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3.8 SAFETY SYSTEM CLASSIFICATION

3.8.1 Introduction

Section 3.8 provides details on those facility structures, systems, and components (SSCs) that are classified as Q or AQ as a result of the hazard and accident analysis presented in Chapter 4. SSC classification is based on the criteria for Q and AQ SSCs given in Section 4.2.2.

Chapter 4 provides a description of the methodology used to select the essential controls that are necessary to operate the plant within the appropriate Evaluation Guidelines. The technical basis for determining the SSCs that are necessary to provide these essential controls is derived from the results of the hazard and accident analysis described in Chapter 4. Descriptions are provided of the attributes (i.e., functional requirements and performance criteria) required to support the safety functions identified in the hazard and accident analyses and to support subsequent derivation of the Technical Safety Requirements (TSRs). Information provided in this section includes:

- Identification of Q and AQ SSCs, including their safety functions;
- Identification of support systems necessary for these SSCs to perform their safety functions;
- Identification of the functional requirements necessary for Q and AQ SSCs to perform their required safety functions;
- Identification of the performance criteria necessary to provide reasonable assurance that the functional requirements will be met; and
- Specific classification of Q and AQ portions of SSCs and definition of the overall SSC boundaries.

Systems and controls that are used to prevent criticality are identified in the Nuclear Criticality Safety (NCS) program. Those systems that serve as Active Engineered Features (AEFs) are identified, along with their boundaries, in Section 3.8.10.

Other SSCs were not specifically classified as a result of the hazard and accident analysis but are identified as AQ due to their importance to facility operations. The boundaries for these systems are included in Table 3.8-2.

The application of the graded approach to this chapter provides a guide to determining the classification of SSCs (i.e., Q or AQ) and the level of documentation and analysis needed to support the attributes of the SSCs. As defined in Section 4.2.2, Q SSCs are required to prevent and/or mitigate Evaluation Basis Events (EBEs) that could exceed any EBE off-site EG. AQ SSCs are more concerned with on-site accident consequences (worker safety). In general, because of their importance to the protection of off-site public health and safety, Q SSCs require more formality in establishing functional requirements and performance criteria than do AQ SSCs.

The safety function and functional requirements are defined commensurate with the level of detail from the hazard and accident analysis. For example, the hazard and accident analysis identifies that the compressor motor manual trip system (Section 3.8.3.1) is important to prevent or minimize releases from the cascade in events such as a B-stream block valve closure event. The safety function and functional requirements are developed based on this level of detail to include trip systems associated with all "00" and "000" cell compressor motors, compressor motors in the purge cascade, and interbuilding booster compressor motors. The system evaluation and system classification subsections further delineate the essential portions of the system required to meet the safety functions and functional requirements to include a justification for any exceptions. The boundaries of Q, AQ, and NCS AEF SSCs are provided in Tables 3.8-1, 3.8-2, and 3.8-3, respectively. Support system boundaries are included in the boundaries of the supported SSCs if loss of the support system does not result in the supported SSC failing in a safe manner.

3.8.2 UF_6 Feed Facilities

3.8.2.1 Autoclave Shell High Pressure Containment Shutdown System

3.8.2.1.1 Safety Function

The autoclave shell high pressure containment shutdown system is designed to contain a release of UF_6 inside the autoclave. The system detects high autoclave pressure and isolates all active isolation valves to ensure that the following safety objectives are accomplished:

- The UF_6 primary system temperature for the UF_6 cylinder being heated inside an autoclave is maintained below the temperature that assures an ullage inside the cylinder is maintained.
- The release of UF_6 and its reaction products to the atmosphere from a UF_6 primary system failure inside an autoclave is maintained below the amount that would result in exceeding either the radiological or nonradiological off-site exposure EGs for the EBE category.

3.8.2.1.2 Functional Requirements

The autoclave shell high pressure containment shutdown system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply to the facility.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- The system shall be capable of having two detectors to sense autoclave high pressure.
- Isolation of the autoclave active valves shall be accomplished within 15 seconds from autoclave pressure exceeding the required actuation pressure for the system.

3.8.2.1.3 System Evaluation

The autoclave shell high pressure containment shutdown system was evaluated to assess its ability to accomplish its required safety functions. Two separate calculations were performed to analyze transient conditions involving specific limiting events associated with the safety functions. In addition, a fault tree analysis was performed to determine the system's ability to accomplish the safety functions. The results of these evaluations are provided in this section.

Safety function analysis. The first safety function required of this system is to protect the integrity of the UF_6 cylinder being heated. A review of the autoclave operations determined that the limiting event for evaluating this safety function is autoclave steam control valve fails open (see Section 4.3.2.2.2). For this event, the steam control valve fails open, resulting in a pressure increase (transient) in the autoclave. The primary concern for this event is cylinder overheating, which leads to cylinder overpressure from loss of ullage, and possibly leading to cylinder rupture. Two different evaluations were performed to verify the maximum temperature of the cylinder being heated was maintained below the allowable values. Two different initial conditions were evaluated. The first condition was for a 14-ton, 48G thin-wall cylinder filled to 28,000 lb (12,700 kg) with the maximum allowable noncondensables. This cylinder must be heated to greater than 235°F (112°C) before dropping below 5% ullage based on ANSI N14.1. This evaluation assumed the maximum amount of allowable noncondensables inside the cylinder, all UF_6 is liquified, and the cylinder is filled to 28,000 lb (12,700 kg) to ensure that protection would be provided for the most limiting event. The evaluation also assumed that the initial temperature inside the autoclave is less than 225°F (107°C). The UF_6 cylinder high-temperature autoclave steam shutoff system (see Section 3.8.2.7) ensures that the initial temperature conditions inside the autoclave are maintained. The second initial condition assumed the initial temperature was 240°F (116°C). Although the same cylinder (i.e., 48G thinwall, high-volume) would not be allowed to be heated at this temperature, the heat transfer rates were considered conservative to determine if 250°F (121°C) would be exceeded.

When the steam control valve fails open, a rapid pressure rise occurs inside the autoclave and quickly reaches the 15-psig (205 kPa) actuation pressure of the autoclave high pressure isolation system. The analysis assumes that (1) it takes 15 seconds for the steam isolation valves to terminate the event after the 15 psig (205 kPa) actuation pressure is reached and (2) steam flow into the autoclave remains full until the valves are completely closed. Using a conservative assumption that all of the heat added to the autoclave during the transient is then transferred to the liquid UF_6, the final temperature of the UF_6 would still be less than 235°F (112°C) for the lower initial temperature and less than 250°F(121°C) for the higher initial temperature. The present steam supply isolation valves have a valve-stroke time less than the assumed 15 seconds and are tested periodically to verify that the system can complete an isolation of the steam supply within 15 seconds. Based on this analysis, the autoclave shell high pressure containment shutdown system will prevent the UF_6 primary system pressure from exceeding the allowable temperatures for the most limiting cylinder and worst-case transient, provided the actuation pressure is $\leq$15 psig (205 kPa) and the steam supply valve will close in $\leq$15 seconds after the actuation pressure is reached.

In the event of a UF_6 release inside the autoclave, the second safety function of this system is to limit the release of UF_6 reaction products to the atmosphere to less than the radiological and nonradiological EGs for the EBE category. To accomplish this safety function, the autoclave shell high pressure containment shutdown system works with the autoclave primary containment system to detect high pressure inside the autoclave and close the autoclave containment isolation valves before the release and subsequent exposures exceed these guidelines. A review of the autoclave operations determined that the limiting event for evaluating this safety function is cylinder failure inside the autoclave (see Section 4.3.2.2.14). For this event, the cylinder integrity is lost and UF_6 is released inside the autoclave. The primary concern for this event is isolating the autoclave and limiting the amount of material released to the atmosphere.

To determine the amount of UF_6 released and the consequences of a release, the following initial conditions were assumed. The initial temperature of the UF_6 is assumed to be ≤240°F (116°C), the autoclave is closed and the steam valves are open, UF_6 is completely liquefied and the water level in the autoclave is below the shell of the autoclave at the drain. The only requirement to be addressed for this system is to detect the failure of the UF_6 primary system and accomplish isolation of the autoclave to prevent exceeding the EGs. Once isolation is accomplished, the requirement for containing the reaction products of the release is addressed by the autoclave primary containment system. This event was evaluated in Section 4.3.2.2.14, and the consequences were determined to be below the applicable EGs.

Due to the rapid response of this system upon detection of high autoclave pressure (i.e., 15-seconds isolation), the environmental conditions associated with the system during operation are basically normal operational conditions.

Based on this analysis, the autoclave shell high pressure containment shutdown system will prevent exceeding the off-site EGs for the most limiting UF_6 primary system integrity failure inside an autoclave, provided the actuation pressure is ≤15 psig (205 kPa) and the autoclave isolation valves will close in ≤15 seconds after the actuation pressure is reached.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The ability of the system to meet the required functional requirements is described below. The fault tree analysis concluded that the system can meet the functional requirements described previously. However, some discussion of the specific configuration is warranted.

The autoclave pressure relief line is isolated by a passive rupture disk and a passive relief valve. A second penetration provides vacuum relief and is isolated by an automatic isolation valve and a passive relief valve. No corrective action is necessary because multiple failures are required for a release from either penetration.

The motor buffer has an air supply line and a vent line. The air supply to the motor buffer for the non-upgraded autoclaves has an active isolation valve and a passive check valve. No corrective action is necessary. However, the autoclaves (except for autoclaves 3 & 4, which are no longer used to heat cylinders) have an additional fail-safe containment valve installed on the buffer air supply line. The motor buffer vent line has two isolation valves; however, only one of these receives a signal to close from the autoclave shell high pressure containment shutdown system.

Loss of plant air or AC power will result in failure of the feed control valve (PV-*06) to close on a containment isolation signal. Failure of PV-*06 to isolate the feed header could result in reaction products being fed to the cascade. This would not result in a safety hazard but might cause operational problems in the cascade. This is because the reaction products, HF and UO_2F_2, would be a small quantity relative to the normal cascade feed rates and interstage flows. Therefore, no corrective actions are necessary.

In addition to the fault tree analysis for isolation of all autoclave penetrations, the autoclave hydraulic system was reviewed to ensure that the autoclave shell could not be opened while an isolation signal was present. The review identified a potential capability for opening an autoclave after a UF_6 release event has occurred. The potential capability is under administrative control and is interlocked with the autoclave locking ring interlock system (see Section 3.8.2.6). Issue 3 of the Compliance Plan addresses other deficiencies that would prevent the system from accomplishing the required safety function (only applicable to autoclaves 3 & 4 which are no longer used for cylinder heating).

Based on the above discussions, the autoclave shell high pressure containment shutdown system can perform its required safety functions, except for the conditions identified.

3.8.2.1.4 System Classification

The autoclave shell high pressure containment shutdown system is required to perform the following functions:

- Prevent a cylinder failure inside the autoclave as a result of overheating the cylinder (e.g., autoclave steam control valve fails open)
- Mitigate releases to the atmosphere from releases inside the autoclave (e.g., a pigtail line failure inside autoclave, or cylinder failure inside an autoclave).

These release events are classified as EBEs whose consequences could exceed the off-site radiological/nonradiological EGs if the autoclave shell high pressure containment shutdown system failed to perform its safety functions. Therefore, the autoclave shell high pressure containment shutdown system meets the criteria for classification as a Q system.

3.8.2.1.5 Boundary

The Q boundaries for the autoclave shell high pressure containment shutdown system are defined in Table 3.8-1.

3.8.2.2 Pigtail Line Isolation System

3.8.2.2.1 Safety Function

The autoclave pigtail line isolation system shall initiate UF_6 line isolation upon operator action to ensure that the release of UF_6 and its reaction products for isolable events outside the autoclave are maintained below the radiological and nonradiological EGs for the EBE category.

3.8.2.2.2 Functional Requirements

The pigtail line isolation system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply to the facility.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- Isolation of the autoclave active valves shall be accomplished within 30 seconds from detection of the release.
- Remote switches shall be located where operator action can be accomplished upon evacuation of the facility.

3.8.2.2.3 System Evaluation

The pigtail line isolation system was evaluated to assess its ability to accomplish its required safety function. A fault tree analysis was performed to determine the system's capability to meet the safety function. The results of the evaluation are provided in this section.

Safety function analysis. The safety function required of this system is to limit the quantity of UF_6 released to less than the radiological and nonradiological EGs for the EBE category. A review of facility operations determined that pigtail/line failure outside autoclave event is the limiting event for this system (see Section 4.3.2.2.10). Specifically, two scenarios could result from this initiating event: (1) rupture of a feed line while feeding a cylinder to the cascade and (2) failure of an evacuation header while heeling a cylinder. For both scenarios, operators in the facility are capable of detecting the release. For significant releases of UF_6, visual detection of the release is easily accomplished due to the reaction products forming smoke.

For each scenario, a rupture in a feed line while feeding a 14-ton cylinder to the cascade results in the worst-case gaseous release (see Section 4.3.2.2.10). The requirements for this system are to provide the capability to isolate the lines within a 30-second time frame after actuation of the system and have accessibility for the operators to actuate the system. Operator response to the event is addressed in Section 4.3.2.2.10. As indicated in the system description (see Section 3.2.1.1.1.2.4), the system can isolate the required valves to perform the required safety function. The environmental conditions associated with this circuitry is not significantly different, other than the "smoke" generated from the reaction of UF_6 and the moist air, than normal operation due to the required response time and the operator. For an evaluation of the remaining functional requirements, see the qualitative fault tree analysis below.

Based on the operator presence in the facility for these types of releases, the pigtail line isolation system can accomplish the required safety functions and prevent exceeding the EBE EGs for the facility.

Qualitative fault tree analysis. In addition to the safety function analysis, a qualitative fault tree analysis was performed in accordance with Section 4.3.1.1.3. The fault tree analysis concluded that the system can meet the functional requirements described previously, with the exception of being independent of 120-VAC power for the facility. However, some discussion of the specific configuration is warranted.

In X-342-A, the handswitches (4 in number) for the system are located at the following locations:

1. One at the feed control panel in the high bay area.
2. One inside the Fluorine Control Room.
3. One at the North East exit door on the outside wall.
4. One at the South Center exit door on the outside wall.

In X-343, the handswitches for the system are located in the control room. Surveillance requirements for these handswitches require periodic operability testing.

Based on the discussion above, the pigtail line isolation system can accomplish its required safety function and meet its functional requirements.

3.8.2.2.4 System Classification

The pigtail line isolation system is required to perform the following safety function:

- Mitigate a line failure outside of the autoclave.

This release event is classified as an EBE whose consequences could exceed the off-site radiological/nonradiological EGs if the pigtail line isolation system fails to perform its safety function. Therefore, the pigtail line isolation system meets the criteria for classification as a Q system.

3.8.2.2.5 Boundary

The Q boundaries for the pigtail line isolation system are defined in Table 3.8-1.

3.8.2.3 Autoclave Primary Containment System

3.8.2.3.1 Safety Function

This system is required to prevent a release of UF_6 from exceeding the off-site radiological and nonradiological EGs for the EBE category during modes when the autoclave is closed.

3.8.2.3.2 Functional Requirements

The autoclave primary containment shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be designed to withstand the evaluation basis earthquake and maintain UF_6 primary system integrity when connected to the UF_6 primary system.
- The system shall be designed to withstand the evaluation basis wind loading and maintain UF_6 primary system integrity when connected to the UF_6 primary system.
- The system shall be designed to withstand the maximum pressure generated after a release of UF_6 should a breach occur during operation without structural failure of the autoclave (other active systems may be considered in combination with this requirement).

- Penetrations to the autoclave shall be protected by one of the following methods: (1) two automatic isolation valves, (2) one valve that is normally closed and manually operated or the autoclave pressure relief system configuration, or (3) a closed piping system outside the autoclave (e.g., instrument lines/instruments) which are rated for the same pressure as the autoclaves.

3.8.2.3.3 System Evaluation

This system is required to prevent a release of UF_6 from exceeding the off-site radiological and nonradiological EGs for the EBE category. As indicated in the functional requirements, there are four different functional requirements associated with meeting the required safety action.

The first and second functional requirements for this system are associated with preventing failure of the UF_6 primary system during earthquakes and high winds. The autoclaves have been evaluated for natural phenomena effects and have been found to meet the functional requirements. Since the integrity of the UF_6 primary system is maintained, there is no requirement to accomplish autoclave isolation during the EBE natural phenomena events.

The last two functional requirements are associated with UF_6 primary system integrity failures occurring inside the autoclave during normal operations. The autoclave is required to minimize the release of the reaction products to the atmosphere to prevent exceeding the EBE EGs. The fourth functional requirement is associated with requiring all penetrations to have isolation capability. Any actions required to meet this requirement are addressed by the analysis presented in Section 3.8.2.1.3. Therefore, this functional requirement is met.

The last functional requirement deals with the autoclave environment after a failure has occurred in the UF_6 primary system. Failure of the autoclave containment boundary could result in an uncontrolled release of UF_6 and its reaction products that exceeds the off-site radiological/nonradiological EGs. A review of the autoclave operations determined that the limiting (bounding) event for evaluating this safety function is cylinder failure (see Section 4.3.2.2.14). For this event, the initial temperature of the UF_6 is assumed to be ≤240°F (116°C), the autoclave is closed and the steam valves are open, UF_6 is completely liquefied, and the water level in the autoclave is below the shell of the autoclave at the drain. These conditions are identical to those described in Section 3.8.2.1.3 for a cylinder failure inside the autoclave. The primary concern for this event is the pressure rise inside the autoclave due to the reaction of UF_6 and steam. A large UF_6 release into an autoclave could threaten the MAWP of the autoclave.

Two different sources of water are available inside an autoclave to react with a postulated release of UF_6. The first source is the steam supply for heating the autoclave. Assuming a 100-psig (791 kPa) steam supply [PORTS is currently limited to 60 psig], the flow of steam into the autoclave is prevented when the pressure in the autoclave exceeds 100 psig (791 kPa). Therefore, only the moisture allowed into the autoclave prior to its reaching 100 psig (791 kPa) will be available for the reaction with UF_6. Isolation of the steam supply is completed within 15 seconds after 15 psig (205 kPa) is reached in the autoclave by the autoclave shell high pressure containment shutdown system (see Section 3.8.2.1).

The second source of water for reaction with the UF_6 is the steam condensate collecting in the bottom of the autoclave, on the equipment inside the autoclave, and in the drain system. Normal operation of the autoclave requires the drain line to remain open to prevent a buildup of water in the bottom of the autoclave. The autoclave high condensate level shutoff system (see Section 3.8.2.5) provides additional assurance that condensate does not accumulate in the autoclave by detecting a buildup of water in the drain and initiating isolation of the steam supply line. Based on these controls, the amount of water available for reaction with UF_6 is limited to the amount of water that is normally present inside the autoclave during heating conditions. The analysis for this scenario predicted a final pressure that is less than the autoclave's MAWP for all cylinder and autoclave configurations. Based on this analysis, this system will withstand the potential pressures generated after a cylinder failure inside an autoclave provided the initial conditions are maintained.

Although the structural integrity of the autoclave is not threatened by the pressure transient, two other concerns must also be addressed. These are the temperatures associated with the transient and the potential for leakage past the autoclave seal and associated isolation valves. The autoclave design temperature rating is 250°F (121°C). The analysis discussed above also determined the temperature transient associated with the event. Although the reaction products of the release (i.e., HF and UO_2F_2) have a relatively high temperature, the transient is short lived, and very little impact on the temperature of the autoclave shell and valves is experienced. The temperature effects on the autoclave seal were also reviewed and found to be within allowable temperatures. This keeps the autoclave and its components below its design temperature rating. The final area of concern is associated with the leak rate of the autoclave at the elevated pressures/temperatures. A periodic leak-rate test of the autoclave is performed to ensure that the system is capable of maintaining containment if the shell is pressurized. These tests are performed at 90 psig (722 kPa) with an allowable leak rate of 10 psi/hr (69 kPa/hr) or 12 scfm (20.4 m^3/h). These values were considered in the analysis and the source term/consequence was also considered in the accident analysis in Section 4.3.2.2.14 with acceptable results. Based on these analyses, the autoclave primary containment system can accomplish the required safety function and functional requirements.

3.8.2.3.4 System Classification

The autoclave primary containment system, the autoclave vessel and penetrations out to the isolation valves, is required to mitigate the following:

- Releases of UF_6 inside an autoclave (e.g., pigtail line failure inside an autoclave); and
- Releases of UF_6 inside an autoclave due to cylinder failure.

These release events are classified as EBEs whose consequences could exceed the off-site radiological/nonradiological EGs if the autoclave does not maintain integrity. Therefore, the autoclave primary containment system is classified as a Q system.

3.8.2.3.5 Boundary

The Q boundaries for the autoclave primary containment system are defined in Table 3.8-1.

3.8.2.4 UF_6 Primary System

3.8.2.4.1 Safety Function

The UF_6 primary system shall provide UF_6 primary system integrity for the processes that contain gaseous and liquid UF_6.

3.8.2.4.2 Functional Requirements

The UF_6 primary system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be designed to withstand the evaluation basis earthquake and maintain UF_6 primary system integrity.
- The system shall be designed to withstand the evaluation basis wind loading and maintain UF_6 primary system integrity.
- The system shall be designed to withstand the normal operating temperatures and pressures and maintain UF_6 primary system integrity.

3.8.2.4.3 System Evaluation

This system is required to provide UF_6 primary system integrity for the processes that contain gaseous and liquid UF_6. The safety function is accomplished by retaining integrity during normal operations and upset events (e.g., autoclave steam control valve fails open in Section 4.3.2.2.2). The system is designed to withstand normal pressures and temperatures encountered during feed operations. Pressure-reducing devices (i.e., flow control valves, etc.) are used where the design of the UF_6 primary system is not the same value as that encountered inside the cylinder for the autoclaves. Additionally, the pigtails used inside the autoclaves are pressure and leak tested prior to introduction of the UF_6 after each new connection is made.

In addition, the system is required to maintain UF_6 primary system integrity during an evaluation basis earthquake and evaluation basis wind loading. The UF_6 primary system was evaluated to assess its ability to withstand earthquake and high wind events. The results of this evaluation indicated that the UF_6 primary system piping could withstand the wind loadings and any potential impacts from debris. Also, this evaluation showed that the system is capable of performing its safety function following an evaluation basis earthquake. The feed facility UF_6 primary system can accomplish its required safety function.

3.8.2.4.4 System Classification

The UF_6 primary system is required to:

- Prevent a large release of UF_6 to the atmosphere during normal operations; and
- Prevent a large release of UF_6 during upset events that do not specifically address failures of the UF_6 primary system.

An unmitigated liquid/gaseous UF_6 release from a cylinder in an autoclave has the potential to exceed off-site EGs. Therefore, the portions of the UF_6 primary system in the feed facilities up to the second isolation valve meet the criteria for classification as a Q system. Portions of the UF_6 primary system after the second isolation valve to the cascade will only contain gaseous UF_6 and are classified as AQ consistent with the UF_6 primary system in the cascade (see Section 3.8.3.3).

3.8.2.4.5 <u>Boundary</u>

The Q and AQ boundaries for the UF_6 primary system for the feed processes are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.2.5 High Condensate Level Shutoff System

3.8.2.5.1 <u>Safety Function</u>

The high condensate level shutoff system limits the amount of water present inside the autoclave during normal operation to ensure initial conditions are preserved.

3.8.2.5.2 <u>Functional Requirements</u>

The high condensate level shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety functions independent of any support systems.
- The system shall detect condensate levels that exceed the top of the drain at the autoclave shell and isolate sources of the steam to the autoclave.

3.8.2.5.3 <u>System Evaluation</u>

The high condensate level shutoff system was evaluated to assess its ability to accomplish its required safety function. In addition, a qualitative fault tree analysis was performed to determine the system's capability to accomplish the required safety function. The results of these analyses are provided in this section.

Safety function analysis. The required safety function for the high condensate level shutoff system is to maintain the initial condition assumed by the accident analysis: during normal operation, the autoclave drain valves are open to provide a condensate drain path when steam is being applied to the autoclave environment, preventing accumulation of condensate in the drain. The analysis described in Sections 3.8.2.1 and 3.8.2.3 assumed the level of water inside the autoclave is no higher than the top of the drain at the autoclave shell. The detectors in the drain line are located below this assumed elevation. The high condensate level shutoff system accomplishes its safety function by detecting a high condensate level prior to reaching the assumed level and isolating the steam supply to the autoclave.

Therefore, provided the high condensate level shutoff system can detect water levels prior to reaching the top of the drain line, and provided the same system initiates steam line isolation, the safety function is met.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The fault tree analysis concluded that the high condensate level shutoff system can meet the functional requirements described previously.

3.8.2.5.4 System Classification

The high condensate level shutoff system is required to preserve an initial condition of the accident analysis (i.e., limit the initial amount of water present in the autoclave during normal operation); but the system provides no safety function to mitigate the event. Therefore, the high condensate level shutoff system meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.2.1). Therefore, the high condensate level shutoff system is classified as AQ-NCS.

3.8.2.5.5 Boundary

The AQ-NCS boundaries for the high condensate level shutoff system are defined in Table 3.8-3.

3.8.2.6 UF_6 Cylinder High Pressure Autoclave Steam Shutoff System

3.8.2.6.1 Safety Function

The UF_6 cylinder high pressure autoclave steam shutoff system ensures that the following safety functions are accomplished:

- The system ensures that UF_6 will not reach the liquid state in the controlled feeding mode of operation.
- The system minimizes the potential for a loss of UF_6 primary system integrity during upset events that cause a pressure increase in the UF_6 primary system.

3.8.2.6.2 Functional Requirements

The UF_6 cylinder high pressure autoclave steam shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety function independent of any support systems.
- The system shall detect high-cylinder pressure and isolate the sources of steam to the autoclave.

3.8.2.6.3 System Evaluation

The UF_6 cylinder high pressure autoclave steam shutoff system was evaluated to assess its ability to accomplish the required safety function. The results of this evaluation are provided in this section.

The safety function is to maintain the normal operating pressure of the UF_6 primary system below the MAWP of the cylinder, based on the type of cylinder being fed. This function provides direct control of the UF_6 pressure inside the cylinder. The system is designed to detect a cylinder pressure equal to or less than the actuation pressure for the system and to close the steam supply block valves. For the controlled feeding mode, the actuation must occur at ≤22 psia (152 kPa). This maximum initial pressure is assumed in the controlled feeding mode of operation and analysis of each of the initiating events for this operating mode (see Section 4.2.2.3.2). The cylinder with the lowest MAWP is rated for 100 psig (791 kPa). Therefore, the system actuation is set at ≤100 psig (791 kPa) during normal heating cycles. Based on these requirements, the safety function for this system can be accomplished.

3.8.2.6.4 System Classification

The UF_6 cylinder high pressure autoclave steam shutoff system is required to:

- Maintain the initial conditions assumed in the accident analysis for the controlled feeding mode; and
- Minimize the potential for UF_6 primary system integrity failures due to pressure transients.

This minimizes the potential for on-site personnel exposure. However, no credit is taken for this system to mitigate an event to meet off-site EGs for the EBE frequency. Therefore, the UF_6 cylinder high pressure autoclave steam shutoff system meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.2.2). Therefore, the UF_6 cylinder high pressure autoclave steam shutoff system is classified as AQ-NCS.

3.8.2.6.5 Boundary

The AQ-NCS boundaries for the UF_6 cylinder high pressure autoclave steam shutoff system are defined in Table 3.8-3.

3.8.2.7 UF_6 Cylinder High Temperature Autoclave Steam Shutoff System

3.8.2.7.1 Safety Function

The UF_6 cylinder high temperature autoclave steam shutoff system ensures that the UF_6 cylinder temperatures will not exceed the initial conditions assumed for different cylinder types when steam is being supplied to the autoclave environment. It is used to ensure that cylinder hydrostatic or zero ullage limitations will not be exceeded; or, in the case of controlled feeding, to ensure that the UF_6 is not liquified by overheating.

3.8.2.7.2 Functional Requirements

The UF_6 cylinder high temperature autoclave steam shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of any support system.
- The system shall detect high cylinder temperature and close the steam supply block valve.

3.8.2.7.3 System Evaluation

The UF_6 cylinder high temperature autoclave steam shutoff system was evaluated to assess its ability to accomplish its required safety function. In addition, a fault tree analysis was performed to determine the system's capability to accomplish the safety function. The results of these evaluations are provided in this section.

Safety function analysis. The UF_6 cylinder high temperature autoclave steam shutoff system is required to maintain the UF_6 cylinder temperature to below the values assumed in the accident analyses. During normal heating operations (controlled feeding mode excluded), the autoclave is supplied with saturated steam in a pressurized autoclave. The analysis described in Sections 3.8.2.1 and 3.8.2.3 assumed the initial temperature of the UF_6 was no higher than 240°F (116°C) or 225°F (107°C) depending on cylinder category. The UF_6 cylinder high temperature autoclave steam shutoff system accomplishes its safety function by detecting a high cylinder temperature at the assumed value and isolating the steam supply to the autoclave. Therefore, the safety function for this system can be accomplished.

For the controlled feeding mode, the safety function for the UF_6 cylinder high temperature autoclave steam shutoff system is to maintain the cylinder temperature below 147°F (64°C), which corresponds to an internal cylinder pressure of less than 22 psia (152 kPa). At this actuation temperature, the UF_6 cylinder high temperature autoclave steam shutoff system prevents liquefaction of the UF_6 and provides indirect control of the UF_6 pressure inside the cylinder. The initial condition assumed by the accident analysis for each initiating event was that the internal pressure for a cylinder in the controlled feeding mode is 22 psia (152 kPa).

The UF_6 cylinder high temperature autoclave steam shutoff system is designed to detect high cylinder wall temperature and isolate the steam supply to the autoclave. Therefore, the safety function for this system can be accomplished.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The fault tree analysis concluded that the UF_6 cylinder high temperature autoclave steam shutoff system can meet the required functional requirements previously described.

3.8.2.7.4 System Classification

This system is required to perform the following function:

- Preserve initial conditions assumed in the accident analysis (i.e., limit the initial cylinder temperature to ≤240°F [116°C]).

Once an initiating event occurs, the UF_6 cylinder high temperature autoclave steam shutoff system provides no safety function to mitigate the events. Therefore, this system's safety function, preserving the initial temperature conditions of the analysis, meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.2.5). Therefore, the UF_6 cylinder high temperature autoclave steam shutoff system is classified as AQ-NCS.

3.8.2.7.5 Boundary

The AQ-NCS boundaries for the UF_6 cylinder high temperature autoclave steam shutoff system are defined in Table 3.8-3.

3.8.2.8 Autoclave Locking Ring Interlock System

3.8.2.8.1 Safety Function

The autoclave locking ring interlock system prevents opening of the autoclave shell after a release of UF_6 or any time pressure is greater than the actuation pressure, when the containment bypass switch has been actuated and the autoclave pressure is greater than the autoclave high pressure containment shutdown system actuation pressure.

3.8.2.8.2 Functional Requirements

The autoclave locking ring interlock system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- The system shall prevent movement of the autoclave shell when pressure inside the autoclave exceeds the autoclave high pressure containment shutdown system actuation pressure.

3.8.2.8.3 System Evaluation

The autoclave locking ring interlock system was analyzed to assess its ability to accomplish its required safety function. The results of this evaluation are presented below.

Safety function analysis. The safety function required of this system is to prevent opening the autoclave shell following a release of UF_6 inside the autoclave and actuating the containment bypass switch (see Section 3.8.2.1). This system maintains the containment isolation by providing an isolation signal to the hydraulic fluid supply in addition to the one provided by the autoclave shell high pressure containment shutdown system for those autoclaves modified in accordance with Issue 3 of the Compliance Plan (except autoclaves 3 & 4). The signal provided by the autoclave shell high pressure containment shutdown system can be bypassed by the emergency autoclave operation switch. However, the autoclave locking ring interlock system is designed to isolate the hydraulic fluid supply if the pressure inside the autoclave is greater than 0.5 psig (105 kPa) and to provide an interlock against opening the autoclave shell if the autoclave is pressurized (e.g., a release of UF_6 inside the autoclave has occurred). Because the actuation pressure for this system is significantly less than the 15-psig (205-kPa) actuation pressure of the autoclave shell high pressure containment shutdown system, this system will accomplish the required safety function. This interlock will function even if the emergency autoclave operation switch is pressed.

Based on this discussion, the autoclave locking ring interlock system can perform its required safety function.

3.8.2.8.4 System Classification

The autoclave locking ring interlock system is required to:

- Prevent the autoclave from being opened via the emergency autoclave operation switch following a release of UF_6 inside the autoclave.

Failure of the system after a UF_6 release inside the containment could result in significant local effects. Therefore, the autoclave locking ring interlock system meets the criteria for classification as an AQ system.

3.8.2.8.5 Boundary

The AQ boundaries for the autoclave locking ring interlock system are defined in Table 3.8-2.

3.8.2.9 Low Cylinder Pressure Shutoff System

3.8.2.9.1 Safety Function

The autoclave low cylinder pressure shutoff system shall prevent over-pressurization of a UF_6 cylinder during the heating process which could result from a blockage in the UF_6 line between the cylinder and the pressure transmitter (cylinder valve not open).

3.8.2.9.2 System Classification

Although the low cylinder pressure shutoff system does not meet the Q or AQ classification criteria specified in Section 4.2.2, the low cylinder pressure shutoff system is conservatively classified as Q.

3.8.2.9.3 Boundary

The Q boundaries for the low cylinder pressure shutoff system are defined in Table 3.8-1.

3.8.2.10 Autoclave Shell High Pressure Relief System

3.8.2.10.1 Safety Function

The autoclave shell high pressure relief system shall prevent over-pressurization of an autoclave by relieving excess pressure and reclosing of the vent path following a release.

3.8.2.10.2 System Classification

Although the autoclave shell high pressure relief system does not meet the Q or AQ classification criteria specified in Section 4.2.2, the autoclave shell high pressure relief system is conservatively classified as Q.

3.8.2.10.3 Boundary

The Q boundaries for the autoclave shell high pressure relief system are defined in Table 3.8-1.

3.8.2.11 X-343 Cold Trapping Operation Pressure and Temperature Control

3.8.2.11.1 Safety Function

There is the potential for a pressure excursion during the X-343 cold trapping process, if the ClF_3 and R-114 are present in concentration levels that exceed explosive limits. The X-343 cold trapping operation pressure and temperature control shall prevent liquefaction of R-114 and the potential for pressure excursions in the cold trap cylinder.

3.8.2.11.2 System Classification

Although the X-343 cold trapping operation pressure and temperature control system does not meet the Q or AQ classification criteria specified in Section 4.2.2, this system is conservatively classified as AQ.

3.8.2.11.3 Boundary

The AQ boundaries for the X-343 cold trapping operation pressure and temperature control system are defined in Table 3.8-2.

3.8.2.12 X-343 and X-344 Cold Trap Defrost Operation Control

3.8.2.12.1 Safety Function

There is the potential for overfilling a cold trap cylinder and subsequent rupture during the defrost cycle in X-343 and X-344. Controlling the defrost cycle prevents heating a cold trap cylinder to temperature levels above the UF_6 triple point.

3.8.2.12.2 System Classification

Although the X-343 and X-344 cold trap defrost operation control system does not meet the Q or AQ classification criteria specified in Section 4.2.2, this system is conservatively classified as AQ.

3.8.2.12.3 Boundary

The AQ boundaries for the X-343 and X-344 cold trap defrost operation control system are defined in Table 3.8-2.

3.8.3 Enrichment Facilities

3.8.3.1 Compressor Motor Manual Trip System

The compressor motor manual trip system is part of the enrichment cascade, purge cascade, interbuilding booster, and evacuation booster (EBS) compressor motors. The DC Power Distribution System is discussed in Section 3.8.3.2.

3.8.3.1.1 Safety Function

The compressor motor manual trip system shall shut down all applicable motors connected to the trip circuit to:

- Reduce the operating pressure/temperature to minimize the potential for UF_6 primary system integrity failure and
- Reduce the operating pressure to minimize the release of UF_6 and its reaction products to the atmosphere after a failure in the UF_6 primary system integrity.

3.8.3.1.2 Functional Requirements

The compressor motor manual trip system shall be capable of:

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- Tripping the cell and booster compressor motors in the enrichment and purge cascades from the area control room (ACR) and
- Tripping the cell and interbuilding booster compressor motors in the enrichment cascade from the plant control facility (PCF).

3.8.3.1.3 System Evaluation

The compressor motor manual trip system was evaluated to assess its ability to accomplish its required safety function. In addition, a fault tree analysis was performed to determine the system capability to accomplish its safety function. The results of these evaluations are provided in this section.

The compressor motor manual trip system is made up of various circuits associated with the enrichment cascade, purge cascade, interbuilding booster, and EBS booster compressor motors. Some of the trip circuits shut down individual compressors (i.e., interbuilding boosters and EBS boosters) and others shut down all compressors within a cell (i.e., enrichment and purge cascades). The remote switch will energize a relay coil, resulting in a trip signal to the trip coil of the circuit breaker (air or electrical) inside the switchgear. The trip coil will then energize via the switchgear DC control power supply and trip the associated breaker which disconnects motive power to the associated compressors.

Safety function analysis. The hazards and accident analysis took credit for tripping operating compressors for several different transients to reduce UF_6 primary system pressure and temperature to minimize the potential for a loss of UF_6 primary system integrity. In addition, tripping operating compressors was also assumed to occur for several UF_6 release events to reduce UF_6 primary system pressure and minimize releases from the operating equipment. Tripping the compressors (cell or booster compressor motors) will accomplish all of these safety functions. Compressor operation provides the main source of pressurization for the UF_6 primary system. In addition, the heat of compression is the primary source of heat input for the UF_6 primary system. Therefore, by tripping the compressors associated with operating equipment, both UF_6 primary system pressure and the need for UF_6 primary system cooling are significantly reduced to accomplish the required safety function. Tripping of the compressors is the only requirement needed to bring a cell or interbuilding booster below atmospheric pressure. When cell motors are stopped, the cell pressure decreases rapidly (i.e., within seconds based on operational history) due to pressure equalization between the A-line and B-line. Repressurization of the cell is inhibited by the flow resistance of the compressors and other equipment within the cell. A trip of the compressors eliminates the heat input into the system generated by the compression process. The time response associated with these events could range from several seconds up to several minutes depending on the initial operating conditions of the cell (e.g., above or below atmospheric pressure) and the severity of the operational transient (e.g., B-line block valve closure, loss of recirculating cooling water [RCW]).

