemical release and/or acute chemical exposure to an individual that:

- (i) Could endanger the life of a worker, or
- (ii) Could lead to irreversible or other serious, long-lasting health effects to any individual located outside the controlled area.

It is noted here, that uranium hexafluoride (UF_6) is the only licensed material-related chemical of concern (EREF Class 1) that will be used at the facility. There are no non-licensed chemicals of concern at the facility.

6.1.1.2 Interaction Chemicals (Class 2)

Interaction chemicals (EREF Class 2) are those chemicals/chemical systems that require evaluation for their potential to precipitate or propagate accidents in chemical of concern (EREF Class 1) systems, but by themselves are not chemicals of concern.

6.1.1.3 Incidental Chemicals (Class 3)

The facility will use other chemicals that are neither chemicals of concern nor interaction chemicals. Some of these incidental chemicals (EREF Class 3) include those that have the potential to result in injurious occupational and/or environmental exposure, but represent no potential for acute exposure to the public and which via their nature, quantity, and/or use, have no potential for impacting chemicals of concern (EREF Class 1).

These chemicals will not be subject to chemical process safety controls. Controls will be placed on incidental chemical storage, use and handling as necessary and as follows:

1. General occupational chemical safety controls will be in place for protection of facility employees in the storage, handling, and use of all chemicals as required by 29 CFR 1910 (CFR, 2008h)
2. Environmental protection controls required to prevent and/or mitigate environmental damage due to spills and discharges and to control anticipated effluents and waste are detailed in Chapter 9, Environmental Protection, and the EREF Environmental Report.

6.1.2 Chemicals of Concern - Properties

This section summarizes the chemical properties for chemicals of concern and their key byproducts.

6.1.2.1 Uranium Hexafluoride - Chemical Properties

6.1.2.1.1 Physical

Uranium hexafluoride (UF_6) is a chemical compound consisting of one atom of uranium combined with six atoms of fluorine. It is the chemical form of uranium that is used during the uranium enrichment process.

UF_6 can be a solid, liquid, or gas, depending on its temperature and pressure. Multiple phases coexist in equilibrium only under exact combinations of temperature and pressure. These properties are shown in Figure 6.1-1, UF_6 Phase Diagram, which presents the different physical forms of UF_6 as a function of temperature and pressure. The three phases are identified as regions on the diagram separated by lines representing a plot of equilibrium combinations of temperature and pressure. These boundaries all converge at one unique point on the diagram, called the triple point, where all three phases coexist in equilibrium. The triple point of UF_6 is 64°C (147°F) and 152 kPa (22 psia).

Liquid UF_6 is formed only at temperatures and pressures greater than the triple point. Below the triple point, solid UF_6 will change phase directly to UF_6 gas (sublimation) when the temperature is raised and/or the pressure is lowered at continuous points along the solid/gas interface line. This will occur without the UF_6 progressing through a liquid phase. Solid UF_6 is a white, dense, crystalline material that resembles rock salt. Both liquid and gaseous UF_6 are colorless.

Pure UF_6 follows its phase diagram consistently regardless of isotopic content. Impurities in a UF_6 cylinder will cause deviations in the normal phase behavior. The most common gaseous impurities in UF_6 feed are air and hydrogen fluoride (HF) which are generated from the reaction of UF_6 with moisture in the air. Since these light gas impurities have a higher vapor pressure than UF_6, their presence can be detected by measuring the static pressure of cylinders and comparing the results to the UF_6 phase diagram (when the UF_6 temperature is known).

UF_6 exhibits significant expansion when going from solid to liquid phase and continues to expand as the liquid temperature increases. This is illustrated in Figure 6.1-2, Densities of Solid and Liquid UF_6. This figure shows that UF_6 expands roughly 53% going from a solid at 21°C (70°F) to a liquid at 113°C (235°F). Department of Transportation cylinder fill limits are based on UF_6 density at 121°C (250°F) and provide five percent ullage or free volume as a safety factor to prevent hydraulic rupture due to heating.

Other physical properties of UF_6 are presented in Table 6.1-7, Physical Properties of UF_6.

6.1.2.1.2 Reactivity

UF_6 does not react with oxygen, nitrogen, carbon dioxide, or dry air, but it does react with water. For this reason, UF_6 is handled in leak tight containers and processing equipment. When UF_6 comes into contact with water, such as the water vapor in the air, the UF_6 and water react, forming hydrogen fluoride (HF) gas and a solid uranium-oxyfluoride compound (UO_2F_2) which is commonly referred to as uranyl fluoride. Additional information on UF_6 reactions with water is provided in Section 6.2.1, Chemistry and Chemical Reactions.

UF_6 is also incompatible with a number of other chemicals including hydrocarbons and aromatics but none of these chemicals are used in or within proximity of UF_6 process systems.

6.1.2.1.3 Toxicological

If UF_6 is released to the atmosphere, the uranium compounds and HF that are formed by reaction with moisture in the air are chemically toxic. Uranium is a heavy metal that, in addition to being radioactive, can have toxic chemical effects (primarily on the kidneys) if it enters the bloodstream by means of ingestion or inhalation. HF is an extremely corrosive gas that can damage the lungs and cause death if inhaled at high enough concentrations. Additional information on the toxicological parameters used for evaluating exposure is provided in Section 6.3, Chemical Hazards Analysis.

6.1.2.1.4 Flammability

UF_6 is not flammable and does not disassociate to flammable constituents under conditions at which it will be handled at the facility.

6.1.2.2 Hydrogen Fluoride - Chemical Properties

Hydrogen fluoride (HF) is not a direct chemical of concern (EREF Class 1), however, it is one of two byproducts of concern that would be developed in the event of most accident scenarios at the facility. Understanding its properties therefore is important in evaluating chemical process conditions.

6.1.2.2.1 Physical

HF can exist as a gas or as a liquid under pressure (anhydrous hydrogen fluoride) or as an aqueous solution of varying strengths (aqueous hydrofluoric acid). HF vapors are colorless with a pungent odor which is detectable at concentrations above 1 ppm. It is soluble in water with a release of heat.

Releases of anhydrous hydrogen fluoride would typically fume (due to the reaction with water vapor) so that any significant release would be visible at the point of release and in the immediate vicinity.

6.1.2.2.2 Reactivity

In both gaseous and aqueous form, HF is extremely reactive, attacking certain metals, glass and other silicon-containing components, leather and natural rubber. Additional information regarding the corrosion properties and metal attack are provided in Section 6.2.1.3, UF_6 and Construction Materials.

6.1.2.2.3 Toxicological

HF in both gaseous and aqueous forms is strongly corrosive and causes severe burns to the skin, eyes and mucous membranes, and severe respiratory irritation.

Inhalation of HF causes an intolerable prickling, burning sensation in the nose and throat, with cough and pain beneath the sternum. Nausea, vomiting, diarrhea and ulceration of the gums may also occur. In low concentrations, irritation of the nasal passages, dryness, bleeding from the nose and sinus disorders may result, while continued exposure can lead to ulceration and perforation of the nasal septum. Exposure to high concentrations can cause laryngitis, bronchitis and pulmonary edema which may not become apparent until 12-24 hours after the exposure.

Chronic exposure to excessive quantities of gaseous or particulate fluoride results in nausea, vomiting, loss of appetite, and diarrhea or constipation. Fluorosis and other chronic effects may result from significant acute exposures. Systemic fluoride poisoning can cause hypocalcaemia which may lead to cardiac arrhythmias and/or renal failure. Chronic exposure to gaseous or particulate fluoride is not expected at the facility.

Skin exposure to concentrated liquid HF will result in aggressive chemical burns. Burns from exposure to dilute solutions (1-20%) of hydrofluoric acid (aqueous HF) or moderate concentrations of vapor may not be immediately painful or visible. Symptoms of skin exposure include immediate or delayed throbbing, burning pain followed by localized destruction of tissue and blood vessels that may penetrate to the bone. Exposure to liquid forms of HF is not expected at the facility.

Ocular exposure to HF causes a burning sensation, redness, and secretion. Splashes of aqueous hydrofluoric acid to the eye rapidly produce conjunctivitis, keratitis, and more serious destructive effects but these are not expected at the facility.

6.1.2.2.4 Flammability

HF is not flammable or combustible. HF can react exothermically with water to generate sufficient heat to ignite nearby combustibles. HF in reaction with certain metals can offgas hydrogen which is flammable. Both of these reactions would be more typical for bulk, concentrated HF interaction where large masses (i.e., bulk HF storage) of material are involved. These types of interactions are not expected at the facility.

6.1.2.3 Uranyl Fluoride - Chemical Properties

Uranyl fluoride (UO_2F_2) is not a direct chemical of concern (EREF Class 1), however, it is the second of two byproducts of concern (HF is the other) that would be developed in the event of a UF_6 release at the facility. Understanding its properties therefore is important in evaluating chemical process conditions.

6.1.2.3.1 Physical

UO_2F_2 is an intermediate in the conversion of UF_6 to a uranium oxide or metal form and is a direct product of the reaction of UF_6 with moisture in the air. It exists as a yellow, hygroscopic solid. UO_2F_2 formation and dispersion is governed by the conditions of the atmosphere in which the release is occurring. UF_6 will be continually hydrolyzed in the presence of water vapor. The resulting UF_6/HF cloud will include UO_2F_2 particulate matter within the gaseous stream. As this stream diffuses into larger volumes and additional UF_6 hydrolysis occurs, UO_2F_2 particulate will

settle on surfaces as a solid flake-like compound. This deposition will occur within piping/equipment, on lower surfaces within enclosures/rooms, and/or on the ground – wherever the UF_6 hydrolysis reaction is occurring.