In case of an earthquake, all of the compressor motors in the process buildings can be manually tripped from the switchyard. An evaluation basis earthquake will typically cause a loss of power which will stop the compressors. If the power is still available, the switchyard will still be functional, and the switchgear should still be capable of tripping the power to the process buildings and the compressor motors. Assuming that the compressors can be tripped from the switchyard eliminates the need for DC control power following an evaluation basis earthquake to trip the compressor motors (see Section 3.8.3.2).

The functional requirements associated with this system are addressed below in the qualitative fault tree analysis. Based on the analysis above, the system can accomplish the required safety functions.

Qualitative fault tree analysis. In addition to the safety function analysis, a qualitative fault tree analysis of the compressor motor manual trip system was performed in accordance with Section 4.3.1.1.3.

The functional requirement for this system is the ability to trip compressors from (1) the associated ACR for all of the equipment and (2) the PCF for the cell and interbuilding booster compressors within the enrichment cascade. The fault tree analysis indicates that all of the cell compressor motors and the EBS motors can be tripped from the ACR and the PCF. The interbuilding booster compressor motors can be tripped from the ACR and the PCF, with the exception that the A-line boosters to Building X-326 cannot be tripped from the ACR. Therefore the functional requirements for this system are met. The amount of UF_6 material at risk in the purge cascade and the portion of the enrichment cascade in X-326 is very small. The threshold analyses indicate that a UF_6 release for 30 min from a failure of the discharge piping of the withdrawal compressors in the ERP facility will not exceed 10 mg U intake at the site boundary (see Section 4.3.2.2.12). A UF_6 release from the cascade processes in X-326 would be much smaller because these cells operate below atmospheric pressure. The exposure of workers within the building from these small releases will be minimized by evacuation. In addition, compressor motors in X-326 can be stopped by tripping the X-326 cells at the cell panels, and process gas flow to and from X-326 may be stopped by splitting the cascade between X-330 and X-326. Thus, it is not essential to trip the compressors in X-326 from the ACR or PCF. Additional trip capabilities for all of the compressor motors are also provided at the applicable switchgear; however, these additional locations are not required to accomplish the safety function.

The interbuilding boosters are part of the enrichment process and are typically fed from an operating cell and then discharged to another operating cell. Therefore, for the purpose of accomplishing a reduction of UF_6 primary system pressure, tripping of cells upstream and downstream of the interbuilding booster compressors from the ACR can accomplish the required safety function for the interbuilding booster that does not have trip capability in the ACR. In addition, if necessary, tripping of the boosters can be accomplished from the PCF. Additional trip capabilities are also provided at the local control center (LCC) and the applicable switchgear, if necessary, to accomplish the safety function in emergency situations. However, these additional locations are not required to accomplish the safety function.

In addition, there are several locations available to trip a cell or booster station including feeder breakers upstream of the cell or booster station feeder breakers. If a cell or booster station breaker failed to trip, the probability of the failure of the next breaker in series becomes multiplicative. Thus the probability is reduced to a low value. In addition, the probability of the failure occurring at the same time and in the same area where the UF_6 release occurs is multiplicative. If a cell or booster station cannot be tripped, the compressor motors in the cells upstream and downstream can be tripped, which will also reduce the pressure in the area of concern.

The air circuit breakers have individual air reservoirs to provide the pneumatic force needed to open the breaker if the normal air supply provided by the compressed air stations for the switchgear is lost. If air is lost in an air reservoir for one of the air circuit breakers, other circuit breakers in that feed path may be tripped.

One specific area of concern associated with this system that could impact the system's ability to accomplish its required function is the location of some of the circuits in the tunnels from the process buildings to the PCF. These areas have the potential for some localized flooding during large storms. The electrical circuits associated with the compressor trip circuit are the control circuits that are 250 VDC and lower. The motive power circuits are typically routed from the operating floor up to the compressors, with the exception being those fed directly from the switchyard. The switchyard power circuits are routed either underground or in overhead dedicated banks of electrical cable trays. The only cables that could be affected by localized flooding during large storms would be those routed underground. The most likely failure mode for motive power cables routed underground would be either an open circuit or a short to ground. Either case would result in tripping of the associated load, which would accomplish the required safety function. Hot shorts, associated with these cables, which are caused by water intrusion, would be unlikely due to the grounding effects of water. This is not considered credible. Spurious operation of the control trip circuits would accomplish the required safety function and is not addressed further. An open circuit in the control cables could result in the inability to accomplish the required safety function from the ACR or PCF. However, the likelihood of several simultaneous failures (required to prevent accomplishing the required safety function) is unlikely and is not considered credible. Single circuit failures are considered credible based on past operational history. If the capability to trip one or more compressors is lost (e.g., due to a loss of DC control power), the capability to trip cells upstream and downstream of the affected areas or to trip the affected cells from an alternate location is still available to reduce overall pressure. In addition, the capability is also provided to accomplish one trip of the compressors at the applicable switchgear via a push button without the aid of DC control power or the trip circuit. If necessary, these actions could be taken to accomplish the required function. Local trip capability of switchgear is provided independent of the functional requirements on all switchgear.

Based on the diversity of the capability to trip operating compressors via various breakers, and the low probability of failure, the compressor motor manual trip system has the capability to meet the functional requirements.

3.8.3.1.4 System Classification

Trip capability from the ACR associated with the "00" and "000" enrichment cells in X-330 and X-333 is required to prevent or mitigate UF_6 primary system failure accidents to maintain site boundary consequences within EGs. Therefore, these trip systems are classified as Q.

Failures associated with the interbuilding booster and EBS booster compressors can be mitigated by tripping adjacent enrichment cell compressor motors. Therefore, the trip systems associated with the interbuilding boosters and EBS boosters are classified as NS, and the trip systems in the ACR for the associated adjacent enrichment cell compressor motors are classified as Q.

Due to the low UF_6 pressures and mass flow rates in Building X-326, and personnel evacuation action in the event of a UF_6 primary system failure, trip capability for the X-326 compressors is not essential. Although the trip capability for the X-326 compressors does not meet the Q or AQ classification criteria specified in Section 4.2.2, the ACR and PCF trip for X-326 compressors is conservatively classified as AQ.

Trip capability from the PCF associated with the enrichment cells in X-330 and X-333 is required during a facility evacuation to maintain initial conditions. Therefore, this system is classified as AQ.

3.8.3.1.5 Boundary

The Q and AQ boundaries of the compressor motor manual trip system are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.3.2 DC Power Distribution System

The DC power distribution system consists of the 250-VDC and 125-VDC distribution systems that are required to support the compressor motor manual trip system described in Section 3.8.3.1. 250-VDC power is required to trip compressor motors from the ACRs and the PCF, and 125-VDC power is only required to trip compressor motors from the PCF.

3.8.3.2.1 Safety Function

The DC power distribution system shall provide the support control power required by the compressor motor manual trip system to perform its safety function.

3.8.3.2.2 Functional Requirements

The DC power distribution system shall have the capability to operate the compressor motor manual trip system following a loss of AC power.

3.8.3.2.3 System Evaluation

The safety function required of the DC control power system is to provide the support control power required by the compressor motor manual trip system to perform its safety function. The DC power distribution system consists of standard industrial batteries, controls, and distribution circuits that supply 250-V and 125-VDC power to operate the compressor motor circuit breakers from the remote locations. Cell tripping is classified as a momentary load per IEEE Standard 485-1983 (Reference 3.8-1), and as such, it represents a small instantaneous ampere-hour load on the total battery banks. Based on this, the batteries can provide sufficient DC power upon the loss of the normal AC power supply to perform a momentary trip of the compressor motors. If the DC control power systems are lost, other breakers upstream of the cell feeder breakers can be used to trip the compressor motors. For some equipment (e.g., "00" compressors), the upstream feeder breakers are served by separate DC control power systems in the switch houses that would be available if the DC control power system in the process building should fail. For other equipment (e.g., "000" compressors), the motor circuit breakers are located in the switchyard or in the process buildings, and these use the DC control power systems in the switch houses or the process buildings. In all cases, the circuit breakers can be tripped manually at the switchgear if the DC control power system in the switch house should fail. The system is not required to withstand the effects of natural phenomena hazards (see Section 3.8.3.1.3). Environmental conditions for this equipment would be similar to the compressor motor manual trip system since they are also located on the ground floor, in the switchyard, or in the PCF. Based on the analysis above, the system can accomplish the required safety function and meet the functional requirement.

3.8.3.2.4 System Classification

The 250-VDC power distribution system is required for the operation of the Q and AQ compressor motor manual trip systems (see Section 3.8.3.1). Consequently it is classified as Q. The 125-VDC power distribution system is only required for operation of the AQ compressor motor manual trip system. Therefore it is classified as AQ.

3.8.3.2.5 Boundary

The Q and AQ boundaries of the DC power system are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.3.3 UF_6 Primary System

The UF_6 primary system is the UF_6 containment barrier in the enrichment cascade and associated equipment. The UF_6 primary system includes the enrichment cascade equipment, cascade auxiliary equipment, purge cascade equipment, freezer/sublimer (F/S) UF_6 process equipment, freon degraders and cold recovery process equipment.

3.8.3.3.1 Safety Function

The UF_6 primary system shall provide UF_6 primary system integrity for the processes that contain gaseous UF_6 in the enrichment and purge cascade facilities to prevent the release of UF_6 during normal operation, and to prevent gross failures during evaluation basis natural phenomena events.

3.8.3.3.2 Functional Requirements

The UF_6 primary systems in the cascade facilities shall be designed to maintain UF_6 primary system integrity during normal operating temperatures/pressures and to prevent gross failure following evaluation basis natural phenomena events.

3.8.3.3.3 System Evaluation

The UF_6 primary system for the enrichment cascade handles gaseous UF_6 from the feed points to the withdrawal points. The converters, vessels, piping, coolers, compressors, valve bodies, etc., provide the UF_6 primary system integrity for the enrichment cascade process. The enrichment cascade also includes the cascade auxiliary equipment connected to the cascade to provide support for cascade operations. This equipment includes booster systems, surge drums, piping, valves, seal systems, seal exhaust systems, wet air evacuation systems, etc., that handle gaseous UF_6 and that provide the UF_6 primary system integrity for these processes. The purge cascade uses the same type of equipment as does the enrichment cascade. It extends from the withdrawal points to the vents where purged light gases are released to the atmosphere. The UF_6 primary systems also include the F/S, freon degrader and cold recovery systems.

The UF_6 primary system is required to provide integrity for the cascades and the supporting processes that handle UF_6. This safety function is accomplished by retaining UF_6 primary system integrity during normal operating temperatures/pressures.

The UF_6 primary system in the enrichment cascade which is intended to operate above atmospheric pressure is also required to maintain UF_6 primary system integrity during evaluation basis natural phenomena events. The effects of evaluation basis natural phenomena events on the UF_6 primary system of the enrichment cascade in X-330, X-333, and the tie lines (X-326 cascade piping is subatmospheric) were evaluated. The results indicate that (1) the UF_6 primary system integrity is maintained in the evaluation basis high wind event (if the structures do not cause a failure) and that (2) the piping and equipment in the enrichment cascade facilities that are intended to operate above atmospheric pressure will maintain integrity in the most severe evaluation basis earthquake event (EBE) with a 250-yr return period. Other portions of the enrichment cascade facilities operating at subatmospheric pressures may experience some minor failures in the earthquake event but the result would be inleakage into the cascade equipment. Failures of any cascade piping due to facility structural weaknesses is addressed in Section 4.3.2.5.

The capacity-limiting member or weak link in the X-333 process gas system and its location in the gaseous diffusion process is given in Table 3.8-4. The high-confidence-low-probability-of-failure (HCLPF) capacity reported in the table is the capacity of the weakest structural member(s) whose failure could potentially cause a UF_6 release in the process gas system. Only one component evaluated had a capacity less than the evaluation basis earthquake. The HCLPF capacity was determined by seismic database comparison methods. For this item, the seismic capacity, annual probability of failure, location, and comments are provided. This item was evaluated further using finite element analysis and empirical test data to determine if a loss of pressure boundary was likely and to estimate the hole size, if the pressure boundary was breached. The analysis indicated that although some deformation could be experienced, the deformation would not be sufficient to affect the pressure boundary. All process gas piping and stage components in Building X-330 have capacities greater than the EBE. In addition, the potential seismic interaction of the cell housings was evaluated and determined to not adversely impact a UF_6 pressure boundary.

The portions of the enrichment cascade that are intended to operate above atmospheric pressure will accomplish the safety function of not having gross failures of the UF_6 primary system integrity in evaluation basis natural phenomena events (except due to facility structural weaknesses). For the portions of the enrichment cascade that are operated only at subatmospheric pressure and the purge cascade, the capacity to retain their UF_6 primary system integrity is not required in evaluation basis natural phenomena events. This is based on the subatmospheric pressure and minimal releases should the UF_6 primary system fail.

Based on these evaluations, the UF_6 primary system can accomplish the required safety function, with the exception noted.

3.8.3.3.4 System Classification

The essential functions of the UF_6 primary system are to (1) maintain UF_6 primary system integrity during normal operating temperatures and pressures, and (2) prevent failures in the above atmospheric portions of the enrichment cascade beyond those assumed in the evaluation basis earthquake analysis. The system provides no additional protection once a release occurs. The UF_6 primary system is classified as AQ in accordance with the criteria in Section 4.2.2. This classification applies to process piping 2 inches and larger, expansion joints, valves, and process equipment that provide the UF_6 containment pressure boundary. Process piping less than 2 inches is classified as NS.

3.8.3.3.5 Boundary

The AQ boundaries for the UF_6 primary system for the enrichment processes are defined in Table 3.8-2.

3.8.3.4 High-Pressure Relief Systems

3.8.3.4.1 Safety Function

The coolant high-pressure relief system in the enrichment cascade and in the purge cascade, F/S UF_6 high-pressure relief system in the F/S process, the cold trap pressure relief system in the cold recovery process, and the condenser coolant overpressure relief systems at the ERP and LAW withdrawal facilities provide pressure relief to prevent overpressurizing the interfacing UF_6 primary system. The potential for a release of UF_6 from an overpressure failure of the UF_6 primary system is minimized. This minimizes the potential for the exposure of on-site personnel.

3.8.3.4.2 Functional Requirements

Each system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- Each relief system shall provide pressure relief for the primary UF_6 system or the coolant system to minimize the potential for the failure of the UF_6 primary system integrity of these systems.
- Each relief device shall be rated at or below the design pressure rating of the equipment they are protecting.
- Each relief system shall be capable of providing overpressure protection without control signals, AC, or DC power.

3.8.3.4.3 <u>System Evaluation</u>

The coolant high-pressure relief system for each cell coolant system consists of a manual block valve, one or two rupture disks, and associated piping. All of the rupture disk assemblies are separated from the coolant system by the manual block valve that must be sealed in the open position when the coolant system is in operation.

The F/S UF_6 high-pressure relief system for each F/S system consists of a rupture disk, a block valve, and associated piping that provides a relief path to the A-line of the cascade.

The cold recovery system cold trap pressure relief system consists of a pressure relief control valve and associated solenoid valve, pressure sensing instrumentation, rupture disk, inlet and relief piping and valves, and the relief drum.

The condenser coolant overpressure relief systems at the ERP and LAW facilities consists of a rupture disk on the coolant condenser shell that relieves on high coolant pressure.

No support systems are needed for the relief systems to perform their safety functions.

The coolant high-pressure relief system in the enrichment cascade and the purge cascade prevents excess coolant pressure from rupturing the coolant system and releasing coolant into the UF_6 primary system that could result in the subsequent loss of UF_6 due to overpressurization of the UF_6 system. The coolant system pressure may increase following an event that results in a loss of cooling, such as a loss of RCW to the coolant system. The rupture disks are rated at or below the MAWP of the system being protected. This rating (with its allowable tolerances) will minimize the potential for the failure of the coolant system primary integrity. The accident analysis identified rupture of the coolant system into an off-stream cell as the only credible means for the event to progress to a failure of the UF_6 system integrity. In this condition, the amount of UF_6 is limited, and there is no potential for exceeding any of the off-site EGs.

The F/S UF_6 high-pressure relief system and the cold trap pressure relief system prevent overpressurization of the UF_6 primary system for (1) a release of coolant into the F/S vessel or cold trap vessel or (2) overheating. These events can only threaten the integrity of the UF_6 system when the F/S or cold recovery systems are isolated from the cascade. These systems prevent the pressure from exceeding the capabilities of the UF_6 primary system. When the F/S or cold recovery systems are isolated, the systems are operating at subatmospheric pressure which would minimize the mass of UF_6 released. Thus, there is no potential for exceeding any of the off-site EGs.

The coolant overpressure relief systems at the ERP and LAW withdrawal facilities was evaluated to assess its ability to accomplish its required safety function. The safety function is to minimize the potential for failure of the UF_6 primary system by relieving high coolant pressure before the UF_6 primary system integrity is threatened. To minimize the potential for failure in the coolant system and a potential UF_6 release through the coolant system, the system is designed to relieve at or below the MAWP of the coolant system.

The relief systems do not require control signals or AC or DC power to perform their functions. Based on the analysis above, the systems can accomplish the required safety functions and functional requirements.

3.8.3.4.4 System Classification

The high-pressure relief systems are used to minimize the potential overpressurization of the primary UF_6 or the coolant system. This prevents the potential loss of UF_6 primary system integrity and minimizes the potential exposure of on-site personnel to UF_6. Because the system operates to prevent an accident but cannot directly result in exceeding off-site EGs, the high-pressure relief systems are classified as AQ.

3.8.3.4.5 Boundary

The AQ boundaries of the high-pressure relief systems are defined in Table 3.8-2.

3.8.3.5 Freezer/Sublimer UF_6 High-High Weight Trip System

3.8.3.5.1 Safety Function

The F/S UF_6 high-high weight trip system detects an accumulation of excessive solid UF_6 material inside the F/S vessel, isolates the vessel from the cascade supply and transfers out of the freeze operating mode to prevent further accumulation.

3.8.3.5.2 Functional Requirements

The F/S UF_6 high-high weight trip system shall automatically close the B-line that is supplying UF_6 to the F/S system upon detection of a weight greater than or equal to the system actuation weight to prevent excessive material from accumulating inside the F/S vessel.

3.8.3.5.3 System Evaluation

The F/S UF_6 high-high weight trip system was evaluated to assess its ability to accomplish the required safety functions. In addition, a qualitative fault tree analysis was performed to determine the system capability to accomplish the safety functions. The results of these analyses are provided in this section.

The high-high weight trip system consists of three load (weight) cells mounted in the F/S vessel supports. Two separate instrument channels sum these three measurements to determine the total weight of the F/S vessel contents (R-114 coolant and UF_6). These weight measurements are compared to setpoints and if the setpoints are exceeded, the F/S vessel is isolated from the cascade B-Line and the F/S system is placed in a trip configuration. Either action terminates the continued UF_6 accumulation in the vessel.

The high-high weight trip system requires 480 VAC, 120 VAC and 24 VDC electric power to perform its primary safety action, the isolation of the cascade B-Line.

Safety function analysis. The safety function of the system is to prevent excessive UF_6 from freezing in the vessel during the freeze mode of operation. Overfilling the F/S vessel could stress the tubes and the vessel walls due to thermal expansion of the solid UF_6 during a subsequent sublime mode. Rupture of the vessel violates the UF_6 primary system integrity and could allow a release of UF_6. Limiting the amount of material inside the vessel assures that solid UF_6 will not bridge the space between the tubes or between the tubes and the vessel wall. An analysis was conducted to determine the maximum amounts of UF_6 which could be frozen in the F/S vessels while preventing bridging of solid UF_6 between tubes or between tubes and the vessel walls. The maximum amount of UF_6 material is 11,900 lb (5398 kg) of UF_6. The system trip setpont is established below this maximum amount (with additional margin for any material that continues to enter the vessel during the time required for the B-line valve to close) to ensure bridging cannot occur. The current system setting is 9,000 lb (4336 kg) net weight of UF_6. Based on the analysis above, the system can accomplish the required safety functions.

Qualitative fault tree analysis. In addition to the safety function analysis, a qualitative fault tree analysis was performed in accordance with Section 4.3.1.1.3. The analysis identifies the components that are required to function for the system to accomplish its safety functions. Although not required for the safety function, the diesel generators will provide backup power to trip the system and close the B-line block valve if normal AC power is lost. The fault tree analysis indicated that the equipment and its configuration can accomplish the function of isolating the F/S vessel from the B-line supply. Even if the system fails to trip or the B-line does not close the UF_6 primary system integrity would not fail unless the F/S was placed in the sublime mode. The failures that would prevent the system from tripping would also prevent the system from being placed in the sublime mode. The safety function analysis above indicates that the actuation of the system at the trip setpoint will prevent the accumulation of excessive UF_6 material in the F/S vessel. Thus, the system can accomplish the required functional requirements.

3.8.3.5.4 <u>System Classification</u>

The F/S UF_6 high-high weight system prevents the overfilling and the potentially resulting rupture of the F/S vessel. Prevention of this accident prevents exposure of on-site personnel to UF_6. The system is classified as AQ on this basis.

3.8.3.5.5 <u>Boundary</u>

The AQ boundaries of the freezer/sublimer UF_6 high-high weight trip system are defined in Table 3.8-2.

3.8.3.6 Motor Load Indicators

3.8.3.6.1 Safety Function

The motor load indicators shall provide an indication of significant changes in compressor motor loads (e.g., surging of the compressors and the compressor motors).

3.8.3.6.2 Functional Requirements

The motor load indicators shall provide an indication of large changes in the compressor motor loads for:

- The cell and interbuilding booster compressor motors in the enrichment and purge cascades in the ACR,
- The cell compressor motors (enrichment cascade only) in the PCF, and;
- The second stage withdrawal compressor motors in Building X-326 in the LCR, and in Buildings X-330 and X-333 in the ACR.

3.8.3.6.3 System Evaluation

The primary function of the motor load indicators is to provide an indication of abnormal compressor operation that could lead to failure. Using ammeter indications in the ACR for the individual compressor motors, operators can quickly identify various malfunctions of process equipment. Any inexplicable change in normal amp load is quickly investigated by the operators. Compressor load changes can be caused by such events as compressor failures, inadvertent B-stream block valve closure (see Section 4.3.2.1.3), stage control valve closure (see Section 4.3.2.1.2), or failures of the UF_6 primary system pressure boundary that cause inleakage or a release of UF_6. Compressor surging will produce large swings in the motor loads. The load swings caused by compressor surging are large enough to be seen even during plant load changes. These early indications alert the operator that one of these events may be occurring and minimize the response time to take mitigative actions. If an ammeter should malfunction, the load changes can be seen on the ammeters for the compressor motors in stages adjacent to the stage that is experiencing the compressor surging.

Monitoring of the X-326 compressors is not considered essential. The amount of UF_6 material at risk in the purge cascade and the portion of the enrichment cascade in X-326 is very small. The threshold analyses indicate that a UF_6 release for 30 min from a failure of the discharge piping of the withdrawal compressors in the ERP facility will not exceed 10 mg U intake at the site boundary (see Section 4.3.2.2.12). A UF_6 release from the cascade processes in X-326 would be much smaller because these cells operate below atmospheric pressure. The exposure of workers within the building from these releases will be minimized by evacuation.

Motor load indicators are provided in the ACR for interbuilding booster compressors, however, they are not considered essential. Motor load indicators associated with the adjacent enrichment cell compressor motors will provide adequate indication of a booster compressor abnormality that could lead to an analyzed UF_6 release.

In scenarios involving evacuation of the process buildings, motor load indicators in the PCF are used to monitor the compressors for the enrichment cascade and inform the operator to trip their motors if there is an indication of large load changes that could be representative of a pressure increase after the evacuation. The motor load indicators in the PCF monitor the total cell load for all of the compressors in a cell rather than for each individual stage. Although the motor load indicators in the PCF will be less sensitive than those in the ACR, they will be able to indicate significant compressor load changes.

Based on this evaluation, the system can accomplish the required safety function and functional requirements.

3.8.3.6.4 System Classification

The motor load indicators are used to monitor the performance of UF_6 compressors and provide an indication of abnormal compressor motor operation. The essential portions of the system include ammeters in the ACR and PCF associated with the "00" and "000" compressor motors. The system is used to prevent UF_6 release accidents but it is not essential to mitigate these accidents to protect the off-site public. Based on these considerations, the system is classified as AQ.

3.8.3.6.5 Boundary

The AQ boundaries of the motor load indicator system are defined in Table 3.8-2.

3.8.3.7 Datum Systems

3.8.3.7.1 Safety Function

A datum system is a fixed volume system of precisely controlled air pressure. This pressure is used as an absolute reference pressure to process differential pressure transmitters. Accurate pressure measurements from the datum system are also of primary importance to account for uranium in the cascade. A datum pressure makes it possible to use narrower range instruments to take measurements in wide pressure ranges. NMC&A requirements for inventory measurements are accomplished by the unit datum system, which is comprised of the high datum system, the cell datum system and the standby datum system.

3.8.3.7.2 Functional Requirements

See Section 3.1.1.6.2 and the Fundamental Nuclear Materials Control Plan, Section 5.2, for the functional requirements for this system.

3.8.3.7.3 System Evaluation

See Section 3.1.1.6.2 and the Fundamental Nuclear Materials Control Plan, Section 5.2, for the description of this system.

3.8.3.7.4 System Classification

Although the datum systems do not meet the Q or AQ classification criteria specified in Section 4.2.2, the datum systems are conservatively classified as AQ.

3.8.3.7.5 Boundary

The AQ boundaries for the datum system are defined in Table 3.8-2.

3.8.3.8 Freon Degrader Fluorine Flow System

3.8.3.8.1 Safety Function

The freon degrader fluorine flow system shall restrict the amount of fluorine introduced to the cascade via the degrader to prevent the accumulation of an unacceptable concentration of fluorine in the cascade.

3.8.3.8.2 System Classification

Although the freon degrader fluorine flow system does not meet the Q or AQ classification criteria specified in Section 4.2.2, the freon degrader fluorine flow system is conservatively classified as AQ.

3.8.3.8.3 Boundary

The AQ boundaries for the freon degrader fluorine flow system are defined in Table 3.8-2.

3.8.4 Withdrawal Facilities

3.8.4.1 Pigtail Line Isolation System

3.8.4.1.1 Safety Function

The pigtail line isolation system shall be capable of isolating the withdrawal position to prevent exceeding the radiological/nonradiological EGs for the EBE category.

3.8.4.1.2 Functional Requirements

The pigtail line isolation system includes (1) automatic UF_6 detection and isolation and (2) manual isolation. The system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety function independent of the plant air supply.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- The automatic detection and isolation portion of the system shall be capable of detecting UF_6 and isolating the withdrawal position pigtail at both ends.
- The automatic detection and isolation portion of the system shall isolate the withdrawal position within 30 seconds after actuation of the ionization detectors.
- The manual isolation portion of the system shall be capable of isolating the liquid source and shall be accessible outside the withdrawal room.

3.8.4.1.3 System Evaluation

The pigtail line isolation system was evaluated to assess its ability to accomplish its required safety function. In addition, a qualitative fault tree analysis was performed to determine the system's capability to accomplish its safety function. The results of this evaluation are provided in this section.

Safety function analysis. The safety function required of this system is to limit the release of UF_6 and its reaction products to less than the radiological/nonradiological EGs for an EBE. A review of the withdrawal facility operations determined that the bounding event for this system is pigtail failure at withdrawal position, described in Section 4.3.2.2.11. In order for the pigtail line isolation system to accomplish its safety function, the system must detect a UF_6 release at the withdrawal position and close the isolation valve at each end of the pigtail to prevent exceeding these guidelines. In addition, manual isolation must be capable of isolating the line between the manifold safety valve and the accumulators/condenser.

The hazards and accident analysis assumed that a significant UF_6 release at a withdrawal position would be detected by the withdrawal position detectors within 15 seconds and the liquid source would be automatically isolated (i.e., the pigtail isolation valves close, isolating the pigtail from the accumulator and the cylinder) within 30 seconds after initiation to close. This event was evaluated in Section 4.3.2.2.11 and the consequences were determined to be below the applicable EGs.

The manual isolation capability for the system is provided for defense-in-depth only. A continuous surveillance of the withdrawal room would be capable of detecting a release and manually activating the isolation system upon exiting the area. However, TSRs for the withdrawal facilities require isolation of the cylinder and the withdrawal manifold should the automatic detection system become inoperable.

Based on this analysis, the pigtail line isolation system will prevent exceeding the radiological and nonradiological EGs for the most limiting UF_6 primary system integrity failure at a withdrawal position provided the system automatically closes the isolation valves within 45 seconds after the release occurs. Events where the cylinder valve can not be closed due to the event are addressed in Section 4.3.2.2.11.

Qualitative fault tree analysis. In addition to the safety function analysis, a qualitative fault tree analysis of the pigtail line isolation system was performed in accordance with Section 4.3.1.1.3 to evaluate the capability of the system to accomplish its required safety function. The ability of the system to meet the functional requirements is described below.

As indicated in the functional requirements, the system is required to accomplish the required safety function independent of plant air and electric supply. The system configuration can accomplish its required safety function independent of the plant air and electrical distribution systems with the exception of the local air storage volumes (valve closures) and the 24-VDC power supply (UF_6 detectors). The power supply and air storage volumes, back to the interface (i.e., check valves) with the plant air system, are considered part of this system and are required to be tested periodically to verify their operability. Therefore, the system can accomplish its required safety function independent of plant air and electrical power.

UF_6 release detectors are required for the automatic detection system. Should theautomatic detection system become inoperable, the TSRs require isolation of the cylinder and the withdrawal manifold.

In addition to the functional requirements associated with a loss of electric power and air, the automatic operation of the system is required to isolate equipment within 30 seconds after actuation of the UF_6 detectors. The analysis assumes the detectors will actuate within 15 seconds after a significant release. Past operational history with the UF_6 detectors has indicated a response time less than 15 seconds for any significant release as a result of the significant amount of smoke generated by the release. Valve closure time is verified periodically by surveillance tests to ensure that the 30-second closure time is met. Therefore, the system can accomplish the required automatic detection and isolation.

The location of the manual isolation capability is outside the immediate area of the release with a closed door providing limited protection for the operations personnel. Therefore, the manual isolation functional requirement is also achieved by the system configuration.

Based on the capability to detect and isolate a release and the various controls associated with the pigtail cylinder valve, the pigtail line isolation system can meet its function requirements.

3.8.4.1.4 System Classification

The pigtail line isolation system is required for mitigation of a pigtail failure at withdrawal position event (see Section 4.3.2.2.11). This release event is classified as an EBE that could exceed the off-site nonradiological EGs if the pigtail line isolation system fails to perform its safety function. Therefore, the pigtail line isolation system meets the criteria for classification as a Q system.

3.8.4.1.5 Boundary

The Q boundaries for the pigtail line isolation system are defined in Table 3.8-1.

3.8.4.2 Compressor Motor Manual Trip System

The compressor motor manual trip system provides the capability to rapidly deenergize the withdrawal compressor motors. This trip capability is actuated from the applicable ACR. For the ERP station, individual motor trips are provided in the LCR. The ERP station ACR trip function provides complete station motive shutdown.

3.8.4.2.1 Safety Function

The compressor motor manual trip system for the second stage compressors shall shut down all applicable motors connected to the trip circuit to (1) minimize the source of frictional heating associated with a compressor failure that would cause a UF_6/hot metal reaction and (2) minimize the amount of UF_6 released in events involving failure of the UF_6 primary system.

3.8.4.2.2 Functional Requirements

The compressor motor manual trip system shall be capable of tripping the compressor motors from the ACR (LCR for ERP) to ensure the system's capability to accomplish the required safety function.

3.8.4.2.3 System Evaluation

The compressor motor manual trip system was evaluated to assess its ability to accomplish its required safety function. The results of this evaluation are provided below

Safety function analysis. The accident analysis credited the compressor motor manual trip system for tripping the second stage compressors to (1) minimize the source of frictional heating associated with a compressor failure that would cause a UF_6/hot metal reaction and (2) minimize the amount of UF_6 released in events involving failure of the UF_6 primary system. Tripping the compressor will quickly reduce the frictional heating associated with various compressor failures, thereby minimizing the potential for a self-sustaining UF_6/hot metal reaction. Should a self-sustaining UF_6/hot metal reaction or other primary system failure event occur, then tripping the compressors would also minimize the potential UF_6 release associated with the UF_6 primary system failures. However, release mitigation associated with the system is only required for protection of on-site workers since consequence analysis indicates that unmitigated failure events (Sections 4.3.2.2.1 and 4.3.2.2.12) do not exceed off-site exposure guidelines.

Should the ACR or LCR be evacuated for any reason, the operators would have the capability to trip the compressors from the X-300 building or other locations.

Based on the analysis above, the compressor motor manual trip system can accomplish the required safety functions.

3.8.4.2.4 System Classification

The compressor motor manual trip is required to minimize UF_6 exposure to on-site personnel This meets the criteria for classification as an AQ system.

3.8.4.2.5 Boundary

The AQ boundaries for the compressor motor manual trip system are defined in Table 3.8-2.

3.8.4.3 DC Power Distribution System

Except for certain compressors, as described below the compressor motor manual trip circuit for second stage compressors requires 250-VDC control power to trip the compressor motor circuit breakers from the ACR/LCR. This DC power system is basically the same as that described in Section 3.8.3.2, however, PCF capability is not required.

Certain withdrawal station(second stage) compressor motor manual trip circuits are fail-safe and do not require the DC power system to perform their safety function. If power is lost to these trip circuits the respective compressor motors trip. The withdrawal station second stage compressors that do not need the DC power sytem as a support system are:

- ERP: Compressor W-2
- LAW: All second stage compressors

The DC power distribution system supports the compressor motor manual trip system for certain second stage compressors at the withdrawal facilities; therefore, it meets the criteria for classification as an AQ system.

3.8.4.4 Motor Load Indicators

The motor load indicators system is designated as an AQ system for the withdrawal facilities and is basically the same as that described in Section 3.8.3.6.

3.8.4.5 UF_6 Primary System

3.8.4.5.1 Safety Function

The UF_6 primary system shall provide UF_6 primary system integrity for the withdrawal processes that contain gaseous and liquid UF_6.

3.8.4.5.2 Functional Requirements

The UF_6 primary system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be designed to withstand the evaluation basis earthquake and maintain UF_6 primary system integrity.
- The system shall be designed to withstand the evaluation basis wind loading and maintain UF_6 primary system integrity.

- The system shall be designed to withstand the normal operating temperatures/pressures and maintain UF_6 primary system integrity.

3.8.4.5.3 System Evaluation

This system is required to provide UF_6 primary system integrity for the processes that contain gaseous and liquid UF_6. The safety function is accomplished by retaining integrity during normal operations and upset events. The system is designed to withstand normal pressures and temperatures encountered during withdrawal operations. The pigtails used at the withdrawal stations are pressure and leak tested prior to introduction of the UF_6 after each new connection is made.

In addition, the system is required to maintain UF_6 primary system integrity during an evaluation basis earthquake and evaluation basis wind loading. The UF_6 primary system was evaluated to assess its ability to withstand earthquake and high wind events. The results of this evaluation indicated that the UF_6 primary system piping could withstand the wind loadings and any potential impacts from debris. Also, this evaluation showed that the system is capable of performing its safety function following an evaluation basis earthquake.

The UF_6 primary system for the withdrawal facilities can accomplish its required safety function.

3.8.4.5.4 System Classification

The UF_6 withdrawal primary system is required to:

- Prevent a large release of UF_6 to the atmosphere during normal operations; and
- Prevent a large release of UF_6 during upset conditions not specifically related to failure of the UF_6 primary system.

A large release of liquid UF_6 has the potential to exceed off-site EGs if the UF_6 primary system integrity fails. Therefore, the portions of the UF_6 withdrawal primary system that could contain liquid UF_6 (e.g., condensers, accumulators, piping downstream of the condensers) meet the criteria for classification as Q.

The process line failure at compression discharge event was evaluated in Section 4.3.2.2.12. The results indicate that consequences would remain below the off-site EBE EGs with only the building holdup function. Therefore, the portions of the UF_6 withdrawal primary system that could contain only gaseous UF_6 (e.g., piping upstream of the condensers, compressors, vent system) are required for on-site protection, not off-site protection, and are classified as AQ systems.

3.8.4.5.5 Boundary

The Q and AQ boundaries for the UF_6 primary system for the withdrawal processes are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.4.6 Coolant High-Pressure Relief Systems

See Section 3.8.3.4 for information on the safety function, functional requirements, system description, system evaluation, justification for system classification, and boundaries for the withdrawal condenser coolant high-pressure relief systems for the withdrawal facilities.

3.8.4.7 Mass Spectrometers

3.8.4.7.1 Safety Function

The mass spectrometers shall perform a safeguard function for NCS and NMC&A activities by providing an on-line means for operations to monitor material enrichment at withdrawal stations and to ensure the enrichment limitations are not exceeded.

3.8.4.7.2 System Classification

Although the mass spectrometers do not meet the Q or AQ classification criteria specified in Section 4.2.2, the mass spectrometers are conservatively classified as AQ.

3.8.4.7.3 Boundary

The AQ boundaries for the mass spectrometers are defined in Table 3.8-2.

3.8.4.8 Gamma Spectrometers

3.8.4.8.1 Safety Function

The gamma spectrometers measure the assay in the withdrawal liquid line and actuate an isolation valve located between the accumulator and the withdrawal manifold if assay exceeds a value established in accordance with NCS requirements.

3.8.4.8.2 System Classification

Although the gamma spectrometers do not meet the Q or AQ classification criteria specified in Section 4.2.2, the gamma spectrometers are conservatively classified as AQ.

3.8.4.8.3 Boundary

The AQ boundary for the gamma spectrometers is defined in Table 3.8-2.

3.8.5 UF_6 Sampling and Transfer Facilities

3.8.5.1 Autoclave Shell High Pressure Containment Shutdown System

3.8.5.1.1 Safety Function

The autoclave shell high pressure containment shutdown system is designed to contain a release of UF_6 inside the autoclave. The system detects high autoclave pressure and isolates all active isolation valves to ensure that the following safety objectives are accomplished:

- The UF_6 primary system temperature for the UF_6 cylinder being heated inside an autoclave is maintained below the temperature that assures an ullage inside the cylinder is maintained.
- The release of UF_6 and its reaction products to the atmosphere from a UF_6 primary system failure inside an autoclave is maintained below the amount that would result in exceeding either the radiological or nonradiological exposure EGs for the EBE category.