6.1.2.3.2 Reactivity

UO_2F_2 is reported to be stable in air to 300°C (570°F). It does not have a melting point because it undergoes thermal decomposition to triuranium octoxide (U_3O_8) above this temperature. When heated to decomposition, UO_2F_2 emits toxic fluoride fumes. UO_2F_2 is hygroscopic and water-soluble and will change in color from brilliant orange to yellow after reacting with water.

6.1.2.3.3 Toxicological

UO_2F_2 is radiologically and chemically toxic due to its uranium content and solubility. Once inhaled, uranyl fluoride is easily absorbed into the bloodstream because of its solubility. If large quantities are inhaled, the uranium in the uranyl complex acts as a heavy metal poison that affects the kidneys. Because of low specific activity values, the radiological toxicity of UF_6 and the UO_2F_2 byproduct are typically of less concern than the chemical toxicity.

6.1.2.3.4 Flammability

UO_2F_2 is not combustible and will not decompose to combustible constituents under conditions at which it will be handled at the facility.

6.2 CHEMICAL PROCESS INFORMATION

This section characterizes chemical reactions between chemicals of concern and interaction chemicals and other substances as applicable. This section also provides a basic discussion of the chemical processes associated with UF_6 process systems.

6.2.1 Chemistry and Chemical Reactions

Although the separation of isotopes is a physical rather than chemical process, chemical principles play an important role in the design of the facility. The phase behavior of UF_6 is critical to the design of all aspects of the plant. UF_6 has a high affinity for water and will react exothermically with water and water vapor in the air. The products of UF_6 hydrolysis, solid UO_2F_2 and gaseous HF, are both toxic. HF is also corrosive, particularly in the presence of water vapor. Because this chemical reaction results in undesirable by-products, UF_6 is isolated from moisture in the air through proper design of primary containment (i.e., piping, components, and cylinders).

Other chemical reactions occur in systems that decontaminate equipment, remove contaminants from effluent streams, and as part of other cleansing processes. Side reactions can include the corrosion and deterioration of construction materials, which influences their specification. These reactions are further described below.

6.2.1.1 UF_6 and Water

Liquid and gaseous UF_6 react rapidly with water and water vapor as does the exposed surface of solid UF_6. UF_6 reacts with water so rapidly that the HF formed is always anhydrous when in the presence of UF_6, significantly reducing its corrosive potential in cylinders, piping, and equipment. The reaction of gaseous UF_6 with water vapor at elevated temperatures is shown in Equation 6.2-1.

$$\underset{\text{(gas)}}{UF_6} + \underset{\text{(vapor)}}{2\,H_2O} \rightarrow \underset{\text{(solid)}}{UO_2F_2} + \underset{\text{(gas)}}{4HF} + \text{heat} \qquad \text{(Eq. 6.2-1)}$$

At room temperature, depending on the relative humidity of the air, the products of this reaction are UO_2F_2 hydrates and HF- H_2O fog, which will be seen as a white cloud. A typical reaction with excess water is given in Equation 6.2-2.

$$\underset{\text{(gas)}}{UF_6} + \underset{\text{(vapor)}}{(2+4x)H_2O)} \rightarrow \underset{\text{(solid)}}{UO_2F_2 *2\,H_2O} + \underset{\text{(fog)}}{4HF*x\,H_2O} + \text{heat} \qquad \text{(Eq. 6.2-2)}$$

If, because of extremely low humidity, the HF- H_2O fog is not formed, the finely divided uranyl fluoride (UO_2F_2) causes only a faint haze. UO_2F_2 is a water-soluble, yellow solid whose exact coloring depends on the degree of hydration as well as the particle size.

The heat release for the reaction in Equation 6.2-1 is 288.4 kJ/kg (124 BTU/lbm) of UF_6 gas reacted. The heat release is much larger if the UO_2F_2 is hydrated and HF-H2O fog is formed with a heat release of 2,459 kJ/kg (1,057 BTU/lbm) of UF_6 vapor.

These reactions, if occurring in the gaseous phase at ambient or higher temperatures, are very rapid, near instantaneous. Continuing reactions between solid UF_6 and excess water vapor occur more slowly as a uranyl fluoride layer will form on surface of the solid UF_6 which inhibits the rate of chemical reaction.

UF_6 reactions with interaction chemicals are discussed below. These include chemical reactions associated with lubricants and other chemicals directly exposed to UF_6, as well as

chemicals used capture trace UF_6, uranium compounds, and HF from effluent streams. UF_6 reactions with materials of construction are addressed in Section 6.2.1.3, UF_6 and Construction Material.

6.2.1.2 UF_6 and Interaction Chemicals

The chemistry of UF_6 is significantly affected by its fluorination and oxidation potential. Many of the chemical properties of UF_6 are attributable to the stability of the UO_2++ ion, which permits reactions with water, oxides, and salts containing oxygen-bearing anions such as SO_4--, NO_3--, and CO_3-- without liberation of the O_2 molecule.

The following subsection describes potential chemical interactions between the UF_6 process streams and interaction chemicals. Detailed descriptions of the chemical and/or utility systems utilizing interaction chemicals can be found in Chapter 3, Integrated Safety Analysis Summary.

6.2.1.2.1 PFPE Oil

The reaction of UF_6 with hydrocarbons is undesirable and can be violent. Gaseous UF_6 reacts with hydrocarbons to form a black residue of uranium-carbon compounds. Hydrocarbons can be explosively oxidized if they are mixed with UF_6 in the liquid phase or at elevated temperatures. It is for this reason that non-fluorinated hydrocarbon lubricants are not utilized in any UF_6 system at the EREF.

UF_6 vacuum pumps are lubricated using perfluorinated polyether (PFPE) oil. PFPE oil is inert, fully fluorinated and does not react with UF_6 under any operating conditions.

Small quantities of uranium compounds and traces of hydrocarbons may be contained in PFPE oil used in the UF_6 vacuum pumping systems. The UF_6 degrades in the oil or reacts with trace hydrocarbons to form crystalline compounds – primarily uranyl fluoride (UO_2F_2) and uranium tetrafluoride (UF_4) particles – that gradually thicken the oil and reduce pump capacity.

Unlike NEF, the EREF does not have a PFPE oil recovery system (referred to as Fomblin oil recovery for NEF).

Failures associated with PFPE oil were evaluated in the Integrated Safety Analysis.

6.2.1.2.2 Chemical Traps - Activated Carbon, Aluminum Oxide, and Sodium Fluoride

Adsorption is the attraction of gas molecules to the surface of an activated solid. There are two classifications of adsorption: physical and chemical. At ordinary temperatures, adsorption is usually caused by molecular forces rather than by the formation of chemical bonds. In this type of adsorption, called physical adsorption, very little heat is evolved. If a chemical reaction takes place between the gas and the solid surface, the process is known as chemisorption. In chemisorption, the reaction between surface and gas molecules occurs in a stoichiometric manner and heat is liberated during the reaction.

Chemisorption is used in the removal of UF_6 and HF from gaseous effluent streams. It is also used to remove oil mist from vacuum pumps operating upstream of gaseous effluent ventilation systems. Adsorbent materials are placed on stationary beds in chemical traps downstream of the various cold traps. These materials capture HF and the trace amounts of UF_6 that escape desublimation during feed purification or during venting of residual UF_6 contained in hoses and/or piping that is bled down before disconnection.

The chemical traps are placed in series downstream of the cold traps in the exhaust streams to the Gaseous Effluent Ventilation Systems (GEVS) and may include one or more of a series of two different types of chemical traps. The first type of trap contains a charge of activated carbon to capture the small amounts of UF_6 that escape desublimation. Since chemisorption is a pressure sensitive process, HF is not fully adsorbed on carbon at low pressures. This necessitates a second type of trap containing a charge of aluminum oxide (Al_2O_3) to remove HF from the gaseous effluent stream. One or more of a series of these individual or mixed bed (part activated carbon/part activated alumina) traps is used depending on the process system being served. Additionally, an alumina trap is present on the inlet of the vacuum pumps which discharge to the GEVS to prevent any of the pump oil from migrating back into the UF_6 cold traps.

Chemisorption of UF_6 on activated carbon evolves considerable thermal energy. This is not normally a problem in the chemical traps downstream of the cold traps because very little UF_6 escapes desublimation. If multiple equipment failures and/or operator errors occur, significant quantities of UF_6 could enter the chemical traps containing activated carbon. This could cause significant overheating leading to release. Failures associated with the carbon traps were evaluated in the Integrated Safety Analysis.

Activated carbon cannot be used in the Dump System because the relatively high UF_6 flow rates during this non-routine operation could lead to severe overheating. A chemical trap containing sodium fluoride (NaF) is installed in the contingency dump flow path to trap UF_6. NaF is used because the heat of UF_6 chemisorption on NaF is significantly lower than the heat of UF_6 chemisorption on activated carbon. Failures associated with the NaF traps were evaluated in the Integrated Safety Analysis.

There are no specific concerns with heat of adsorption of either UF_6 or HF with Al_2O_3. Failures associated with the aluminum oxide traps were evaluated in the Integrated Safety Analysis.

The properties of these chemical adsorbents are provided in Table 6.2-1, Properties of Chemical Adsorbents.