3.8.5.1.2 Functional Requirements

The autoclave shell high pressure containment shutdown system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply to the facility.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- The detection of high autoclave pressure shall be accomplished with two pressure sensors.
- Isolation of the autoclave active valves shall be accomplished within 15 seconds from autoclave pressure exceeding the required actuation pressure for the system.

3.8.5.1.3 System Evaluation

The autoclave shell high pressure containment shutdown system was evaluated to assess its ability to accomplish its required safety functions. Two separate calculations were performed to analyze transient conditions involving specific limiting events associated with the safety functions. In addition, a fault tree analysis was performed to determine the system's ability to accomplish the safety functions. The results of these evaluations are provided in this section.

Safety function analysis. The first safety function required of this system is to protect the integrity of the UF_6 cylinder being heated. A review of the autoclave operations determined that the limiting event for evaluating this safety function is autoclave steam control valve fails open (see Section 4.3.2.2.2). For this event, the steam control valve fails open, resulting in a pressure increase (transient) in the autoclave. The primary concern for this event is cylinder overheating, which leads to cylinder overpressure from loss of ullage, and possibly leading to cylinder rupture. Two different evaluations were performed to verify the maximum temperature of the cylinder being heated was maintained below the allowable values. Two different initial conditions were evaluated. The first condition was for a 14-ton, 48G thin-wall cylinder filled to 28,000 lb (12,700 kg) with the maximum allowable noncondensables. This cylinder must be heated to greater than 235°F (112°C) before dropping below 5% ullage based on ANSI N14.1. This evaluation assumed the maximum amount of allowable noncondensables inside the cylinder, all UF_6 is liquified, and the cylinder is filled to 28,000 lb (12,700 kg) to ensure that protection would be provided for the most limiting event. The evaluation also assumed that the initial temperature inside the autoclave is less than 225°F (107°C). The UF_6 cylinder high-temperature autoclave steam shutoff system (see Section 3.8.5.7) ensures that the initial temperature conditions inside the autoclave will be maintained. The second initial condition assumed the initial temperature was 240°F (116°C). Although the same cylinder (i.e., 48G thinwall, high-volume) would not be allowed to be heated at this temperature, the heat transfer rates were considered conservative to determine if 250°F (121°C) would be exceeded.

When the steam control valve fails open, a rapid pressure rise occurs inside the autoclave and quickly reaches the 15-psig (205 kPa) actuation pressure of the autoclave high pressure isolation system. The analysis assumes that (1) it takes 15 seconds for the steam isolation valves to terminate the event after the 15 psig (205 kPa) actuation pressure is reached and (2) steam flow into the autoclave remains full until the valves are completely closed. Using a conservative assumption that all of the heat added to the autoclave during the transient is then transferred to the liquid UF_6, the final temperature of the UF_6 would still be less than 235°F (112°C) for the lower initial temperature and less than 250°F(121°C) for the higher initial temperature. The present steam supply isolation valves have a valve-stroke time less than the assumed 15 seconds and are tested periodically to verify that the system can complete an isolation of the steam supply within 15 seconds. Based on this analysis, the autoclave shell high pressure containment shutdown system will prevent the UF_6 primary system pressure from exceeding the allowable temperatures for the most limiting cylinder and worst-case transient, provided the actuation pressure is ≤15 psig (205 kPa) and the steam supply valve will close in ≤15 seconds after the actuation pressure is reached.

In the event of a UF_6 release inside the autoclave, the second safety function of this system is to limit the release of UF_6 reaction products to the atmosphere to less than the radiological and nonradiological EGs for the EBE category. To accomplish this safety function, the autoclave shell high pressure containment shutdown system works with the autoclave primary containment system to detect high pressure inside the autoclave and close the autoclave containment isolation valves before the release and subsequent exposures exceed these guidelines. A review of the autoclave operations determined that the limiting event for evaluating this safety function is cylinder failure inside autoclave (see Section 4.3.2.2.14). For this event, the cylinder integrity is lost and UF_6 is released inside the autoclave. The primary concern for this event is isolating the autoclave and limiting the amount of material released to the atmosphere.

To determine the amount of UF_6 released and the consequences of a release, the following initial conditions were assumed. The initial temperature of the UF_6 is assumed to be ≤240°F (116°C), the autoclave is closed and the steam valves are open, UF_6 is completely liquefied and the water level in the autoclave is below the shell of the autoclave at the drain. The only requirement to be addressed for this system is to detect the failure of the UF_6 primary system and accomplish isolation of the autoclave to prevent exceeding the EGs. Once isolation is accomplished, the requirement for containing the reaction products of the release is addressed by the autoclave primary containment system. This event was evaluated in Section 4.3.2.2.14, and the consequences were determined to be below the applicable EGs.

Due to the rapid response of this system upon detection of high autoclave pressure (i.e., 15-second isolation), the environmental conditions associated with the system during operation are basically normal operational conditions.

Based on this analysis, the autoclave shell high pressure containment shutdown system will prevent exceeding the off-site EGs for the most limiting UF_6 primary system integrity failure inside an autoclave, provided the actuation pressure is ≤15 psig (205 kPa) and the autoclave isolation valves will close in ≤15 seconds after the actuation pressure is reached.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The ability of the system to meet the required functional requirements is described below. The fault tree analysis concluded that the system can meet the functional requirements described previously. However, some discussion of the specific configuration is warranted.

The autoclave pressure relief line has a pressure relief branch that is isolated by a passive rupture disk and a passive relief valve. A second branch provides vacuum relief and is isolated by an automatic isolation valve and a passive relief valve on the non-upgraded autoclaves. No corrective action is necessary because multiple failures are required for a release from either branch. However, the autoclaves have an additional fail-safe containment valve installed on the vacuum relief line.

Each non-upgraded autoclave has two separate conductivity lines per autoclave. Each conductivity line has a branch that is cut and capped downstream of a normally closed manual valve and a second branch that goes to the conductivity panel. The branch that is cut and capped downstream of a normally closed manual valve is isolated by an active isolation valve common to both branches and the normally closed manual valve. The branch on each line that goes to the conductivity panel is isolated by the common active isolation valve and a second active isolation valve in the branch. The fault tree analysis could not verify that the active isolation valves on the conductivity lines failed closed on loss of power. In addition, the current valves do not provide positive indication of position so that verification of position on loss of power could be made. Issue 3 of the Compliance Plan requires the installation of fail-safe containment valves.

The motor buffer has an air supply line and a vent line. The air supply to the motor buffer for the non-upgraded autoclaves has an active isolation valve and a passive check valve. No corrective action is necessary. However, the autoclaves have an additional fail-safe containment valve installed on the buffer air supply line. The motor buffer vent line has two isolation valves; however, only one of these receives a signal to close from the autoclave shell high pressure containment shutdown system. The second isolation valve on the motor buffer vent line is controlled by a limit switch. This limit switch prevents the valve from opening unless the autoclave shell is opened. No corrective action is necessary.

Autoclaves 1 and 2 have air ejection lines that use an active isolation valve and a normally closed manual valve to provide isolation. Because multiple failures are required to allow a release from this path, no corrective action is necessary.

It should also be noted that isolation of the transfer line for each autoclave consists of the parent cylinder safety valve inside the autoclave and an isolation valve on the transfer line outside the autoclave. For events that could damage the safety valve inside the autoclave, credit is taken for UF_6 primary system integrity outside the autoclave to prevent a release.

In addition to the fault tree analysis for isolation of all autoclave penetrations, the autoclave hydraulic system was reviewed to ensure that the autoclave shell could not be opened while an isolation signal was present.

Based on the above discussions, the autoclave shell high pressure containment shutdown system can perform its required safety function, except for the conditions identified.

3.8.5.1.4 System Classification

The autoclave shell high pressure containment shutdown system is required to perform the following functions:

- Prevent a cylinder failure inside the autoclave as a result of overheating the cylinder (e.g., autoclave steam control valve fails open)
- Mitigate releases to the atmosphere from releases inside the autoclave (e.g., a pigtail line failure inside autoclave, or cylinder failure inside an autoclave).

These release events are classified as EBEs whose consequences could exceed the off-site radiological/nonradiological EGs if the autoclave shell high pressure containment shutdown system failed to perform its safety function. Therefore, the autoclave shell high pressure containment shutdown system meets the criteria for classification as a Q system.

3.8.5.1.5 Boundary

The Q boundaries for the autoclave shell high pressure containment shutdown system are defined in Table 3.8-1.

3.8.5.2 Pigtail Line Isolation System

3.8.5.2.1 Safety Function

The autoclave pigtail line isolation system shall initiate the UF_6 line and receiving cylinder isolation upon operator action to ensure that the release of UF_6 and its reaction products for isolable events outside the autoclave is maintained below the radiological and nonradiological EGs for the EBE category.

3.8.5.2.2 Functional Requirements

The pigtail line isolation system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply to the facility.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- Isolation of the autoclave active valves shall be accomplished within 30 seconds from initiation of the system.
- Remote switches shall be located where operator action can be accomplished upon evacuation of the facility.

3.8.5.2.3 System Evaluation

The pigtail line isolation system was evaluated to assess its ability to accomplish its required safety function. In addition, a fault tree analysis was performed to determine the system's capability to accomplish the safety function. The results of the evaluations are presented in this section.

Safety function analysis. The safety function required of this system is to limit the quantity of UF_6 released to less than the radiological and nonradiological EGs for the EBE category. A review of facility operations determined that a pigtail/line failure outside autoclave event is the limiting event for this system (see Section 4.3.2.2.10). Specifically, two scenarios could result from this initiating event: (1) rupture of a transfer line while transferring to a receiving cylinder where the receiving cylinder is isolable and (2) where the receiving cylinder is not isolable. For both scenarios, operators in the facility are capable of detecting the release. For significant releases of UF_6, visual detection of the release is easily accomplished due to the reaction products forming smoke.

For each scenario, a rupture in a transfer line while transferring from a parent cylinder to a receiving cylinder results in the worst-case release (see Section 4.3.2.2.10). The requirements for this system are to provide the capability to isolate the lines within a 30-second time frame after actuation of the system and have accessibility for the operators to actuate the system. Operator response to the event is addressed in Section 4.3.2.2.10. As indicated in the system description (see Section 3.2.1.3.1.2.4), the system can isolate the required valves to perform the required safety function. The environmental conditions associated with this circuitry is not significantly different, other than the "smoke" generated from the reaction of UF_6 and the moist air, than normal operation due to the required response time and the operator. For an evaluation of the remaining functional requirements, see the qualitative fault tree analysis below.

Based on this analysis, the system will prevent exceeding the radiological and nonradiological EGs for the most limiting UF_6 primary system integrity failure at a transfer or sample station provided the system automatically closes the isolation valves within 30 seconds after initiation by the operator. Events where the cylinder valve can not be closed due to the event are addressed in Section 4.3.2.2.10.

Qualitative fault tree analysis. In addition to the safety function analysis, a qualitative fault tree analysis of the pigtail line isolation system was performed in accordance with Section 4.3.1.1.3. The ability of the system to meet the functional requirements is described below. The fault tree analysis concluded that the system can meet the functional requirements described previously, with the exception of being independent of the plant air system. However, some discussion of the specific configuration is warranted.

There are two valves that provide isolation at the parent cylinder source term. These are the parent cylinder safety valve and the UF_6 drain line autoclave containment valve. The UF_6 drain line valve is fail-safe on loss of plant air and thus will close on loss of air to accomplish the safety function. The building air supply provides the motive power for closure of the parent cylinder safety valve; a back-up air supply is provided, however, a containment signal or operator action is required to initiate closure of the valve.

The receiving cylinder for each autoclave is isolated by only one valve. The receiving cylinder safety valve provides this isolation. The building air supply system provides the motive power for the receiving cylinder safety valve to close. A backup air supply is provided.

Based on the discussion above, the pigtail line isolation system has the capability to accomplish its safety function and meet its functional requirements, with the exception of the building air supply.

3.8.5.2.4 System Classification

The pigtail line isolation system is required to perform the following safety function:

- Mitigate a pigtail/line failure outside of the autoclave.

This release event is classified as an EBE whose consequences could exceed the off-site radiological/nonradiological EGs if the pigtail line isolation system fails to perform its safety function. Therefore, the pigtail line isolation system meets the criteria for classification as a Q system.

3.8.5.2.5 Boundary

The Q boundaries for the pigtail line isolation system are defined in Table 3.8-1.

3.8.5.3 Autoclave Primary Containment System

3.8.5.3.1 Safety Function

This system is required to prevent a release of UF_6 from exceeding the off-site radiological and nonradiological EGs for the EBE category during modes when the autoclave is closed.

3.8.5.3.2 Functional Requirements

The autoclave primary containment shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be designed to withstand the evaluation basis earthquake and maintain UF_6 primary system integrity when connected to the UF_6 primary system.
- The system shall be designed to withstand the evaluation basis wind loading and maintain UF_6 primary system integrity when connected to the UF_6 primary system.
- The system shall be designed to withstand the maximum pressure generated after a release of liquid UF_6 should a breach occur during operation without structural failure of the autoclave (other active systems may be considered in combination with this requirement).
- Penetrations to the autoclave shall be protected by one of the following methods: (1) two automatic isolation valves, (2) one valve that is normally closed and manually operated or the autoclave pressure relief system configuration, or (3) a closed piping system outside the autoclave (e.g., instrument lines/instruments) which are rated for the same pressure as the autoclaves.

3.8.5.3.3 System Evaluation

The evaluation for this system is identical to the evaluation presented in Section 3.8.2.3.3, the evaluation for the feed facility autoclave primary containment system.

3.8.5.3.4 System Classification

The autoclave primary containment system, the autoclave vessel and penetrations out to the isolation valves, is required to mitigate the following:

- Releases inside an autoclave (e.g., pigtail line failure inside an autoclave); and
- Releases inside an autoclave due to cylinder failure.

These release events are classified as EBEs whose consequences could exceed the off-site radiological/nonradiological EGs if the autoclave does not maintain integrity. Therefore, the autoclave primary containment system is classified as a Q system.

3.8.5.3.5 Boundary

The Q boundaries for the autoclave primary containment system are defined in Table 3.8-1.

3.8.5.4 UF_6 Primary System

3.8.5.4.1 Safety Function

The UF_6 primary system shall provide UF_6 primary system integrity for the processes that contain gaseous and liquid UF_6.

3.8.5.4.2 Functional Requirements

The UF_6 primary system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be designed to withstand the evaluation basis earthquake and maintain UF_6 primary system integrity.
- The system shall be designed to withstand the evaluation basis wind loading and maintain UF_6 primary system integrity.
- The system shall be designed to withstand the normal operating temperatures and pressures and maintain UF_6 primary system integrity.

3.8.5.4.3 System Evaluation

This system is required to provide UF_6 primary system integrity for the processes that contain gaseous and liquid UF_6. The safety function is accomplished by retaining integrity during normal operations and upset events (e.g., autoclave steam control valve fails open in Section 4.3.2.2.2). The system is designed to withstand normal pressures and temperatures encountered during transfer operations. Additionally, the pigtails used inside the autoclaves are pressure and leak tested prior to introduction of the UF_6 after each new connection is made.

In addition, the system is required to maintain UF_6 primary system integrity during an evaluation basis earthquake and evaluation basis wind loading. The UF_6 primary system was evaluated to assess its ability to withstand earthquake and high wind events. The results of this evaluation indicated that the UF_6 primary system piping could withstand the wind loadings and any potential impacts from debris. Also, this evaluation showed that the system is capable of performing its safety function following an evaluation basis earthquake. The toll enrichment services facility UF_6 primary system can accomplish its required safety function.

3.8.5.4.4 System Classification

The UF_6 primary system is required to:

- Prevent a large release of UF_6 to the atmosphere during normal operations; and
- Prevent a large release of UF_6 during upset events that do not specifically address failures of the UF_6 primary system.

A large release of liquid UF_6 has the potential to exceed off-site EGs if the UF_6 primary system integrity fails. The entire UF_6 primary system at the toll enrichment facility contains liquid UF_6 and meets the criteria for classification as a Q system.

3.8.5.4.5 Boundary

The Q boundaries for the UF_6 primary system for the sampling and transfer processes are defined in Table 3.8-1.

3.8.5.5 High Condensate Level Shutoff System

3.8.5.5.1 Safety Function

The high condensate level shutoff system limits the amount of water present inside the autoclave during normal operation to ensure initial conditions are preserved.

3.8.5.5.2 Functional Requirements

The high condensate level shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety functions independent of any support systems.
- The system shall detect condensate levels that exceed the top of the drain at the autoclave shell and isolate sources of the steam to the autoclave.

3.8.5.5.3 System Evaluation

The high-condensate level shutoff system was evaluated to assess its ability to accomplish its required safety function. In addition, a qualitative fault tree analysis was performed to determine the system's capability to accomplish the required safety function. The results of these analyses are provided in this section.

Safety function analysis. The required safety function for the high condensate level shutoff system is to maintain the initial condition assumed by the accident analysis: during normal operation, the autoclave drain valves are open to provide a condensate drain path when steam is being applied to the autoclave environment, preventing accumulation of condensate in the drain. The analysis described in Sections 3.8.5.1 and 3.8.5.3 assumed the level of water inside the autoclave is no higher than the top of the drain at the autoclave shell. The detectors in the drain line are located below this assumed elevation. The high condensate level shutoff system accomplishes its safety function by detecting a high condensate level prior to reaching the assumed level and isolating the steam supply to the autoclave. Therefore, provided the high condensate level shutoff system can detect water levels prior to reaching the top of the drain line, and provided the same system initiates steam line isolation, the safety function is met.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The fault tree analysis concluded that the high condensate level shutoff system can meet the functional requirements described previously.

3.8.5.5.4 System Classification

The high condensate level shutoff system is required to preserve an initial condition of the accident analysis (i.e., limit the initial amount of water present in the autoclave during normal operation); but the system provides no safety function to mitigate the event. Therefore, the high condensate level shutoff system meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.3.1). Therefore, the high condensate level shutoff system is classified as AQ-NCS.

3.8.5.5.5 Boundary

The AQ-NCS boundaries for the high condensate level shutoff system are defined in Table 3.8-3.

3.8.5.6 UF_6 Cylinder High Pressure Autoclave Steam Shutoff System

3.8.5.6.1 Safety Function

The UF_6 cylinder high pressure autoclave steam shutoff system ensures that the following safety functions are accomplished:

- The system ensures that UF_6 will not reach the liquid state in the controlled feeding mode of operation.
- The system minimizes the potential for a loss of UF_6 primary system integrity during upset events that cause a pressure increase in the UF_6 primary system.

3.8.5.6.2 Functional Requirements

The UF_6 cylinder high pressure autoclave steam shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety functions:

- The system shall be capable of accomplishing the required safety function independent of any support systems.
- The system shall detect high cylinder pressure and isolate the sources of steam to the autoclave.

3.8.5.6.3 System Evaluation

The UF_6 cylinder high pressure autoclave steam shutoff system was evaluated to assess its ability to accomplish the required safety function. The results of this evaluation are provided in this section.

The safety function is to maintain the normal operating pressure of the UF_6 primary system below the MAWP of the cylinder, based on the type of cylinder being fed. This function provides direct control of the UF_6 pressure inside the cylinder. The system is designed to detect a cylinder pressure equal to or less than the actuation pressure for the system and to close the steam supply block valves. For the controlled feeding mode, the actuation must occur at ≤22 psia (152 kPa). This maximum initial pressure is assumed in the controlled feeding mode of operation and analysis of each of the initiating events for this operating mode (see Section 4.2.2.3.2). The cylinder with the lowest MAWP is rated for 100 psig (791 kPa). Therefore, the system actuation is set at ≤100 psig (791 kPa) during normal heating cycles. Based on these requirements, the safety function for this system can be accomplished.

3.8.5.6.4 System Classification

The UF_6 cylinder high pressure autoclave steam shutoff system is required to:

- Maintain the initial conditions assumed in the accident analysis for the controlled feeding mode; and
- Minimize the potential for UF_6 primary system integrity failures due to pressure transients.

This minimizes the potential for on-site personnel exposure. However, no credit is taken for this system to mitigate an event to meet off-site EGs for the EBE frequency. Therefore, the UF_6 cylinder high pressure autoclave steam shutoff system meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.3.2). Therefore, the UF_6 cylinder high pressure autoclave steam shutoff system is classified as AQ-NCS.

3.8.5.6.5 Boundary

The AQ-NCS boundaries for the UF_6 cylinder high pressure autoclave steam shutoff system are defined in Table 3.8-3.

3.8.5.7 UF_6 Cylinder High Temperature Autoclave Steam Shutoff System

3.8.5.7.1 Safety Function

The UF_6 cylinder high temperature autoclave steam shutoff system ensures that the UF_6 cylinder temperatures will not exceed the initial conditions assumed for different cylinder types when steam is being supplied to the autoclave environment. It is used to ensure that cylinder hydrostatic or zero ullage limitations will not be exceeded; or, in the case of controlled feeding, to ensure that the UF_6 is not liquified by overheating.

3.8.5.7.2 Functional Requirements

The UF_6 cylinder high temperature autoclave steam shutoff system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of any support system.
- The system shall detect high cylinder temperature and close the steam supply block valve.

3.8.5.7.3 System Evaluation

The UF_6 cylinder high temperature autoclave steam shutoff system was evaluated to assess its ability to accomplish its required safety function. In addition, a fault tree analysis was performed to determine the system's capability to accomplish the safety function. The results of these evaluations are provided in this section.

Safety function analysis. The UF_6 cylinder high temperature autoclave steam shutoff system is required to maintain the UF_6 cylinder temperature to below the values assumed in the accident analyses. During normal heating operations (controlled feeding mode excluded), the autoclave is supplied with saturated steam in a pressurized autoclave. The analysis described in Sections 3.8.5.1 and 3.8.5.3 assumed the initial temperature of the UF_6 was no higher than 240°F (116°C) or 225°F (107°C) depending on cylinder category. The UF_6 cylinder high temperature autoclave steam shutoff system accomplishes its safety function by detecting a high cylinder temperature at the assumed value and isolating the steam supply to the autoclave. Therefore, the safety function for this system can be accomplished.

For the controlled feeding mode, the safety function for the UF_6 cylinder high temperature autoclave steam shutoff system is to maintain the cylinder temperature below 147°F (64°C), which corresponds to an internal cylinder pressure of less than 22 psia (152 kPa). At this actuation temperature, the UF_6 cylinder high temperature autoclave steam shutoff system prevents liquefaction of the UF_6 and provides indirect control of the UF_6 pressure inside the cylinder. The initial condition assumed by the accident analysis for each initiating event was that the internal pressure for a cylinder in the controlled feeding mode is 22 psia (152 kPa).

The UF_6 cylinder high temperature autoclave steam shutoff system is designed to detect high cylinder wall temperature and isolate the steam supply to the autoclave. Therefore, the safety function for this system can be accomplished.

Qualitative fault tree analysis. In addition to the safety function analysis, a fault tree analysis was performed in accordance with Section 4.3.1.1.3. The fault tree analysis concluded that the UF_6 cylinder high temperature autoclave steam shutoff system can meet the required functional requirements previously described.

3.8.5.7.4 System Classification

This system is required to perform the following function:

- Preserve initial conditions assumed in the accident analysis (i.e., limit the initial cylinder temperature to ≤240°F [116°C]).

Once an initiating event occurs, the UF_6 cylinder high temperature autoclave steam shutoff system provides no safety function to mitigate the events. Therefore, this system's safety function, preserving the initial temperature conditions of the analysis, meets the criteria for classification as an AQ system.

This system is also identified as an NCS AEF (see Section 3.8.10.3.5). Therefore, the UF_6 cylinder high temperature autoclave steam shutoff system is classified as AQ-NCS.

3.8.5.7.5 Boundary

The AQ-NCS boundaries for the UF_6 cylinder high temperature autoclave steam shutoff system are defined in Table 3.8-3.

3.8.5.8 Autoclave Locking Ring Interlock System

3.8.5.8.1 Safety Function

The autoclave locking ring interlock system prevents opening of the autoclave shell after a release of UF_6 or any time the pressure is greater than the actuation pressure, when the containment bypass switch has been actuated and the autoclave pressure is greater than the autoclave high pressure containment shutdown system actuation pressure.

3.8.5.8.2 Functional Requirements

The autoclave locking ring interlock system shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall be capable of accomplishing the required safety function independent of the plant/instrument air supply.
- The system shall be capable of accomplishing the required safety function independent of the normal AC power supply to the facility.
- The system shall prevent movement of the autoclave shell when pressure inside the autoclave exceeds the autoclave high pressure containment shutdown system actuation pressure.

3.8.5.8.3 System Evaluation

The autoclave locking ring interlock system was analyzed to assess its ability to accomplish its required safety function. The results of this evaluation are presented below.

Safety function analysis. The safety function required of this system is to prevent opening the autoclave shell following a release of UF_6 inside the autoclave and actuating the containment bypass switch (see Section 3.8.5.1). This system maintains the containment isolation by providing an isolation signal to the hydraulic fluid supply in addition to the one provided by the autoclave shell high pressure containment shutdown system. The signal provided by the autoclave shell high pressure containment shutdown system can be bypassed by the emergency autoclave operation switch. However, the autoclave locking ring interlock system is designed to isolate the hydraulic fluid supply if the pressure inside the autoclave is greater than 0.5 psig (105 kPa) and to provide an interlock against opening the autoclave shell if the autoclave is pressurized (e.g., a release of UF_6 inside the autoclave has occurred). Because the actuation pressure for this system is significantly less than the 15-psig (205-kPa) actuation pressure of the autoclave shell high pressure containment shutdown system, this system will accomplish the required safety function. This interlock will function even if the emergency autoclave operation switch is pressed.

Based on this discussion, the autoclave locking ring interlock system can perform its required safety function.

3.8.5.8.4 System Classification

The autoclave locking ring interlock system is required to:

- Prevent the autoclave from being opened via the emergency autoclave operation switch following a release of UF_6 inside the autoclave.

Failure of the system after a UF_6 release inside the containment could result in significant local effects. Therefore, the autoclave locking ring interlock system meets the criteria for classification as an AQ system.

3.8.5.8.5 Boundary

The AQ boundaries for the autoclave locking ring interlock system are defined in Table 3.8-2.

3.8.5.9 Low Cylinder Pressure Shutoff System

3.8.5.9.1 Safety Function

The autoclave low cylinder pressure shutoff system shall prevent over-pressurization of a UF_6 cylinder during the heating process which could result from a blockage in the UF_6 line between the cylinder and the pressure transmitter (cylinder valve not open).

3.8.5.9.2 System Classification

Although the low cylinder pressure shutoff system does not meet the Q or AQ classification criteria specified in Section 4.2.2, the low cylinder pressure shutoff system is conservatively classified as Q.

3.8.5.9.3 Boundary

The Q boundaries for the low cylinder pressure shutoff system are defined in Table 3.8-1.

3.8.5.10 Autoclave Shell High Pressure Relief System

3.8.5.10.1 Safety Function

The autoclave shell high pressure relief system shall prevent over-pressurization of an autoclave by relieving excess pressure and reclosing of the vent path following a release.

3.8.5.10.2 System Classification

Although the autoclave shell high pressure relief system does not meet the Q or AQ classification criteria specified in Section 4.2.2, the autoclave shell high pressure relief system is conservatively classified as Q.

3.8.5.10.3 Boundary

The Q boundaries for the autoclave shell high pressure relief system are defined in Table 3.8-1.

3.8.6 Cylinder and Cylinder Handling Equipment

3.8.6.1 UF_6 Cylinders

UF_6 cylinders are classified as either Q or AQ depending on their size. This section covers UF_6 cylinders in the following facilities:

- Feed vaporization facilities,
- Withdrawal facilities,
- Toll enrichment facility, and
- UF_6 cylinder handling/storage facilities.

3.8.6.1.1 Safety Function

UF_6 cylinders provide UF_6 primary system integrity to minimize the potential for releasing UF_6 to the atmosphere. Cylinders utilized to contain UF_6 are designed, built, and tested to ANSI N14.1 and used as prescribed in USEC-651 (reference Appendix A of Chapter 1 for clarification). This ensures safe containment of UF_6 throughout the enrichment process, including transport, sampling, feeding, filling cylinders with product or tails UF_6 and preventing a release of liquid UF_6.

3.8.6.1.2 Functional Requirements

UF_6 cylinders shall be designed to meet ANSI N14.1 to ensure the capability to accomplish the required safety function.

3.8.6.1.3 System Evaluation

This system is required to minimize the potential for a release of UF_6 to the atmosphere. The safety function is accomplished by retaining its pressure retention boundary during normal operations and upset events, except those events that specifically address a breach of the UF_6 primary system (e.g., cylinder failure [see Section 4.3.2.2.15]).

The design requirements ensure that the cylinder can withstand the pressures/temperatures assumed in the accident analysis provided that the cylinder is filled within the shipping limits. Cylinders are inspected prior to heating and filling to ensure that there is no obvious damage, their weight is within established limits, and (for heating only) the pressures are $\leq$10 psia (69 kPa). Failure to meet any of these parameters could result in a failure of the cylinder integrity during normal heating or filling. A periodic hydrostatic pressure test is also required to allow filling to ensure that the integrity of the cylinder design is maintained. Cylinders manufactured prior to institution of the ANSI N14.1 standard may not meet the design requirements. These cylinders are designated only for storage of solid UF_6 and may be heated in a closed autoclave. The autoclave provides protection should a breach in the cylinder occur during heating. Prior to being refilled, they must have their free volumes verified and be hydrostatically tested. Based on these requirements, the cylinders can accomplish the required safety function.

3.8.6.1.4 System Classification

UF_6 cylinders are required to perform the following safety functions:

- Prevent a release of UF_6 to the atmosphere during normal operations; and
- Prevent a release of UF_6 to the atmosphere during upset events that do not include a failure of the cylinder.

The following factors were used in determining the system classification of the various UF_6 cylinders in use at the facilities:

- Cylinders approved (i.e., sized) for filling to greater than 500 lb (227 kg) of UF_6 are conservatively assumed to contain a sufficient amount of liquid UF_6 to exceed the off-site Egs for the EBE frequency category if a release were to occur. [A threshold analysis indicated that, in all cases, it takes more than 500 lb (227 kg) to exceed the 30-mg U dose at the site boundary (all cases that exceeded this dose were greater than 1000 lb (454 kg) of UF_6].
- Cylinders that are not approved (i.e. sized) for holding greater than 500 lb (227 kg) of UF_6 do not have the capacity to contain sufficient material to result in significant off-site health effects.
- Cylinders capable of holding greater than 500 lb (227 kg) of UF_6 but not approved for filling may contain only solid UF_6 unless they are being heated in a closed autoclave.

- Cylinders containing only gaseous/solid UF_6, regardless of size, have the potential to exceed only the on-site EGs if the cylinder does not maintain its integrity.

Therefore, cylinders capable of holding more than 500 lb (227 kg) of UF_6 are classified as Q. Smaller cylinders (capable of holding no more than 500 lb [227 kg] of UF_6) are classified as AQ.

3.8.6.1.5 Boundary

The Q and AQ boundaries for the UF_6 cylinders are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.6.2 Liquid UF_6 Cylinder Handling Cranes

The liquid UF_6 cylinder handling cranes consist of those cranes and associated lifting fixtures in the feed, withdrawal, and toll enrichment services facilities that are used to lift liquid-filled UF_6 cylinders. Facility-specific differences are noted where appropriate.

3.8.6.2.1 Safety Function

The liquid UF_6 cylinder handling cranes shall not fail in a manner to cause UF_6 primary system integrity failure. The liquid UF_6 handling cranes provide for the safe movement of liquid UF_6 cylinders. This function is accomplished by assuring liquid UF_6 handling crane lifting components and load braking systems are maintained to prevent an uncontrolled dropping of a cylinder.

3.8.6.2.2 Functional Requirements

The liquid UF_6 handling cranes shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The cranes shall be designed to withstand the evaluation basis earthquake and not fail in a manner such that the load will be dropped.
- The cranes shall be designed to withstand the evaluation basis wind loading and not fail in a manner such that the load will be dropped.
- The cranes shall be designed for the loads they will handle during operation of these facilities.
- The cranes shall be designed so that the load will not be dropped should the controls be released for any reason (e.g., evacuation of facility).

3.8.6.2.3 System Evaluation

The required safety function is to not fail in a manner that causes UF_6 primary system failure (i.e., dropped cylinder) during normal operation, an evacuation of facility event, or natural phenomena events. The cranes are designed for the loads they will handle during normal operation of these facilities. Administrative controls require inspections of the cables, brakes, and other critical items to ensure that the crane can operate correctly (refer to Chapter 1, Appendix A, for commitments to ANSI standard inspection and testing requirements). In addition, the cranes are designed so that when the controls are released (e.g., evacuation of facility event), some small additional movement occurs due to momentum after the crane drive mechanism stops and brakes are applied but these movements have no safety significance. The cranes were evaluated to assess their ability to withstand natural phenomena events. The analyses indicated that the cranes will not have any structural damage, will remain in place, and will not release their loads during an evaluation basis earthquake and wind. Floods do not reach the elevation of the facility to threaten crane integrity.

Failure of the crane lifting components or load braking system while lifting liquid-filled UF_6 cylinder could result in dropping the cylinder and rupturing the cylinder. Therefore, a load test is performed periodically.

Based on the analysis, the cranes can accomplish the required safety function.

3.8.6.2.4 System Classification

The liquid UF_6 cylinder handling cranes are required to perform the following safety function:

- Prevent dropping a liquid-filled cylinder that could result in a cylinder failure event.

The cylinder failure event is classified as an EBE whose consequences could exceed the off-site EGs if the cranes were to fail in a manner that resulted in the drop and failure of a liquid-filled cylinder. Therefore, the liquid UF_6 handling cranes meet the criteria for classification as a Q system.

3.8.6.2.5 Boundary

The Q boundaries for the liquid UF_6 cylinder handling cranes, including associated lifting fixtures, are defined in Table 3.8-1.

3.8.6.3 Liquid UF_6 Cylinder Handling Equipment

3.8.6.3.1 Safety Function

The liquid UF_6 cylinder handling equipment shall not fail in a manner to cause UF_6 primary system failure. The liquid UF_6 cylinder handling equipment provides for the safe movement of liquid UF_6 cylinders.

3.8.6.3.2 Functional Requirements

The liquid UF_6 cylinder handling equipment shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The cylinder handling equipment shall be designed to withstand the evaluation basis earthquake and not fail in a manner such that the cylinder will be dropped and failure will occur.
- The cylinder handling equipment shall be designed to withstand the evaluation basis wind loading and not fail in a manner such that the cylinder will be dropped and failure will occur.

3.8.6.3.3 System Evaluation

This system includes scale carts used for moving cylinders that contain liquid UF_6. The required safety function associated with the liquid UF_6 cylinder handling equipment is that it must not fail in a manner that will result in the failure of a cylinder during normal operation, upset events that do not address failure of the equipment, or natural phenomena events. By protecting the integrity of the cylinders, this system provides protection for on-site personnel and the off-site public from releases that could result if the system failed. Administrative controls require that (1) the UF_6 cylinder handling equipment be approved for the applicable use before handling UF_6 cylinders, (2) filled cylinders must complete a prescribed cooldown period before they are moved with handling equipment not approved for use with liquid UF_6 cylinders, (3) cylinder handling cranes be inspected daily (prior to first use) for obvious defects.

The scale carts were evaluated to assess their ability to withstand natural phenomena events. The analyses indicated that the scale carts will not have any structural damage, will remain in place, and will not release their loads during an evaluation basis earthquake. The scale carts are insensitive to evaluation basis wind loadings. Floods do not reach the elevation of the facility and, therefore, do not threaten equipment capability.

Based on the design requirements and administrative controls, the safety function for the UF_6 cylinder handling equipment can be accomplished.

3.8.6.3.4 System Classification

The liquid UF_6 cylinder handling equipment is required to:

- Prevent dropping a liquid-filled UF_6 cylinder that could result in a cylinder failure event.

The cylinder failure event is classified as an EBE whose consequences could exceed the off-site EGs if the cylinder handling equipment were to fail in a manner that resulted in the failure of a liquid-filled cylinder. Therefore, the liquid UF_6 cylinder handling equipment meet the criteria for classification as a Q system.

A postulated failure of a cylinder that has completed the prescribed cooldown period (see Section 4.3.2.2.3) would result in an initial wet-air in leakage. A relatively minor release could be expected after UF_6 reaction products pressurized the cylinder. However, workers in the immediate area would be able to evacuate before reaction products pressurized the cylinder and were released to the atmosphere.

Therefore, equipment used to handle cylinders containing UF_6 after the prescribed cool down period are classified as non-safety equipment.

3.8.6.3.5 Boundary

The Q boundaries for the liquid UF_6 cylinder handling equipment are defined in Table 3.8-1.

3.8.6.4 Cylinder Weighing System

3.8.6.4.1 Safety Function

The cylinder weighing system shall provide an accurate measure of cylinder weight for NMC&A and to ensure that cylinders are not allowed to solidify (and subsequently be heated) with weights exceeding the allowable limits. The cylinder weighing system shall provide an accurate measure of cylinder weight to ensure that cylinders are not allowed to be heated at the feed and toll enrichment facilities above 147°F (64°C) with weights exceeding the allowable limits.

3.8.6.4.2 Functional Requirements

The cylinder weighing system shall be designed to ensure the capability to accomplish the required safety function.

3.8.6.4.3 System Evaluation

The required safety function of the cylinder weighing system is to provide an accurate measure of cylinder weight. By providing a measure of the cylinder's weight, the system provides a means of indicating the quantity of UF_6 inside the cylinder. By providing a means to detect a cylinder with a weight exceeding the shipping limit, the likelihood of the cylinder being subsequently heated in this condition is reduced. The accountability scales are required to be calibrated for material tracking purposes and to ensure cylinders do not exceed allowable fill and shipping limits. This accuracy requirement is more than adequate for the cylinder weighing system to perform its required safety function. As long as the system is functional, the safety function will be met.

3.8.6.4.4 System Classification

The cylinder weighing system is required to:

- Provide an accurate measure of cylinder weight and contents; and
- Categorize a subsequent event (i.e., heating of a cylinder with excessive UF_6) as an EBE.

The system provides no mitigation should a cylinder with excessive UF_6 be heated inside an autoclave. Therefore, this system's safety function meets the criteria for classification as an AQ system.

3.8.6.4.5 Boundary

The AQ boundaries for the cylinder weighing system are defined in Table 3.8-2.