6.2.1.2.3 Decontamination – Citric Acid

Contaminated components (e.g., pumps, valves, piping), once they are removed from the process areas, undergo decontamination. Oily parts are washed in a hot water wash that will remove the bulk of oil including residual uranic compounds. Once the hot water wash is complete, citric acid is used to remove residual uranic fluoride compound layers that are present on the component surfaces. The reaction of the uranium compounds with the citric acid solution produces various uranyl citrate complexes. After citric acid cleansing, the decontaminated component is subject to two additional water wash/rinse cycles. The entire decontamination operation is conducted in small batches on individual components.

Decontamination of sample bottles, valves, and flexible connectors is also accomplished using citric acid.

Decontamination was evaluated in the Integrated Safety Analysis. Adequate personnel protective features are in place for safely handling decontamination chemicals and byproducts.

6.2.1.2.4 Nitrogen

Gaseous nitrogen is used in the UF_6 systems for purging and filling lines that have been exposed to atmosphere for any of several reasons including: connection and disconnection of cylinders, preparing lines/components for maintenance, providing an air-excluding gaseous

inventory for system vacuum pumps, and filling the interstitial space of the liquid sampling autoclave (secondary containment) prior to cylinder liquefaction.

The nitrogen system consists of a liquid nitrogen bulk storage vessel, vaporizer, gaseous nitrogen heater, liquid and gaseous nitrogen distribution lines and instrumentation. Liquid nitrogen is delivered by tanker and stored in the storage vessel.

Nitrogen is not reactive with UF_6 in any plant operational condition. Failures of the nitrogen system were evaluated in the Integrated Safety Analysis.

6.2.1.2.5 Silicone Oil

Silicone oil is used as a heat exchange medium for the heating/chilling of various cold traps. This oil is external to the UF_6 process stream in all cases and is not expected to interact with UF_6. Failures in the heating/chilling systems were evaluated in the Integrated Safety Analysis.

6.2.1.2.6 Halocarbon Refrigerants

Halocarbon refrigerants (including R23 trifluoromethane, R404A fluoromethane blend, and R507 penta/trifluoromethane) are used in individual package chillers that will provide cooling of UF_6 cylinders and/or silicone oil heat exchange media for take-off stations and cold traps. These halocarbons were selected due to good heat transfer properties, because they satisfy environmental restrictions regarding ozone depletion, and are non-flammable. All halocarbon refrigerants are external to the UF_6 process stream in all cases and are not expected to interact with UF_6. Failures in the heating/chilling systems were evaluated in the Integrated Safety Analysis.

Unlike NEF, the EREF does not have a Chilled Water System. Halocarbon refrigerants will be used for most air cooling. Where water is a heat rejection medium, it is from the Process Water System.

6.2.1.2.7 Centrifuge Cooling Water

Centrifuge cooling water is provided from the Centrifuge Cooling Water Distribution System. The function of this system is to provide a supply of deionized cooling water to the cooling coils of the centrifuges. This system provides stringent control over the operating temperature of the centrifuges to enable their efficient operation. Centrifuge cooling water is external to the UF_6 process stream in all cases and is not expected to interact with UF_6. Failures in the centrifuge cooling water distribution system were evaluated in the Integrated Safety Analysis.

6.2.1.3 UF_6 and Construction Materials

The corrosion of metallic plant components and the deterioration of non-metallic sealing materials is avoided by specifying resistant materials of construction and by controlling process fluid purity.

Direct chemical attack by the process fluid on metallic components is the result of chemical reactions. In many cases, the affinity of the process fluid for the metal produces metallic compounds, suggesting that rapid destruction of the metal would take place. This is usually prevented by the formation of a protective layer on the surface of the metal.

Deterioration of non-metallic materials is caused by exposure to process fluids and conditions. Materials used in gaskets, valves, flexible hoses, and other sealants must be sufficiently inert to have a useful service life.

UF_6 and some of its reaction products are potentially corrosive substances, particularly HF. UF_6 is a fluorinating agent that reacts with most metals. The reaction between UF_6 and metals such as nickel, copper, and aluminum produces a protective fluoride film over the metal that inhibits further reaction. These materials are therefore relatively inert to UF_6 corrosion after passivation and are suitable for UF_6 service. Aluminum is used as piping material for UF_6 systems because it is especially resistant to corrosion in the presence of UF_6. Carbon steels and stainless steels can be attacked by UF_6 at elevated temperatures but are not significantly affected by the presence of UF_6 at the operating temperatures for the facility.

Light gas impurities such as HF and air are removed from UF_6 during the purification process. Although HF is a highly corrosive substance when in solution with water as aqueous hydrofluoric acid, it contributes very little to metal corrosion when in the presence of UF_6. This is due to the fact that UF_6 reacts with water so rapidly that HF remains anhydrous when in the presence of UF_6.

Corrosion rates of certain metals in contact with UF_6 are presented in Table 6.2-2, UF_6 Corrosion Rates, for two different temperatures. This data was provided in the original Safety Analysis Report for the Claiborne Enrichment Center (LES, 1993).

Resistant metal such as stainless steel are used in valve bellows and flex hoses. Aluminum piping is bent to minimize the use of fittings. Connections are welded to minimize the use of flanges and gaskets. As a standard practice, the use of sealant materials is minimized to reduce the number of potential leak paths.

Non-metallic materials are required to seal connections in UF_6 systems to facilitate valve and instrument replacement as well as cylinder connections. They are also used in valve packing and seating applications. All gasketing and packing material used at the facility will be confirmed as appropriate for UF_6 services. Typical materials that are resistant to UF_6 through the range of plant operating conditions include butyl rubber, Teflon, Viton, and Kel-F.

The materials used to contain UF_6 are provided in Table 6.2-3, Materials of Construction for UF_6 Systems. The cylinders to be used at the facility are standard Department of Transportation approved containers for the transport and storage of UF_6, designed and fabricated in accordance with ANSI N14.1 (ANSI, applicable version). The nominal and minimum (for continued service) wall thickness for cylinders listed in Table 6.2-3, are taken from this standard.

The remaining system materials are relatively inert in the presence of UF_6 and the corrosion rates given in Table 6.2-2, indicate that these materials are acceptable for UF_6 service over the life of the plant.

As shown in Table 6.2-3, the cylinders used to store and transport UF_6 are made of carbon steel. Tails cylinders are stored outside in open air where they are exposed to the elements. Feed and product cylinders will also be stored outside but only for durations consistent with shipping receipt and in-processing (feed) and out-processing and off-site shipment to customers (product). Feed and product cylinders will be subject to short duration exterior storage (months) and will be inspected in accordance with requirements of DOT regulations upon receipt and prior to shipment to customers.

Atmospheric corrosion is determined by the exposure to moisture (e.g., rain, snow, atmospheric humidity) and the impurities in the air (such as sulfur). The corrosion rate on the outside

surfaces of the carbon steel cylinders therefore varies accordingly with these conditions. Carbon steel storage cylinders are painted to provide a corrosion barrier to external elements.

External corrosion can occur on the outside cylinder surface and at interface points such as the contact point with the resting blocks and in skirt depressions (at the cylinder ends). According to a paper entitled Monitoring of Corrosion in ORGDP Cylinder Yards (DOE, 1988), the average corrosion rate experienced by cylinders is less than 0.051 mm/yr (2 mils/yr). This corrosion rate is almost exclusively due to exterior rust on the carbon steel. Another report – Prediction of External Corrosion for Steel Cylinders – 2001 Report (ORNL, 2001) – sampled exterior steel cylinders (30A) at Oak Ridge National Laboratories that had been subject to intermittent contact with the ground and found to have average corrosion rates of approximately 0.041 mm/yr (1.6 mils/yr). These values indicate that the expected service life would be greater than 50 years. These rates are conservative based on the tails storage arrangement at the EREF. Tails cylinders are subject to exterior weather conditions and will be periodically inspected to assess corrosion and corrosion rate.

6.2.2 PROCESS - GENERAL ENRICHMENT PROCESS

Uranium enrichment is the process by which the isotopic composition of uranium is modified. Natural uranium consists of three isotopes, uranium 234 (^{234}U), uranium 235 (^{235}U), and uranium 238 (^{238}U), approximately 0.0058 $^{w}/_{o}$, 0.711 $^{w}/_{o}$ and 99.28 $^{w}/_{o}$ respectively. ^{235}U, unlike ^{238}U, is fissile and can sustain a nuclear chain reaction. Light water nuclear power plants (the type in the United States) normally operate on fuel containing between 2 w/o and 5 $^{w}/_{o}$ ^{235}U (low-enriched uranium); therefore, before natural uranium is used in uranium fuel for light water reactors it undergoes "enrichment."

In performing this enrichment, the EREF will receive and enrich natural uranium hexafluoride (UF_6) feed. The isotopes are separated in gas centrifuges arranged in arrays called cascades.

This process will result in the natural UF_6 being mechanically separated into two streams: (1) a product stream which is selectable up to a maximum 5 $^{w}/_{o}$ ^{235}U enrichment, and (2) a tails stream which is depleted to low percentages of ^{235}U (0.32 w/o on average). No chemical reaction occurs during enrichment. Other processes at the plant include product blending, homogenizing and liquid sampling to ensure compliance with customer requirements and to ensure a quality product.

The enrichment process is comprised of the following major systems:

- UF_6 Feed System
- Cascade System
- Product Take-Off System
- Tails Take-Off System
- Product Blending System
- Product Liquid Sampling System.

UF_6 is delivered to the plant in ANSI N14.1 (ANSI, applicable version) standard 48Y international transit cylinders, which are placed in a feed station and connected to the plant via a common manifold. Heated air is circulated around the cylinder to sublime UF_6 gas from the solid phase. The gas is flow controlled through a pressure control system for distribution to the cascade system at subatmospheric pressure.