3.8.7 General Facility Safety Support

3.8.7.1 Criticality Accident Alarm System

The criticality accident alarm system (CAAS) is located in the following facilities:

- Cascade facilities (X-326, X-330, and X-333);
- Feed vaporization facilities (X-342A and X-343);
- Toll enrichment facility (X-344A);
- Withdrawal facilities (in X-326, X-330, and X-333);
- Converter shop and cleaning building, X-700;
- Decontamination building, X-705;
- Technical services building, X-710;
- Maintenance and stores building, X-720;
- Chemical engineering building, X-760;
- Waste Management Staging Facility, XT-847; and
- Other areas at the plant that may require temporary coverage.

3.8.7.1.1 Safety Function

The safety function for the CAAS is to detect neutrons, provide a distinctive, audible signal that will alert personnel to evacuate the areas that are potentially affected, and provide an alarm in the plant control facility for initiation of emergency response activities.

3.8.7.1.2 Functional Requirements

The functional requirements of ANSI/ANS 8.3 are applied to the CAAS system as described in Chapter 1, Appendix A. In addition, the following functional requirement is also applied:

- The local evacuation alarm system shall be able to perform its function without the aid of off-site AC electrical power.

3.8.7.1.3 System Evaluation

The CAAS system meets the requirements of ANSI/ANS 8.3, except as noted in Chapter 1, Appendix A. The local alarm clusters are equipped with a DC battery backup with a design rating of up to 8 hours upon loss of AC power to the cluster unit. This supply will provide sufficient power to all necessary components within the system to actuate the nitrogen-operated horn unit without AC power. Once actuated, the nitrogen horn continues to sound until the nitrogen cylinder is depleted (about 5 to 10 min). This amount of time is sufficient to meet the requirement of Section 4.4.1 of ANSI/ANS 8.3 which states that the alarm signal is for immediate evacuation purposes only.

3.8.7.1.4 System Classification

The CAAS is required to alert on-site personnel of a criticality event and the need for an immediate evacuation to minimize their exposure to radiation. Therefore, the CAAS meets the criteria for classification as an AQ system.

3.8.7.1.5 Boundary

The AQ boundaries for the criticality accident alarm system are defined in Table 3.8-2.

3.8.7.2 Fire Protection System

3.8.7.2.1 Safety Function

The fire protection system performs the following safety functions:

- Provides sufficient fire suppression capability for the cascade process buildings to minimize the likelihood of a large fire; and
- Provides fire suppression for the X-343 facility and withdrawal facilities in areas associated with handling liquid UF_6 to minimize the likelihood of a fire large enough to cause a breach in the UF_6 primary system.

3.8.7.2.2 Functional Requirements

The fire protection system accomplishes the required safety functions by satisfying the following functional requirements:

- Provide an average discharge density in excess of the required sprinkler discharge density for the cell floor and operating floor sprinkler systems in X-326, X-330, and X-333;
- Deliver the required discharge density to only one floor of a single building at a time;
- Deliver the required discharge density independent of pump operability for up to 30 min;
- Automatically initiates from a fire in any of the required buildings; and
- Provide automatic fire suppression capability to X-343 to minimize the likelihood of large fires.

3.8.7.2.3 System Evaluation

Automatic sprinkler systems. An unmitigated lube oil fire in Buildings X-326, X-330, or X-333 could lead to significant consequences for on-site personnel. Similarly, an unmitigated fire in X-343 could lead to significant consequences to onsite personnel. Based on the credible fire scenarios and an analysis of unmitigated fire effects, operator action cannot be solely relied upon to prevent or mitigate large fires. Therefore, the automatic sprinkler systems protecting these buildings are required. The water used by the sprinkler systems is supplied by the high pressure fire water system (HPFWS). This system has a gridded distribution piping network, several fire water pumps, and an elevated storage tank.

For PORTS, a hydraulic effectiveness study was performed for the existing sprinkler systems of the X-333, X-330, and X-326 process buildings. The calculated sprinkler flow densities and maximum anticipated flow demand were identified. The existing sprinkler systems can provide an average density greater than required by NFPA 13 (as described in Chapter 1, Appendix A).

High pressure fire water system. Buildings X-326, X-330, X-333 and X-343 are on the HPFWS. The system hydraulic evaluation for a lube oil fire considers a sprinkler operating area of 6400 ft^2 for a lube oil spill fire on the cell (second) floors in the process buildings. For the operating (ground) floors, the maximum sprinkler operating area was also determined to be 6400 ft^2. These sprinkler operating areas for the cell and operating floors are used to define the evaluation basis fire demand. The highest fire water flow rate for the evaluation basis fire was calculated to be 3629 gpm for the X-333 operating floor. The total water consumed in 30 min at this rate would be approximately 109,000 gal, which corresponds to about forty percent of the capacity of the X-640-2 elevated storage tank. The water-level drop in the tank for this water consumption is estimated to be 10.4 ft, which corresponds to a pressure reduction of 4.5 psi. The HPFWS fire water pumps each have a capacity that exceeds the 3629 gpm highest fire water flow rate.

Fire protection systems in other buildings. The fire protection system shall also provide automatic fire suppression capability to the UF_6 handling and storage facilities associated with X-343 and withdrawal processes to minimize the potential for large fires. This includes X-343. X-343 receives fire water from the HPFWS. Information related to the fire protection system in this building is provided below:

- The X-343 feed, vaporization, and sampling facility is protected by one wet-pipe sprinkler system.

3.8.7.2.4 <u>System Classification</u>

The fire protection system within the process buildings is required to:

- Minimize the potential for a large fire that could damage the UF_6 primary system integrity in the enrichment cascade; the large fire event was not considered as having the potential for exceeding the off-site EBE EGs.
- Minimize the likelihood of a large fire that could threaten UF_6 primary system integrity in the X-343 facility and withdrawal facilities.

The combustible fuel loading in these facilities is maintained relatively low in accordance with the Fire Protection Program (see Section 5.4). Based on this, the fire protection systems within the scope of this section meet the criteria for classification as an AQ system.

3.8.7.2.5 Boundary

The AQ boundary of the high pressure fire water system is defined in Table 3.8-2.

3.8.7.3 UF_6 Release Detection System

3.8.7.3.1 Safety Function

The UF_6 release detection system shall detect and annunciate in the ACR, UF_6 releases in any enrichment cascade operating equipment that is operated above atmospheric pressure. The compressor UF_6 outleakage detection system and the UF_6 release detection systems in the feed vaporization facilities and the toll enrichment services facility shall detect UF_6 releases to the atmosphere and provide an alarm to alert personnel to take appropriate action (i.e., investigate to verify a release occurred and, if necessary, evacuate the area affected by the release). Other systems that perform alarm and mitigation functions are discussed in Sections 3.8.2.2, 3.8.4.1 and 3.8.5.2.

3.8.7.3.2 Functional Requirements

Each of the UF_6 detection systems in the areas of the enrichment cascade that are intended to be operated above atmospheric pressure, the withdrawal, the feed vaporization, and the toll enrichment services facilities shall be designed in accordance with the following functional requirements to ensure the capability to accomplish the required safety function:

- The system shall monitor the designated areas of the facility for UF_6 releases outside of the UF_6 primary system.
- The system shall provide, in the ACR, an alarm indication of a UF_6 release from the UF_6 primary system.

3.8.7.3.3 System Evaluation

Enrichment cascade. The safety function of the system is to detect a UF_6 release from the UF_6 primary system and provide an alarm to alert on-site personnel in the ACR. This facilitates early detection by the operators allowing them to initiate required actions to minimize the release. The system is designed to detect releases in those areas that have the potential for a UF_6 release and provide an alarm in the ACR.

The detector heads are located in areas that are intended to be operated above atmospheric pressure in the "00", "000", and interbuilding booster stations. Operation of these detector heads is required during a UF_6 release. The detectors heads would be subjected to an environment associated with the release of UF_6 and its reaction products. However, the response time is relatively quick once the smoke is detected based on operational history. Once a detection signal is generated, the alarm circuit will be sealed in and operator action will be required to clear the alarm. Therefore, the environmental conditions during an event should not cause failure of the detection system. Additionally, there are multiple detector heads in each area to provide detection capability. Normal operation environments can also cause some spurious operations due to various causes and result in detector failures. These are typically detected during the testing process and the detector head will not reset. However, these are typically limited to one detector at a time. With multiple detectors located in each area, additional protection is provided to ensure system operability. Based on these requirements and evaluation, the system can accomplish the required safety function and meet its functional requirements.

Feed vaporization, withdrawal, and toll enrichment facilities. The safety functions of the withdrawal, feed vaporization, and toll enrichment services facility UF_6 release detection systems are to detect a UF_6 release from the UF_6 primary system and provide an alarm to alert on-site personnel to evacuate the affected area. The system is designed to detect releases in those areas that have the potential for a UF_6 release and provide an alarm inside the facility. Operating history has shown the system to be capable of detecting releases and providing an alarm. Based on these requirements and operating history, the safety function of the system can be accomplished.

3.8.7.3.4 System Classification

The UF_6 release detection system that is located in any "000" or "00" areas that are intended to be operated above atmospheric pressure (including inside the cell housings, cell bypass, unit bypass, and other piping and equipment housings) and in interbuilding booster stations are required to:

- Detect UF_6 releases and annunciate in the ACR; and
- Be used, in conjunction with the compressor motor manual trip system, to reduce the UF_6 primary system pressure and minimize any UF_6 releases.

Use of the system in this manner will minimize exposure of on-site personnel to UF_6 and ensure the off-site EGs are not exceeded. Credit is taken for this system to prevent exceeding the off-site EBE EGs in the large UF_6 release to atmosphere (Section 4.3.2.1.7) EBE. Therefore, this system meets the criteria for classification as a Q system.

The UF_6 release detection systems in the withdrawal, feed vaporization, and toll enrichment facilities are required to:

- Aid in detection of UF_6 releases for several events; and
- Minimize the exposure to on-site personnel.

However, these systems are not essential for the protection of the off-site public since for any significant release of UF_6 material that could threaten off-site EBE EGs, other methods of indicating that a release has occurred are also available (i.e., visual detection). Therefore, these systems meet the criteria for classification as an AQ system.

3.8.7.3.5 Boundary

The Q and AQ boundaries for the UF_6 release detection system are defined in Tables 3.8-1 and 3.8-2, respectively.

3.8.7.4 Public Warning Systems

3.8.7.4.1 Safety Function

The public warning systems provide warning to the public within a two mile radius of the plant in the event of an incident requiring evacuation or sheltering of the public.

3.8.7.4.2 Functional Requirements

See the Emergency Plan, Sections 5.4 and 6.2.

3.8.7.4.3 System Evaluation

See the Emergency Plan, Sections 5.4 and 6.2.

3.8.7.4.4 System Classification

Although the public warning systems do not meet the Q or AQ classification criteria specified in Section 4.2.2, the public warning systems are conservatively classified as AQ.

3.8.7.4.5 Boundary

The AQ boundaries for the public warning systems are defined in Table 3.8-2.

3.8.7.5 Onsite Warning/Evacuation Systems

3.8.7.5.1 Safety Function

The onsite warning/evacuation systems provide evacuation instructions or notification in the event of an incident requiring evacuation or sheltering of plant personnel.

3.8.7.5.2 Functional Requirements

See Section 3.6.5 and the Emergency Plan, Sections 5.4 and 6.2.

3.8.7.5.3 System Evaluation

See Section 3.6.5 and the Emergency Plan, Sections 5.4 and 6.2.

3.8.7.5.4 System Classification

Although the onsite warning/evacuation systems do not meet the Q or AQ classification criteria specified in Section 4.2.2, the onsite warning/evacuation systems are conservatively classified as AQ.

3.8.7.5.5 Boundary

The AQ boundaries for the onsite warning/evacuation systems are defined in Table 3.8-2.

3.8.7.6 Radiation Calibration Facility Interlocks

3.8.7.6.1 Safety Function

The radiation calibration facility interlocks prevent entry into the radiation calibration facility and potential exposure to a significant radiation source when the source is in an unshielded position.

3.8.7.6.2 Functional Requirements

See Section 3.5.1.

3.8.7.6.3 System Evaluation

See Section 3.5.1.

3.8.7.6.4 System Classification

Although the radiation calibration facility interlocks do not meet the Q or AQ classification criteria specified in Section 4.2.2, the radiation calibration facility interlocks are conservatively classified as AQ.

3.8.7.6.5 Boundary

The AQ boundaries for the radiation calibration facility interlocks are defined in Table 3.8-2.

3.8.7.7 Surge Drum Pressure/Room Temperature Instrumentation

3.8.7.7.1 Safety Function

The surge drum pressure instrumentation and room temperature instrumentation perform a safeguard function to provide pressure and temperature readings utilized in the NMC&A inventory calculations.

3.8.7.7.2 Functional Requirements

The functional requirement for the system is to provide temperature readings to ensure UF_6 in the surge drums is in a gseous state. Also see the Fundamental Nuclear Materials Control Plan.

3.8.7.7.3 System Evaluation

See Sections 3.1.1.5 and 3.1.4.3 and the Fundamental Nuclear Materials Control Plan.

3.8.7.7.4 System Classification

Although the surge drum pressure/room temperature instrumentation does not meet the Q or AQ classification criteria specified in Section 4.2.2, the surge drum pressure/room temperature instrumentation is conservatively classified as AQ.

3.8.7.7.5 Boundary

The AQ boundaries for the surge drum pressure/room temperature instrumentation are defined in Table 3.8-2.

3.8.8 Non-Radiological Chemical Systems

These systems provide containment of non-radiological chemicals identified as part of the Chemical Safety Program in Section 5.6.

The non-radiological chemical systems are defined for the following chemicals:

- Fluorine,
- Chlorine,
- Hydrogen fluoride, and
- Chlorine trifluoride.

3.8.8.1 Chemical Safety Function

The non-radiological chemical systems are required to perform the following chemical safety functions:

- Maintain integrity to the process, which minimizes the potential for releasing toxic gas into the atmosphere.
- Ensure that the fluorine primary system is relieved on high pressure to minimize the potential for a failure of the primary system integrity.
- Detect releases from the primary system and provide a local alarm indication of the release.

3.8.8.2 Functional Requirements

The non-radiological chemical systems shall be designed and maintained for the intended service. The fluorine system pressure relief system shall be available on storage tanks that contain fluorine at pressures greater than atmospheric. The system shall actuate at or below the MAWP for the fluorine storage tank and discharge to an elevated stack. The toxic gas leakage detection system shall be designed to provide local alarm indications upon detection of releases from the primary system.

3.8.8.3 System Evaluation

The non-radiological chemical systems are required to prevent releases of toxic gas to the atmosphere during normal operations. This safety function is accomplished by retaining system integrity during normal operations and upset events. The design requirements ensure that the primary systems can withstand the operating conditions assumed in the accident analysis and are appropriate for the chemical being used.

Primary ClF_3 system integrity is protected by minimizing the potential for a release of ClF_3 from the storage tanks at X-330 and X-333. A release of ClF_3 from a ruptured primary system could result in an uncontrolled release at ground level. The system accomplishes its safety function by monitoring and maintaining tank pressures to less than atmospheric pressure.

Primary fluorine system integrity is protected by minimizing the potential for a release of fluorine from a line at the storage tank at X-342B caused by overpressurization. A release of fluorine from a ruptured primary system could result in an uncontrolled release at ground level. The system accomplishes its safety function by relieving excessive pressure to the atmosphere through an elevated stack.

Toxic gas detectors are located in areas where a significant release of toxic gas could occur. The required safety action is to detect a release and provide local indications of the release. The safety action is accomplished by having detectors appropriate to the toxic gas present (chlorine, fluorine, etc.) and providing both audible and visual alarm indications at the facility. The system provides on-site protection for personnel by detecting a release and alerting personnel to immediately evacuate the area.

3.8.8.4 System Classification

The non-radiological chemical systems are required to:

- Provide primary system integrity during normal operation for the toxic gas distribution process to minimize the consequences to on-site personnel from releases of toxic gases from the process (e.g., distribution system breaches).
- Minimize the potential for failure of the primary system integrity and provide protection for on-site personnel during pressure increase events.
- Detect a toxic gas release and provide alarm for personnel in the immediate vicinity of the release.

The non-radiological chemical systems are classified as AQ systems.

3.8.8.5 Boundary

The AQ boundaries for the non-radiological chemical systems are defined in Table 3.8-2.

3.8.9 Building Structures and Confinement

3.8.9.1 Process Buildings

The process buildings house the UF_6 primary systems including the feed vaporization facilities, enrichment and purge cascades, withdrawal facilities, and the toll enrichment services. These buildings include the enrichment process buildings (X-330, X-333 and X-326), the feed vaporization buildings (X-342-A and X-343), and the toll enrichment facility (X-344-A).

3.8.9.1.1 Safety Function

The process buildings provide a significant role in minimizing both the on-site and off-site releases of UF_6 and ensure that the following safety functions are accomplished:

- Provide limited holdup of UF_6 releases to allow deposition of uranium and slower release rates to the atmosphere (cascade facilities and withdrawal facilities only), and;
- Maintain structural integrity during evaluation basis natural phenomena events (i.e., earthquakes, high winds, and flooding) to the degree needed to prevent failure of the UF_6 primary system.

3.8.9.1.2 Functional Requirements

The functional requirements are no different than the safety function.

3.8.9.1.3 System Evaluation

Process buildings X-326, X-330, and X-333 are the structural facilities housing the operations associated with the enrichment and purge cascade facilities and the product and tails withdrawal processes. The process buildings are generally steel-framed structures with concrete block and corrugated cement (transite) walls. The roofs are generally steel frame covered with concrete or steel decking. The ground floors are reinforced, poured concrete.

The process buildings are inherently capable of providing holdup to minimize consequences from UF_6 releases originating inside the buildings for on-site personnel located outside of the process buildings and for the off-site public. Credit is taken for building holdup and deposition in the calculations of the estimated consequences of UF_6 releases in the hazard analyses in Section 4.2 and in the subsequent accident analyses in Section 4.3 for events such as the large UF_6 release to atmosphere event (see Section 4.3.2.1.7). The exterior of the process buildings at the cell floor and above are the only portions of the building that are essential to accomplish this safety function. In addition, the safety function can be met regardless of ventilation system configuration. The building siding is credited for minimizing the available circulation paths for air and UF_6 reaction products. The safety function of the building siding is to control the air flow (building to atmosphere and vice versa) and thus give the internal UO_2F_2 particulates a chance to settle. Openings in the building siding which do not significantly increase the air flow of the building to atmosphere beyond that assumed for the summer conditions (all fans running with once-through circulation) are not expected to decrease the conservatism of the analysis results. Examples of openings which do not affect the analysis include openings in the cell floor access hatches or access doors, or openings below the cell floor.

The process buildings are also required to prevent a large release of UF_6 resulting from evaluation basis natural phenomena events. This safety function is accomplished by requiring the building support structures to maintain structural integrity during evaluation basis natural phenomena events to the degree needed to prevent failure of the UF_6 primary system. Table 3.8-5 summarizes the results of the natural phenomena evaluations for the process buildings. As indicated in the table, the process buildings and tie line structures will not experience any structural damage that would damage the UF_6 primary system during an evaluation basis natural phenomena event. As indicated in Table 3.8-5, Buildings X-326, X-330, X-333 and X-705 could experience some inleakage of water that may develop because of local ponding on the roof from heavy rainfall events (10,000-yr event). The analysis assumed all of the normal drainage paths were clogged, allowing no draining except over the parapets. The event would occur over a period of time, which allows for additional operator intervention prior to any inleakage occurring. The impact of water inleakage in a typical process building was reviewed, and no adverse impacts (i.e., loss of primary system integrity) were identified. Any inleakage to the cell floor would typically run to the open stairwells and floor drains, which would drain to the lower elevations. Some electrical equipment may be affected because of the water flow path. However, the likelihood of the combination of a heavy rainfall, all drainage paths being clogged, no operator intervention, and multiple electrical failures was not considered credible for these large buildings. It should be noted that compressor trip capability could also be accomplished from the switchyard if necessary to mitigate the effects of this event if it were to occur. The process buildings help minimize the consequences to on-site and off-site personnel and thus help ensure that the EGs for the facility are not exceeded to the extent possible as a result of any of the events that are postulated for the facility. Based on these requirements and supporting evaluations, the X-326, X-330 and X-333 process buildings can accomplish the required safety function.

Buildings X-342-A, X-343, and X-344-A are required to maintain structural integrity during evaluation basis natural phenomena events to the degree needed to prevent failure of the UF_6 primary system. This safety function is accomplished by requiring the structures to withstand evaluation basis natural phenomena events that could result in failures of the UF_6 primary system should the structure fail to maintain structural integrity. These buildings will not see any structural damage due to evaluation basis earthquake or flood events. However, some of the siding at X-342-A may be pulled off due to winds greater than 50 mph, and X-343 could experience structural damage at winds greater than 70 mph. The siding is not a threat to the UF_6 primary system integrity since it is pulled away from the interior of the building and would not impact any equipment. The structural damage for X-343 will not result in failure of the structure nor impact any UF_6 systems. Based on these requirements and evaluations, these buildings can accomplish the required safety functions.

3.8.9.1.4 System Classification

The process building structures are required to (1) minimize the consequences of releases of UF_6 (see Section 4.3.2.1.7) and (2) prevent a release of UF_6 to the atmosphere as a result of building structural failure during natural phenomena events (see Section 4.3.2.5). Based on the criteria in Section 4.2.2, these structures are classified as AQ.

3.8.9.1.5 Boundary

The AQ boundaries of the process building structures are defined in Table 3.8-2.

3.8.9.2 Cell Floor Process Building Cranes

The process building cranes on the cell floor consist of the overhead bridge cranes and associated equipment in the enrichment facilities and withdrawal facilities (Buildings X-326, X-330 and X-333). Process building cranes that are within the scope of this discussion include one crane in Building X-333 that is normally parked over unit bypass piping, and any process building crane that is used to transport heavy equipment above/around cascade equipment that is intended to be operated above atmospheric pressure.

3.8.9.2.1 Safety Function

The cell floor process building cranes shall not fail in a manner that will cause a large UF_6 release during:

- Normal operation
- Natural phenomena events with the cranes in the parked position; and
- An evacuation event due to a release of the controls.

3.8.9.2.2 Functional Requirements

The system shall meet the following functional requirements to ensure the capability to accomplish the required safety functions:

- The process building cranes shall not fail from the parked position in a manner that will cause UF_6 primary system failure during an evaluation basis natural phenomena event.
- The process building cranes shall be designed to prevent dropping of the load should the controls be released for any reason (e.g., evacuation of the facility).
- The process building cranes shall be designed for the loads they will handle during operation of these facilities.

3.8.9.2.3 System Evaluation

The process building cranes are required to be designed so that evaluation basis natural phenomena events will not result in a large release of UF_6 when the cranes are in the parked position. This safety function is accomplished by requiring the cranes to withstand evaluation basis natural phenomena events to the extent necessary to prevent failure of the UF_6 primary system. The process building cranes are parked in a standby location when not in use. There is one crane in Building X-333 that is normally parked over unit bypass piping. Analysis indicates that this process building crane will not fall from its parked positions during an evaluation basis earthquake, and it is not affected by the evaluation basis flood or high wind events. The use of the building cranes for moving a heavy load is infrequent because they are only needed when a piece of major equipment must be replaced. They are also used for other infrequent tasks such as replacing lights. Thus, the moving of a heavy load with a crane or the use of a crane for other activities concurrent with an evaluation basis natural phenomena event is not considered a credible event.

The process building cranes are also required to be designed so that a large release of UF_6 will not occur during an evacuation of the cascade process building (see Section 4.3.2.1.5) due to a release of the manual controls. This safety function and associated functional requirement are accomplished by the cranes being designed to not allow the load to be dropped after the operator moves the crane to his egress location and releases the controls. In addition, only small compensatory movements (to prevent the load from swinging) occur upon a release of the crane controls.

The other functional requirement is accomplished since the process building cranes were originally designed for the loads they will handle during operation of these facilities and their design capacities are maintained in accordance with the rated capacities.

The assurance of crane operability is provided by ongoing inspections and tests (refer to Chapter 1, Appendix A, for commitments to ANSI standard inspection and testing requirements). Failure of the crane lifting components or load braking system while lifting heavy loads could result in the dropping of the load and a subsequent rupture of the UF_6 primary system piping inside the process building (see Section 4.3.2.1.8).

Based on these requirements and evaluations, the process building cranes can accomplish the required safety functions and functional requirements.

3.8.9.2.4 System Classification

The Building X-333 crane that is normally parked over unit bypass piping, and the Building X-326, X-330 and X-333 cranes that are used to move heavy equipment above/around equipment intended to be operated above atmospheric pressure are classified as AQ because their failure could impact the UF_6 primary system and initiate a large UF_6 release.

3.8.9.2.5 Boundary

The AQ boundaries of the cell floor process building cranes are defined in Table 3.8-2.

3.8.9.3 Cascade Equipment Housings

The cascade equipment housings enclose UF_6 primary system equipment in the enrichment cascade, F/S process, purge cascade, and portions of the withdrawal facilities to maintain normal operating temperatures. Although their principal function is to thermally insulate the high temperature equipment, they do provide holdup capacity in the event of a UF_6 release from the UF_6 primary system.

3.8.9.3.1 Safety Function

The cascade equipment housings shall provide a barrier for the release of UF_6 from a UF_6 primary system failure within the housing.

3.8.9.3.2 Functional Requirements

The functional requirement is to prevent an unimpeded release of UF_6 to the building following a UF_6 release within the housing from the UF_6 primary system.

3.8.9.3.3 System Evaluation

The cascade equipment housings are inherently capable of providing a barrier to UF_6 releases from UF_6 primary system failure within the housings. This function serves to minimize exposure of local workers to UF_6, however the function is not considered essential for this receptor. Specific credit is taken in the accident analysis for holdup and deposition of UF_6 releases within the housing for events whose unmitigated consequences have the potential to impact the off-site public (see Sections 4.3.2.1.3 and 4.3.2.1.7). These events involve cascade equipment (cells or interbuilding boosters) that are operating above atmospheric pressure. The accident analysis modeling (see Section 4.3.2.1.7) shows that the UF_6 released into the equipment housing quickly escapes (via cracks, untightened seams, and a door that is assumed to swing open to the outside) to the remainder of the unit and eventually to other units (mostly to neighboring units). The model (MELCOR) used to characterize a release into a cell housing modeled the air flow rate from the housing, during normal operation, based on 1/12 of the ceiling surface area being open which accounts for 70%-90% of the air flow rate. The remainder of the air flow rate from the housing is comprised of leakage through the cell walls.

The only cascade equipment housings that are required as essential controls are those housings that could be configured in a manner that could invalidate the results of the accident analysis where specific credit is taken for holdup and deposition of material released into and ultimately out of the building. The cascade equipment housings that fall into this category are the housings that enclose cells or interbuilding booster stations which are intended to be operated above atmospheric pressure.

3.8.9.3.4 System Classification

In areas of the cascade that are operated above atmospheric pressure, the cell and interbuilding booster station housings are credited as reducing the amount of UF_6 released from the building by holdup and deposition of a portion of the release within the housings. These structures, in areas of the cascade that are intended to be operated above atmospheric pressure, are classified as AQ consistent with the process buildings and UF_6 primary system classification.

3.8.9.3.5 Boundary

The AQ boundary of the cascade cell equipment housings is defined in Table 3.8-2.

3.8.9.4 Miscellaneous Waste Storage & Handling and Support Structures

The miscellaneous waste storage & handling and support structures include the primary control facility (X-300), the decontamination building (X-705), the technical services building (X-710), the maintenance and stores building (X-720), and the Waste Management Staging Facility (XT-847).

3.8.9.4.1 Safety Function

These miscellaneous buildings ensure the following safety function is accomplished:

- Maintain necessary structural integrity during evaluation basis natural phenomenon events (i.e., earthquakes, high winds, and flooding).

3.8.9.4.2 Functional Requirements

The functional requirements are no different than the safety function.

3.8.9.4.3 System Evaluation

These miscellaneous buildings are required to maintain structural integrity during evaluation basis natural phenomena events. As indicated in Table 3.8-5 and clarified below, these buildings will not experience structural damage that would prohibit accomplishment of the required safety functions. Building X-705 could experience some inleakage of water that may develop because of local ponding on the roof from heavy rainfall events (10,000-yr event). The impact of this inleakage was reviewed and no adverse impacts were identified. Additionally, some of the siding at X-705 may be pulled off due to winds greater than 70 mph. This condition was determined to have no effect on equipment inside the building.

Building XT-847 was determined to meet the maximum wind loading and peak ground acceleration values for the seismic events. The building meets the EBE guidelines for high winds and earthquakes. Based on the current facility operations with fissile material, it is considered highly unlikely that any random structure failure of XT-847 would result in an unsafe geometry being created with the materials currently staged in the building .

Based on these requirements and evaluations, these buildings can accomplish the required safety function.

3.8.9.4.4 System Classification

These miscellaneous building structures are required to prevent building structural failure during natural phenomena events (see Section 4.3.2.5). Based on the criteria in Section 4.2.2, these structures are classified as AQ.

3.8.9.4.5 Boundary

The AQ boundaries of the miscellaneous waste storage & handling and support structures are defined in Table 3.8-2.

3.8.10 Nuclear Criticality Safety Active Engineered Features (AEFs)

This section provides a description of AEFs that are relied upon for nuclear criticality safety, as discussed in Appendix A to Section 5.2. AEFs are defined as those systems that provide an automatic hardware response to particular process variables. These systems may be electrical, mechanical, hydraulic, or pneumatic in nature. AEFs do not include indicators and/or alarm functions that require operator response, since this response is administrative in nature. AEFs also do not include physical designs or properties of systems that are passive in nature.

3.8.10.1 ERP, LAW and Tails Withdrawal Facilities

3.8.10.1.1 ERP Pressure Blind Controller

3.8.10.1.1.1 Safety Function

The ERP PBC (pressure blind controller) automatically closes the RCW control valves when the coolant pressure drops below set point value. This will maintain the coolant pressure greater than the RCW pressure, thus ensuring that the UF_6 and RCW will not mix in the event the physical barrier between the systems is breached.

3.8.10.1.1.2 Functional Requirements

The PBC automatically closes the RCW control valves when the coolant pressure drops below the set point value.

3.8.10.1.1.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.1.1.4 System Classification

The ERP pressure blind controller is classified as AQ-NCS.

3.8.10.1.1.5 Boundary

The AQ-NCS boundary for the pressure blind controller is defined in Table 3.8-3.

3.8.10.1.2 ERP and LAW Pressure Switches

3.8.10.1.2.1 Safety Function

PBSs (pressure blind switches) automatically close the RCW block valve when the RCW pressure exceeds the set point or coolant pressure drops below the set point value. This will maintain the coolant pressure greater than the RCW pressure, thus ensuring that the UF_6 and RCW will not mix in the event the physical barrier between the system is breached.

3.8.10.1.2.2 Functional Requirements

The PBSs automatically close the RCW block valve when either the RCW pressure exceeds the set point or the coolant pressure drops below the set point value.

3.8.10.1.2.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.1.2.4 System Classification

The ERP and LAW pressure switches are classified as AQ-NCS.

3.8.10.1.2.5 Boundary

The AQ-NCS boundary for the ERP and LAW pressure switches is defined in Table 3.8-3.

3.8.10.2 X-342A and X-343 UF_6 Feed Facilities

3.8.10.2.1 High Condensate Level Shutoff System

3.8.10.2.1.1 Safety Function

The high condensate level shutoff system prevents an undesirable water inventory level in the autoclave which, in the event of a UF_6 release could cause over-pressurization or a nuclear criticality. The system function is to detect an unacceptable water level resulting from a drain line plug or restriction and to shut off the steam flow to the autoclave.

3.8.10.2.1.2 Functional Requirements

The high condensate level shutoff system shall isolate the steam supply ensuring a water inventory less than the maximum acceptable water inventory within the autoclave.

3.8.10.2.1.3 System Evaluation

See Section 3.8.2.5.3 and Section 5.2, Appendix A.

3.8.10.2.1.4 System Classification

The high condensate level shutoff system is classified as AQ-NCS. See also Section 3.8.2.5.4.

3.8.10.2.1.5 Boundary

The AQ-NCS boundary for the high condensate level shutoff system is defined in Table 3.8-3.

3.8.10.2.2 UF_6 Cylinder High Pressure Autoclave Steam Shutoff System

3.8.10.2.2.1 Safety Function

The UF_6 cylinder high pressure autoclave steam shutoff system prevents over-pressurization of a UF_6 cylinder during the heating process which could result from excessive "light" gases or overfilling. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.2.2.2 Functional Requirements

The UF_6 cylinder high pressure autoclave steam shutoff system shall detect autoclave pressure and initiate closure of the steam block valve above system actuation pressures.

3.8.10.2.2.3 System Evaluation

See Section 3.8.2.6.3 and Section 5.2, Appendix A.

3.8.10.2.2.4 System Classification

The UF_6 cylinder high pressure autoclave steam shutoff system is classified as AQ-NCS. See also Section 3.8.2.6.4.

3.8.10.2.2.5 Boundary

The AQ-NCS boundary for the UF_6 cylinder high pressure autoclave steam shutoff system is defined in Table 3.8-3.

3.8.10.2.3 Autoclave Shell High Pressure Containment Shutdown System

3.8.10.2.3.1 Safety Function

The autoclave shell high pressure containment shutdown system is designed to contain a release of UF_6 inside the autoclave. It actuates at the lowest pressure which can be assumed to not be due to a steam control failure and still give an early indication of a UF_6 release in progress. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.2.3.2 Functional Requirements

The autoclave shell high pressure containment shutdown system shall detect high pressure inside the autoclave and initiate autoclave isolation when the actuation pressure is exceeded.

3.8.10.2.3.3 System Evaluation

See Section 3.8.2.1.3 and Section 5.2, Appendix A.

3.8.10.2.3.4 System Classification

The autoclave shell high pressure containment shutdown system is classified as Q. See Section 3.8.2.1.4.

3.8.10.2.3.5 Boundary

The Q boundary for the autoclave shell high pressure containment shutdown system is defined in Table 3.8-1.

3.8.10.2.4 Autoclave Shell High Steam Pressure Shutdown System

3.8.10.2.4.1 Safety Function

The autoclave shell high steam pressure shutdown system ensures that a cylinder is not overheated due to an instrument of steam supply system failure, which could create a high cylinder pressure situation leading to a UF_6 release. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.2.4.2 Functional Requirements

The autoclave shell high steam pressure shutdown system shall detect internal autoclave pressure and close the steam block valve for pressures exceeding the system actuation pressure.

3.8.10.2.4.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.2.4.4 System Classification

The autoclave shell high steam pressure shutdown system is classified as AQ-NCS.

3.8.10.2.4.5 Boundary

The AQ-NCS boundary for the autoclave shell high steam pressure shutdown system is defined in Table 3.8-3.

3.8.10.2.5 UF_6 Cylinder High Temperature Autoclave Steam Shutoff System

3.8.10.2.5.1 Safety Function

The UF_6 cylinder high temperature autoclave steam shutoff system ensures that cylinder hydrostatic or zero ullage limitations will not be exceeded; or, in the case of controlled feeding, ensures that the UF_6 is not liquified by overheating. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.2.5.2 Functional Requirements

See Section 3.8.2.7.2.

3.8.10.2.5.3 System Evaluation

See Section 3.8.2.7.3 and Section 5.2, Appendix A.

3.8.10.2.5.4 System Classification

The UF_6 cylinder high temperature autoclave steam shutoff system is classified as AQ-NCS. See also Section 3.8.2.7.4.

3.8.10.2.5.5 Boundary

The AQ-NCS boundary for the UF_6 cylinder high temperature autoclave steam shutoff system is defined in Table 3.8-3.

3.8.10.2.6 Autoclave Conductivity Monitoring System

3.8.10.2.6.1 Safety Function

The autoclave conductivity monitoring system continuously samples the steam condensate in the autoclave for high conductivity, which can be a result of UF_6 reacting with water forming HF. Detection of high conductivity results in autoclave containment, thus preventing a possible release to unfavorable geometry, such as the building drain system.

3.8.10.2.6.2 Functional Requirements

The autoclave conductivity monitoring system shall detect conductivity of steam condensate and provide a signal to put the autoclave into containment when the actuation conductivity is exceeded.

3.8.10.2.6.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.2.6.4 System Classification

The autoclave conductivity monitoring system is classified as AQ-NCS.

3.8.10.2.6.5 Boundary

The AQ-NCS boundary for the conductivity monitoring system is defined in Table 3.8-3.

3.8.10.3 X-344A Toll Enrichment Services Facilities

3.8.10.3.1 High Condensate Level Shutoff System

3.8.10.3.1.1 Safety Function

The high condensate level shutoff system prevents an undesirable water inventory level in the autoclave which, in the event of a UF_6 release could cause over-pressurization or a nuclear criticality. The system function is to detect an unacceptable water level resulting from a drain line plug or restriction and to shut off the steam flow to the autoclave.

3.8.10.3.1.2 Functional Requirements

The high condensate level shutoff system shall isolate the steam supply ensuring a water inventory less than the maximum acceptable water inventory within the autoclave.

3.8.10.3.1.3 System Evaluation

See Section 3.8.5.5.3 and Section 5.2, Appendix A.

3.8.10.3.1.4 System Classification

The high condensate level shutoff system is classified as AQ-NCS. See also Section 3.8.5.5.4.

3.8.10.3.1.5 Boundary

The AQ-NCS boundary for the high condensate level shutoff system is defined in Table 3.8-3.

3.8.10.3.2 UF_6 Cylinder High Pressure Autoclave Steam Shutoff System

3.8.10.3.2.1 Safety Function

The UF_6 cylinder high pressure autoclave steam shutoff system prevents over-pressurization of a UF_6 cylinder during the heating process which could result from excessive "light" gases or overfilling. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.3.2.2 Functional Requirements

The UF_6 cylinder high pressure autoclave steam shutoff system shall detect autoclave pressure and initiate closure of the steam block valve above system actuation pressures.

3.8.10.3.2.3 System Evaluation

See Section 3.8.5.6.3 and Section 5.2, Appendix A.

3.8.10.3.2.4 System Classification

The UF_6 cylinder high pressure autoclave steam shutoff system is classified as AQ-NCS. See also Section 3.8.5.6.4.

3.8.10.3.2.5 Boundary

The AQ-NCS boundary for the UF_6 cylinder high pressure autoclave steam shutoff system is defined in Table 3.8-3.

3.8.10.3.3 Autoclave Shell High Pressure Containment Shutdown System

3.8.10.3.3.1 Safety Function

The autoclave shell high pressure containment shutdown system is designed to contain a release of UF_6 inside the autoclave. It actuates at the lowest pressure which can be assumed to not be due to a steam control failure and still give an early indication of a UF_6 release in progress. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.2.3.2 Functional Requirements

The autoclave shell high pressure containment shutdown system shall detect high pressure inside the autoclave and initiate autoclave isolation when the actuation pressure is exceeded.