Individual centrifuges are not able to produce the desired product and tails concentration in a single step. They are therefore grouped together in series and in parallel to form arrays known as cascades. A typical cascade is comprised of many centrifuges.

UF_6 is drawn through cascades with vacuum pumps and compressed to a higher subatmospheric pressure at which it can desublime in the receiving cylinders. Highly reliable UF_6 resistant pumps will be used for transferring the process gas.

Tails material and product material are desublimed at separate chilled take-off stations. Tails material is desublimed into 48Y cylinders. Product material is desublimed into either 48Y or smaller 30B cylinders.

With the exception of liquid sampling operations, the entire enrichment process operates at subatmospheric pressure. This safety feature helps ensure that releases of UF_6 or HF are minimized because leakage would typically be inward to the system. During sampling operations, UF_6 is liquefied within an autoclave which provides the heating required to homogenize the material for sampling. The autoclave is a rated pressure vessel which serves as secondary containment for the UF_6 product cylinders while the UF_6 is in a liquid state.

There are numerous subsystems associated with each of the major enrichment process systems as well as other facility support and utility systems. These include systems supporting venting, cooling, electrical power, air and water supply, instrumentation and control and handling functions among others.

6.2.3 Process System Descriptions

Detailed system descriptions and design information for enrichment process and process support systems are provided in the EREF Integrated Safety Analysis (ISA) Summary. These descriptions include information on process technology including materials of construction, process parameters (e.g., flow, temperature, pressure, etc.), key instrumentation and control including alarms/interlocks, and items relied on for safety (IROFS).

6.2.4 Utility and Support System Descriptions

The UF_6 Enrichment Systems also interface with a number of supporting utility systems. Detailed system descriptions and design information for these utility and support systems are provided in the EREF ISA Summary. These descriptions include information on process technology including materials of construction; process parameters (e.g., flow, temperature, pressure, etc.), key instrumentation and control including alarms/interlocks, and IROFS.

6.2.5 Safety Features

There are a number of safety features in place to help prevent, detect, and mitigate potential releases of UF_6. Some of these features are classified as IROFS as determined in the ISA. A listing of IROFS associated with process, utility and supporting systems as well as those applicable to the facility and its operations (e.g., administrative controls) is presented in the EREF ISA Summary.

In addition to IROFS, there are other process system features that are intended to protect systems from damage that would result in an economic loss. Many of these features have a secondary benefit of enhancing safety by detecting, alarming, and/or interlocking process equipment – either prior to or subsequent to failures that result in a release of material.

6.3 CHEMICAL HAZARDS ANALYSIS

6.3.1 Integrated Safety Analysis

AES has prepared an Integrated Safety Analysis (ISA) as required under 10 CFR 70.62 (CFR, 2008c). The ISA:

- Provides a list of the accident sequences which have the potential to result in radiological and non-radiological releases of chemicals of concern
- Provides reasonable estimates for the likelihood and consequences of each accident identified
- Applies acceptable methods to estimate potential impacts of accidental releases.

The ISA also:

- Identifies adequate engineering and/or administrative controls (IROFS) for each accident sequence of significance
- Satisfies principles of the baseline design criteria and performance requirements in 10 CFR 70.61 (CFR, 2008b) by applying defense-in-depth to high risk chemical release scenarios
- Assures adequate levels of these controls are provided so those items relied on for safety (IROFS) will satisfactorily perform their safety functions.

The ISA demonstrates that the facility and its operations have adequate engineering and/or administrative controls in place to prevent or mitigate high and intermediate consequences from the accident sequences identified and analyzed.

6.3.2 Consequence Analysis Methodology

This section describes the methodology used to determine chemical exposure/dose and radiochemical exposure/dose criteria used to evaluate potential impact to the workers and the public in the event of material release. This section limits itself to the potential effects associated with accidental release conditions. Potential impacts from chronic (e.g., long-term) discharges from the facility are detailed in the Environmental Report.

6.3.2.1 Defining Consequence Severity Categories

The accident sequences identified by the ISA need to be categorized into one of three consequence categories (high, intermediate, or low) based on their forecast radiological, chemical, and/or environmental impacts. Section 6.1.1, Chemical Screening and Classification, presented the radiological and chemical consequence severity limits defined by 10 CFR 70.61 (CFR, 2008b) for the high and intermediate consequence categories.

To quantify criteria of 10 CFR 70.61 (CFR, 2008b) for chemical exposure, standards for each applicable hazardous chemical must be applied to determine exposure that could: (a) endanger the life of a worker; (b) lead to irreversible or other serious long-lasting health effects to an individual; and (c) cause mild transient health effects to an individual. Per NUREG-1520 (NRC 2002), acceptable exposure standards include the Emergency Response Planning Guidelines (ERPG) established by the American Industrial Hygiene Association and the Acute Exposure Guideline Levels (AEGL) established by the National Advisory Committee for Acute Guideline Levels for Hazardous Substances. The definitions of various ERPG and AEGL levels are contained in Table 6.3-1, ERPG and AEGL Level Definitions.

The exposure severity limits of 10 CFR 70.61 (CFR, 2008b) have been summarized and the values selected for numerical criteria development are presented in Table 6.3-2, Licensed material Exposure Severity Categories. The severity limits defined in this table come from regulation or known reference criteria. Numerical values for applying these severity categories were developed as defined below.

The toxicity of UF_6 is due to its two hydrolysis products, hydrogen fluoride (HF) and uranyl fluoride (UO_2F_2). The toxicological effects of UF_6 as well as these byproducts were previously described in Section 6.1.2. The NEF SAR indicates AEGL and NUREG-1391 (NRC, 1991) values for HF and UF_6 were utilized for evaluation of chemotoxic exposure. At EREF, the AEGL values for HF and UF_6 were utilized for evaluation of chemotoxic exposure. Additionally, since UO_2F_2 is a soluble uranium compound, the values presented in NUREG-1391 (NRC, 1991) were utilized for evaluating soluble uranium (U) exposure in terms of both chemical toxicity and radiological dose. In general, the chemotoxicity of uranium inhalation/ingestions is of more significance than radiation dose resulting from internal U exposure. The ERPG and AEGL values for HF are presented in Table 6.3-3, ERPG and AEGL values for Hydrogen Fluoride. The ERPG and AEGL values for UF_6 are presented in Table 6.3-4, ERPG and AEGL values for Uranium Hexafluoride. The values from NUREG-1391 (NRC, 1991) for soluble uranium are presented in Table 6.3-5, Health Effects from Intake of Soluble Uranium. The values from Table 6.3-5 were selected for evaluating the severity of public (individuals outside the controlled area boundary) exposure to soluble uranium. The methodology calculates the total intake of U without crediting any reduction in uptake that would occur through exhalation and compares this conservative intake against the NUREG-1391 body-burden limit (the amount of uranium that stays in the body). The high consequence limit selected is a 21 mg body burden which represents an exposure threshold causing irreversible or other long-lasting health effects. It is more conservative than the 30 mg intake limit given in 10 CFR 70.61 (2008b). The intermediate consequence limit selected is a 4.06 mg body burden which represents an exposure threshold for transient renal injury or effect.

The uranium intake limits from NUREG-1391 (NRC, 1991) are not applied for worker cases because the worker is more conservatively protected by the UF_6 AEGL limits reflected in Table 6.3-6. At a standard respiration rate, the amount of uranium intake that would occur at AEGL limits is lower than NUREG-1391 values.

Table 6.3-6, Definition of Consequence Severity Categories, summarizes the values used to define consequence severities considering both HF and UF_6 exposures as derived from the AEGL and NUREG-1391 (NRC, 1991) values. The assumptions associated with the application of these values are listed below.

6.3.2.1.1 Worker Exposure Assumptions

Individual accidents are hypothesized as a release of UF_6 into the room of concern over a period of time while a worker is present. The UF_6 is assumed to instantaneously mix in the room free volume, with no leakage producing a constantly increasing concentration until the release stops. The consequence to the worker is computed two ways: with the UF_6 unchanged in chemical form; and with UF_6 completely reacted with the humidity in the air to form HF and UO_2F_2. The exposure is evaluated for: radiation dose via inhalation of uranium in the form of soluble UO_2F_2; chemical toxicity from the inhaled uranium or UF_6; and chemical toxicity from the inhaled HF. The worker exposure duration is independent of the release duration, and the consequences are computed on the time-averaged concentration.

Any release from UF_6 systems/cylinders at the facility would predominantly consist of HF with some potential entrainment of UO_2F_2 particulate. An HF release would cause a visible cloud

and a pungent odor. The odor threshold for HF is less than 1 ppm and the irritating effects of HF are intolerable at concentrations well below those that could cause permanent injury or which produce escape-impairing symptoms. Employees are trained in proper actions to take in response to a release and it can be confidently predicted that workers will take immediate self-protective action to escape a release area upon detecting any significant HF odor. Accordingly, ten-minute AEGL values were used to evaluate worker exposure durations which are 10 minutes or less. These values are conservative compared to initial NEF values. Actual releases would be detected by the worker(s) who can reliably evacuate all areas of concern within the evaluated exposure durations.