3.8.10.3.3.3 System Evaluation

See Section 3.8.5.1.3 and Section 5.2, Appendix A.

3.8.10.3.3.4 System Classification

The autoclave shell high pressure containment shutdown system is classified as Q. See Section 3.8.5.1.4.

3.8.10.3.3.5 Boundary

The Q boundary for the autoclave shell high pressure containment shutdown system is defined in Table 3.8-1.

3.8.10.3.4 Autoclave Shell High Steam Pressure Shutdown System

3.8.10.3.4.1 Safety Function

The autoclave shell high steam pressure shutdown system ensures that a cylinder is not overheated due to an instrument of steam supply system failure, which could create a high cylinder pressure situation leading to a UF_6 release. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.3.4.2 Functional Requirements

The autoclave shell high steam pressure shutdown system shall detect internal autoclave pressure and close the steam block valve for pressures exceeding the system actuation pressure.

3.8.10.3.4.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.3.4.4 System Classification

The autoclave shell high steam pressure shutdown system is classified as AQ-NCS.

3.8.10.3.4.5 Boundary

The AQ-NCS boundary for the autoclave shell high steam pressure shutdown system is defined in Table 3.8-3.

3.8.10.3.5 UF_6 Cylinder High Temperature Autoclave Steam Shutoff System

3.8.10.3.5.1 Safety Function

The UF_6 cylinder high temperature autoclave steam shutoff system ensures that cylinder hydrostatic or zero ullage limitations will not be exceeded; or, in the case of controlled feeding, ensures that the UF_6 is not liquified by overheating. The system contributes to nuclear criticality safety by preventing the release of UF_6 to areas outside the autoclaves with unfavorable geometry.

3.8.10.3.5.2 Functional Requirements

See Section 3.8.5.7.2.

3.8.10.3.5.3 System Evaluation

See Section 3.8.5.7.3 and Section 5.2, Appendix A.

3.8.10.3.5.4 System Classification

The UF_6 cylinder high temperature autoclave steam shutoff system is classified as AQ-NCS. See also Section 3.8.5.7.4.

3.8.10.3.5.5 Boundary

The AQ-NCS boundary for the UF_6 cylinder high temperature cutoff system is defined in Table 3.8-3.

3.8.10.3.6 Autoclave Conductivity Monitoring System

3.8.10.3.6.1 Safety Function

The autoclave conductivity monitoring system continuously samples the steam condensate in the autoclave for high conductivity, which can be a result of UF_6 reacting with water forming HF. Detection of high conductivity results in autoclave containment, thus preventing a possible release to unfavorable geometry, such as the building drain system.

3.8.10.3.6.2 Functional Requirements

The autoclave conductivity monitoring system shall detect conductivity of steam condensate and provide a signal to put the autoclave into containment when the actuation conductivity is exceeded.

3.8.10.3.6.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.3.6.4 System Classification

The autoclave conductivity monitoring system is classified as AQ-NCS.

3.8.10.3.6.5 Boundary

The AQ-NCS boundary for the conductivity monitoring system is defined in Table 3.8-3.

3.8.10.3.7 Section Deleted

3.8.10.4 Uranium Recovery and Chemical Systems

3.8.10.4.1 X-705 Microfiltration pH Shutdown System

3.8.10.4.1.1 Safety Function

The microfiltration pH shutdown system is required to maintain the solution pH at a level where there is not a sufficient amount of uranium contained in the effluent stream entering the effluent tank to cause a nuclear criticality.

3.8.10.4.1.2 Functional Requirements

The microfiltration pH shutdown system shall detect the system pH and shut down the system when the actuation pH is exceeded.

3.8.10.4.1.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.1.4 System Classification

The microfiltration pH shutdown system is classified as AQ-NCS.

3.8.10.4.1.5 Boundary

The AQ-NCS boundary for the microfiltration pH shutdown system is defined in Table 3.8-3.

3.8.10.4.2 X-705 Microfiltration Permeate Effluent Bag Filter System

3.8.10.4.2.1 Safety Function

The microfiltration permeate effluent bag filter system detects failure of the microfiltration system. The effluent bag filter collects solids, while maintaining a safe differential pressure across the filter. If differential pressure increases to an unacceptable level the discharge valve will close to prevent solids from reaching the effluent tank.

3.8.10.4.2.2 Functional Requirements

The microfiltration permeate effluent bag filter system shall detect differential pressure across the bag filter and close the microfiltration system discharge valve if differential pressure increases above the actuation differential pressure.

3.8.10.4.2.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.2.4 System Classification

The microfiltration permeate effluent bag filter system is classified as AQ-NCS.

3.8.10.4.2.5 Boundary

The AQ-NCS boundary for the microfiltration permeate effluent bag filter system is defined in Table 3.8-3.

3.8.10.4.3 X-705 B-Area Condensate Drain System

3.8.10.4.3.1 Safety Function

The X-705 B-area condensate drain system continuously samples the evaporator steam condensate for high conductivity, which can be a result of UF_6 reacting with water and forming HF. Detection of high conductivity results in a diversion of flow to favorable geometry storage tanks, in place of the unfavorable geometry storm sewer.

3.8.10.4.3.2 Functional Requirements

The B-area condensate drain system shall divert condensate flow to favorable geometry storage tanks upon detection of high conductivity.

3.8.10.4.3.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.3.4 System Classification

The B-area condensate drain system is classified as AQ-NCS.

3.8.10.4.3.5 Boundary

The AQ-NCS boundary for the X-705 B-area condensate drain system is defined in Table 3.8-3.

3.8.10.4.4 X-705 Calciner High-High Temperature Shutoff System

3.8.10.4.4.1 Safety Function

The X-705 calciner high-high temperature shutoff system prevents calciner tube failure at high temperatures, which could result in leaking of highly concentrated (uranyl nitrate) solutions or oxides into a geometrically unfavorable calciner heating cavity. High temperature is detected by temperature sensing elements located inside the heated housing at the calciner tubes.

3.8.10.4.4.2 Functional Requirements

The calciner high-high temperature shutoff system shall sense high temperatures and close the flow safety block valve and shut off the heaters.

3.8.10.4.4.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.4.4 System Classification

The calciner high-high temperature shutoff system is classifies as AQ-NCS.

3.8.10.4.4.5 Boundary

The AQ-NCS boundary for the calciner high-high temperature shutoff system is defined in Table 3.8-3.

3.8.10.4.5 X-705 Calciner Discharge Collector Probe Detection System

3.8.10.4.5.1 Safety Function

The X-705 calciner discharge collector probe detection system is used to control uranium oxide backing up into the calciner discharge throat, which is an unfavorable geometry.

3.8.10.4.5.2 Functional Requirements

The calciner discharge throat level control system shall sense high level in the discharge throat and close the flow safety block valve.

3.8.10.4.5.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.5.4 System Classification

The calciner discharge collector probe detection system is classified as AQ-NCS.

3.8.10.4.5.5 Boundary

The AQ-NCS boundary for the calciner discharge collector probe detection system is defined in Table 3.8-3.

3.8.10.4.6 X-705 Calciner Can Level Probe Detection System

3.8.10.4.6.1 Safety Function

The X-705 calciner can level probe detection system prevents uranium oxide from overflowing out of the can into the glove box, which could be an unfavorable geometry.

3.8.10.4.6.2 Functional Requirements

The calciner can level control system shall detect high can level and close the flow safety block valve.

3.8.10.4.6.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.6.4 System Classification

The calciner can level probe detection system is classified as AQ-NCS.

3.8.10.4.6.5 Boundary

The AQ-NCS boundary of the calciner can level probe detection system is defined in Table 3.8-3.

3.8.10.4.7 X-705 Calciner Tube Rotation Interlock System

3.8.10.4.7.1 Safety Function

The X-705 calciner tube rotation interlock system is to prevent calciner tube failure at too high temperatures caused by uneven heating. This could occur if tube rotation remains stopped for an extended period of time during heating. Failure could result in leaking of highly concentrated uranyl nitrate solutions or oxides into a geometrically unfavorable calciner heating cavity.

3.8.10.4.7.2 Functional Requirements

A switch monitoring tube rotation and the rotation drive motor contactor must both be made up for the heater and feed pump contactors to be energized.

3.8.10.4.7.3 System Evaluation

See Section 5.2, Appendix A.

3.8.10.4.7.4 System Classification

The calciner tube rotation interlock system is classified as AQ-NCS.

3.8.10.4.7.5 Boundary

The AQ-NCS boundary for the calciner tube rotation interlock system is defined in Table 3.8-3.

3.8.11 Nuclear Criticality Safety Passive SSCs

Passive structures, systems and components that (1) are necessary to meet the double contingency principle for the prevention of an accidental nuclear criticality or (2) represent the single contingent control to prevent an accidental nuclear criticality where the double contingency principle is not met are identified in NCSEs/NCSAs.

Reference for Section 3.8

3.8-1 *Recommended Practice of Sizing Large Lead Storage Batteries for Generating Stations and Substations*, IEEE Standard 485-1983.

Table 3.8-1. Boundary Definition for Q Structures, Systems, and Components

System	Facility	Boundary Definition	Support Systems
Compressor Motor Manual Trip System and DC Power Distribution System (Sections 3.8.3.1, 3.8.3.2)	X-333 X-533	1. Manual trip switches in the ACR for the X-333 "000" enrichment compressor motors 2. At X-533, associated ACB trip coils, contacts and 250 VDC circuit breakers for X-333 3. At X-533, associated 13.8 kV ACB air receiver, check valve and associated piping 4. Associated relays, switches and control wiring 5. Associated 250 VDC power supplies - 250 VDC battery banks associated with the ACR trip circuits - Associated 250 VDC control and alarm power breakers in distribution cabinets - DC circuit breakers in switchgear and substation supply - The associated wiring circuits to connect the relays and trip coils to the batteries 1. Manual trip switches in the ACR for the X-330 "00" enrichment compressor motors 2. Associated 2400 VAC substation circuit breakers, including trip coils, for the X-330 "00" compressor motors 3. Associated relays, switches and control wiring 4. Associated 250 VDC power supplies - 250 VDC battery banks associated with the ACR trip circuits - Associated 250 VDC control and alarm power breakers in distribution cabinets - DC circuit breakers in switchgear and substation supply - The associated wiring circuits to connect the relays and trip coils to the batteries Note: The trip systems for the EBS motors and the interbuilding booster compressor motors are excluded from this boundary.	250 VDC Control Power (Section 3.8.3.2)
Low Cylinder Pressure Shutoff System (Sections 3.8.2.9, 3.8.5.9)	X-342A X-343 X-344A	1. Pressure sensing instrumentation 2. Timer 3. Steam block valve 4. Solenoid valve (operates the steam block valve) 5. Programmable logic controller (includes input-output modules) 6. Connecting electrical signal and pneumatic lines	This system is fail safe upon loss of electric power or air

Table 3.8-1. Boundary Definition for Q Structures, Systems, and Components (continued)

System	Facility	Boundary Definition	Support Systems
Autoclave Shell High Pressure Containment Shutdown System (Sections 3.8.2.1, 3.8.5.1, 3.8.10.2.3, 3.8.10.3.3)	X-342A X-343 X-344A	1. Pressure sensing instrumentation 2. Containment block valves (and (when applicable) associated air reserve tank, pilot valve and check valve), including steam supply, condensate drain, vent, feed header, purge air, conductivity sample and steam exhaust 3. Solenoid valves (operates the containment block valves) 4. Programmable logic controller (includes input/output modules) 5. Process piping from the autoclave shell to containment block valves, including piping between redundant containment block valves 6. Autoclave shell, o-ring, shell locking ring, shell penetrations and connecting electrical signal and pneumatic lines 7. Associated circuitry to close the containment block valves 8. Associated circuitry to de-energize the air supply and solenoid valves back to the first interrupt device 9. Hydraulic interlocks and associated circuitry	This system is fail safe upon loss of electric power or air with the following exceptions for non-upgraded autoclaves: The "F" valve located in the feed line of each autoclave, which will fail as-is (X-343 autoclaves 3 & 4)
Pigtail Line Isolation Systems (Sections 3.8.2.2, 3.8.5.2)	X-342A X-343 X-344A	1. Containment Switches 2. Programmable logic controller (includes input/output modules) 3. UF6 line isolation valves, including backup air volume on the cylinder safety valve 4. Solenoid valves (operates UF6 line isolation valves)	This system is fail safe upon loss of electric power or air with the following exceptions for non-upgraded autoclaves: The "F" valve located in the feed line of each autoclave, which will fail as-is (X-343 autoclaves 3 & 4)

Table 3.8-1. Boundary Definition for Q Structures, Systems, and Components (continued)

System	Facility	Boundary Definition	Support Systems
Autoclave Primary Containment Systems (Sections 3.8.2.3, 3.8.5.3)	X-342A X-343 X-344A	1. Autoclave vessel 2. Autoclave penetrations and isolation valves 3. Autoclave instrument lines 4. Autoclave pressure relief line up to and including the rupture disk	No support systems required.
Autoclave Shell High Pressure Relief System (Sections 3.8.2.10, 3.8.5.10)	X-342A X-343 X-344A	In addition to the autoclave pressure relief line up to and including the rupture disk, which is part of the autoclave primary containment system, the boundary includes: 1. Pressure relief valve 2. Piping between rupture disk and pressure relief valve 3. Manual block valve and pressure indicator installed in autoclave pressure relief line 4. Vent line piping to atmosphere	No support systems required.
UF_6 Cylinder Pigtail (Sections 3.8.2.4, 3.8.4.5, 3.8.5.4)	X-326 X-330 X-333 X-342A X-343 X-344A	1. Pigtail assembly, including tubing, fittings and valve 2. Gasket	No support systems are required.
UF_6 Withdrawal Primary System (Section 3.8.4.5)	X-326 X-330 X-333	1. Condensers 2. Accumulators 3. Manifold valves 4. Vent line block valve 5. Piping between the condensers and the manifold and vent line valves. Also the crossover piping between withdrawal points.	No support systems are required.

Table 3.8-1. Boundary Definition for Q Structures, Systems, and Components (continued)

System	Facility	Boundary Definition	Support Systems
UF_6 Primary System (Section 3.8.5.4)	X-344A	The UF_6 Primary System includes all UF_6 transfer and sample piping outside the second autoclave containment isolation valve.	No support systems required.
Liquid UF6 Cylinder (Section 3.8.6.1)	X-326 X-330 X-333 X-342A X-343 X-344A	1. Cylinders with the capacity of holding more than 500 lb of UF_6. 2. Cylinder valve 3. Cylinder plug Cylinder valve protector is classified as AQ. See Table 3.8-2.	No support systems are required.
Liquid UF_6 Cylinder Handling Cranes (Section 3.8.6.2)	X-326 X-330 X-333 X-342A X-343 X-344A	1. Hoist brakes 2. Hoist motor 3. Upper movement paddle limit switch 4. Wire rope and hook 5. Hoist shaft/coupling 6. Pendant control/ radio control 7. Passive mechanical and load bearing structural aspects of the crane and supports as indicated on plant boundary drawings 8. Geared up/down limit switch	The crane braking system is fail safe upon loss of the electrical support system
Liquid UF_6 Cylinder Lifting Fixtures (Section 3.8.6.2)	X-326 X-330 X-333 X-342A X-343 X-344A	1. Lifting fixture assembly, inload path, 2. Wire rope or chain legs (belly bands for X-344A cranes)	No support systems are required.
Liquid UF_6 Cylinder Handling Equipment (Section 3.8.6.3)	X-326 X-330 X-333 X-344A	1. Scale carts (including cradles)	No support systems are required

Table 3.8-1. Boundary Definition for Q Structures, Systems, and Components (continued)

System	Facility	Boundary Definition	Support Systems
Pigtail Line Isolation System (Section 3.8.4.1, 3.8.10.1.1)	X-326 X-330 X-333	1. UF6 detector heads located above each withdrawal position 2. UF6 line isolation valves (manifold and pigtail), including the associated air reserve tank, pilot valve, handswitch, and check valve 3. Solenoid valves (operates UF6 line isolation valves) 4. Connecting electrical signal and pneumatic lines 5. Pyrotronics control unit 6. Block valve between accumulator and withdrawal manifold.	This system is fail safe upon loss of the electrical or air support system.
UF6 Release Detection System (Section 3.8.7.3)	X-330 X-333	The UF_6 release detection system that is located in any "000" or "00" areas that are intended to be operated above atmospheric pressure (including inside the cell housings, cell bypass, unit bypass, and other piping and equipment housings) and in interbuilding booster stations, including: 1. Detector heads - CADP System 2. Associated signal conditioners 3. Signal cable from the detector heads to the signal conditioner 4. Alarm indication, including connecting electrical signal lines 5. Electrical supply from and including the auxiliary substation breaker to the CADP signal conditioner, including breaker, transformer and wiring. Redundant power supplies are provided to the auxiliary substation.	120-VAC electric power is required for the system to perform its required safety function. In the automatic mode, this system will fail into a trouble alarm upon loss of the electrical support system, thereby alerting the operator that compensatory measures must be provided to continue operations.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components

System	Facility	Boundary Definition	Support Systems
Compressor Motor Manual Trip System and DC Power Distribution System (Sections 3.8.3.1, 3.8.3.2)	X-326 X-330 X-333 X-300	1. Manual trip switches in the ACR for the X-326 and X-330 "0" enrichment compressor motors 2. Associated 250 VDC power supplies for X-326 and X-330 "0" ACR trip circuits - 250 VDC battery banks associated with the ACR trip circuits - Associated 250 VDC control and alarm power breakers in distribution cabinets - DC circuit breakers in switchgear and substation supply - The associated wiring circuits to connect the relays and trip coils to the batteries 3. Manual trip switches in the PCF for the X-330 and X-333 enrichment compressor motors 4. 125 VDC auxiliary trip relays for PCF trips 5. Associated ACB relays, switches and control wiring 6. Associated wiring circuits to connect the relays and trip coils to the batteries 7. Automatic transfer switch between normal and battery power in PCF 8. Associated 2400 VAC (X-330 "0") and 480 VAC (X-326) substation circuit breakers, including trip coils Note: The trip systems for the EBS motors and the interbuilding booster compressor motors are excluded from this boundary.	250 VDC Control Power 125 VDC Control Power (Sections 3.8.3.2, 3.8.4.3)
Compressor Motor Manual Trip System and DC Power Distribution System (Withdrawal Stations) (Sections 3.8.4.2, 3.8.4.3)	X-326 ERP X-330 Tails X-333 LAW	1. Manual trip buttons/switches in the ACR (LCR for ERP) for the withdrawal station second stage compressor motors 2. Associated 250 VDC power supplies - 250 VDC battery banks associated with the ACR(LCR for ERP) trip circuits - Associated 250 VDC control and alarm power breakers in distribution cabinets - DC circuit breakers in switchgear supply - The associated wiring circuits to connect the relays and trip coils to the batteries 3. Associated 480 VAC MCC circuit breakers, including trip coils	250 VDC control power (Section 3.8.4.3) - except for ERP compressor W-2 and all LAW second stage compressors. ERP compressor W-2 and all LAW second stage compressors utilize a trip system that is fail-safe on loss of power.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Mass Spectrometers (Section 3.8.4.7)	X-326 X-330 X-333	The on-line assay mass spectrometer boundary includes the following: 1. Two known laboratory standards. There is a constant comparison of the spectrometer reading to the standards to ensure accuracy. 2. The computer software. It compares the two known standards against the gas sample being delivered to the spectrometer.	Failure of any component of this system, other than the standards and software, would stop a reading from being taken and require alternate laboratory sampling to be taken.
Gamma Spectrometers (Section 3.8.4.8)	X-326 ERP X-333 LAW X-330 Tails	The gamma spectrometers consist of a spectrometer indicating analyzer and the gamma ray detector and source.	Operator surveillance is required to ensure assay limits are not exceeded. This is accomplished by assay spectrometer monitoring or samples being taken. Since operator interaction is required and an alternate method of sampling is approved, support system failure is not a concern.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
UF6 Primary Systems (Sections 3.8.2.4, 3.8.3.3, 3.8.5.4)	X-326 X-330 X-333 X-342A X-343	1. UF_6 primary system including UF_6 process gas piping 2 in. and larger, expansion joints, process gas coolers, valves, and equipment containing UF_6. Only the characteristics of the systems listed below which provide the containment function are controlled as AQ SSCs. Internal parts (e.g., compressor blades, barrier, etc.) that do not form part of the UF_6 pressure boundary are not AQ. a. X-342A, X-343 - From, but not including, the second autoclave containment valve to the exit point from the building. b. X-326, X-330, X-333 - From the entry point(s) into the building to the exit points(s) from the building or up to, but not including, UF_6 condenser(s) in the withdrawal stations. c. X-333 F/S - From the cell "A" and "B" process piping up to, and including, the Freezer/Sublimer vessels and vessel cooler fins. d. UF_6 tie lines - Interbuilding tie lines from the exit points from a building to the entry point(s) to the next building. 2. Covers that are temporarily or permanently attached to openings on installed or removed equipment when the purpose of the cover is to provide a containment boundary, including the prevention of wet air inleakage.	No support systems are required.
Coolant High-Pressure Relief System, Withdrawal Condenser Coolant Relief Systems, and Freezer/Sublimer High Pressure Relief System (Section 3.8.3.4)	X-326 X-330 X-333	1. Coolant High Pressure Relief System, Withdrawal Condenser Coolant Relief Systems at ERP and LAW: - rupture disks - piping and manual valve between the coolant condenser and the rupture disk 2 Freezer/Sublimer High Pressure Relief System - rupture disks - vent line from F/S vessel to A-line bypass - block valves AFS(unit)C(cell)V1 in Units 2- 7 - block valves AFS(unit)C(cell)V2 in Units 4 and 6	No support systems are required.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Freezer/Sublimer UF_6 High-High Weight Trip System (Section 3.8.3.5)	X-333	1. "B" Line (inlet block) valves 2. Weight control relays (electrical) 3. Weight rate control valve 4. Solenoid valves (operates pneumatic weight control valves) 5. Weight sensing instrumentation and associated circuitry 6. Electrical supply from Auxiliary MCC to "B" line valve operators, including breakers and wiring.	Pneumatic valves are fail safe on loss of electric power and air; high-high weight switches are not fail safe on loss of electric power, but the control relays, which are energized from the same power source are fail safe and will place the system in a safe state.
Motor Load Indicators (Sections 3.8.3.6, 3.8.4.4)	X-326 ERP X-330 X-333	1. Motor load indicators (ammeters) for each enrichment cascade and second stage withdrawal station compressor motor in the ACR (LCR for ERP) 2. Total cell motor load indicators for each enrichment cascade cell in the PCF 3. Cabling connecting ACR and PCF indicators to compressor motor AC power buses	No support systems are required
Autoclave Locking Ring Interlock System (Sections 3.8.2.8, 3.8.5.8)	X-342A X-343 X-344A	1. Pressure switch 2. Control relay	This system is fail safe. Electrical or control circuit interruption causes the pressure switch contact and the control relay contact to be open, which in turn deactivates the hydraulic system keeping the locking ring from disengaging.
UF6 Cylinder Valve Protector (Section 3.8.6.5)		1. Cylinder valve protector installed on 2.5, 10 and 14 ton Q and AQ cylinders	No support systems are required.
UF6 Cylinders (Section 3.8.6.1)		1. Cylinders with a capacity of holding no more than 500 lb of UF6 2. 1S cylinders - these sample cylinders consist of the cylinder body plus adapters and cylinder valve. 3. 2S cylinders - these sample cylinders consist of the cylinder body plus adapters and cylinder valve.	No support systems are required. Note: 2S Cylinder valve body is also classified as an AQ-NCS passive control.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
UF6 Cylinder Weighing System (Section 3.8.6.4)		1. Field Accountability Scales 2. Laboratory Accountability Balances 3. Mass Standard Calibration Balances 4. ERP, LAW, Tails Withdrawal station Production Scales Included within the boundary are the scale/balance to include the electronics of the scale and any utility up to, but not including, the point of connection to the building utility, i.e., electrical service.	No support systems are required
Criticality Accident Alarm System (Section 3.8.7.1)	X-326 X-330 X-333 X-342A X-343 X-344A X-700 X-705 X-710 X-720 X-760 XT-847	1. Radiation detector cluster unit 2. N_2 Strombos horn 3. N_2 supply 4. Associated N_2 piping, tubing and components necessary to maintain N_2 pressure 5. Circuitry associated with the local alarm 6. Cluster and slave facility trouble relays, switches, indication, and associated circuitry 7. Slave facility alarm relays and associated circuitry 8. Slave facility N_2 horn warning system 9. CAAS horns (other than N_2 horns), air horn solenoid valves and associated circuitry 10. Cluster and slave facility criticality alarm building lights 11. Air supply back to but not including the main air supply header (for process building air horns); and 12. Power source back to and including the automatic transfer switch (only for process building air horn solenoid valves and X-300 alarm/trouble indication). Associated slaved buildings are shown in Table 3.6.2-1.	This system is fail safe upon loss of the electrical support system (cluster only) For X-326, X-330 and X-333 Process Buildings: 1. Power source for process building air horn solenoid valves 2. Air supply to process building air horns For X-300 PCF: 1. Power source for CAAS alarm/trouble indication For slave facilities and alerting of the PCF: The power supplied to the building CAAS horns and exterior lights is monitored and a trouble alarm will be initiated in X-300 upon loss of power. Therefore, the electrical support system is not included in the boundary.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Freon Degrader Fluorine Flow System (Section 3.8.3.8)	X-326	F_2 Flow control capillary tubes necessary to prevent an unacceptable concentration of fluorine in the cascade	No support systems are required
UF6 Release Detection System (Section 3.8.7.3)	X-326 (ERP) X-330 (TAILS) X-333 (LAW)	1. Detector heads - CADP System 2. Signal conditioner 3. Signal cable from the detector head to the signal conditioner 4. Alarms and associated circuitry 5. Electrical supply from and including the auxiliary substation breaker to the signal conditioner including breakers, transformer and wiring.	120-VAC electric power is required for the system to perform its required safety function. In the automatic mode at the withdrawal stations, this system will fail into a trouble alarm upon loss of the electrical support system, thereby alerting the operator that compensatory measures must be provided to continue operations. Redundant power supplies are provided to the auxilary substation
	X-342A X-343 X-344A	1. Detector heads - Pyrotronics System 2. Control unit 3. Alarms and associated circuitry 4. Signal cable from detector heads to control unit 5. Electrical supply back to and including the first breaker in the electrical distribution panel.	Loss of power to the electrical distribution panel will be evident to operations personnel, who will initiate compensatory actions.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Onsite Warning/Evacuation Systems (Section 3.8.7.5)	PA is used for X-site facilities; other system is for cascade buildings only.	The Onsite Warning/Evacuation Systems are used to provide evacuation instructions or notification in the event of an incident requiring evacuation or sheltering of plant personnel. See the Emergency Plan Sections 6.2 and Section 3.6.2. The Public Address (PA) System boundary includes: 1. Speakers; 2. Microphones - two at X-300 and 1 at X-1020; 3. Power amplifiers and mixer/preamps and tone generators; 4. Lo-signal relays; 5. Wiring and fiber optic links between the PA microphones and speakers; and 6. Distributed process controller and installed software. The Cascade Building Evacuation Alarm System boundary includes: 1. Horns; 2. Pushbuttons (ACR and X-300 console); 3. Horn contactors, relays, wiring and associated circuitry; 4. Solenoid valves (process building horns only); 5. Power source back to and including the automatic DC transfer switch (for building air horn solenoid valves only); 6. Wiring necessary to provide an evacuation alarm to portions of the Cascade Buildings where the PA systems is not effective; and 7. Air supply (to air horns) back to the main air supply header.	Air supply to air horns in cascade buildings The X-300 and X-1020 PA control consoles receive a feedback from each addressed facility to indicate that a message was or wasn't received. The X-300/X-1020 PA control console power source is backed up with an uninterruptible power supply and is continuously manned. Failure of both normal and UPS power sources would be obvious to the PA operator, which would result in the operator initiating an alternate method.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
High Pressure Fire Water System (Section 3.8.7.2)	X-326 X-330 X-333 X-343 X-611 X-640-1 X-640-2 X-6644	**Water Reservoirs** 1. 1,700,000-gallon basins at X-611. This includes the underground piping and valves to the X-640-1 pumphouse. 2. 300,000-gallon elevated steel storage tank at X-640-2. This includes the underground piping and valve to the underground piping around the Process Buildings. 3. Two 2,000,000-gallon suction tanks near the X-6644 pumphouse and the associated underground piping and valves to the pumphouses. **Pumphouses** X-640-1 contains three fire pumps. Two of these pumps are electric fire pumps, and their power source from controller in X-633 pumphouse are included. The third fire pump is a stand alone diesel fire pump. Piping to and from the underground and valves in the pumphouse, the underground to the underground loop around the Process Buildings, and the electrical supply (for electrical fire pumps) to, and including, the breaker in the building power panel, are included. Also included is one electric jockey pump. the diesel fuel supply tank for the diesel fire water pump and all connecting fuel lines are included within the boundary.	Power source from the building power panel for the electric fire pumps Loss of power to the building power panel will be evident to operations personnel, who will initiate compensatory actions.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
High Pressure Fire Water System (cont'd)		X-6644 contains three fire pumps. Two of these pumps are electric fire pumps, and their power from the controller in X-6644 are included. The third fire pump is a stand alone diesel fire pump. Piping and valves associated with HPFWS, in the pumphouse and the underground to the underground loop around the Process Buildings, and the electrical supply up to, and including, the breaker in the building power panel, are included. The diesel fuel supply tank for the diesel fire water pump and all connecting lines are included within the boundary. The associated electrical and control circuitry for local (pumphouse) manual start of the pumps is included within the boundary. **Underground** The underground consists of the piping, and sectional valves, around the three Process Buildings, which supply the water to the sprinkler systems in these buildings. It also includes the lead-in, and the control valves on the lead-in, to the sprinklers in the Process Buildings and X-343. The Gaseous Centrifuge Enrichment Plant (GCEP) underground is connected to the GDP at three locations. This includes these three tie-in points, the piping, and associated sectional valves, around X-3001 and X-3002, X-7725 and X-7721. **Sprinklers** In the Process Buildings and X-343 it includes piping and valves from the underground lead-in to and including the sprinkler heads. It does not include the piping to the alarm or the alarm itself, or Fire Department connection to the sprinkler riser.	
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Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Public Warning System (Section 3.8.7.4)		The Public Warning System provides warning to the public within a two-mile radius of the plant in the event of an incident requiring evacuation or sheltering of the public. The boundary includes: 1. Sirens; 2. Towers/Poles (5 locations); 3. Control stations necessary to operate the public warning system to include power supplies, battery backup units and any connecting wiring (one at each tower); and 4. Electronic siren controllers at X-300 PCF, X-1020 and Pike County Sheriff Department.	Battery backup exists at towers and backup power supplies exist at electronic controllers, thus no electric support system required.
Cold Trap Pressure Relief System (Section 3.8.3.4)	X-330 X-333	The Cold Trap Pressure Relief System is to prevent inadvertent over-pressurization and rupturing of the Cold Trap which could result in the release of UF_6 and other toxic gases such as ClF_3. This can only occur if some gas other than UF_6 was liquified or solidified in the cold trap during freeze mode. The boundary includes the following: 1. Pressure relief control valve; 2. Pressure sensing instrumentation; 3. Solenoid valve (operates the pressure relief control valve); 4. rupture disk; 5. Piping on the cold trap inlet side to the first manual valve and to the relief drum, including the two manual valves in the relief line; 6. Relief drum. 7. Power source for PBS's and solenoid valves back to and including the first breaker in the power panel; and 8. Air supply required for PBMs back to, but not including, the main air supply header	Power source for the cold trap pressure relief switches. Air supply to the cold trap pressure relief transmitter.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Datum Systems (Section 3.8.3.7)	X-326 X-330 X-333	The Datum Systems provide a means to control the Cascade pressure to ensure it does not exceed the limit specified for each type of cascade equipment. The Datum Systems also provide an indication of Unit/Cell pressure used for Nuclear Material Control and Accountability (NMC&A). The boundary includes: Those portions of the Datum system that are required to control the operating pressure of the Cascade and provide direct indication of the Cascade Systems pressure used in the NMC&A process. This includes the following items associated with the High Datum System, the Standby Datum System and the cell datum system: 1.a. X-326 and X-330 Unit Datum System boundary includes: IBR; PIC (datum and stage control); PBM (datum and stage control); surge volume tank; pneumatic lines between the PBM, PIC, PBS and IBR; piping/tubing, including valves, from the surge volume tank up to, but not including, the datum exhaust header, and the dry air header; unit high datum header; cell high datum header; piping/tubing at the stage to provide connections between the cell high datum header and stage control DBM; piping/tubing to provide connections between the stage B-line and the stage control DBM;	Power source for the datum system pressure control and alarm instrumentation.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Datum Systems (cont'd)		Datum pressure control valve (CV) and solenoid valve (SV); ACR high/low datum pressure alarm, including instrumentation and associated circuitry; datum exhaust pressure PBM/PBS and circuitry; low instrument air PBS and circuitry; and power source back to and including the dc automatic transfer switch. b. X-326 and X-330 Standby and Cell Datum System PIX; PBM; and piping/tubing, including valves; (1) from the unit datum PIX and PBM to, but not including, the datum exhaust header and the dry air header and (2) from the cell datum PBM and PIX to the unit high datum header and from the cell datum PIX to, but not including, the seal exhaust header and nitrogen header 2.a. X-333 Unit Datum System IBR; PIC (datum and stage control); DBM (datum and stage control); surge volume tank; pneumatic lines between the DBM, PIC, PBS and IBR; piping/tubing, including valves, from the surge volume tank up to, but not including, the datum exhaust header and the dry air header; unit high datum header; cell high datum header; piping/tubing at the stage to provide connections between the cell high datum header and stage control DBM;	

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Datum Systems (cont'd)		piping/tubing to provide connections between the stage B-line and the stage control DBM; Datum pressure control valve (CV) and solenoid valve (SV); ACR high/low datum pressure alarm, including instrumentation and associated circuitry; datum exhaust pressure PBM/PBS and circuitry; low instrument air PBS and circuitry; and power source back to and including the dc automatic transfer switch. b. X-333 Standby and Cell Datum System PIX; DBM/PBM; and piping/tubing, including valves, (1) from the unit datum PIX and DBM to, but not including, the datum exhaust header and the dry air header and (2) from the cell datum PBM and PIX to the unit high datum header and from the cell datum PIX to, but not including, the seal exhaust header and nitrogen header.	
Surge Drum Pressure/Room Temperature Instrumentation (Section 3.8.7.7)	X-326 X-330 X-333	The safeguard function of the Surge Drum pressure instrumentation and room temperature instrumentation is to provide pressure and temperature readings utilized in the NMC&A inventory calculations. Temperature readings are necessary to ensure UF_6 in surge drums is in a gaseous state. The boundary instruments are: 1. Pressure transducers/transmitters; 2. Pressure indicators; and 3. Temperature elements and indicators.	Failure is obvious. Operator surveillance is required to check readings to ensure limits are not exceeded. Operator actions will be taken upon loss of primary instruments. These actions can be the use of portable instruments or return of materials to the cascade. No support system is included in this boundary.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Process Buildings (Section 3.8.9.1)	X-326 X-330 X-333 X-342A X-343 X-344	1. Foundations 2. Base Plates 3. Building frames 4. Column anchorage 5. Load bearing walls 6. Reinforcing tees 7. Bracing 8. Seismic expansion joints (gaps between floor sections 9. Structural steel connectors 10.Transite siding at the cell floor and above 11.Roof	No support systems are required
Cascade Equipment Housings (Section 3.8.9.3)	X-330 X-333	For housings over cells or interbuilding booster stations that are intended to be operated above atmospheric pressure: 1. Steel frame surrounding UF_6 primary systems 2. Transite or sheet metal panels attached to the framing.	No support systems are required
Cell Floor Process Building Cranes (Section 3.8.9.2)	X-326 X-330 X-333	1. Bridge crane rails and structural supports for the X-333 crane parked over unit bypass piping 2. For cranes that are used to transport heavy equipment above/around the UF_6 primary system that is intended to be operated above atmospheric pressure: a. associated rigging (slings and fixtures) b. motor controls c. load braking system d. bridge crane rails and structural supports	Electric power is required to release the brake for movement. Loss of power causes brake to engage. No support system required

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Radiation Calibration Facility Interlocks (Section 3.8.7.6)	X-700	The boundary of the radiation calibration facility safety interlock system includes the facility beam room, door, and following electrical compartments: 1. Entrance door closure switch; 2. Beam room sliding radiation shielding door closure switch; 3. Interior motion detectors; 4. Gamma and neutron detectors; 5. Manual scram pushbuttons; 6. Beam room walls (approximately 3 feet thick); and 7. Beam room sliding radiation shielding door; 8. Source rod assembly; 9. Control relays; and 10.Solenoid valves.	An open circuit, power failure, switch failure, detector failure, etc. removes power to the source rod assembly and the spring loaded rod retracts the radition source to the shielded position; no support systems are required.
Miscellaneous Waste Storage and Handling and Support Structures (Section 3.8.9.4)	X-300 X-705 X-710 X-720 XT-847	1. Foundations 2. Building frames 3. Bracing 4. Structural steel connectors	No support systems are required

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Non-Radiological Chemical Systems (Section 3.8.8.1)	X-611E X-330 X-333 X-342A X-342B	These systems provide containment of non-radiological chemicals identified as part of the Chemical Safety Program in Section 5.6. The boundaries include: Cl_2 Systems a. The boundary of this system extends from the pigtail connection at the vendor-supplied cylinder valve through the Cl_2 injectors, including associated piping, gauges, and instrumentation as defined in the 29 CFR 1910.119 Process Hazard Analysis for Cl_2 systems. b. Chlorine leak detectors and associated alarms are also included in the boundary. ClF_3 Systems The boundaries of these systems extend from the pigtail connection at the vendor-supplied cylinder valve to the distribution header, including associated piping, components, gauges, and instrumentation as defined in the 29 CFR 1910.119 Process Hazard Analysis for ClF_3 systems. Also, the air supply required for PBMs back to, but not including, the main air header. HF/F_2 System a. The boundary of this system includes the HF cylinder and extends through the feeding orifices to the F_2 distribution system located in the X-342A Trap Room, including associated piping, components, gauges, and instrumentation as defined in the 29 CFR 1910.119 Process Hazard Analysis for HF/F_2 systems. b. Hydrogen fluoride and fluorine leak detectors and associated alarms are also included in this boundary.	The Cl_2 detection units have battery backup on loss of power. Loss of power to the chlorinators and chlorine injectors does not affect the AQ function. Therefore, no support system is required for the Cl_2 system. Upon loss of 115 VAC or 125VDC power to the ClF_3 system, the valve associated with the ClF_3 cylinders will close, containing flow. Also, general indications will be evident to operations personnel. Therefore, no support system is required for the ClF_3 system. The HF/F_2 system "Q" circuit fails safe on loss of power. Therefore, no support system is required for the HF/F_2 system.