Another assumption made in conducting consequence severity analysis is that for releases precipitated by a fire event, only public exposure was considered in determining consequence severity; worker exposures were not considered. The worker is assumed to evacuate the area of concern once the fire is detected by the worker. Fires of sufficient magnitude to cause chemical/radiological release must be of a severity to either have caused failure of a mechanical system/component or involve substantive combustibles containing uranic content. In either case, the space would be untenable for unprotected workers. Sufficient time is available for the worker to reliably detect and evacuate the area of concern prior to release. Fire brigade/fire department members responding to emergencies are required by emergency response procedure (and regulation) to have suitable respiratory and personal protective equipment.

6.3.2.1.2 Public Exposure Assumptions

Potential exposures to members of the public were also evaluated using conservative assumptions for both exposure concentrations and durations. Exposure was evaluated for consequence severity against chemotoxic, radiotoxic, and radiological dose.

Individual accidents are postulated in the same manner as described for the worker case – a release of UF_6 into the room of concern over a period of time with water vapor mixing to form UO_2F_2 and HF. These chemicals escape from the room through the ventilation system and are carried via atmospheric dispersion to the controlled area boundary where exposure to both HF and UO_2F_2 is assumed. UF_6 is assumed to have completely reacted with humidity in the air by the time the material reaches the controlled area boundary, so the UF_6 AEGL values are not applied for the individual at the boundary. The methodology assumes immediate exposure (does not account for the time of chemical transport to the boundary) and the exposure duration to the individual at the controlled area boundary is independent of the release duration. The consequence to the individual at the controlled area boundary is evaluated against: radiation dose via inhalation of uranium in the form of soluble uranyl fluoride; chemical toxicity from the inhaled uranium; and chemical toxicity from the inhaled hydrogen fluoride. The consequences are calculated based on the average concentration over the duration of public exposure which is assumed to be 30 minutes. This is consistent with self-protective criteria for UF_6/HF plumes listed in NUREG-1140 (NRC, 1988).

6.3.2.1.3 Environmental Exposure Assumptions

10 CFR 70.61 (CFR, 2008b) also requires a limit on the amount of material release to the environment irrespective if such a release results in exposure to an individual. The limit is defined as a 24-hour averaged release of radioactive material outside the restricted area in concentrations exceeding 5000 times the values in Table 2 of Appendix B to 10 CFR 20 (CFR, 2008e). This value is only influenced by the amount of uranyl fluoride released (HF is not radioactive) and is further dependent on the enrichment level of the released material. The methodology developed a correlation to airborne concentrations of U at a given enrichment

level. At 6% enrichment, the maximum allowable U concentration value for a 24 hour average concentration is 5.47 mg/m3.

6.3.2.2 Chemical Release Scenarios

The EREF ISA Summary presents the evaluation level chemical release scenarios based on the criteria applied in the ISA. Information on the criteria for the development of these scenarios is also provided in the EREF ISA Summary.

6.3.2.3 Source Term

The methodologies used to determine source term are those prescribed in NUREG/CR-6410 (NRC, 1998) and supporting documents.

6.3.2.3.1 Dispersion Methodology

In estimating the dispersion of chemical releases from the facility, conservative dispersion methodologies were utilized. Site boundary atmospheric dispersion factors were generated using a computer code based on Regulatory Guide 1.145 (NRC, 1982) methodology. The code was executed using five years (2003-2007) of meteorological data collected at Argonne National Lab-West (EBR) which is now identified as MFC (Materials and Fuels Complex), a mesonet station on the Idaho National Laboratory (INL) property that is located 18 kilometers (11 miles) west of the EREF site. This station was judged to be representative of the EREF site because both are located in the Eastern Snake River Plain and have similar climates and topography.

The specific modeling methods utilized follow consistent and conservative methods for source term determination, release fraction, dispersion factors, and meteorological conditions as prescribed in NRC Regulatory Guide 1.145 (NRC, 1982).

For releases inside of buildings, conservative leak path fractions were assumed as recommended by NUREG/CR-6410 (NRC, 1998) and ventilation on and off cases were evaluated for consideration of volumetric dilution and mixing efficiency prior to release to atmosphere.

6.3.2.4 Chemical Hazard Evaluation

This section is focused on presenting potential deleterious effects that might occur as a result of chemical release from the facility. As required by 10 CFR 70 (CFR, 2008a), the likelihood of these accidental releases fall into either unlikely or highly unlikely categories.

6.3.2.4.1 Potential Effects to Workers/Public

The toxicological properties of potential chemicals of concern were detailed in Section 6.2, Chemical Process Information. The EREF ISA Summary presents the evaluation level accident scenarios identified in the Integrated Safety Analysis and presents the potential consequence severities to facility workers or members of the public.

All postulated incidents have been determined to present low consequences to the workers/public, or where determined to have the potential for intermediate or high consequences, are protected with IROFS to values less than the likelihood thresholds required by 10 CFR 70.61 (CFR, 2008b).

6.3.2.4.2 Potential Effects to Facility

All postulated incidents have been determined to present inherently low consequences to the facility. No individual incident scenarios were identified that propagate additional consequence to the facility process systems or process equipment. The impact of external events on the facility, and their ability to impact process systems or equipment of concern is discussed in the EREF ISA Summary.

6.4 CHEMICAL SAFETY ASSURANCE

The facility will be designed, constructed, and operated such that injurious chemical release events are prevented. Chemical process safety at the facility is assured by designing the structures, systems and components with safety margins such that safe conditions are maintained under normal and abnormal process conditions and during any credible accident or external event.

6.4.1 Management Structure and Concepts

The criteria used for chemical process safety encompasses principles stated in NUREG-1601, Chemical Process Safety at Fuel Cycle Facilities (NRC, 1997). It is also supported by concepts advocated in 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals (CFR, 2008f), and 40 CFR, 68, Accidental Release Prevention Requirements (CFR, 2008g), although it is noted here that there are no chemicals at this facility which exceed threshold planning quantities of either standard.

The intent of chemical safety management principles is to identify, evaluate, and control the risk of chemical release through engineered, administrative, and related safeguards.

The chemical safety philosophy for the facility is to apply sufficient control to identify, evaluate, and control the risk of accidental chemical releases associated with licensed material production to acceptable levels in accordance with 10 CFR 70.61(b) and (c) (CFR, 2008b).

The identification and evaluation of chemical release risk has been developed through the conduct of an ISA. The development of these scenarios, and the dispersion analysis and chemical/radiological dose assessment associated with each accident sequence was performed and was conducted in accordance with NUREG/CR-6410, Nuclear Fuel Cycle Facility Accident Analysis Handbook (NRC, 1998) as was described previously in Section 6.3, Chemical Hazards Analysis.

The control of chemical release risk is ensured through numerous features that are described in the following sections.

6.4.2 System Design

The design of chemical process systems includes numerous controls for maintaining safe conditions during process operations. This is accomplished through several means including managing the arrangement and size of material containers and processes, selection and use of materials compatible with process chemicals, providing inherently safer operating conditions (e.g., vacuum handling), providing process interlocks, controls, and alarming within the chemical processes. All of these plant and equipment features help assure prevention of chemical release. Process piping and components, (e.g., centrifuges, traps, vents, etc.) are maintained safe by limits placed on their operating parameters.

With respect to chemical process safety design features recommended in NUREG-1601 (NRC, 1997), this section briefly details the features provided for the UF_6 system which is the only chemical of concern (Class 1) process system.

6.4.2.1 Physical Barriers

Double-Walled Piping and Tanks - The UF_6 system piping operates at subatmospheric pressure throughout the plant except for the liquid sampling operation which is conducted within a

secondary containment autoclave. As such, UF_6 system piping is not double-walled. Criticality design has been addressed for this vessel.

Liquid Confinement Dikes – Dikes are provided in areas where uranic material is present in solution in tankage. Criticality design constraints were applied to these containment areas. Confinement dikes are also present for chemical spillage control in TSB areas.

Glove Boxes – Glove boxes are utilized for a small number of decontamination operations (e.g., sample bottles, flex hoses). They are not needed for other operations as the levels of specific activity are low. To confine potential HF/uranic material effluent, flexible exhaust hoses connected to the GEVS are provided for locations where UF_6 systems will be opened (e.g., hose connect/disconnect, maintenance, etc.) to capture any fumes remaining after purging operations. GEVS flexible exhaust hoses and fume hoods are present in the TSB where uranic material containers are opened during laboratory and waste handling operations.

Splash Shields – There are no areas where bulk liquid hazardous chemicals will be handled. Lab operations with hazardous chemicals will be conducted in hoods and/or with appropriate personnel protective equipment for these small-scale operations.

Fire Walls – Fire walls are provided to separate UF_6 and uranic material handling areas from other areas of the facility.

Protective Cages – Protective barriers are provided to protect UF_6 system susceptible components (e.g., piping, small equipment) in areas where there is major traffic.

Backflow Preventers and Siphon Breaks – Liquid systems with high uranic content (i.e., not trace waste streams) are provided with means to prevent backflow or siphon. For the UF_6 gaseous piping, design features are provided to prevent UF_6 migration into the few systems which are required to be interconnected to UF_6.

Overflow vessel – UF_6 is not handled in liquid form in any continuous process and any batch handling is performed in small lab quantities or in a secondary containment autoclave. For those systems where uranic material is in solution, overflow protection features are provided.

Chemical Traps and Filters - Chemical traps and filters are provided on vent and ventilation systems which capture UF_6 to remove HF and uranic contaminants prior to any discharge to atmosphere.

6.4.2.2 Mitigative Features

Driving Force Controls – Driving force controls are provided to isolate heating/cooling equipment at UF_6 take-off stations and cold traps as well as other uranic material containing systems. Other driving force controls include relief valves and cut-offs on the nitrogen system to protect the UF_6 system from overpressure.