Table 3.8-2 Boundary Definition for AQ Structures, Systems, and Components (Continued)

System	Facility	Boundary Definition	Support Systems
Cold Trapping Operation Pressure and Temperature Control System (Section 3.8.2.11)	X-343	1. Pressure transmitters 2. Pressure indicating controllers 3. Pressure transducers (I/P) 4. Pressure control valves 5. Temperature elements 6. Temperature indicating controllers 7. Temperature indicating switches 8. Temperature alarms 9. Software associated with the temperature switches and alarms	This system is fail-safe upon loss of power or air
Cold Trap Defrost Operation Control System (Section 3.8.2.12)	X-343 X-344	1. Temperature switch 2. Solenoid valve	This system is fail-safe on loss of power.

Table 3.8-3. Boundary Definition for NCS AEF Structures, Systems, and Components.

System	Facility	Boundary Definition	Support Systems
ERP Pressure Blind Controller (Section 3.8.10.1.1)	X-326 ERP	1. Pressure Blind Multiplier (PBM) 2. Pressure Indicating Transmitter (PIX) 3. Pressure Blind Controller (PBC) 4. Control Valves (2)(CV)	No support systems required
ERP and LAW Pressure Switches (Section 3.8.10.1.2)	X-326 ERP X-333 LAW	Pressure switches and associated circuitry.	No support systems required
High Condensate Level Shutoff System (Sections 3.8.2.5, 3.8.5.5, 3.8.10.2.1, 3.8.10.3.1)	X-342A X-343 X-344A	1. Level probes and level switches (2) 2. Steam block valve 3. Solenoid valve (operates the steam block valve) 4. Solid state logic modules/programmable logic controller (includes input/output modules) 5. Connecting electrical signal and pneumatic lines 6. Autoclave drain line to, and including, the second containment isolation valve	System is fail safe upon loss of electric power or air
UF6 Cylinder High Pressure Autoclave Steam Shutoff System (Sections 3.8.2.6, 3.8.5.6, 3.8.10.2.2, 3.8.10.3.2)	X-342A X-343 X-344A	1. Pressure sensing instrumentation 2. Steam block valve 3. Solenoid valve (operates the steam block valve) 4. Solid state logic modules/programmable logic controller (includes input/output modules) 5. Connecting electrical signal and pneumatic lines	This system is fail safe upon loss of electric power or air.
UF6 Cylinder High Temperature Autoclave Steam Shutoff System (Sections 3.8.2.7, 3.8.5.7, 3.8.10.2.5, 3.8.10.3.5)	X-342A X-343 X-344A	1. Temperature switch 2. Temperature element/thermocouple/feed thru 3. Steam block valve 4. Solenoid valve (operates the steam block valve) 5. Solid state logic modules/programmable logic controller (includes input/output modules) 6. Connecting electrical signal and pneumatic lines	This system is fail safe upon loss of electric power or air.

Table 3.8-3. Boundary Definition for NCS AEF Structures, Systems, and Components (Continued).

System	Facility	Boundary Definition	Support Systems
Autoclave Shell High Steam Pressure Shutdown System (Sections 3.8.10.2.4, 3.8.10.3.4)	X-342A X-343 X-344A	1. Pressure sensing instrumentation 2. Steam block valves 3. Solenoid valves (operates the steam block valve) 4. Solid state logic modules/programmable logic controller (includes input/output modules) 5. Connecting electrical signal and pneumatic lines	System is fail safe upon loss of the electrical or air support system
Autoclave Conductivity Monitoring System (Sections 3.8.10.2.6, 3.8.10.3.6)	X-342A X-343 X-344A	1. Conductivity cell and conductivity indicating switch 2. Steam condenser 3. Piping from second containment valves to the conductivity elements 4. Pressure sensing instrumentation 5. Solenoid valves and associated containment isolation valves 6. Solid state logic modules/programmable logic controller (includes input/output modules) 7. Connecting electrical signal and pneumatic lines	System is fail safe upon loss of the electrical or air support system
Evacuation System and Cold Traps (Section 3.8.10.3.7)	X-344A	Cold trap heater timer.	No support systems required.
Microfiltration pH Shutdown System (Section 3.8.10.4.1)	X-705	1. pH probes/switches, control relays and associated wiring 2. Flow control valve and associated solenoid valve	System is fail safe upon loss of the electrical or air support system
Microfiltration Permeate Effluent Bag Filter System (Section 3.8.10.4.2)	X-705	1. Permeate bag filters 2. Pressure differential switches 3. Time delay relays 4. Flow control valve and associated solenoid valve	System is fail safe upon loss of the electrical or air support system

Table 3.8-3. Boundary Definition for NCS AEF Structures, Systems, and Components (Continued).

System	Facility	Boundary Definition	Support Systems
B-Area Condensate Drain System (Section 3.8.10.4.3)	X-705	1 Conductivity cells, conductivity indicating switch, control relays and associated wiring 2. Safe storage control valve, drain control valves and associated solenoid valves	System is fail safe upon loss of the electrical or air support system
Calciner High-High Temperature Shutoff System (Section 3.8.10.4.4)	X-705	The system boundary includes: 1. Temperature sensing/switching instrumentation; 2. Control relay; 3. Flow Safety block valve; 4. Solenoid valve (operates the flow safety block valve); and 5. Heater relay contactor.	The system is fail safe upon loss of the electrical or air support system.
Calciner Discharge Collector Probe Detection System (Section 3.8.10.4.5)	X-705	The system boundary includes: 1. Level probes/switches; 2. Control relay; 3. Flow Safety block valve; and 4. Solenoid valve (operates the flow safety block valve).	The system is fail safe upon loss of the electrical or air support system.
Calciner Can Level Probe System (Section 3.8.10.4.6)	X-705	The system boundary includes: 1. Level probes/switches; 2. Control relay; 3. Flow Safety block valve; and 4. Solenoid valve (operates the flow safety block valve).	The system is fail safe upon loss of the electrical or air support system.
Calciner Tube Rotation Interlock System (Section 3.8.10.4.7)	X-705	1. Rotation monitoring switch; 2. Control relay (tube rotation); 3. Rotation drive motor contactor; 4. Rotation drive motor; 5. Heater relay contactor; and 6. Temperature alarm module.	This system is fail safe upon loss of the electrical support system.

Table 3.8-4. Seismic Capabilities of Process Gas Piping and Equipment in X-333

Component	Location	Capacity (g)	Annual Probability of Failure	Location	Comment
H-29* (Single Exp. Joint)	A-stream	<0.05	$>1.4 \times 10^3$	Cells	The H-29 single bellows type expansion joints with three convolutions subject to differential building movements. Two H-29 bellows types were inspected and one has three convolutions and the other has seven convolutions. Only the three convolution bellows have capacities less than EBE. (This condition can occur at 36 different locations in the building, i.e., where the piping on the cell floor is routed between cells at structural boundaries.)
All other equipment, piping, and components had capabilities ≥ the evaluation basis earthquake.					

* Pressure boundary is not likely to be adversely affected.

Table 3.8-5. Natural Phenomena Capacities of Buildings.

Structure	Seismic (OK > 0.05 g)	Wind OK > 75 mph (121 km/h) Structure	Wind OK > 75 mph (121 km/h) Components	Flood
X-300	OK	OK	OK	OK
X-326	OK	OK	60[a] (97)	Inleakage[b]
X-330	OK	OK	65[a] (105)	Inleakage[b]
X-333	OK	OK	60[a] (97)	Inleakage[b]
X-343	OK	OK	70[c] (113)	OK
X-344-A/342	OK	OK	70[a] (113)	OK
X-345	OK	OK	OK	OK
X-705	OK	OK	70[a] (113)	Inleakage[b]
X-710	OK	OK	OK	OK
X-720	OK	OK	OK	OK
XT-847	OK	OK	OK	OK
Tie lines	OK	OK	OK	OK

a. Siding pulls off.
b. Roof ponding.
c. Limited roof displacement

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3.9 ITEMS ADDRESSED BY COMPLIANCE PLAN

This section is implemented as described with exceptions as listed below. The listing of the exceptions also contains a brief description of what is currently in place at the plant. The Compliance Plan provides a description of the exceptions (noncompliances), a justification for continued operation, a description of the actions to be taken to achieve compliance and the schedule for completion of those actions.

3.9.1 Conformance of the Facility and Process Description to Plant Configuration

The existing FSAR for the Portsmouth Gaseous Diffusion Plant, GAT/GDP-1073, was used as the basis for the information presented in Sections 3.0 to 3.6 of the SAR, while the information in Section 3.7 was developed from the project description for HEU Refeed. The following guidelines were used in developing this information:

- Concentrate on systems, structures and components (SSCs) that correspond to the Accident Analysis presented in Section 4,
- Utilize approved plant changes, upgrades or equipment removals to describe the current plant configuration,
- Provide supplementary information/technical detail as necessary to support the Accident Analysis and the Technical Safety Requirements.

As a result of these guidelines, certain information dealing with plant facilities and support systems have not been fully updated to accurately and comprehensively reflect the current plant configuration. As part of the SAR upgrade activity, revisions will be made to the Accident Analysis that will require revisions to the Facility and Process Description. As part of that process, the Facility and Process Description will be revised and updated to ensure consistency with the results of the Upgrade Program and reflect adjustments resulting from the completion of other program upgrades identified in the Compliance Plan, such as the Configuration Management Program.

3.9.2 Autoclave Upgrades

The current design of the X-342, X-343 and X-344 autoclave containment systems do not provide for individual testing of the containment valves. In addition, the UF_6 feed isolation and control valves, which are also used as containment valves, are not suited for containment purposes. The autoclave isolation system will continued to be operated with the existing valves in accordance with TSR until the modifications are made to allow individual valve testing. The internal autoclave and UF_6 pressure systems have too high a range and insufficient temperature compensation to perform within the calibration tolerances needed. There are no alarms to alert operators to possible upset conditions prior to the activation of a safety system. The autoclave steam supply and condensate removal systems are not adequate to remove condensate from the autoclave rapidly enough to keep the High Condensate Level Cutoff System from activating. The head/shell sealing surfaces are experiencing significant corrosion, which could affect their ability to seal. The containment isolation valve on the liquid UF_6 line is not fail-safe on autoclaves 3 and 4 in X-344. The daughter cylinder isolation valves on the autoclaves in X-344A do not fail closed on loss of air nor do they have a backup air supply. Autoclave 2 in X-344 does not have a low instrument air pressure switch to initiate containment upon loss of instrument air. The autoclaves in X-342, X-343, and X-344 are not prevented from being inadvertently opened when an Autoclave Shell High-Pressure Containment Shutdown System containment isolation signal is present.

The design of the X-342, X-343 and X-344 autoclaves containment system, as described in Section 3.2, will be upgraded as follows:

1. Provide the capability for separate testing of the inner loop and outer loop containment valves on thirteen autoclaves;

2. Install containment valves upstream of the UF_6 feed isolation and control valve on nine autoclaves;

3. Modify the programmable logic control systems on each autoclave to accommodate these changes.

4. Modify the internal autoclave and UF_6 pressure systems to improve their accuracy in the operating range.

5. Provide operational alarms on autoclave safety systems to alert operators to potential upset conditions.

6. Modify the autoclave steam supply and condensate removal systems to minimize the back-up of condensate in an autoclave.

7. Restore head/shell sealing surfaces.

8. The containment isolation valve on the liquid UF_6 line will be modified to make it fail-safe on autoclaves 3 and 4 in X-344.

9. Replace or modify the daughter cylinder isolation valves on the autoclaves in X-344A to fail in the closed position on loss of air or provide a backup air supply.

10. Autoclave 2 in X-344 will be modified to replace the existing pneumatic transmitter with an electronic transmitter, which will not require a pressure switch.

11. The autoclaves in X-342, X-343, and X-344 will be modified to prevent inadvertent opening when an Autoclave Shell High-Pressure Containment Shutdown System containment isolation signal is present.

3.9.3 Section Deleted

3.9.4 Section Deleted

3.9.5 Section Deleted

3.9.6 Cylinder Pressure Relief

USEC will seek an interpretation from the ASME Code Committee regarding cylinder pressure relief. Based on that interpretation and the existing level of safety provided, USEC will assess the need for modifications to affected systems or operations and submit the ASME Code interpretation and assessment to NRC for review and approval.

3.9.7 Section Deleted

3.9.8 Determination of Q and AQ Support Systems

Section 3.8 contains a listing of the Q and AQ systems and the associated boundary definitions. An initial determination has been made regarding which systems are required to support the parent system's Q or AQ function(s) (e.g., circuitry to carry an isolation signal to an isolation valve). As discussed in Section 3.8, the support systems (including electrical power, plant air, and control and instrumentation power) will continue to be evaluated, and included in the boundary definitions if appropriate. Section 3.8 will be revised accordingly as this work is completed.

3.9.9 Design Modifications to Support Q and AQ Boundary Definitions

As part of the SAR Upgrade activity, an engineering evaluation will be performed to assess the following issues to determine if modifications are necessary to place the plant in a fail safe configuration. If modifications are necessary, they will be initiated.

- Currently valves located in the autoclave feed lines will fail as-is (reference Sections 3.8.1.4.4, 3.8.1.4.8, 3.8.1.5.4 and 3.8.1.5.8).

- Currently the autoclave UF_6 drain line valves will fail as-is on loss of electric or air (reference Sections 3.8.1.6.4 and 3.8.1.6.8).

- Currently the autoclave smoke detection systems do not fail to a trouble alarm.

3.9.10 Section Deleted

3.9.11 Section Deleted

3.9.12 Section Deleted

4.0 HAZARD AND ACCIDENT ANALYSIS

4.1 INTRODUCTION

This chapter describes the hazard and accident analysis performed for the Portsmouth Gaseous Diffusion Plant (PORTS).

The hazard analysis methodology consists of the identification and evaluation of facility hazards. Hazard identification is a comprehensive assessment of process-related, natural phenomena and external hazards that may result in onsite or offsite consequences of interest if an accident occurs. Hazard evaluation generates the largely qualitative consequence and likelihood estimates used to characterize hazards in the context of potential accidents. This method provides a thorough, predominantly qualitative evaluation of the spectrum of risks to the public, onsite personnel, and the environment resulting from potential accidents involving the identified hazards. The results of the hazard analysis include the identification of a reasonable spectrum of initiating events for evaluation in the accident analysis.

The initiating events that are chosen for evaluation in the accident analysis are defined as limiting initiating events. Limiting initiating events are those initiating events that can result in the most severe accident in a given frequency category (see Section 4.2.5.3). All limiting initiating events are compared with Evaluation Guidelines (EGs) to identify and assess the adequacy of existing SSCs.

Selection criteria are applied to the results of the hazard and accident analyses to derive the Technical Safety Requirements (TSRs).[1]

The hazard and accident analysis uses a graded approach to determine the level of analysis applied to each identified hazard. This approach requires that the level of analysis and documentation for each facility be commensurate with the following:

- The magnitude of the hazards being addressed.
- The stage or stages of the facility life cycle.
- The complexity of the facility and/or systems being relied on to maintain an acceptable level of risk.

In general, because grading is a function of both hazard potential and complexity, a graded approach dictates an assessment of complex, higher-hazard facilities that is more thoroughly documented than assessments of simple, lower-hazard facilities. If a hazard poses a more significant threat for the facility (i.e., health consequences), a more detailed analysis is performed. Note that standard industrial hazards for which national consensus codes and/or standards [e.g., Occupational Safety and Health Administration (OSHA) regulations] exist are not in the scope of this SAR except where these hazards are identified as initiators or

[1]Certain TSR Limiting Conditions for Operation were not derived from the hazard and accident analysis and may not satisfy the TSR selection criteria described in Section 4.2.3. These "legacy" TSRs are a carryover from previous OSR/TSR documents (i.e., prior to SARUP).

contributors to accidents in the facility.

Grading was also applied at each of the four major steps of the analysis process:

- Hazard identification and screening.
- Hazard classification.
- Hazard analysis.
- Accident analysis and development of safety controls.

Hazard identification and screening was used to review facility hazards to determine whether any safety analysis was required. This was accomplished by comparing the hazards with a screening value as described in Section 4.2.4. If the identified hazards remained below the screening values, the results were documented, and no additional analysis was required for the facility. The second step of the process involved classifying the facility in accordance with DOE-STD-1027-92 (Reference 1). The third step required analysis of the hazards associated with the facility. One of the elements of the graded approach for hazard analysis is a function of selecting techniques for hazard evaluation depending on the complexity of the process and the significance of the hazard. The techniques used for hazard evaluation can range from simple checklists or "What If" analyses to systematic parameter examinations. The technique selected need not be more sophisticated or detailed than is necessary to provide a comprehensive examination of the hazards associated with the facility operations. For example, a simple storage operation may be adequately evaluated by a preliminary hazard analysis or a structured "What If" analysis. The final step of the overall process involved taking the most significant hazards within the facility, determining specific accident scenarios, identifying safety controls that can minimize the frequency of the event, and identifying safety controls that can be used to mitigate the consequences should the event occur.

The hazard analysis methodology and results, presented in Section 4.2, include the hazard identification, classification, and evaluation tasks, including limiting initiating event selection. Section 4.3 describes the accident analysis methodology and results for each of the limiting initiating events identified in Section 4.2. The discussion summarizes the accident scenario development, source-term analysis, and consequence analysis, provides a comparison with guidelines, and summarizes SSCs and TSR controls.

4.2 HAZARD ANALYSIS

This section describes the hazard analysis methodology and results. The overall methodology integrated the hazard analysis, accident analysis, system classification, and TSR selection to ensure consistency throughout the analysis process. The methodology description also addresses the generic parts of the analysis and the specific portions that relate to hazard analysis.

Section 4.2.1 provides a discussion of the Evaluation Guidelines established for the hazard and accident analysis. The Evaluation Guidelines are used to identify and assess the adequacy of existing structures, systems, and components (SSCs). Section 4.2.2 establishes SSC classification criteria. These criteria are applied to the results of the hazard and accident analyses to establish the level of quality to be applied to SSCs based on their relative importance to safety. Section 4.2.3 identifies the selection criteria for deriving the Technical Safety Requirements (TSRs). Section 4.2.4 provides a discussion of the screening thresholds established as part of the hazard analysis. Sections 4.2.5 and 4.2.6 present the hazard analysis methodology and hazard analysis results, respectively.

4.2.1 Evaluation Guidelines

A key element of the analysis methodology is the establishment of Evaluation Guidelines (EGs) to ensure a consistent and systematic approach in all steps of the analysis process. The overall objective of establishing EGs is to limit consequences to smaller values for initiating events of higher frequency. This approach provides a logical response to different levels of risk by providing greater protection as the potential consequences increase. To accomplish this objective, plant Operating Conditions (OCs) and consequence guidelines for each plant operating condition were established. Together, this information forms the EGs for the hazard and accident analysis process.

It is important to note that because PORTS is an existing, operating facility, these Evaluation Guidelines may *not* be achievable for all accident sequences. Design conditions were not applied to PORTS specifically for the protection of the public. This analysis has identified and addressed those situations.

4.2.1.1 Initiating Event Frequency Categories

Consistent with the objective of providing protection commensurate with risk (i.e., potential consequences over the full range of plant Operating Conditions), initiating event frequency categories were first defined. 10 CFR 76.85 requires an assessment of accidents be performed by reviewing the full range of operation using an expected release rate resulting from anticipated operational occurrences and accidents. This statement implies three basic frequency categories or Operating Conditions that have been established for the accident analysis as shown in Table 4.2-1: Normal Operation, Anticipated Events (AEs), and Evaluation Basis Events (EBEs). The bases for these categories are provided as follows:

<u>Normal Operation (OC-1)</u>

The Normal Operation frequency category is based on normal operations that are planned for plant facilities. Normal operation of the facility was evaluated to determine initial conditions assumed in the accident analysis as well as any normal operational safety programs (e.g., radiation protection) and administrative controls used to prevent an initiating event.

Anticipated Events (OC-2)

The Anticipated Event frequency category addresses deviations from normal operation that are anticipated to occur during the life of the facility. This category ranges from normal operation to those that have an initiating event frequency of greater than or equal to 10^{-2} per year or consistent with an event expected to occur in the life of a new facility. The AE frequency category was established with a 10^{-2} per year lower bound to provide a conservative margin based on the qualititative definition. Based on the relatively short remaining life of the plant, this category provides a conservative binning of initiating events estimated to occur more frequently than 10^{-2} per year.

Evaluation Basis Events (OC-3)

These initiating events address the remaining events for the GDPs considered credible.

4.2.1.2 Evaluation Guidelines

Evaluation Guidelines (EGs 1 through 6) were established for each initiating event frequency category to ensure operational requirements are met during all plant conditions. The EGs used in the GDP accident analysis methodology were adapted from the commercial reactor industry (Reference 1) and are provided in Table 4.2-2. Limiting initiating events (see Section 4.2.5.3) are compared with the Evaluation Guidelines to identify and assess the adequacy of existing SSCs. The basis for each of the EGs is as follows:

Evaluation Guideline 1 (EG 1)

The purpose of EG 1 is to establish radiological dose guidelines for members of the offsite public and onsite personnel.

The following radiological dose guidelines were established for the offsite public:

- For Normal Operation (OC-1), 10 CFR 20.1301 identifies dose limits for individual members of the public.
- For Anticipated Events (OC-2), the value of 5 rem TEDE/event was established for the offsite public based on onsite requirements for adult occupational dose limits defined in 10 CFR 20.1201(a)(1)(i). This limit was conservatively applied to the offsite public for Anticipated Events.
- For Evaluation Basis Events (OC-3), the value of 25 rem TEDE/event was established based on 10 CFR 100 and the Statements of Consideration for the 10 CFR 76 final rule which references this value in Part C of the "Summary of Requirements and Analysis of Public Comments" (Federal Register, Vol. 59, No. 184, 9/23/94, page 48954).

The following radiological dose guidelines were established for onsite personnel:

- For Normal Operation (OC-1), 10 CFR 20.1201 identifies occupational dose limits for adults.
- For Anticipated Events (OC-2) and Evaluation Basis Events (OC-3), the guideline established was to ensure that onsite personnel are not exposed to life-threatening or serious health effects from the release of radioactive materials.

Because NRC regulations do not specify limits (or evaluation guidelines) for accident exposures to onsite personnel, specific radiological exposure values for AEs and EBEs were not established for onsite personnel as part of EG 1. For releases of UF_6, HF, and other corrosive gases, the "see and flee" policy trains employees to flee an area immediately upon detection by sight or smell of releases of UF_6 or other corrosive gases. Operating experience at the plants has demonstrated the effectiveness of the see and flee policy because no individual has been significantly injured by a UF_6 release. This policy, coupled with the requirements of the programmatic TSR on worker protection from UF_6 process hazards and the characteristics of UF_6, HF, and other toxic gases, adequately controls potential onsite toxic consequences. Qualitiative evaluations have been performed as part of the hazard and accident analyses to assess the potential for life-threatening or serious health effects to onsite personnel from the release of radioactive materials.

<u>Evaluation Guideline 2 (EG 2)</u>

The purpose of EG 2 is to establish nonradiological dose guidelines for members of the offsite public and onsite personnel due to a release of radioactive materials.

The following nonradiological dose guidelines were established for the offsite public:

- For Normal Operation (OC-1), 10 CFR 20.1301 identifies uranium dose limits for individual members of the public.
- For Anticipated Events (OC-2), the value of 10 mg soluble uranium intake/event is based on 10 CFR 20.1201(e), which uses this value for onsite workers for a period of 1 week. This limit was conservatively applied to the offsite public for Anticipated Events.
- For Evaluation Basis Events (OC-3), the value of 30 mg soluble uranium intake/event was established based on the Statements of Consideration for the 10 CFR 76 final rule which references this value in Part C of the "Summary of Requirements and Analysis of Public Comments" (Federal Register, Vol. 59, No. 184, 9/23/94, page 48954).

The following nonradiological dose guidelines were established for onsite personnel:

- For Normal Operation (OC-1), 10 CFR 20.1201 identifies occupational uranium dose limits for adults.

- For Anticipated Events (OC-2) and Evaluation Basis Events (OC-3), the guideline established was to ensure that onsite personnel are not exposed to life-threatening or serious health effects from the release of radioactive materials.

For the same reasons discussed above for EG 1, specific nonradiological exposure values for AEs and EBEs were not established for onsite personnel as part of EG 2. Qualitiative evaluations have been performed as part of the hazard and accident analyses to assess the potential for life-threatening or serious health effects to onsite personnel from the release of radioactive materials.

In addition to the radiological and uranium toxicity concerns, the by-product of a UF_6-moisture reaction [i.e., hydrogen fluoride (HF)] could result in potential health effects. Because HF is produced in direct proportion to the amount of UO_2F_2 produced, the AE and EBE guideline values for soluble uranium provide adequate control of HF. Consequently, consistent with the Statements of Consideration for the 10 CFR 76 final rule, no specific criterion for HF exposure was established. However, potential HF concentrations have been calculated and characterized as part of the consequence analyses.

Evaluation Guideline 3 (EG 3)

The purpose of EG 3 is to establish pressure and temperature guidelines.

EG 3 requires that system pressure and temperature be controlled to minimize the potential for a loss of primary system integrity. This guideline only applies when a postulated failure of the primary system could exceed EGs 1 or 2 (i.e., if a failure of the primary system would not exceed EG 1 or 2, then EG 3 is not applicable). Additionally, EG 3 would not apply if the event is a loss of primary system integrity since the intent of EG 3 is to prevent failure.

For Normal Operation (OC-1), temperatures should be maintained within the design rating for the equipment. Primary system pressure should be maintained below the Maximum Allowable Working Pressure (MAWP), or design pressure rating if the MAWP is not available during normal operation.

For Anticipated Events (OC-2), primary system pressure should be maintained below the MAWP (or design rating) plus the ASME code allowable stresses for overpressure protection. (Refer to Appendix A of Chapter 1 for a discussion of ASME code applicability.)

For Evaluation Basis Events (OC-3), primary containment system pressure (when a containment system is present to contain hazardous releases) should not exceed the system's hydrostatic test pressure.

Evaluation Guideline 4 (EG 4)

The purpose of EG 4 is to require that the normal operation or initiating event be controlled within the guidelines of the double contingency principle for nuclear criticality safety.

For Normal Operation (OC-1), EG 4 is satisfied when the process is provided with two independent criticality safety controls.

For Anticipated Events (OC-2), one of the two independent criticality safety controls is assumed to fail. Therefore, one criticality safety control is required to be available for an AE.

For Evaluation Basis Events (OC-3), EG 4 does not apply because an EBE postulates the loss of controls resulting in a criticality accident.

The Nuclear Criticality Safety (NCS) program described in Section 5.2 documents the required NCS controls. Any exceptions to the double contingency principle are identified and discussed in Section 5.2.

Evaluation Guideline 5 (EG 5)

The purpose of EG 5 is to identify controls required to ensure normal operations are conducted within the assumptions and initial conditions of the accident analysis.

Evaluation Guideline 6 (EG 6)

The purpose of EG 6 is to ensure a habitable environment for operations personnel to perform required manual safety actions in response to an initiating event. In accordance with the see and flee policy, operator actions are only assumed to reliably occur if they can be accomplished during evacuation of the area or if the operator is provided with personal protective equipment (PPE) such as breathing apparatus. As a result, the accident analysis evaluated "evacuation of the area" as a potential initiating event for all nuclear operations.

The safety of operations involving toxic (but non-nuclear) chemicals is provided through compliance with OSHA Process Safety Management (PSM) requirements. Therefore, Evaluation Guidelines for postulated chemical releases (e.g., flourine, chlorine) have not been established as part of EGs 1 through 6. In addition, specific controls for these operations are not specified through the accident analysis or facility-specific TSRs. The programmatic TSR on the chemical safety program requires that a chemical safety program be established, implemented, and maintained as described in Section 5.6. Section 5.6 includes a commitment to implementing the OSHA PSM requirements. A summary of the process for how potential hazards from chemical releases are evaluated and controlled is as follows:

1. Determine which chemicals exceed the process safety management (PSM) threshold values as defined in 29 CFR 1910.119.
2. For those chemicals that have values greater than the threshold values, evaluate and control the process in accordance with the 29 CFR 1910.119 requirements and determine the potential impact of releases on nuclear-related operations (see EG 6 for how this is evaluated).
3. For those chemicals that have values less than the threshold values, treat the hazard as a standard industrial hazard and determine the potential impact of releases on nuclear-related operations (see EG 6 for how this is evaluated).

4.2.2 Criteria for the Classification of Structures, Systems, and Components

Structures, systems, and components are either (1) important to safety or (2) non-safety. Important to safety SSCs are classified as either Q or AQ. Non-safety SSCs are identified as NS.

SSCs will be classified in accordance with the following criteria based on the initiating events analyzed. These criteria are applied to the results of the hazard and accident analyses to establish the level of quality to be applied to SSCs based on their relative importance to safety.

<u>Category Q</u>

Category Q structures, systems, and components are those important to safety SSCs that are necessary to prevent or mitigate the consequences of postulated accidents that could result in a member of the general public located offsite being exposed to:

- More than 25 rem total effective dose equivalent (TEDE) over the course of the event
- Inhalation of more than 30 mg of soluble uranium over the course of the event

These limits correspond to the guideline values established in EGs 1 and 2 for Evaluation Basis Events. See the discussion in Section 4.2.1.2.

<u>Category AQ</u>

Category AQ structures, systems, and components are those important to safety SSCs that:

- Are necessary to maintain an initial condition required to support the accident analysis
- Are necessary to prevent or mitigate the consequences of events that could result in life-threatening or serious health effects to onsite personnel from the release of radioactive materials
- Are necessary to meet the double contingency principle for the prevention of an accidental nuclear criticality
- Represent the single contingent control to prevent an accidental nuclear criticality where the double contingency principle is not met
- Are necessary to detect and alarm an accidental nuclear criticality
- Are necessary to mitigate the consequences of a fire (fixed fire suppression systems only)

- Are part of the cascade piping and equipment including UF_6 process piping 2 inches and larger, expansion joints, valves, and process equipment that provide the UF_6 containment pressure boundary
- Are structures or portions of enrichment process facilities necessary to physically support process piping, equipment, and their support systems

Category NS

Category NS includes non-safety structures, systems, and components.

Refer to Section 3.8 for an identification of Q and AQ SSCs. Refer to the Quality Assurance Program Description in Volume 3 for the quality assurance requirements applied to Q and AQ SSCs.

4.2.3 Criteria for Technical Safety Requirement Selection

Technical Safety Requirements (TSRs) will be established as required by 10 CFR 76.87 to include safety limits, limiting control settings, limiting conditions for operation, design features, surveillance requirements, and administrative controls.

Based on the limiting initiating events analyzed in Section 4.3.2, a TSR limiting condition for operation will be established for each item meeting one or more of the following criteria:

1. An active structure, system, or component that prevents exceeding the EG 1 or EG 2 offsite evaluation guidelines for Anticipated Events and Evaluation Basis Events (see Table 4.2-2).
2. A process variable or operating restriction that preserves an initial condition for the analysis of an Anticipated Event or Evaluation Basis Event that could otherwise exceed the EG 1 or EG 2 offsite evaluation guidelines.
3. An active structure, system, or component that prevents or mitigates an event that could result in life-threatening or serious health effects to onsite personnel from the release of radioactive materials.
4. A single contingent control to prevent an accidental nuclear criticality where the double contingency principle is not met.
5. Installed instrumentation that is used to detect and alarm an accidental nuclear criticality.

Refer to the individual accident scenarios in Section 4.3.2 for an identification of essential controls that require TSRs.

4.2.4 Hazard Screening and Threshold Analysis

In addition to the Evaluation Guidelines, screening thresholds were established as part of the hazard analysis to distinguish the different levels of analysis and the level of documentation necessary to support a graded approach. Table 4.2-3 summarizes the screening thresholds and the level of documentation used for the hazard analysis. The consequences listed in Table 4.2-3 assume that no mitigation is provided. The basis for each of the thresholds is provided below.

Preliminary hazard screening (PHS) threshold. The PHS threshold uses the reportable quantity values in 40 CFR 302, Table 302.4, plus those in Appendix B of 40 CFR 302. These values establish the lowest threshold of concern for the hazard analysis process.

Process hazard analysis (PrHA) threshold. The PrHA radiological threshold uses the inventory of radiological materials specified in Appendix A of DOE-STD-1027-92 (Reference 2) for Category 3 facilities. For nonradiological hazards, the PrHA screening threshold is not easily based on a threshold quantity of material because of the different types of hazards that could be present and the different consequences that could result. Therefore, the nonradiological PrHA screening threshold is considered exceeded when a release of the applicable nonstandard hazard could result in life-threatening or serious health effects in the vicinity of the event. This threshold limits the hazard and unmitigated consequences to a value at which operating personnel are capable of evacuating the area and minimizes the risk of serious health effects caused by a release of the hazard. This threshold also considers that operating personnel are trained in the type of operation they are asked to perform and the hazards involved in accordance with OSHA standards and regulations and the plant procedure and training program.

Plant safety operational analysis (PSOA) threshold. The PSOA threshold is established to ensure that any hazard that can result in potentially significant onsite consequences (i.e., significant consequences beyond the immediate area) or offsite consequences is evaluated in detail to establish controls that may prevent exceeding the EGs. The PSOA radiological and nonradiological thresholds for offsite consequences are the same as the EGs for the Anticipated Event frequency category. The PSOA onsite radiological threshold was established by using the inventory of radiological materials specified in Appendix A of DOE-STD-1027-92 for Category 2 facilities as well as the EG for the Anticipated Event frequency category. Nonradiological health effects were established to ensure that a detailed analysis is performed of initiating events and hazards that could result in life-threatening or serious health effects beyond the immediate area of the facility.

These thresholds, in combination with the EGs, aided in ensuring that a consistent level of analysis was applied to various types of hazards and that a graded approach was used based on the potential unmitigated consequences associated with the hazards of concern. Different levels of analysis are provided depending on which thresholds are exceeded. The different levels of analysis, methods for performing the analysis, and documentation requirements are described in Section 4.2.5.1.

4.2.5 Hazard Analysis Methodology

Hazard analysis is the process of identifying facility hazards and evaluating potential initiating events, consequences that may result from accidents involving these hazards, and controls that can be used to prevent or mitigate the consequences. The hazard analysis was divided into two parts: hazard identification and hazard evaluation.

Hazard identification involved selecting those facilities that possess nonstandard industrial hazards that present a threat to the health and safety of on-site workers or the general public. Hazard identification also involved determining which hazards require more detailed analysis based on the consequence screening criteria. Hazards that were not "screened out" in this process were subject to hazard evaluation.

Hazard evaluation involved qualitatively determining the unmitigated consequences of potential accidents involving a given hazard, the initiating events for the accident, the frequency of the initiating events, and controls that can be used to prevent or mitigate the initiating events. The unmitigated consequences were compared with threshold consequence values to determine whether more detailed accident analysis may be required. The hazard analysis (1) documented the hazards of concern, (2) determined the initiating events and consequences, (3) identified controls to minimize potential consequences, (4) identified limiting initiating events that require more detailed analysis, and (5) selected controls that were determined to be AQ because of their importance in the event scenario for protecting onsite workers.

4.2.5.1 Hazard Identification

PORTS consists of many facilities and processes. The first step of the hazard analysis was to identify the plant facilities and track each facility for evaluation. Figure 4.2-1 outlines the steps in the hazard identification task.

The hazard analysis involved identifying facilities with nonstandard industrial hazards that may threaten onsite workers or the offsite public. Because many facilities have only standard industrial hazards encountered elsewhere in industry, a screening process was used to focus on the nonstandard industrial hazards. The Preliminary Hazard Screening (PHS) was this initial screening process. In the PHS process, the PHS screening threshold from Table 4.2-3 was used to determine whether a facility "screens in" or "screens out." The first step of the PHS was a brief examination of the facilities to identify those that obviously exceed the PHS threshold. These facilities were automatically screened in to the next level of analysis without any additional review or screening. The remaining facilities were evaluated using the PHS thresholds listed in Table 4.2-3. If the threshold values associated with the various hazards were not exceeded, no additional analysis was required. If one or more of the hazards in a facility exceeded a threshold value, then the facility required additional review, and completion of the PHS form was not required. The PHS process provides the safety analysis documentation for the facilities that screen out.

The next step of the hazard identification process was to establish a hazard category for the facility in accordance with DOE-STD-1027-92. This standard provides a categorization of nuclear facilities (Categories 1, 2, and 3; Category 1 is the highest-hazard category) based on inventory of radiological material. Hazard categorization was also used as input to applying the graded approach. If the facility did not exceed the Category 3 threshold quantities listed in DOE-STD-1027-92 and if it exceeded the PHS threshold for radiological material, the facility was categorized as a "radiological" facility.

The final step of the hazard identification task was to determine the facilities that exceeded the PrHA threshold. The analysis statement level of documentation indicated in Table 4.2-3 was applied to the facilities that exceeded the PHS threshold but did not exceed the PrHA threshold. This level of documentation was typically used for facilities that exceeded the low PHS threshold but have no release mechanisms that could cause any significant health effects to onsite or offsite personnel. Typically, these facilities were reviewed to determine whether the hazard was controlled by existing facility safety management programs. If the hazard was controlled, a statement was provided to document this decision in the PrHA for the facility, and no additional analysis was required for the facility. If the hazard was not controlled, the facility progressed to the hazard evaluation task described in Section 4.2.5.2.

To summarize, the final product of the hazard identification task was a listing of facilities that contain hazards exceeding the PrHA threshold and that have a radiological hazards categorization. Nonstandard industrial hazards that required additional analysis were identified by comparing their potential unmitigated consequences with PHS and PrHA threshold values (Table 4.2-3). This set of facilities was analyzed in the hazard evaluation task described in Section 4.2.5.2.