Solenoid and Control Valves – These types of valves are provided to stop and/or regulate the flow of UF_6 in the event of abnormal operating conditions.

Spray Systems – Spray systems are not provided for vapor mitigation of UF_6 systems or system areas due to criticality control requirements. Fire sprinkler systems are provided in select process areas as described in SAR Section 7.5.1.4.

Alarm Systems – Alarm systems are provided which will alarm in the Control Room for abnormal process parameter (e.g., flow, temperature, pressure, level, etc.) conditions in the UF_6 system and some supporting systems. Leak detection is also provided to detect the release of UF_6/HF in the facility GEVS systems and other ventilation systems. Alarm measures are in

place to notify facility employees of the need to evacuate process areas and/or the facility in the event of a serious chemical release.

6.4.2.3 Baseline Design Criteria and Defense in Depth

The ISA demonstrates that the design and construction complies with the baseline design criteria (BDC) of 10 CFR 70.64(a) (CFR, 2008d) and the defense-in-depth requirements of 10 CFR 70.64(b) (CFR, 2008d). The design provides 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. The EREF is not proposing any facility-specific or process-specific relaxations or additions to applicable BDC features.

6.4.3 Configuration Management

Configuration management includes those controls which ensure that the facility design basis is thoroughly documented and maintained, and that changes to the design basis are controlled. This includes the following:

A. That management commitment and staffing is appropriate to ensure configuration management is maintained

B. That proper quality assurance (QA) is in place for design control, document control, and records management

C. That all structures, systems, and components, including IROFS, are under appropriate configuration management.

A more detailed description of the configuration management system can be found in Section 11.1, Configuration Management (CM).

6.4.4 Maintenance

The EREF helps maintain chemical process safety through the implementation of administrative controls that ensure that process system integrity is maintained and that IROFS and other engineered controls are available and operate reliably. These controls include planned and scheduled maintenance of equipment and controls so that design features will function when required. Appropriate plant management is responsible for ensuring the operational readiness of IROFS under this control. For this reason, the maintenance function is closely coupled to operations. The maintenance function plans, schedules, tracks, and maintains records for maintenance activities.

Maintenance activities generally fall into the following categories:

A. Surveillance/monitoring

B. Corrective maintenance

C. Preventive maintenance

D. Functional testing.

A more detailed description of the maintenance program and maintenance management system can be found in Section 11.2, Maintenance.

6.4.5 Training

Training in chemical process safety is provided to individuals who handle licensed materials and other chemicals at the facility. The training program is developed and implemented with input from the chemical safety staff, training staff, and management. The program includes the following:

A. Analysis of jobs and tasks to determine what a worker must know to perform tasks efficiently

B. Design and development of learning objectives based upon the analysis of jobs and tasks that reflect the knowledge, skills, and abilities needed by the worker

C. Design and development of qualification requirements for positions where a level of technical capability must be achieved and demonstrated for safe and reliable performance of the job function

D. Development and implementation of standard and temporary operating procedures

E. Development and implementation of proper inspection, test, and maintenance programs and procedures

F. Development of chemical safety awareness throughout the facility so that all individuals know what their roles and responsibilities are in coordinating chemical release mitigation activities - in support of the Emergency Plan - in the event of a severe chemical release

G. Coordination of chemical process safety training curriculum with that of other areas including, radiological safety, criticality safety, facility operations, emergency response, and related areas.

A more detailed description of the training program can be found in Section 11.3, Training and Qualifications.

6.4.6 Procedures

A key element of chemical process safety is the development and implementation of procedures that help ensure reliable and safe operation of chemical process systems.

Generally, four types of plant procedures are used to control activities: operating procedures, administrative procedures, maintenance procedures, and emergency procedures.

Operating procedures, developed for workstation and Control Room operators, are used to directly control process operations. Operating procedures include:

- Directions for normal operations, including startup and some testing, operation, and shutdown, as well as off-normal conditions of operation, including alarm response
- Required actions to ensure radiological and nuclear criticality safety, chemical safety, fire protection, emergency planning, and environmental protection
- Operating limits, controls and specific direction regarding administrative controls to ensure operational safety
- Safety checkpoints such as hold points for radiological or criticality safety checks, QA verifications, or operator independent verification.

Administrative procedures are used to perform activities that support the process operations, including, but not limited to, management measures such as the following:

- Configuration management
- Nuclear criticality, radiation, chemical, and fire safety
- Quality assurance
- Design control
- Plant personnel training and qualification
- Audits and assessments
- Incident investigations
- Record keeping and document control
- Reporting.

Administrative procedures are also used for:

- Implementing the Fundamental Nuclear Material Control (FNMC) Plan
- Implementing the Emergency Plan
- Implementing the Physical Security Plan
- Implementing the Standard Practice Procedures Plan for the Protection of Classified Matter.

Maintenance procedures address:

- Preventive and corrective maintenance of IROFS
- Surveillance (includes calibration, inspection, and other surveillance testing)
- Functional testing of IROFS
- Requirements for pre-maintenance activity involving reviews of the work to be performed and reviews of procedures.

Emergency procedures address the preplanned actions of operators and other plant personnel in the event of an emergency.

A more detailed description of the procedural development and management program can be found in Section 11.4, Procedures Development and Implementation.

6.4.7 Chemical Safety Audits

Audits are conducted to determine that plant operations are performed in compliance with regulatory requirements, license conditions, and written procedures. As a minimum, they assess activities related to radiation protection, criticality safety control, hazardous chemical safety, fire protection, and environmental protection.

Audits are performed in accordance with a written plan, which identifies and schedules audits to be performed. Audit team members shall not have direct responsibility for the function and area being audited. Team members have technical expertise or experience in the area being audited and are indoctrinated in audit techniques. Audits are conducted on an annual basis on select functions and areas as defined above. The chemical process safety functions and areas will be audited at least triennially.

Qualified staff personnel that are not directly responsible for production activities are utilized to perform routine surveillances/assessments. Deficiencies noted during the inspection requiring

corrective action are forwarded to the manager of the applicable area or function for action. Future surveillances/assessments include a review to evaluate if corrective actions have been effective.

A more detailed description of the audit program can be found in Section 11.5, Audits and Assessments.

6.4.8 Emergency Planning

The EREF has a facility emergency plan and program which includes response to mitigate the potential impact of any process chemical release including requirements for notification and reporting of accidental chemical releases.

The EREF fire brigade/emergency response team is outfitted, equipped, and trained to provide hazardous material response and mitigation commensurate with the requirements of 29 CFR 1910.120, Hazardous waste operations and emergency response (CFR, 2008i) for single initial entry. This includes a technician level qualified entry and backup team, and an incident commander/safety officer. Based on the subatmospheric nature of the plant processes and the ability to isolate most process systems remotely, EREF intends to allow a single entry team (2 members) to perform simple response actions (e.g., drift pinning small leaks, closing a manual valve, or similar) or for purposes of rescuing a worker(s) rendered unconscious from HF exposure. This allows a dedicated backup team for rapid intervention. For purposes of compliance with OSHA, EREF will rely on offsite response agencies to provide medical response support beyond administering oxygen and HF exposure treatment. The offsite response will arrive in a timeframe that will ensure responder safety if entry is required. If an event requires more than one entrant team, EREF will await offsite responders. The safety officer has the additional responsibility to monitor response activities to ensure that moderator concerns are appropriately considered for criticality safety.

The City of Idaho Falls, ID Fire Department (IFFD) is the nearest offsite response agency who can supplement EREF with additional Hazardous Waste Operations and Emergency Response (HAZWOPER) response teams. A baseline needs assessment regarding offsite response determined the IFFD has the needed equipment and training to provide multiple HAZWOPER compliant response teams.

Additional information on emergency response can be found in SAR Section 7.5.2, Fire Emergency Response, and in the EREF Emergency Plan.

6.4.9 Incident Investigation and Corrective Actions

A facility wide incident investigation process exists that includes chemical process related incidents. This process is available for use by any person at the facility for reporting abnormal events and potentially unsafe conditions or activities. Abnormal events that potentially threaten or lessen the effectiveness of health, safety or environmental protection will be identified and reported to and investigated by the Environmental Health, Safety & Licensing Manager. Each event will be considered in terms of its requirements for reporting in accordance with regulations and will be evaluated to determine the level of investigation required. These evaluations and investigations will be conducted in accordance with approved procedures. The depth of the investigation will depend upon the severity of the classified incident in terms of the levels of uranium/chemical released and/or the degree of potential for exposure of workers, the public, or the environment.

A more detailed description of the incident investigation program can be found in Section 11.6, Incident Investigations and Corrective Action Process.