4.2.5.2 Hazard Evaluation

Hazard evaluation is the process of identifying initiating events that can lead to accidents involving the hazards screened in from the hazard identification process (Section 4.2.5.1), qualitatively determining the consequences of such accidents, estimating the initiating event frequencies, comparing the consequences with threshold values, and identifying the controls needed to prevent such accidents or to mitigate their consequences. The objective of this process was to identify AQ SSCs and the limiting initiating events that could exceed EGs. Because of its importance to the accident analysis, the selection of limiting initiating events is presented separately (Section 4.2.5.3). The process used for the hazard evaluation was called Process Hazard Analysis (PrHA) and is outlined in Figure 4.2-2. The PrHA was a largely qualitative process for evaluating hazards that exceed the PrHA threshold as determined during the hazard identification process. One of several evaluation techniques were used for the PrHA, depending on the complexity of the process. The evaluation technique includes justification. The PrHA identified the initiating events and hazard combinations that could result in consequences that exceed the PSOA thresholds listed in Table 4.2-3.

In the first step of the hazard evaluation process, an appropriate analysis technique was determined and applied to the facility and its associated hazards. Several standard techniques are well documented in the industry and provide acceptable methods for performing a PrHA. Some of these analysis techniques include What If, Checklist, Hazard and Operability Analysis (HAZOP), Fault Trees, and Failure Modes and Effects Analysis. The type of analysis selected depended on the hazards present and the complexity of the facility.

The second step of the PrHA process was to evaluate the hazards present that, if released, could exceed the PrHA threshold. Any facility operations and/or controls that could be used to prevent or mitigate an initiating event were also identified. Facility safety programs were also considered and included as potential controls for prevention and mitigation. For hazards related to nuclear criticality, the PrHA identified criticality as a hazard of concern and relied on the Nuclear Criticality Safety (NCS) Program (see Section 5.2) to evaluate the hazards related to accidental criticality. The NCS Program is responsible for identifying the controls necessary to address the double-contingency principle for criticality safety. For fire-related hazards associated with the facility or process, the PrHA identified any specific controls deemed necessary to prevent a fire from causing a significant release of the hazard(s). The Fire Protection Program [which includes an on-site fire department (see Section 5.4)] is responsible for ensuring that sufficient preventive and mitigative controls are in place to minimize the risk of a fire-related event. In addition, for areas with a criticality concern, fire-fighting techniques in these facilities are coordinated with the NCS Program.

The next step of the hazard evaluation process was to develop the following information for each hazard that, if released, could result in unmitigated consequences exceeding the PrHA threshold:

- Process parameter of interest
- Initiating events
- Initiating event frequencies (Table 4.2-1)
- Qualitative consequence categories (Table 4.2-4)
- Preventive and mitigative controls
- Threshold analysis

Providing this information for all PrHAs provided consistency in the analysis results independent of the analysis method (e.g., What If, HAZOP) chosen.

The preventive and mitigative controls identified in the PrHA provide an indication of the defense-in-depth provided by the facility for potential accidents. Programs and plans were also used in the PrHA process to provide preventive and mitigative functions in addition to the facility SSCs. These programs and plans include the Nuclear Criticality Safety Program, Radiation Protection Program, Chemical Safety Program, Fire Protection Program, Emergency Plan, Quality Assurance Program Description, etc. They may apply to any facility in which a relevant hazard is identified, and they provide administrative controls to support defense-in-depth. The programs and plans and their purposes are described in SAR Chapter 5 and Volume 3 of the Certification Application.

To summarize, hazard evaluation resulted in the identification of controls that can help prevent and/or mitigate the consequences of the postulated initiating events. These controls were then reviewed and a summary of their importance to the hazard analysis is presented in Section 4.2.6. Next, the criteria outlined in Section 4.2.2 were used to determine which controls should be classified as AQ. Those controls that require coverage in the TSRs were then determined using the criteria outlined in Section 4.2.3. Initiating events that resulted in accidents that could exceed a PSOA threshold are also identified as possible limiting initiating events and are evaluated as described in Section 4.2.5.3.

4.2.5.3 Accident Selection

The objective of the accident selection portion of the hazard evaluation was to identify a representative set of events for accident analysis. This representative set of events is termed "limiting initiating events" in the remainder of the analysis. Defining the limiting events required consideration of all actions made in response to each initiating event without any mitigative action. If an initiating event could result in a parameter change that might lead to an accident scenario which exceeds any EG, this initiating event is a candidate for a limiting event. For each unmitigated initiating event that can lead to exceeding an EG, the following guidelines were used to determine the set of limiting events:

- The initiating events which result in the most limiting change in a process parameter of interest for each frequency category were selected.

- If different facility protection methods were provided for the same process parameter of interest, a limiting event for each frequency category, each parameter of interest, and each facility protection method was selected.

The process for determining the limiting initiating events consisted of five steps (Figure 4.2-3):

1. Develop facility operating modes
2. Identify specific hazard states for each hazard
3. Develop operating mode–hazard–hazard state matrix
4. Develop initiating event–operating mode–hazard–hazard state matrix
5. Select and define limiting initiating events

The development of specific facility operating modes was key to accomplishing this part of the analysis. These operating modes are also used in the TSRs. These modes were used to ensure that all combinations of operations, hazards, and equipment configurations were considered.

The next step of the process was to define the hazard states for each of the hazards that could result in the PSOA threshold being exceeded. For some hazardous materials, the physical state (e.g., solid, liquid, gas) has a direct bearing on the potential consequences should a release occur. Therefore, identification of the hazard state(s) of interest was required. UF_6 is a primary hazard of interest for the GDPs, and its physical state has a significant impact on potential consequences. The quantity of material at risk was determined by the normal operating mode and the initial conditions at the time of the event.

Once the operating modes and hazard states were identified, a matrix was defined that identified the hazard and hazard state(s) applicable to each operating mode. This matrix was based on facility operations and discussions with facility personnel. This matrix was used to ensure that each initiating event considered the hazard condition and operating condition that could be applicable.

Initiating events from the PrHA that could exceed the PSOA consequence thresholds (Table 4.2-3) were considered with each operating mode and hazard state for which they were applicable. This information was used to develop the combinations as illustrated in the example in Table 4.2-5. This matrix, which includes the operating modes, hazard states, and initiating events along with the process parameters of interest, provides a systematic method of identifying the complete spectrum of hazards, hazard states, operating modes, and initiating events that may result in accidents with consequences of interest. The hazard matrix provides the foundation for detailed analysis to determine the TSRs, system classifications, and accident analyses. Each specific combination required analysis to determine whether protective action is required to prevent exceeding an Evaluation Guideline. An example of one combination taken from Table 4.2-5 follows:

- Process parameter of interest—pressure increase.
- Initiating event—steam control valve fails to open.
- Operating modes—heating and feeding, transfer or sampling.
- Hazard state for each mode—all states (heating); liquid/gas (feeding, transfer, or sampling).

The matrix combinations were evaluated to determine the minimum set of controls that could prevent exceeding the Evaluation Guidelines should the event occur. The combination that results in the most severe consequences (i.e., bounds all other initiating events by consequence) is identified as the limiting initiating event for that combination.

Each combination of initiating event, hazard state, and operating mode was reviewed as described for the operational analysis task (Section 4.3.1.1). Defining the limiting initiating events for a facility required consideration of the integrated response of the facility to each initiating event without any mitigative action. If the initiating event could result in a parameter change with unmitigated consequences that exceed any Evaluation Guideline for the applicable frequency category, the initiating event was a candidate for a limiting initiating event. The definition of a limiting initiating event described above was used to finalize the set of limiting initiating events. The resulting set of limiting initiating events was subjected to the detailed accident analysis described in Section 4.3.2. Initiating events that exceed the PSOA thresholds and are not limiting initiating events are documented in the analysis for the facility with justification provided for them—being bounded by the limiting events along with the controls necessary to support meeting the Evaluation Guidelines.

4.2.6 Hazard Analysis Results

This section presents the results of the hazard analysis. Most of the results are given in summary form. Details of the analyses are provided in the PrHA reports for the respective facilities.

One of the key elements of the hazard analysis was to identify historical events that resulted in accidents of interest. Table 4.2-6 identifies historical release events from 1961 through 1993 at all three GDP sites. Historical release events as well as discussions with operational personnel were a key input to all of the hazard analyses.

A comprehensive listing of all facilities that were included in the hazard analysis is presented in Table 4.2-7. The table shows the level of analysis that was applied to each facility based on the graded approach. It indicates whether a facility required a PHS, PrHA, and/or PSOA review. The hazard categorization based on DOE-STD-1027-92 is also presented. Facilities that were screened out by the PHS did not receive any additional review and are not addressed in the following sections. Facilities that exceeded PHS thresholds but did not exceed PrHA thresholds are documented by an analysis statement (Table 4.2-8). The analysis statement serves as the safety analysis for these facilities, and they are not analyzed any further in the hazard evaluation. All facilities that exceeded PrHA thresholds are reviewed in detail in the hazard evaluation.

4.2.6.1 Hazard Identification

The hazard identification task involved reviewing the facilities listed in Table 4.2-7 and comparing them against the PHS threshold values in Table 4.2-3. The facilities identified by a "Yes" in the "PHS screen in?" column, exceeded the PHS screening threshold. Facilities that exceeded the PHS threshold but did not exceed the PrHA thresholds in Table 4.2-3 were documented by analysis statement. The remaining facilities, identified by a "Yes" in the "PrHA required?" column of Table 4.2-7, contained hazards that exceeded the PrHA thresholds and were examined in the PrHA review.

Table 4.2-9 presents the facilities and their associated processes that contain hazards that exceeded the PrHA threshold values. The facilities are grouped together by process and by the types of hazards identified for those facilities. The Cascade Facilities Group includes facilities involved with the main cascade process and supporting systems. The principal hazards identified for these processes are uranium hexafluoride (UF_6), fluorine (F_2), chlorine trifluoride (ClF_3), and light cascade gases (e.g., combinations of coolant, ClF_3, F_2). Some waste storage areas may also be located in the process buildings in addition to the cascade processes. The UF_6 Handling and Storage Facilities Group includes facilities involved with the autoclave, withdrawal, and cylinder handling and storage operations. The principal hazard here is UF_6. The Toxic Gas Storage and Distribution Group involves processes that store and/or distribute F_2, HF, SO_2, or ClF_3. The Miscellaneous Waste Storage and Handling Facilities Group includes facilities involved with radioactive waste (radwaste) and uranium-bearing compounds. These facilities may also contain mixed wastes, Resource Conservation and Recovery Act of 1976 (RCRA) waste, and Toxic Substances Control Act of 1976 (TSCA) waste. The Miscellaneous Support Facilities Group includes facilities that do not fall into the other groups. Hazardous chemicals in this group include bromine, sulfuric acid, hydrochloric acid, hydroxy acetic acid, sulfur dioxide, and sodium hydroxide. Note that other types of industrial hazards may be present in these facilities, but they do not exceed the PrHA threshold values in Table 4.2-3 and are therefore not considered in this analysis except as potential initiators.

4.2.6.2 Hazard Categorization

Hazard categorization in accordance with DOE-STD-1027-92 was performed during the PHS (i.e., hazard identification) portion of the hazard analysis. The facility hazard categories are indicated in Table 4.2-7. At PORTS, 5 facilities are categorized as radiological, and 22 are in Category 2. The breakdown of facilities by hazard categorization is presented in Table 4.2-10.

4.2.6.3 Hazard Evaluation

The detailed results of the hazard evaluation for the hazards identified in Table 4.2-9 are documented in the PrHA reports for the respective facilities. A summary of the results is presented in the following subsections for facility groupings listed in the table. The evaluation of processes that present a potential nuclear criticality safety hazard is provided in Section 5.2, Appendix A.

4.2.6.3.1 Initiating Events

Table 4.2-11 summarizes the initiating events identified in the hazard analyses for each of the groups identified in Table 4.2-9. The initiating events are arranged according to the affected parameter of interest (e.g., criticality control, external event, pressure increase, primary system integrity). Table 4.2-11 provides a summary of the accidents postulated in the PrHA. For example, the event "autoclave steam control valve fails open" can result in a pressure increase in a UF_6 cylinder located in an autoclave. This event is an anticipated event (AE) that could result in significant off-site radiological and nonradiological consequences if no mitigation is provided. Because this event could result in the PSOA threshold being exceeded, a PSOA is required to provide additional analysis of this specific event. The initiating events that can exceed PSOA thresholds are indicated in Table 4.2-11. These events were evaluated to determine which ones result in the most limiting accidents as described in the applicable sections below. The table shows the initiating events and frequency category, indicates whether the PSOA threshold could be exceeded, and identifies which events are limiting events.

4.2.6.3.2 Threshold Analysis

Based on the initiating events identified, a set of release scenarios was developed for the different types of facilities to bound the range of possible releases. Some of these events were not considered credible but were evaluated to provide input to the hazard analysis consequence categorization. These scenarios were used, along with operational experience and engineering judgment, to assign consequence categories (Table 4.2-4) for the various events. A brief description of the scenarios is provided here; a summary of the threshold analysis results is provided in Table 4.2-12.

Open valve on a solid cylinder. The scenario of an open valve on a solid cylinder involves a cylinder containing solid UF_6 at its triple point. This consideration maximizes the amount of UF_6 released from a cylinder in the solid state. It was conservatively assumed that all of the gaseous UF_6 present in the cylinder [about 60 lb (27 kg)] would be released. However, only about 20 lbs (9.5 kg) of gaseous UF_6 would be released prior to the cylinder reaching atmospheric pressure. Because this conservative amount is small relative to all of the other cases, this release was judged not to have any off-site impact, and no dispersion study was performed for this case.

Open valve on a liquid-filled cylinder, 6 o'clock position. In the scenario of an open valve on a liquid-filled cylinder, 6 o'clock position, the cylinder is in a horizontal position with the valve pointing down. The UF_6 is released as a liquid that flashes to a mixture of vapor and solid at atmospheric pressure.

Open valve on a liquid-filled cylinder, 12 o'clock position. In the scenario of an open valve on a liquid-filled cylinder, 12 o'clock position, the cylinder is in a horizontal position with the valve pointing up. Two scenarios were analyzed: (1) the liquid level is above the valve location, resulting in an initial release of liquid UF_6 that flashes to a vapor and solid mixture at atmospheric pressure followed by a pure vapor release and (2) the liquid level is below the valve location, resulting in a release of only vapor.

Broken pigtail during parent–daughter transfer. The scenario of a broken pigtail during parent–daughter transfer occurs during a transfer of liquid UF_6 from a parent cylinder to a daughter cylinder. Both cylinders are horizontal, with the parent cylinder valve in the 6 o'clock position and the daughter cylinder valve in the 12 o'clock position. The liquid level in the daughter cylinder is assumed to be below the valve opening. The release from the parent cylinder consists of a mixture of vapor and solid UF_6 resulting from the liquid UF_6 flashing, whereas the release from the daughter cylinder is only vapor.

Broken pigtail during withdrawal. The scenario of a broken pigtail during withdrawal involves a broken pigtail in the line from the accumulator to the cylinder. Liquid UF_6 from the accumulator escapes through the broken pigtail, flashing to a mixture of vapor and solid at atmospheric pressure. Simultaneously, there is a vapor release from the cylinder, which has a liquid level below the break. Two scenarios are assumed: (1) both vessels remain open to the ruptured pigtail for the full duration of the release and (2) the accumulator valve is closed after 1 min of liquid release. The vapor from these releases is assumed to exit the process building through open bay doors.

Broken withdrawal compressor discharge. The scenario of broken withdrawal compressor discharge involves a continuous vapor flow from the compressor and a flashing liquid release from the condenser/accumulator until it is empty. The compressor discharge is located in the process building; therefore, the vapor must pass through the building ventilation system. This provides some holdup time, some dilution, and some uranyl fluoride (UO_2F_2) deposition. The UF_6 completely reacts within the building, and the undeposited material is vented at the process building roof.

B-line failure at maximum power. The scenario of B-line failure at maximum power assumes a circumferential break of the B-line with the highest flow rate in the process buildings. The UF_6 reacts with the moist air and forms UO_2F_2 and hydrogen fluoride (HF). The analysis modeled the release from the building and subsequent dispersion. The analysis of the flow from the line continues until the guideline values are reached at the site boundary.

Release from an isolated cell. The scenario of release from an isolated cell involves an isolated cascade cell with the maximum inventory of UF_6. The evaluation for this case assumed that the cell coolant system ruptured into the primary system and caused an overpressurization, resulting in a release of the cell contents into the process building. The UF_6 reacts with the moist air and forms UO_2F_2 and HF. The analysis modeled the release from the building and subsequent dispersion.

Tie-line failure at maximum power. The scenario of tie-line failure at maximum power assumes a circumferential break of the tie-line with the highest flow rate from the process buildings. The consequences were evaluated to determine whether this type of failure could have off-site impact. The UF_6 reacts with the moist air and forms UO_2F_2 and HF. The analysis modeled the release from the line and subsequent dispersion. The analysis of the flow from the line was conservatively assumed to continue until the guideline values are reached at the site boundary.

The analysis did not identify any initiator other than natural phenomena related events for the failure of the tie lines outside the process buildings. For a tie line failure due to natural phenomena, see the external events analysis in Section 4.3.2.5. All other process related gaseous releases were considered bounded by the large release of gaseous UF_6 to atmosphere evaluated in Section 4.3.2.1.7. Therefore, this event type was not considered further.

Source terms for these release scenarios were calculated. Dispersion analyses were performed to estimate the duration of an unmitigated release necessary to exceed EGs. The resulting release durations from the threshold analysis are summarized in Table 4.2-12.

4.2.6.3.3 Preventive/Mitigative Controls

The PrHA also identified the facility controls (procedural and equipment) that can be used to prevent and/or mitigate the initiating events or minimize the consequences of the resulting accidents. The only safety classification that could be made as a result of the PrHA is AQ. The remaining classifications are based on the results of the accident analysis described in Section 4.3. Detailed technical bases for the safety classifications are presented in Section 3.8. In addition to process-specific controls, programs and plans are identified in the PrHA and play an important role in providing worker safety for many of the events evaluated. These programs and plans are described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.3.4 Accident Selection

Accidents selected for the accident analysis are defined by the set of limiting initiating events determined in the hazard evaluation. The limiting initiating events were selected from the events that exceed the PSOA threshold as indicated in Table 4.2-11. The process for selecting the limiting initiating events is described in Section 4.2.5.3.

Operating modes. A review of operations identified normal operating modes for the various processes that had events exceeding the PSOA threshold. These operating modes, described in the TSRs, are used to address potential operations for the defined processes and to develop the limiting initiating events. The modes are not mutually exclusive; operations within a facility may simultaneously involve more than one mode. For example, when one cell is in the *operating* mode, another cell may be in the *standby* mode.

Hazard states. The analysis of normal operation and initiating events must include evaluation of each mode of operation in combination with the hazard states that may be present during that mode. Hazard states for all hazards were identified as solid, liquid, and gas. Where one hazard state is present with another (e.g., gaseous UF_6 is always present with both liquid and solid UF_6), only one of the hazard states is associated with the analysis, but both conditions are considered in establishing the consequences.

Operating mode–initiating event–hazard state matrix. The consequences of unmitigated initiating events were compared with the PSOA screening thresholds to determine whether an event is carried forward to the PSOA. The comparison of the consequences with the PSOA screening thresholds (Table 4.2-3) is provided in the PrHA reports. The evaluation resulted in the set of initiating events indicated in Table 4.2-11.

Limiting initiating events. The set of the initiating events in Table 4.2-11 that were carried forward to the PSOA were evaluated to determine which of these events place the most demand on an essential mitigative system in each initiating event frequency category. Table 4.2-11 indicates the limiting initiating events that are evaluated in detail in Section 4.3.2. The evaluation resulted in a set of limiting events, denoted by a "Yes" under "Limiting event?" in Table 4.2-11.

Detailed descriptions of the accident scenarios associated with these limiting initiating events are presented in Section 4.3.2. Sections 4.2.6.4 through 4.2.6.8 present an overall summary and characterization of the hazard evaluation results for the facility groupings given in Table 4.2-9.

4.2.6.4 Cascade Facilities Group

The Cascade Facilities Group consists of the process buildings (X-326, X-330, and X-333) and the associated tie lines (X-232C1, C2, C3, C4, and C5). The principal hazards identified for this group are UF_6 and its reaction products, toxic gases (ClF_3 and F_2), light cascade gases (e.g., combinations of coolant, ClF_3, F_2), and miscellaneous waste storage areas. The miscellaneous waste storage areas are addressed in the group for waste storage (Section 4.2.6.7). Because these are complex facilities that contain a significant hazard, the principle hazard evaluation performed for the cascade facilities involved a more detailed analysis method. This hazard evaluation combined an operational review, the What If method, and the PSOA approach to evaluate potential initiating events and consequences. A separate hazard evaluation was performed for the cascade facilities to focus on shutdown scenarios. This hazard evaluation combined a failure modes and effects analysis and event tree sequence analysis to identify potential accident sequences and consequences. The PORTS enrichment operations were shutdown by USEC in 2001. Equipment sufficient to allow for a stand alone enrichment capability of 3 million SWU per year was placed in a "cold standby" condition. This equipment is currently being treated for removal of residual deposits and some equipment removal and decontamination is in progress. The remaining cascade equipment is being treated for deposit removal and/or is being maintained in a "cold shutdown" condition. Decontamination and decommissioning of this equipment is in progress under DOE control. A description of the condition of the enrichment equipment and the activities associated with it is provided in SAR Section 3.1.1.1.5. The remainder of the SAR Section 3.1 provides a description of the enrichment operations certified at the time of the shutdown of the uranium enrichment operations at PORTS.

The risk of all accidents described in this accident analysis of the enrichment cascade operations is lower for the "cold standby" condition. The accident scenarios postulating the release of toxic materials have lower probability and lower consequences than stated since the remaining inventory of UF_6 is much less than the analyzed condition and the process pressures of cascade systems containing UF_6 are all below atmospheric pressure. The potential risk of a criticality accident is also lower due to the greatly reduced inventory of uranium and the reduction of the potential sources of moderation associated with the RCW and lube oil systems. The risk from a fire is also lower due to removal of the lube oil from the shutdown process equipment, the shutdown of the compressors and the reduction in energized electrical equipment. While the additional space heaters introduce some potential fire risk, there is little combustible loading associated with the heaters themselves and the overall risk of fire is much lower than is the case for an operating enrichment cascade. The risk of an exothermic reaction or explosion is also greatly reduced due to the reduction in the amount of operating equipment, coolant and oxidant that could be present. The following discussion summarizes the results of these hazard evaluations for UF_6 in these facilities.

4.2.6.4.1 Process Definitions

The enrichment and purge cascades include the cascade auxiliary equipment (e.g., booster systems, surge systems, coolant systems, seal systems, seal exhaust systems, wet air evacuation systems, datum systems) that supports the operation of the cascades. In addition to the cascades, the enrichment and purge cascade facilities also include the following processes that provide support for the operation of the main cascades:

- Freezer/Sublimer (F/S) Process.
- Cold Recovery Process.
- Freon Degrader Process.
- Side Feed Process.
- Toxic Gas Storage and Distribution Process.

The F/S Process consists of F/S vessels and associated support equipment. These vessels are installed in various locations within X-333 to allow excess UF_6 inventory to be rapidly removed from the cascade by freezing it in storage vessels and then returning it to the cascade by sublimation when required. Cascade inventory adjustments may periodically be required to accommodate changes in the available power. F/Ss are strategically located where they can be independently or jointly operated to remove excess UF_6 inventory, to conduct emergency power drops, or to adjust the power load to maximize production.

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The Cold Recovery process in X-330 and X-333 removes UF_6 from process gas that has been contaminated with coolant. The gas is evacuated from the cascade to the surge drums. The UF_6 is then separated out in a cold trap and in chemical traps (sodium fluoride and alumina) while the coolant is vented to the atmosphere. The UF_6 is then sublimed to surge drums and returned to the cascade.

The Freon Degrader Process located in X-326 removes coolant that collects in the Purge Cascade and the top process cells. Coolant in a process gas side stream is decomposed by reaction with F_2 in the Freon degrader vessel to produce low molecular weight gases which are returned to the purge cascade where the lighter products are purged out.

The Side Feed Process is primarily located in the X-326 Product Withdrawal area. This process involves the connection of small cylinders containing LEU material being connected to a manifold and limited heat being applied to cause sublimation of the material into the process piping. The material is fed through piping to the cascade for blending with the main process stream. The process was evaluated and considered to be another location for controlled feeding of UF_6 cylinders. This process is evaluated in the UF_6 Cylinder Handling and Storage Group.

The Toxic Gas Distribution Process includes the storage and distribution of ClF_3 and F_2 within the process buildings.

4.2.6.4.2 Hazards

The hazardous materials in the Cascade Facilities Group were reviewed to determine which needed to be evaluated in the PrHA and PSOA. The results of this review are indicated in Table 4.2-9. All the hazardous materials, except those indicated in the table, were characterized as being standard industrial hazards that are commonly found in industrial facilities. These were screened out from further analysis in the PrHA because the amounts of the material are insufficient to cause any significant local health effects. These hazards are adequately controlled by site administrative programs and plans, and no additional analysis was required.

The energy sources identified in the hazards analysis that have the potential for causing releases of hazardous materials are (1) steam energy used to heat the building, (2) electrical energy, (3) chemical energy from the reaction between UF_6 and a coolant/oxidant, (4) potential energy associated with the process building cranes and the lifting of heavy equipment, (5) kinetic energy associated with the process gas compressors and the various types of vehicles, (6) flammable materials (7) combustible materials (e.g., lube, hydraulic oil), and (8) compressed gases (e.g., coolant, nitrogen).

The Enrichment and Purge Cascade Facilities were categorized as Hazard Category 2 nuclear facilities because they contain quantities of the ^{235}U component of the UF_6 sufficient to exceed the threshold quantity for Hazard Category 2 in Table A.1 of DOE-STD-1027-92.

4.2.6.4.3 Parameters of Concern

The first step of the principle hazard evaluation was to identify potential initiating events associated with the Cascade Facilities Group to identify the process parameters that, if changed, could result in a release of the hazard that could exceed the screening thresholds for either PrHA or PSOA. The process parameter changes that could lead to a release of the hazards are (1) a temperature change in the primary system that exceeds the primary system temperature limits, (2) a pressure change in the primary system that exceeds the primary system pressure limits, (3) a failure in the primary system integrity, and (4) a loss of criticality safety controls.

Based on the groupings described, four process parameters should be addressed for each operating condition to ensure that potential types of events are considered in the hazard analysis. The potential ways of releasing hazardous materials that are caused by things such as energy sources and natural phenomena were evaluated for each operating mode to determine whether they might cause a change in one of the four process parameters. Table 4.2-11 summarizes the different initiating events by parameter. These events were developed by considering operational history, operator input, and systematic evaluations.

The first step of the hazard evaluation associated with the shutdown scenarios was to identify the specific scenarios to be evaluated. The scenarios chosen for the evaluation included:

- Prompt total shutdown of a cell or multiple cells, a unit or multiple units, a partial building or complete building or multiple buildings with UF_6 inventory.
- Controlled shutdown of multiple cells, a unit or multiple units, a partial building or complete building or multiple buildings with UF_6 inventory.
- Controlled shutdown of multiple cells, a unit or multiple units, a partial building or complete building or multiple buildings following UF_6 evacuation.
- Shutdown of a purge cascade

The evaluation developed failure modes and effects analyses to identify failures that could initiate these scenarios and then analyzed the bounding initiating events via event trees to identify the range of potential scenario outcomes.

As noted earlier, the enrichment operations have been shutdown and the majority of the cascade equipment has the UF_6 inventory removed and a dry gas buffer applied. While some equipment is undergoing treatment for deposit removal and maintenance for equipment removal (for eventual D&D) or for maintaining the "cold standby" requirements, the shutdown of any operating equipment will have a lower risk than was present for an operating enrichment cascade.

4.2.6.4.4 Summary of Results

As indicated in Table 4.2-11, the events considered for the Cascade Facilities Group included a wide range of process-related events, external events, shutdown scenarios, and controls for minimizing the potential risks. A brief summary of the hazard analyses are presented below for each process.

4.2.6.4.4.1 Enrichment Cascade

Table 4.2-11 identifies all of the events associated with the Enrichment Cascade Process that were considered in the hazard analyses. Twelve of these events were identified as having the potential to exceed the PSOA threshold, with only one of these (stage control valve closure) not being a limiting event (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The primary administrative control identified for this process is to limit operating pressures for the cascade auxiliary equipment that processes UF_6. This equipment is maintained below atmospheric pressure to minimize releases of UF_6

should a failure in the primary system occur. In addition to the auxiliary equipment, a large portion of the Enrichment Cascade Process is also operated below atmospheric pressure. These portions of the cascade were not considered to have the potential to exceed the PSOA threshold except where the stage control valve closure event or the B-stream block valve closure event could still cause the pressures to increase above atmospheric pressure. In these cases, the PrHA does not postulate that a catastrophic rupture will occur due to the extended period of time to detect and mitigate the event. However, limited UF_6 releases (see Section 4.3.2.1.4) are possible during the transient due to the pressure increase. The remaining controls identified for the enrichment cascade process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.4.4.2 Purge Cascade

The Purge Cascade Process is similar to the Enrichment Cascade Process (i.e., same type of equipment and initiators) but does not have any significant inventory of hazardous material that could exceed the PSOA threshold except for criticality. Therefore, the analyses were very similar to that for the Enrichment Cascade Process where pressures remain below atmosphere.

4.2.6.4.4.3 Freezer/Sublimers

Table 4.2-11 identifies all of the events associated with the Freezer/Sublimer (F/S) Process that were considered in the hazard analyses. Seven were identified as having the potential to exceed the PSOA threshold, and all seven events were limiting events (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The only significant energy source associated with this process is the coolant used to heat and cool the UF_6 during operations. During the freeze mode of operation, the primary concern is to prevent overfilling the vessel with UF_6 (overfilling could result in failure of the primary system during a subsequent sublime mode). Expansion of UF_6 from a solid to gas in the sublime mode could result in stress failure of the coolant tubes. This event was evaluated in the hazard analysis and was determined to cause only local effects because the F/S is connected to the A-line during the sublime mode, which is at extremely low pressures. The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.4.4.4 Cold Recovery

Table 4.2-11 identifies all of the events associated with the Cold Recovery Process that were considered in the hazard analyses. Only two of these events (criticality and evacuation) were identified as having the potential to exceed the PSOA threshold (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The primary administrative control identified for this process is to limit operating pressures to below atmospheric pressure to minimize releases of UF_6 should a failure in the primary system occur. The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.4.4.5 Freon Degrader

Table 4.2-11 identifies all of the events associated with the Freon Degrader Process that were considered in the hazard analyses. Only two of these events (i.e., criticality and evacuation) were identified as having the potential to exceed the PSOA threshold (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The primary administrative control identified for this process is to limit operating pressures below atmospheric pressures to minimize releases of UF_6 should a failure in the primary system occur. The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.4.4.6 Toxic Gas Distribution

Table 4.2-11 identifies all of the events associated with the Toxic Gas Distribution Process that were considered in the hazard analyses. Only one of these events (evacuation) was identified as having the potential to exceed the PSOA threshold (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.5 UF_6 Handling and Storage Facilities Group

The UF_6 Handling and Storage Facilities Group consists of the feed vaporization buildings [X-342A (UF_6 portion only), X-343], the toll enrichment services facility (X-344A), the withdrawal facilities (located in X-326, X-330, and X-333), and the cylinder storage yards (X-745B, D, F, and G). The principal hazard identified for this group is UF_6 and its reaction products. Because these are complex facilities that contain a significant hazard, the principle hazard evaluation performed for the liquid UF_6 facilities (i.e., X-342A, X-343, withdrawal, X-344A) involved a more detailed analysis method. This hazard evaluation combined an operational review, the What If method, and the PSOA approach to evaluate potential initiating events and consequences. A separate hazard evaluation was performed for the withdrawal facilities to focus on shutdown scenarios. This hazard evaluation combined a failure modes and effects analysis and event tree sequence analysis to identify potential accident sequences and consequences. The shutdown of uranium enrichment operations has reduced the overall risk associated with these facilities since the cascade feed is greatly reduced and the Tails and LAW withdrawal facilities have been placed in a "cold standby" condition. Also, the amount of product withdrawn from the enrichment cascade at ERP is a fraction of a percent of the withdrawal rates initially evaluated. The overall level of cylinder handling and processing activity at the X-344A and X-343 buildings remains bounded by the operations as originally analyzed. The mission of the X-343 has changed to be solely the processing of product cylinders (primarily from the PGDP enrichment operations); feed operations in support of the enrichment operations at PORTS have been terminated. The following discussion summarizes the results of these hazard evaluations for UF_6 in these facilities.

4.2.6.5.1 Process Definitions

The UF_6 Handling and Storage Facilities Group consists of liquid UF_6 handling facilities and large UF_6 cylinder storage and handling operations. These operations consist of equipment such as autoclaves, cranes, UF_6 compression equipment, condensers, piping, and other support equipment.

The X-344A toll enrichment services facility provides systems for the receiving, sampling, transferring, and shipping of cylinders containing UF_6. This facility provides all operations necessary for the fulfillment of enrichment service contracts with private industry. Toll product is withdrawn from the enrichment cascade into cylinders. Before the material can be shipped, it must be sampled on a statistical basis and/or transferred into cylinders approved for transport over highways and railways. Special shipping packages are used to protect the full product cylinders during shipment.

The feed and sampling facilities are used to supply UF_6 to the cascade as well as sample, on a statistical basis, the contents for analysis. Both feed facilities have feed and sampling autoclaves and overhead cranes that are used to transfer cylinders to and from the autoclaves.

The withdrawal facilities are used for withdrawing UF_6 from the cascade into cylinders. UF_6 is withdrawn from the cascade using the compressors. After being compressed, the UF_6 passes through the condensers and collects in the accumulators or drains into cylinders at the withdrawal stations. After the cylinders have been filled, a scale cart is used to move the cylinders from the withdrawal stations to a cooldown area. Cylinders remain at this facility until the UF_6 inside the cylinders solidifies. The cylinders are allowed to solidify on the scale carts and rail cars, or they are moved by an overhead crane to a cooldown area.

The cylinder storage yards are open facilities for storing various sizes of cylinders mostly containing depleted UF_6.

As noted earlier, the shutdown of enrichment operations have eliminated the feed to the cascade and the X-342A facility provides only limited feed. The withdrawal facilities are essentially shutdown with limited product withdrawal still occurring at ERP to support deposit removal activities. Limited withdrawals are performed at PW and as side withdrawals by solidifying gaseous UF_6 in small cylinders. These evolutions were screened out from further analysis due to the small amounts of material and subatmospheric pressures; these conditions are insufficient to cause any significant effects.

4.2.6.5.2 Hazards

The hazardous materials in the UF_6 Handling and Storage Facilities Group were reviewed to determine which needed to be evaluated in the PrHA and PSOA. The results of this review are indicated in Table 4.2-9. All the hazardous materials, except those indicated in the table, were characterized as being standard industrial hazards that are commonly found in industrial facilities. These were screened out from further analysis in the PrHA because the amounts of the material are insufficient to cause any significant local health effects. These hazards are adequately controlled by site administrative programs and plans, and no additional analysis was required.

The energy sources associated with the facility that have the potential for causing releases of the hazardous materials are (1) steam energy used to heat the autoclaves; (2) electrical energy used in heat tracing; (3) chemical energy from the reactivity of the UF_6; (4) potential energy associated with the lifting of cylinders; (5) kinetic energy associated with the various types of vehicles; (6) thermal energy associated with the steam used to heat the equipment enclosures for the compressors, coolers, accumulators, manifolds, and associated piping; (7) kinetic energy associated with the compressors; and (8) chemical energy from the reactivity of oxidant/coolant gas mixtures.

All facilities in this group were categorized as Hazard Category 2 nuclear facilities because they contain quantities of the ^{235}U component of the UF_6 sufficient to exceed the threshold quantity for Hazard Category 2 in Table A.1 of DOE-STD-1027-92.

4.2.6.5.3 Parameters of Concern

The first step of the principle hazard evaluation was to identify potential initiating events associated with the UF_6 Handling and Storage Facilities Group to identify the process parameters that, if changed, could result in a release of the hazard that could exceed the screening thresholds for either the PrHA or PSOA. The process parameter changes that could lead to a release of UF_6 are (1) a temperature change in the primary system that exceeds the primary system temperature limits, (2) a pressure change in the primary system that exceeds the primary system pressure limits, (3) a failure in the primary system integrity, and (4) a loss of criticality safety controls.

Based on the groupings described, four process parameters should be addressed for each operating condition to ensure that potential types of events are considered in the hazard analysis. The potential ways of releasing hazardous materials that are caused by things such as energy sources and natural phenomena were evaluated for each operating mode to determine whether they might cause a change in one of the four process parameters. Table 4.2-11 summarizes the different initiating events by parameter. These events were developed by considering operational history, operator input, and systematic evaluations.

The first step of the hazard evaluation associated with the withdrawal shutdown scenarios was to identify the specific scenarios to be evaluated. The scenarios chosen for evaluation included:

- Shutdown of PORTS product withdrawal capability
- Shutdown of X-330 tails withdrawal capability

The evaluation developed failure modes and effects analyses to identify failures that could initiate these scenarios, and then analyzed the bounding initiating events via event trees to identify the range of potential scenario outcomes.

4.2.6.5.4 Summary of Results

As indicated in Table 4.2-11, the events considered for UF_6 Handling and Storage Facilities Group included a wide range of process-related events, external events, shutdown scenarios, and controls for minimizing the potential risks. A brief summary of the hazard analysis is presented below for each process.

4.2.6.5.4.1 Toll Enrichment

Table 4.2-11 identifies all of the events associated with the Toll Transfer and Sampling Process that were considered in the hazard analyses. Fourteen were identified as having the potential to exceed the PSOA threshold, with only one of these (pigtail line failure inside autoclave) not being a limiting event (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure to on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The primary administrative controls identified for this process are associated with preventing a release of liquid UF_6 resulting from a cylinder or primary system failure. These controls are also addressed in the accident analysis. The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.5.4.2 Feed Facilities

The Feed Facilities Process is similar to the Toll Transfer and Sampling Process (i.e., same type of equipment and initiators). Table 4.2-11 identifies all of the events associated with the Feed Facilities Process that were considered in the hazard analyses. Fourteen of these events are identified as having the potential to exceed the PSOA threshold (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2).