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TABLES

Table 6.1-1 Chemical Hazard Classification [Note 1]
(Page 1 of 2)

Chemical	EREF Class	Formula	Phase(s) Note 2	Radioactive	Toxic	Corrosive	Water Reactive	Flammable	Combustible	Oxidizer	Other	Comments
uranium hexafluoride [Note 3]	1	UF_6	S/L/G	•	•	•	•					
uranic compounds	NA	UO_2F_2, UF_4, U_3O_8,	S/L	•	•	•	•					UF_6 reaction byproducts, deposits & in solution
hydrogen fluoride	NA	HF	G		•	•	•					UF_6 reaction byproduct
sodium fluoride	2	NaF	S		•							granules
aluminum oxide (activated)	2	Al_2O_3	S								•	irritant, powder / granules
carbon (activated)	2	C	S						•			powder / granules
paper, polymers	3		S						•			ventilation filter media, anti-contamination clothing, ion exchange resin, etc.
potassium hydroxide	3	KOH	S		•	•						
phosphate	3		S								•	surfactant, irritant, P-3 Plastoclin 4100 B
scrap metals	3		S	•								contaminated scrap/parts
citric acid	2	$C_6H_8O_4$	S/L			•						crystals & solution (5-10%)
sodium hydroxide	3	NaOH	S/L		•	•						powder & solution (0.1N)
hydrocarbon oils / greases	3	varies	S/L						•			
hydrocarbon sludges	3	varies	S/L						•			
perfluoropolyether fluids	2	varies	L								•	irritant, long chain perfluorocarbons
methylene chloride	3	CH_2Cl_2	L								•	Health hazard
polydimethylsiloxane (silicone oil)	2	varies	L						•			
hydrocarbon / polar solvents and liquids	3	varies	L					•				ethanol, acetone, toluene, petroleum ether, paint, cutting oils
nitric acid	3	HNO_3	L			•						(50-70%) weight concentration
hydrofluoric acid	3	HF (H_2O)	L			•						38% weight concentration
hydrogen peroxide	3	H_2O_2	L							•		
sulfuric acid	3	H_2SO_4	L			•						
phosphoric acid	3	H_3PO_4	L			•						(10-25%) weight concentration

Table 6.1-1 Chemical Hazard Classification [Note 1]
(Page 2 of 2)

Chemical	EREF Class	Formula	Phase(s) Note 2	Radioactive	Toxic	Corrosive	Water Reactive	Flammable	Combustible	Oxidizer	Other	Comments
diesel fuel	3	varies	L						•			generator / vehicle fuel
deionized water	3	H_2O	L			•						
hydrofluorocarbons	3	varies	L/G								•	refrigerant, irritant
nitrogen	2	N_2	L/G								•	asphyxiant, test gas / purge gas
propane	3	C_3H_8	L/G					•				test gas
hydrogen	3	H_2	G					•				test gas
acetylene	3	C_2H_2	G					•				welding gas
oxygen	3	O_2	G							•		test gas / welding gas
argon	3	Ar	G								•	asphyxiant, test gas / welding gas
helium	3	He	G								•	asphyxiant, test gas

Notes:

1: Hazardous material classifications per the International Fire Code (IFC). Radioactive classification has also been included although not identified as a specific IFC classification.

2: Lists the phases applicable based on facility use of chemical; S – solid, L – liquid, G – gas/vapor.

3: Solid UF_6 cylinders also have ullage space containing vapor UF_6 and traces of HF, air, non-condensables and U non-volatiles (<1% total wt)

Table 6.1-2 Chemical Inventory – Separations Building Module (SBM)[Note 1] and Blending, Sampling and Preparation Building (BSPB), contains Security-Related Information Withheld Under 10 CFR 2.390

Table 6.1-3 Chemical Inventory – Centrifuge Assembly Building, contains Security-Related Information Withheld Under 10 CFR 2.390

Table 6.1-4 Chemical Inventory – Technical Support Building (TSB) and Operation Support Building (OSB), contains Security-Related Information Withheld Under 10 CFR 2.390

Table 6.1-5 Chemical Inventory – Mechanical Services Building (MSB) and Electrical Services Building (ESB), contains Security-Related Information Withheld Under 10 CFR 2.390

Table 6.1-6 Chemical Inventory – Exterior Areas, contains Security-Related Information Withheld Under 10 CFR 2.390

Table 6.1-7 Physical Properties of UF_6
(Page 1 of 1)

Property	Value
Sublimation Point at 1.01 bar abs (14.7 psia)	56.6°C (133.8°F)
Triple Point	1.52 bar abs (22 psia) 64.1°C (147.3°F)
Density	
Solid @ 20°C (68°F)	5.1 g/cc (317.8 lb/ft^3)
Liquid @ 64.1°C (147.3°F)	3.6 g/cc (227.7 lb/ft^3)
Liquid @ 93°C (200°F)	3.5 g/cc (215.6 lb/ft^3)
Liquid @ 113°C (235°F)	3.3 g/cc (207.1 lb/ft^3)
Liquid @ 121°C (250°F)	3.3 g/cc (203.3 lb/ft^3)
Heat of Sublimation @ 64.1°C (147.3°F)	135,373 J/kg (58.2 BTU/lb)
Heat of Fusion @ 64.1°C (147.3°F)	54,661 J/kg (23.5 BTU/lb)
Heat of Vaporization @ 64.1°C (147.3°F)	81,643 J/kg (35.1 BTU/lb)
Specific Heat	
Solid @ 27°C (81°F)	477 J/kg/°K (0.114 BTU/lb/°F)
Liquid @ 72°C (162°F)	544 J/kg/°K (0.130 BTU/lb/°F)
Critical Pressure	46.10 bar abs (668.8 psia)
Critical Temperature	230.2°C (446.4°F)

Table 6.2-1 Properties of Chemical Adsorbents
(Page 1 of 1)

Adsorbent (solid)/ Adsorbate (gas)	Heat of Adsorption	Capacity of Adsorption by weight
Activated Carbon/UF_6	293 kJ/kg (126 BTU/lb)	1:1
Activated Carbon/HF	negligible	negligible at low pressure
Aluminum Oxide/UF_6	negligible	0.2:1
Aluminum Oxide/HF	negligible	0.2:1
Activated NaF/UF_6	186 kJ/kg (80 BTU/lb)	1.0-1.5:1
Activated NaF/HF	4,052 kJ/kg (1,742 BTU/lb)	1:0.5

Table 6.2-2 UF_6 Corrosion Rates
(Page 1 of 1)

Material	Corrosion Rate @ 20°C (68°F) per year	Corrosion Rate @ 100°C (212°F) per year
Aluminum	6.6E-7 mm (2.6E-5 mils)	8.4E-5 mm (3.3E-3 mils)
Stainless Steel	1.4E-4 mm (5.5E-3 mils)	0.03 mm (1.2 mils)
Copper	1.2E-4 mm (4.7E-3 mils)	3.3E-3 mm (1.3E-1 mils)
Nickel	< 0.05 mm (< 2.0 mils)	< 0.05 mm (< 2.0 mils)

Table 6.2-3 Materials of Construction for UF_6 Systems
(Page 1 of 1)

Component	Material	Wall Thickness (nominal)	Wall Thickness (minimum)
UF_6 Feed and Tail Cylinders UF_6 Product Storage (Onsite Use Only) (48Y)	Carbon Steel ASTM A516	16 mm (0.625 inch)	12.7 mm (0.5 inch)
UF_6 Product Cylinder (30B)	Carbon Steel ASTM A516	12.7 mm (0.5 inch)	8 mm (0.3125 inch)
Sample Bottle (1S)	Nickel/Monel ASTM B162	1.6 mm (0.0625 inch)	1.6 mm (0.0625 inch)
UF_6 Piping	Aluminum & Stainless Steel	3.7 mm (0.147 inch)	not applicable
UF_6 Valves	Aluminum & Stainless Steel	> 3.7 mm (> 0.147 inch)	not applicable
Cold Trap	Stainless Steel	8 mm (0.315 inch)	not applicable

Table 6.3-1 ERPG and AEGL Level Definitions
(Page 1 of 1)

Emergency Response Planning Guideline (ERPG)		Acute Exposure Guideline Level (AEGL)	
General Definition	Values intended to provide estimates of concentration ranges above which one could be responsibly anticipate observing health effects.	**General Definition**	Threshold exposure limits for the protection of the general public, which are applicable to emergency exposure periods ranging from 10 minutes to 8 hours. It is believed that the recommended exposure levels are applicable to general population including infants and children, and other individuals who may be sensitive and susceptible.
ERPG-1	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing more than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.	**AEGL-1** (non-disabling)	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation or certain asymptomatic, non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.
ERPG-2	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.	**AEGL-2** (disabling)	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects, or an impaired ability to escape.
ERPG-3	The maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.	**AEGL-3** (lethality)	The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Table 6.3-2 Licensed Material Exposure Severity Categories
(Page 1 of 1)

Severity of Consequence	Receptor		
	Worker	**Offsite Public**	**Environment**
Category 3 High Consequence	Radiation Dose: >1 Sievert (100 rem) Chemical Dose: >AEGL-3 for UF_6 >AEGL-3 for HF	Radiation Dose: >0.25 Sievert (25 rem) Chemical Dose: >NUREG 1391 for permanent renal damage >AEGL-2 for HF	No values specified.
Category 2 Intermediate Consequence	Radiation Dose: >0.25 Sievert (25 rem) Chemical Dose: >AEGL-2 for UF_6 >AEGL-2 for HF	Radiation Dose: >0.05 Sievert (5 rem) Chemical Dose: >NUREG 1391 for transient renal injury >AEGL-1 for HF	Radioactive release >5000 times the values in 10 CFR Part 20, Appendix B, Table 2 (24 hour averaged)
Category 3 Low Consequence	Accidents with lower radiological and chemical exposures than those listed above.	Accidents with lower radiological and chemical exposures than those listed above.	Lesser radioactive release than listed above.

Table 6.3-3 ERPG and AEGL Values for Hydrogen Fluoride
(Page 1 of 1)

(Values in mg HF/m^3)

ERPG		AEGL					
	1-hr		10-min	30-min	1-hr	4-hr	8-hr
ERPG-1	1.6	AEGL-1	0.8	0.8	0.8	0.8	0.8
ERPG-2	16.4	AEGL-2	78	28	20	9.8	9.8
ERPG-3	41	AEGL-3	139	51	36	18	18

Table 6.3-4 ERPG and AEGL values for Uranium Hexafluoride
(Page 1 of 1)

Values in mg UF_6/m^3

ERPG		AEGL					
	1-hr		10-min	30-min	1-hr	4-hr	8-hr
ERPG-1	5	AEGL-1	3.6	3.6	3.6	NR	NR
ERPG-2	15	AEGL-2	28	19	9.6	2.4	1.2
ERPG-3	30	AEGL-3	216	72	36	9	4.5

Table 6.3-5 Health Effects of Soluble Uranium
(Page 1 of 1)

Health Effect	Uranium per kg body weight (mg U/kg)	Uranium (mg) in 70 kg person	Uranium Intake (mg) by 70 kg person
50% lethality	1.63	114	230
Threshold for permanent renal damage	0.3	21	40
Threshold for transient renal injury or effect	0.058	4.06	8.3
No effect	0.03	2.1	4.3

Table 6.3-6 Definition of Consequence Severity Categories
(Page 1 of 1)

	Receptor	High Consequence	Intermediate Consequence
Acute Radiological Doses	Worker	>100 rem TEDE	>25 rem TEDE
	Outside Controlled Area	>25 rem TEDE	>5 rem TEDE
Acute Chemical Exposure	Worker	>216 mg UF_6/m^3; >139 mg HF/m^3	>28 mg UF_6/m^3; >78 mg HF/m^3
	Outside Controlled Area (30-min exposure)	>28 mg HF/m^3 >21 mg U intake	>0.8 mg HF/m^3 >4.06 mg U intake
Radiological Release to Environment	Outside Restricted Area	not applicable	>5.47 mg U/m^3 (24-hr average)

FIGURES

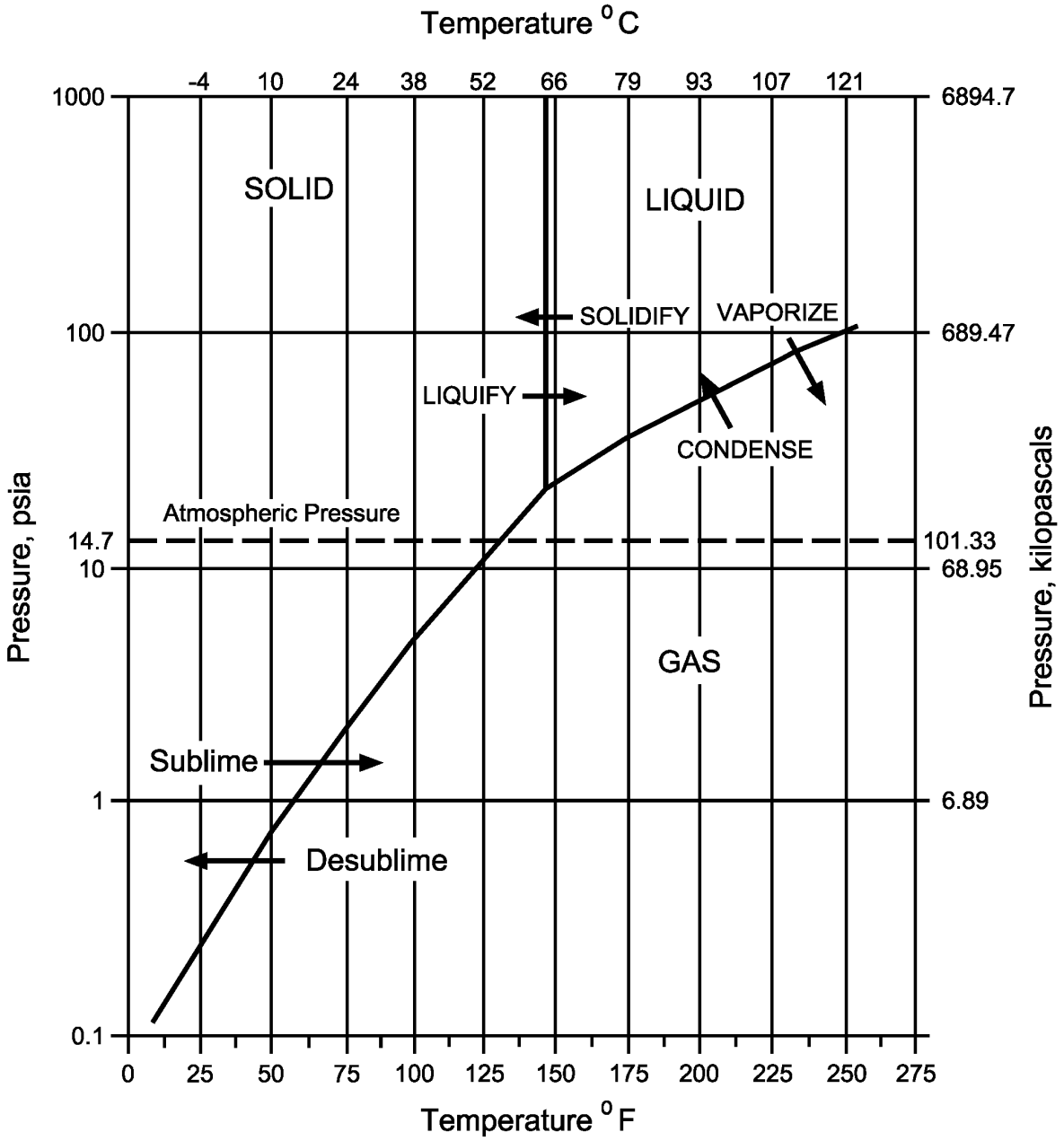

Figure 6.1-1 **Rev. 2**

UF_6 Phase Diagram

EAGLE ROCK ENRICHMENT FACILITY
SAFETY ANALYSIS REPORT

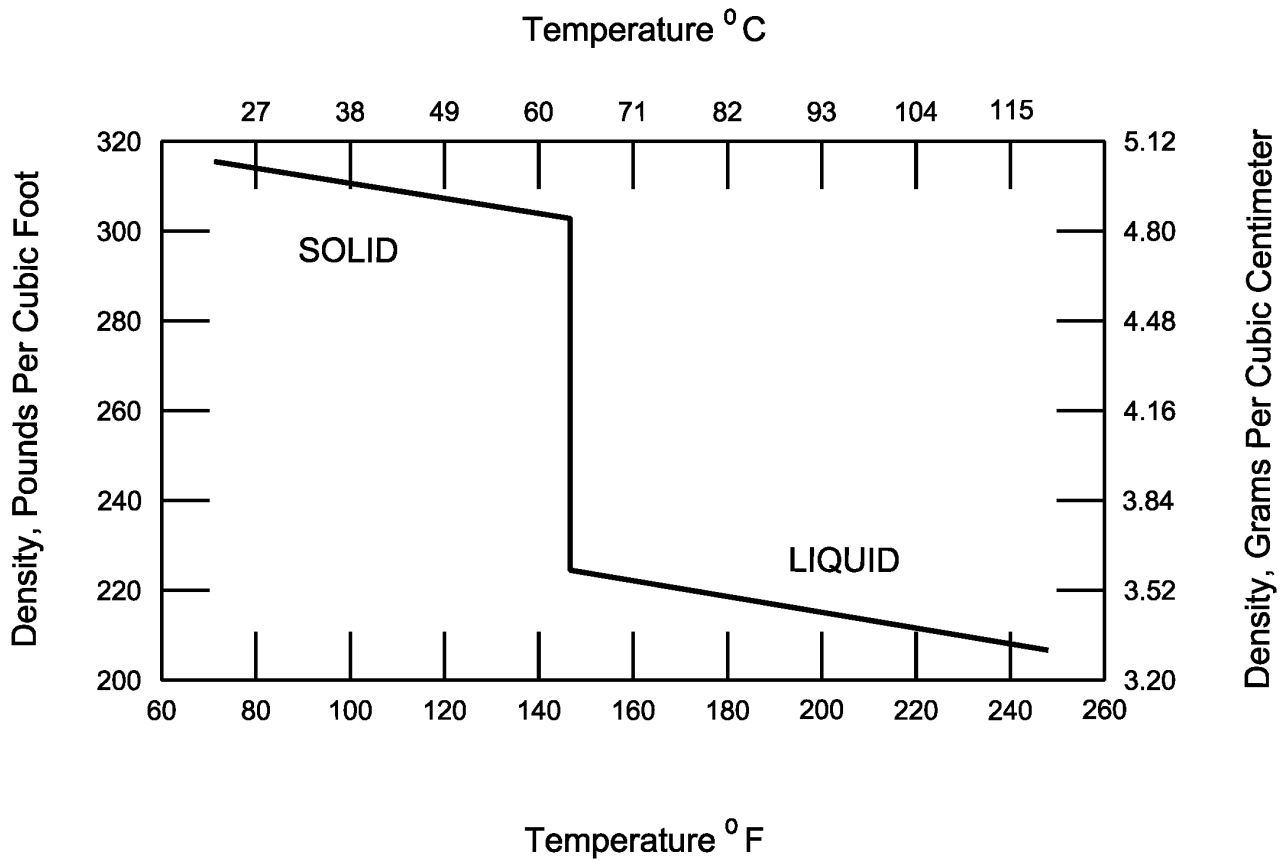

FIGURE 6.1-2 **Rev. 2**

Densities of Solid and Liquid UF_6

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