4.2.6.5.4.3 Withdrawal Facilities

Table 4.2-11 identifies all of the events associated with the Withdrawal Facilities Process that were considered in the hazard analyses. Twelve were identified as having the potential to exceed the PSOA threshold, with all these being limiting events (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Sec 4.3.2). The administrative controls for this facility were similar to those for the facilities with autoclaves. The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.5.4.4 Cylinder Storage and Handling

Table 4.2-11 identifies all of the events associated with the Cylinder Storage and Handling Process that were considered in the hazard analyses. Only one was identified as having the potential to exceed the PSOA threshold (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The primary administrative control for these facilities is not allowing any liquid UF_6 (in 2.5-ton cylinders and larger) to be handled outside the feed, withdrawal, and cylinder storage and handling processes described above. Other administrative controls for the Cylinder Storage and Handling Process include controls for the prevention of criticality so that no alarm coverage can be justified. These controls include the following requirements in addition to any controls described in Section 5.2:

- Cylinders containing UF_6 exceeding 1 wt % ^{235}U are inspected annually.
- Cylinders containing UF_6 exceeding 1 wt % ^{235}U are spaced such that inspection can detect any significant damage or corrosion.
- Cylinders containing UF_6 exceeding 1 wt % ^{235}U are stored on concrete pads or off the ground in saddles that preclude rolling of the stored cylinders.
- Cylinders containing UF_6 exceeding 1 wt % ^{235}U are inspected for damage following occurrence of an earthquake at the site.

In addition, the following administrative controls were identified for minimizing the potential for release of UF_6 during cylinder handling operations:

- Only approved cylinder handling equipment with qualified operators shall be used for the purpose of maneuvering UF_6 cylinders or other heavy loads.
- Cylinder handling equipment will be inspected (once per day when the equipment is used) to detect visible defects before it is used for lifting heavy loads.

If a breached cylinder containing UF_6 (greater than or equal to 1 weight per cent ^{235}U) is discovered during handling or inspection, the Plant Shift Superintendent (PSS) will be notified immediately so that appropriate actions can be initiated. As part of the initial response actions, the cylinder will be covered to prevent entry of precipitation or liquid water from any source, and repairs will be affected in accordance with directions from nuclear criticality safety. Water is not to be sprayed on a cylinder that has been breached; however, CO_2 may be sprayed on the area of the breach to allow for patching. Personnel involved in the handling or repair of breached cylinders will be equipped with personal alarming dosimeters while working in close proximity to the affected cylinder (if the cylinder is not in an area with CAAS coverage).

The remaining controls identified for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.6 Toxic Gas Storage and Distribution Group

The Toxic Gas Storage and Distribution Group consists of facilities with large storage volumes and/or distribution lines containing the following chemicals:

- Hydrogen Fluoride.
- Fluorine.
- Chlorine.
- Sulfur Dioxide.
- Chlorine trifluoride.

The facilities and the applicable hazards that are associated with this group are indicated in Table 4.2-9. These facilities were not considered to be complex in their operation and control systems. Therefore the primary method of performing the hazard analysis was an operational review combined with the What If method to evaluate potential initiating events and consequences. The following discussion summarizes the results of the hazard evaluation for the hazards in these facilities.

4.2.6.6.1 Processes Definitions

As indicated above, the Toxic Gas Storage and Distribution Group is limited to the processes on the site that contain significant quantities of the hazards listed. These processes are located in various facilities. However, this analysis is limited to the primary storage locations and the distribution systems not associated with another facility. Table 4.2-9 lists the facilities associated with this group.

4.2.6.6.2 Hazards

As indicated above, analysis of the Toxic Gas Storage and Distribution Group is limited to the hazards listed. Other hazards located in these facilities (e.g., sulfuric acid) were evaluated with these processes, but any hazards identified were considered standard industrial hazards.

The energy sources that could be associated with these processes that have the potential for causing releases of the hazardous materials are (1) electrical energy, (2) chemical energy from the reactivity of the potential hazards, (3) potential energy associated with the cranes and the lifting of heavy equipment (e.g., cylinders, containers), (4) kinetic energy associated with the various types of vehicles, (5) flammable materials, (6) combustible materials, and (7) compressed gases (e.g., fluorine).

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These facilities did not contain any radiological material and therefore were not categorized according to DOE-STD-1027-92.

4.2.6.6.3 Parameters of Concern

The first step in identifying potential initiating events associated with the Toxic Gas Storage and Distribution Group was to identify the process parameters that, if changed, could result in a release of the hazard that could exceed the screening thresholds for either the PrHA or PSOA. The process parameter changes that could lead to a release of toxic material are (1) a concentration increase, (2) a pressure change in the primary system that exceeds the primary system pressure limits, (3) a failure in the primary system integrity, and (4) a temperature increase.

Based on the groupings described, four process parameters should be addressed for each operating condition to ensure that potential types of events are considered in the hazard analysis. The potential ways of releasing hazardous materials that are caused by things such as energy sources and natural phenomena were evaluated for each operating mode to determine whether they might cause a change in one of the four process parameters. Table 4.2-11 summarizes the different initiating events by parameter. These events were developed by considering operational history, operator input, and systematic evaluations.

4.2.6.6.4 Summary of Results

As indicated in Table 4.2-11, the events considered for the Toxic Gas Storage and Distribution Group included a wide range of process-related events, external events, and controls for minimizing potential risks.

The four different parameter changes were reviewed for this hazard analysis. Table 4.2-11 identifies all of the events associated with the Toxic Gas Distribution Process that were considered in the hazard analyses. Eight were identified as having the potential to exceed the PSOA threshold, with five of these being considered limiting events (Table 4.2-11). However, consistent with 10 CFR 76.85, because these events do not cause a release of radioactive materials, no further discussion is provided in this SAR. The administrative controls for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application, with special emphasis on the Chemical Safety Program [which includes the Process Safety Management (PSM) Program]. The controls identified as being AQ are described in Section 3.8. Application of the PSM is based on the requirements and is not necessarily applicable to all of these processes.

4.2.6.7 Miscellaneous Waste Storage and Handling Facilities Group

The facilities and the applicable hazards that are associated with the Miscellaneous Waste Storage and Handling Facilities Group are indicated in Table 4.2-9. In addition to the facilities that are presently dedicated to storing waste materials, several staging, temporary, and long-term storage areas are also located in different facilities. Therefore, this section addresses typical waste storage and handling operations for different waste classifications. Specific analyses were performed for each facility and are documented in the PrHAs. However, the analyses were considered to be generic in their application regardless of where the waste is stored. Therefore, specific facilities will not be addressed in this section. These facilities were not considered to be complex in their operation and control systems. Therefore, the primary method of performing the hazard analysis was an operational review combined with the What If method to evaluate potential initiating events and consequences. The following discussion summarizes the results of the hazard evaluation for the hazards in these facilities.

4.2.6.7.1 Processes Definitions

As indicated above, the Miscellaneous Waste Storage and Handling Facilities Group is limited to the processes on the site that are used for the storage and handling of waste. These processes are located in various facilities. However, this analysis is limited to the primary storage locations. Table 4.2-9 lists the facilities associated with this group.

4.2.6.7.2 Hazards

The hazardous materials in the Miscellaneous Waste Storage and Handling Facilities Group were reviewed to determine which needed to be evaluated in the PrHA and PSOA. The results of this review are indicated in Table 4.2-9. All the hazardous materials, except those indicated in the table, were characterized as being standard industrial hazards that are commonly found in industrial facilities. These were screened out from further analysis in the PrHA because the amounts of the material are insufficient to cause any significant local health effects. These hazards are adequately controlled by site administrative programs and plans, and no additional analysis was required.

The energy sources that could be associated with these processes that have the potential for causing releases of the hazardous materials are (1) electrical energy, (2) chemical energy from the reactivity of the potential hazards, (3) potential energy associated with the cranes and the lifting of heavy equipment (e.g., containers), (4) kinetic energy associated with the various types of vehicles, (5) flammable materials, and (6) combustible materials.

Facilities in this group were categorized as Hazard Category 2 nuclear facilities if they contained more than 700 g of fissionable material and if the following conditions were met:

- A nuclear criticality safety approval [NCSA (see Section 5.2)] is required for the facility in accordance with plant procedures.
- The NCSA establishes essential restrictions to control the fissionable material *within the facility* (i.e., controls to prevent entry of material into the facility do not meet this restriction) based on the operations to be performed in the facility.
- The restrictions established by the NCSA are not surveillance items associated with ensuring that the facility never exceeds the allowable limits (e.g., so many grams of ^{235}U per container) that need no controls within the facility.
- There is no documented exemption for requiring criticality accident alarm system (CAAS) coverage to the area.

Fissionable material is defined as any material in which a self-sustaining, neutron-induced fission chain reaction can occur. Nearly all the fissions in such a chain reaction are of the fissionable nuclides (e.g., ^{233}U, ^{235}U, or ^{239}Pu) contained in the fissionable material. The remaining facilities containing contaminated waste were categorized as indicated in Table 4.2-7. All categorization was performed in accordance with DOE-STD-1027-92.

4.2.6.7.3 Parameters of Concern

The first step in identifying potential initiating events associated with the Miscellaneous Waste Storage and Handling Facilities Group was to identify the process parameters that, if changed, could result in a release of the hazard that could exceed the screening thresholds for either the PrHA or PSOA. The process parameter changes that could lead to a release of the hazards are (1) a failure in the primary system integrity, (2) exposure to radionuclides, and (3) loss of criticality safety controls.

Based on the groupings described, three process parameters should be addressed for each operating condition to ensure that potential types of events are considered in the hazard analysis. The potential ways of releasing hazardous materials that are caused by things such as energy sources and natural phenomena were evaluated for each operating mode to determine whether they might cause a change in one of the three process parameters. Table 4.2-11 summarizes the different initiating events by parameter. These events were developed by considering operational history, operator input, and systematic evaluations.

4.2.6.7.4 Summary of Results

As indicated in Table 4.2-11, the events considered for the Miscellaneous Waste Storage and Handling Facilities Group included a wide range of process-related events, external events, and controls for minimizing the potential risks. The three different parameter changes were reviewed for this hazard analysis. Two of the evaluated events were identified as having the potential to exceed the PSOA threshold, with both of these being considered limiting events (Table 4.2-11). The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure for on-site personnel, but none were identified as being required to protect the off-site public (Section 4.3.2). The administrative controls for this process are adequately addressed by the programs and plans described in SAR Chapters 5 and 6 and Volume 3 of the Application with special emphasis on the NCS, Radiation Protection, Chemical Safety, Fire Protection, and Radioactive Waste Management Programs.

4.2.6.8 Miscellaneous Support Facilities Group

The facilities and the applicable hazards that are associated with the Miscellaneous Support Facilities Group are indicated in Table 4.2-9. These facilities were not considered to be complex in their operation and control systems. Therefore, the primary method of performing the hazard analysis was an operational review combined with the What If method to evaluate potential initiating events and consequences. The following discussion summarizes the results of the hazard evaluation for the hazards in these facilities.

4.2.6.8.1 Process Definitions

The Miscellaneous Support Facilities Group of facilities includes the X-621, X-700, X-705, X-720, and X-710 buildings and their various processes that required analysis in the PrHA. The processes are defined in Table 4.2-9. Building X-621 required only analysis of the sodium hydroxide for the facility. The remainder of the facility was considered as a standard industrial hazard. The other four facilities had various operations within the facility, with each operation containing hazards exceeding the PrHA threshold being reviewed.

4.2.6.8.2 Hazards

The hazardous materials in the Miscellaneous Support Facilities Group were reviewed to determine which needed to be evaluated in the PrHA and PSOA. The results of this review are indicated in Table 4.2-9. All the hazardous materials, except those indicated in the table, were characterized as being standard industrial hazards that are commonly found in industrial facilities. These were screened out from further analysis in the PrHA because the amounts of the material are insufficient to cause any significant local health effects. These hazards are adequately controlled by site administrative programs and plans, and no additional analysis was required.

The energy sources associated with the facility that have the potential for causing releases of the hazardous materials are various because of the different facilities and missions. However, the primary energy sources are (1) chemical energy from the reactivity of the various hazards, (2) potential energy, (3) kinetic energy associated with the various types of vehicles, (4) flammable and combustible material, and (5) heat associated with heating of process systems.

All facilities in this group except X-621 were categorized as Hazard Category 2 nuclear facilities because they may contain quantities of the ^{235}U component of the UF_6 sufficient to exceed the threshold quantity for Hazard Category 2 in Table A.1 of DOE-STD-1027-92. Building X-621 did not contain any radiological material.

4.2.6.8.3 Parameters of Concern

The first step in identifying potential initiating events associated with the Miscellaneous Support Facilities Group was to identify the process parameters that, if changed, could result in a release of the hazard that could exceed the screening thresholds for either the PrHA or PSOA. The process parameter changes that could lead to an accident of interest are (1) a failure in the primary system integrity, (2) exposure to radionuclides, (3) loss of criticality safety controls, (4) pressure increase, (5) temperature increase, (6) level increase, and (7) concentration increase.

Based on the groupings described, seven process parameters should be addressed for each operating condition to ensure that potential types of events are considered in the hazard analysis. The potential ways of releasing hazardous materials that are caused by things such as energy sources and natural phenomena were evaluated for each operating mode to determine whether they might cause a change in one of the seven process parameters. Table 4.2-11 summarizes the different initiating events by parameter. These events were developed by considering operational history, operator input, and systematic evaluations.

4.2.6.8.4 Summary of Results

As indicated in Table 4.2-11, the events considered for the Miscellaneous Support Facilities Group included a wide range of process-related events, external events, and controls for minimizing the potential risks. A brief summary of the hazard analysis is presented below for each process.

4.2.6.8.4.1 Building X-705 Process

Table 4.2-11 identifies all of the events associated with the Building X-705 Process that were considered in the hazard analyses. Three of these events were identified as having the potential to exceed the PSOA threshold with fire and criticality being considered as limiting events. The release of fluorine was considered to be bounded by the analysis in Section 4.2.6.4.4.5. The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure to on-site personnel but none were identified as being required to protect the off-site public (Section 4.3.2). The remaining controls identified for this facility are adequately controlled by the institutional safety programs described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.8.4.2 Building X-710 Process

Table 4.2-11 identifies all of the events associated with the Building X-710 Process that were considered in the hazard analyses. Four of these events were identified as having the potential to exceed the PSOA threshold with only 2 of these events (i.e., criticality and fire) being limiting events. The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure to on-site personnel but none were identified as being required to protect the off-site public (Section 4.3.2). The remaining controls identified for this facility are adequately controlled by the institutional safety programs described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.8.4.3 Building X-720 Process

Table 4.2-11 identifies all of the events associated with the Building X-720 Process that were considered in the hazard analyses. One of these events were identified as having the potential to exceed the PSOA threshold with only 1 of these events (i.e., criticality) being a limiting event. The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure to on-site personnel but none were identified as being required to protect the off-site public (Section 4.3.2). The remaining controls identified for this facility are adequately controlled by the institutional safety programs described in SAR Chapters 5 and 6 and Volume 3 of the Application.

4.2.6.8.4.4 Building X-621 Process

Table 4.2-11 identifies all of the events associated with the Building X-621 Process that were considered in the hazard analyses. None of these events were identified as having the potential to exceed the PSOA threshold. The controls identified as being AQ are described in Section 3.8. These controls were identified as playing an important role in minimizing the potential exposure to on-site personnel but none were identified as being required to protect the off-site public (Section 4.3.2). The remaining controls identified for this facility are adequately controlled by the institutional safety programs described in SAR Chapters 5 and 6 and Volume 3 of the Application.

Table 4.2-1 Initiating Event Frequency Categories

Operating Condition	Description	Annual Frequency (f)
Normal Operation (OC-1)	Operations that are planned to occur regularly in the course of facility operation (i.e., operating modes).	$f \geq 1$/yr
Anticipated Event (OC-2)	Initiating events of moderate frequency that may occur one or more times during the life of the facility.	10^{-2}/yr $\leq f <$ 1/yr
Evaluation Basis Event (OC-3)	Initiating events which are not expected to occur during the life of the facility but that are postulated because their consequences would include the potential for the release of significant amounts of radioactive material and because they represent upper bounds on failures or accidents with a probability of occurrence sufficiently high to require consideration.	10^{-6}/yr $< f < 10^{-2}$/yr

Table 4.2-2 Evaluation Guidelines

Plant Evaluation Guidelines	Operating Condition		
	Normal Operation (OC-1)	**Anticipated Events (OC-2)**	**Evaluation Basis Events (OC-3)**
EG 1: Radiological Dose			
For the Offsite Public, the normal operation or initiating event shall be controlled such that the radiological dose is within 10 CFR 20 limits for OC-1 and within the guideline values identified for OC-2 and OC-3.	10 CFR 20.1301	5 rem TEDE	25 rem TEDE
For Onsite Personnel, the normal operation or initiating event shall be controlled such that the radiological dose is within 10 CFR 20 limits for OC-1 and does not result in life-threatening or serious health effects for OC-2 and OC-3.	10 CFR 20.1201	No life-threatening or serious health effects to onsite personnel from the release of radioactive materials	No life-threatening or serious health effects to onsite personnel from the release of radioactive materials
EG 2: Nonradiological Dose			
For the Offsite Public, the normal operation or initiating event shall be controlled such that the nonradiological dose is within 10 CFR 20 lmits for OC-1 and within the guideline values identified for OC-2 and OC-3.	10 CFR 20.1301	10 mg U	30 mg U
For Onsite Personnel, the normal operation or initiating event shall be controlled such that the nonradiological dose is within 10 CFR 20 limits for OC-1 and does not result in life-threatening or serious health effects for OC-2 and OC-3.	10 CFR 20.1201	No life-threatening or serious health effects to onsite personnel from the release of radioactive materials	No life-threatening or serious health effects to onsite personnel from the release of radioactive materials

Table 4.2-2 (Continued)

Plant Evaluation Guidelines	Operating Condition		
	Normal Operation (OC-1)	Anticipated Events (OC-2)	Evaluation Basis Events (OC-3)
EG 3: Pressure/Temperature The normal operation or initiating event shall be controlled within the pressure and temperature limits identified.	Maintain temperature within the design rating. Maintain pressure below MAWP or design pressure rating (if MAWP is not available during normal operation)	Maintain pressure below MAWP (or design rating) plus the ASME code allowable stresses for overpressure protection	Primary containment system pressure less than or equal to system hydrostatic test pressure
EG 4: Double Contingency Principle The normal operation or initiating event shall be controlled within the guidelines of the double contingency principle.	Applies	Applies	EG 4 does not apply to OC-3
EG 5: Initial Conditions The normal operation shall be controlled so that there is not a condition outside the accident analysis (i.e., maintain initial conditions).	Applies	EG 5 does not apply to OC-2	EG 5 does not apply to OC-3
EG 6: Control Area Habitability The initiating event shall be controlled to ensure habitability of a required control area is sufficiently maintained to accomplish the required operator action.	EG 6 does not apply to OC-1	Applies	Applies

Table 4.2-3. Screening Thresholds.

	Onsite		Offsite	
Document Type	Radiological	Nonradiological	Radiological	Nonradiological
Preliminary Hazard Screening	≤ 40 CFR 302.4	≤ 40 CFR 302.4	N/A	N/A
Analysis Statement	> 40 CFR 302.4 and < DOE-STD-1027-92 and Category 3 limits	> 40 CFR 302.4 and qualitative consequences would not result in life-threatening health effects close to the event	N/A	N/A
Process Hazards Analysis	≥ DOE-STD-1027-92 Category 3 limits	Qualititative consequences that could result in life-threatening health effects close to the event	N/A	N/A
Plant Safety Operational Analysis	≥ 25 rem anywhere onsite or ≥ DOE-STD-1027-92 Category 2 limits	Qualitative consequences that could result in life-threatening health effects beyond the immediate facility area	≥5 rem	Qualitative consequences that could result in irreversible or other serious health effects that could impair ability to take protective action

Table 4.2-4. Qualitative Consequence Categories.

Consequence code	Description	Screening threshold exceeded
NONE	There are no radiological or nonradiological effects for this event (i.e., no release of the hazard will occur).	None
MINR	Radiological effects are minor (e.g., release of material from contaminated equipment). Radiation Protection Program is sufficient to control the hazard.	PHS - radiological
MINT	Nonradiological effects are minor (e.g., reversible health effects). Chemical Safety Program is sufficient to control the hazard.	PHS - nonradiological
MINRT	Radiological and nonradiological effects are minor. Administrative control programs (Radiation Protection and Chemical Safety) are sufficient to control the hazard.	PHS - radiological & nonradiological
LOWOR	Radiological quantities could exceed DOE-STD-1027-92 Category 3 levels, but off-site radiological effects are negligible.	PrHA - radiological
LOWOT	On-site nonradiological effects could result in life-threatening health effects in area operating personnel. Beyond the immediate area, only reversible health effects are credible.	PrHA - nonradiological
LOWRT	Radiological quantities could exceed DOE-STD-1027-92 Category 3 levels, but off-site radiological effects are negligible. On-site nonradiological effects could result in life-threatening health effects in area operating personnel. Beyond the immediate area, only reversible health effects are credible.	PrHA - radiological & nonradiological
MODOR	On-site radiological effects could exceed 25 rem at the facility.	PSOA - on-site radiological
MODOT	On-site nonradiological effects could result in life-threatening health effects beyond the immediate area.	PSOA - on-site nonradiological
MODRT	On-site radiological effects could exceed 25 rem at the facility and on-site nonradiological effects could result in life-threatening health effects beyond the immediate area.	PSOA - on-site radiological & nonradiological
OFFR2	Off-site radiological exposure could exceed 5 rem.	PSOA - off-site radiological
OFFT2	Off-site nonradiological effects could result in irreversible health effects.	PSOA - off-site nonradiological
SIGRT	Off-site radiological exposure could exceed 5 rem and off-site nonradiological effects could result in irreversible health effects.	PSOA - off-site radiological & nonradiological

Notes: PHS = Preliminary Hazard Screening; PrHA = Process Hazards Analysis; PSOA = Plant Safety Operational Analysis

Table 4.2-5 Example Initiating Event–Operating Mode–Hazard State Matrix[1]

Anticipated initiating event	Cylinder/ Pigtail Operations operating mode	Shutdown/ Containment operating mode	Heating operating mode	Feeding, Transfer or Sampling operating mode
	Hazard state			
Pressure increase				
Autoclave steam control valve fails open	---	---	All states	Liquid/Gas
Temperature increase				
Fires (X-343 only)	All states	All states	All states	Liquid/Gas
Primary system integrity				
Minor leaks of UF_6 inside autoclave	---	All states	All states	Liquid/Gas
Minor leaks of UF_6 to atmosphere	All states	---	---	Liquid/Gas

1. Table represents X-342A and X-343

Table 4.2-6. Historical UF_6 Releases—1956–93.

Site and incident	Location	Date	Description	kg U
Oak Ridge Gaseous Diffusion Plant				
1	Laboratory Development Feed Vaporization	11/61	Cylinder valve failure	193 [a]
2	Liquid Feed Sample	5/69	Pigtail evacuation with cylinder valve open	7 [a]
3	Feed Vaporization	12/70	Pigtail connection leak	153 [a]
4	Test Loop Feed Vaporization	4/71	Pigtail connection failed	11 [a]
5	Liquid Product Transfer	9/75	Cylinder failure resulting from explosive UF_6 oil reaction	6
Paducah Gaseous Diffusion Plant				
1	Product Withdrawal	11/56	Lube oil fire	No estimate
2	Feed Vaporization	11/60	Hydraulic rupture of cylinder	2100
3	Process Building (C-337)	12/62	Exothermic reaction	1000
4	Tails Storage	3/66	Liquid cylinder dropped and ruptured cylinder wall	8
5	Sampling	1/71	Broken pigtail	15 [a]
6	Tails Withdrawal	1/78	Rubbing compressor, UF_6/R-114 reaction	9
7	Process Buildilng (C-337)	12/93	Coupling failure	1
Portsmouth Gaseous Diffusion Plant				
1	Tails Withdrawal	11/60	Pigtail failure	92
2	Feed Vaporization	7/65	Pigtail rupture	14 [a]
3	Tails Withdrawal	7/69	Cylinder valve would not close	460
4	Feed Vaporization	12/70	Pigtail leak	12 [a]
5	Sampling	5/73	Cylinder valve would not close	45 [a]
6	High Assay Sampling	11/75	Pigtail connection leak	11
7	Transfer Bay	9/76	Pigtail connection leak	65 [a]
8	Transfer Autoclave	12/77	Cylinder valve thread leak	6 [a]
9	Feed Vaporization	12/77	Pigtail connection leak	8 [a]
10	Sampling	3/78	Cylinder connection leak, operator error	6 [a]
11	Liquid Cylinder Storage	3/78	Cylinder rupture from straddle error	5926
12	Tails Withdrawal	10/78	Cylinder valve broke as result of transport while connected	561

[a] Autoclave incidents

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-100	Administration Building	No	N/A	No	No
X-100-B	Air Conditioning Equipment Building	No	N/A	No	No
X-100-L	Environmental Control Trailer	No	N/A	No	No
X-1000	Administration Building	No	N/A	No	No
X-1007	Fire Station	No	N/A	No	No
X-101	Dispensary	No	N/A	No	No
X-102	Cafeteria	No	N/A	No	No
X-1020	Emergency Operations Center	No	N/A	No	No
X-103	Auxiliary Office Building	Yes	Radiological	No	No
X-104	Guard Headquarters	Yes	N/A	No	No
X-104-A	Indoor Firing Range Building	No	N/A	No	No
X-105	Electronic Maintenance Building	Yes	Radiological	No	No
X-106	Tactical Response Station	No	N/A	No	No
X-106-B	Fire Training Building	No	N/A	No	No
X-108-A	South Portal and Shelter	No	N/A	No	No
X-108-B	North Portal and Shelter	No	N/A	No	No
X-108-E	Construction Entrance Portal	No	N/A	No	No
X-108-H	Pike Avenue Portal	No	N/A	No	No
X-109-A	Personnel Monitoring Building	No	N/A	No	No
X-109-B	Personnel Monitoring Building	No	N/A	No	No
X-109-C	Personnel Monitoring Trailer	No	N/A	No	No
X-1107-A	Administrative Portal	No	N/A	No	No
X-1107-B	Administrative Portal	No	N/A	No	No
X-1107-BP	Interplant Portal	No	N/A	No	No
X-1107-D	Northeast Portal	No	N/A	No	No
X-111-A	SNM Monitoring Portal, X-326	No	N/A	No	No
X-111-B	SNM Portal Northwest, X-326	No	N/A	No	No
X-112	Data Processing Building	No	N/A	No	No
X-114-A	Pistol Range	No	N/A	No	No
X-120H	Meteorological Tower	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-200	Site Preparation, Grading, and Landscaping	No	N/A	No	No
X-201	Land and Land Rights	No	N/A	No	No
X-202	Roads	No	N/A	No	No
X-204	Railroad and Railroad Overpass	No	N/A	No	No
X-206-A	Main Parking Lot, North	No	N/A	No	No
X-206-B	Main Parking Lot, South	No	N/A	No	No
X-206-E	Construction Parking Lot	No	N/A	No	No
X-206-H	Pike Avenue Parking Lot	No	N/A	No	No
X-206-J	South Office Parking Lot	No	N/A	No	No
X-208	Security Fence	No	N/A	No	No
X-210	Sidewalks	No	N/A	No	No
X-215-A	Electrical Distribution to Process Buildings	No	N/A	No	No
X-215-B	Electrical Distribution to Areas Other than Process	No	N/A	No	No
X-215-C	Exterior Lighting Facilities	No	N/A	No	No
X-215-D	Electric Power Tunnels	No	N/A	No	No
X-220-A	Instrumentation Tunnels	No	N/A	No	No
X-220-B1	Process Instrumentation Lines	No	N/A	No	No
X-220-B2	Carrier Communications System	No	N/A	No	No
X-220-B3	Water Supply Telemetering Lines	No	N/A	No	No
X-220-C	Superior American Alarm System	No	N/A	No	No
X-220-D1	General Telephone System	No	N/A	No	No
X-220-D2	Process Telephone System	No	N/A	No	No
X-220-D3	Emergency Telephone System	No	N/A	No	No
X-220-E1	Evacuation Public Address System	No	N/A	No	No
X-220-E2	Process Public Address System	No	N/A	No	No
X-220-E3	Power Public Address system	No	N/A	No	No
X-220-F	Plant Radio System	No	N/A	No	No
X-220-G	Pneumatic Dispatch System	No	N/A	No	No
X-220-H	McCulloh Alarm System	No	N/A	No	No
X-220-J	Radiation Alarm System	No	N/A	No	No
X-220-K	Cascade Automatic Data Process System	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-220-L	Classified Computer System	No	N/A	No	No
X-220-N	Security Alarm and Surveillance System	No	N/A	No	No
X-220-P	Maintenance Work Authorization and Control System	No	N/A	No	No
X-220-R	Public Warning Siren System	No	N/A	No	No
X-220-S	Power Operations SCADA System	No	N/A	No	No
X-2200	Site Preparation, Grading, and Landscaping	No	N/A	No	No
X-2202	Roads (GCEP)	No	N/A	No	No
X-2204	GCEP Railroads	No	N/A	No	No
X-2207-A	GCEP Administrative Parking Lot	No	N/A	No	No
X-2207-D	Northwest Parking Lot	No	N/A	No	No
X-2208	Security Fence	No	N/A	No	No
X-2210	Sidewalks	No	N/A	No	No
X-2215-A	Underground Electrical Distribution to Process Buildings	No	N/A	No	No
X-2215-B	Electrical Distribution to Areas Other than Process Buildings	No	N/A	No	No
X-2215-C	Exterior Light Fixtures	No	N/A	No	No
X-2220-C	Fire and Supervisory Alarm System	No	N/A	No	No
X-2220-D	Telephone System	No	N/A	No	No
X-2220-L	Classified Computer System	No	N/A	No	No
X-2220-N	Security Access Control and Alarm System	No	N/A	No	No
X-2230-A	Sanitary Water Distribution System	No	N/A	No	No
X-2230-B	GCEP Sanitary Sewers	No	N/A	No	No
X-2230-C	Storm Sewers	No	N/A	No	No
X-2230-F	Raw Water Supply Line	No	N/A	No	No
X-2230-G	Recirculating Water System	No	N/A	No	No
X-2230-H	Fire Water Distribution System	No	N/A	No	No
X-2230-J	Liquid Effluent System	No	N/A	No	No
X-2230-T	Recirculating Heating Water System	No	N/A	No	No
X-2232-A	Nitrogen Distribution System	No	N/A	No	No
X-2232-B	Dry Air Distribution System	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-2232-D	Steam and Condensate System	No	N/A	No	No
X-2232-G	Supports for Distribution Lines	No	N/A	No	No
X-230	Water Supply Line	No	N/A	No	No
X-230-A	Sanitary and Fire Water Distribution System (Fire Hydrant/Sprinkler Portion)	No	N/A	No	No
X-230A-3	Ambient Air Monitoring Stations (A-6, 8, 9, 10, 12, 15, 23, 24, 28, 29, 36,37, 40)	No	N/A	No	No
X-230-B	Sanitary Sewers	No	N/A	No	No
X-230-C	Storm Sewers	No	N/A	No	No
X-230-D	Softened Water Distribution System	No	N/A	No	No
X-230-E	Plant Water System (Makeup to Cooling Tower)	No	N/A	No	No
X-230-F	Raw Water Supply Line	No	N/A	No	No
X-230-G	Recirculating Water System (between buildings)	No	N/A	No	No
X-230-H	Fire Water Distribution System	No	N/A	No	No
X-230-J1	Environmental Monitoring Station	No	N/A	No	No
X-230-J2	South Environmental Sampling Building	No	N/A	No	No
X-230-J3	West Environmental Sampling Building	No	N/A	No	No
X-230-J4	Environmental Air Monitoring Station	No	N/A	No	No
X-230-J5	West Monitoring Facility	No	N/A	No	No
X-230-J6	Northeast Monitoring Facility	No	N/A	No	No
X-230-J7	East Monitoring Facility	No	N/A	No	No
X-230-J8	Environmental Storage Building	No	N/A	No	No
X-230-J9	North Environmental Sampling Building	No	N/A	No	No
X-230-K	South Holding Pond	No	N/A	No	No
X-230-L	North Holding Pond	No	N/A	No	No
X-232-A	Nitrogen Distribution System	No	N/A	No	No
X-232-B	Dry Air Distribution System	No	N/A	No	No
X-232-C1	Tie Line No. 1; X-342 to X-330	Yes	Category 2	Yes	Yes
X-232-C2	Tie Line No. 2; X-330 to X-326	Yes	Category 2	Yes	Yes
X-232-C3	Tie Line No. 3; X-330 too X-333	Yes	Category 2	Yes	Yes
X-232-C4	Tie Line No. 4; X-326 to X-770	Yes	Category 2	Yes	Yes
X-232-C5	Tie Line No. 5; X-343 to X-333	Yes	Category 2	Yes	Yes

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-232-D	Steam and Condensate System	No	N/A	No	No
X-232-E	Freon Distribution Lines	No	N/A	No	No
X-232-F	Fluorine Distribution Systems	No	N/A	No	No
X-232-G	Supports for Distribution Lines	No	N/A	No	No
X-240-A	RCW System (Cathodic Protection)	No	N/A	No	No
X-300	Plant Control Facility	No	N/A	No	No
X-300-A	Process Monitoring Building	No	N/A	No	No
X-300-B	Plant Control Facility Carport	No	N/A	No	No
X-300-C	Emergency Communications Antenna	No	N/A	No	No
X-3000	Electronics Maintenance	No	N/A	No	No
X-326	Process Building	Yes	Category 2	Yes	Yes
X-330	Process Building	Yes	Category 2	Yes	Yes
X-333	Process Building	Yes	Category 2	Yes	Yes
X-334	Transformer Storage and Cleaning Building	Yes	N/A	No	No
X-342-A	Feed Vaporization and Fluorine Generation Building	Yes	Category 2	Yes	Yes
X-342-B	Fluorine Storage Building	Yes	Radiological	Yes	Yes
X-343	Feed Vaporization and Sampling Facility	Yes	Category 2	Yes	Yes
X-344-A	Toll Enrichment Services Facility	Yes	Category 2	Yes	Yes
X-344-B	Maintenance Storage Building	No	N/A	No	No
X-5000	Switch House	No	N/A	No	No
X-5001	Substation	No	N/A	No	No
X-5001-A	Valve House	No	N/A	No	No
X-5001-B	Oil Pumping Station	No	N/A	No	No
X-501	Substation	No	N/A	No	No
X-501-A	Substation	No	N/A	No	No
X-5015	HV Electrical System	No	N/A	No	No
X-502	Substation	No	N/A	No	No
X-515	330-k V Tie Line (between X-530 and X-533)	No	N/A	No	No
X-530-A	Switchyard	No	N/A	No	No
X-530-B	Switch House	No	N/A	No	No
X-530-C	Test and Repair Building	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-530-D	Oil House	No	N/A	No	No
X-530-E	Valve House	No	N/A	No	No
X-530-F	Valve House	No	N/A	No	No
X-533-A	Switchyard	No	N/A	No	No
X-533-B	Switch House	No	N/A	No	No
X-533-C	Test and Repair Building	No	N/A	No	No
X-533-D	Oil House	No	N/A	No	No
X-533-E	Valve House	No	N/A	No	No
X-533-F	Valve House	No	N/A	No	No
X-533-G	GCEP Oil Pumping Station	No	N/A	No	No
X-533-H	Gas Reclaiming Cart Garage	No	N/A	No	No
X-540	General Telephone Building	No	N/A	No	No
X-600	Steam Plant	Yes	N/A	No	No
X-600-A	Coal Pile Yard	No	N/A	No	No
X-600-B	Steam Plant Shop Building	No	N/A	No	No
X-600-C	Ash Wash Treatment Building	No	N/A	No	No
X-6000	GCEP Cooling Tower Pump House	Yes	N/A	Yes	Yes
X-6001	Cooling Tower	No	N/A	No	No
X-6001-A	Valve House	No	N/A	No	No
X-605	Sanitary Water Control House	No	N/A	No	No
X-605-A	Sanitary Water Wells	No	N/A	No	No
X-605-H	Booster Pump House and Appurtenances	No	N/A	No	No
X-605-I	Chlorinator Building	No	N/A	No	No
X-605-J	Diesel Generator Building	No	N/A	No	No
X-608	Raw Water Pump House	No	N/A	No	No
X-608-A	Raw Water Wells (Nos. 1 to 4)	No	N/A	No	No
X-608-B	Raw Water Wells (Nos. 5 to 15)	No	N/A	No	No
X-611	Water Treatment Plant and Appurtenances	Yes	N/A	Yes	Yes
X-611-B	Sludge Lagoon	Yes	N/A	Yes	No
X-611-C	Filter Building	Yes	N/A	Yes	No
X-611-D	Recarbonization Instrument Building	Yes	N/A	Yes	No
X-611-E	Chlorine Treatment Facility	Yes	N/A	Yes	Yes
X-612	Elevated Water Tank	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-614-A	Sewage Pumping Station	No	N/A	No	No
X-614-B	Sewage Lift Station	No	N/A	No	No
X-614-D	South Sewage Lift Station	No	N/A	No	No
X-614-P	Northeast Sewage Lift Station	No	N/A	No	No
X-616	Liquid Effluent Control Facility	Yes	N/A	Yes	Yes
X-617	South pH Control Facility	Yes	N/A	No	No
X-618	North Holding Pond Storage Building	No	N/A	No	No
X-621	Coal Pile Runoff Treatment Facility	Yes	N/A	Yes	No
X-626-1	Recirculating Water Pump House	Yes	N/A	Yes	Yes
X-626-2	Cooling Tower	No	N/A	No	No
X-630-1	Recirculating Water Pump House	Yes	N/A	Yes	Yes
X-630-2A	Cooling Tower	No	N/A	No	No
X-630-2B	Cooling Tower	No	N/A	No	No
X-630-3	Acid Handling Station	Yes	N/A	No	No
X-633-1	Recirculating Water Pump House	Yes	N/A	Yes	Yes
X-633-2A	Cooling Tower	No	N/A	No	No
X-633-2B	Cooling Tower	No	N/A	No	No
X-633-2C	Cooling Tower	No	N/A	No	No
X-633-2D	Cooling Tower	No	N/A	No	No
X-640-1	Pump House	No	N/A	No	No
X-640-2	Elevated Water Tank	No	N/A	No	No
X-6609	Raw Water Wells	No	N/A	No	No
X-6613	Sanitary Water Storage Tank	No	N/A	No	No
X-6614-E	Sewage Lift Station	No	N/A	No	No
X-6614-G	Sewage Lift Station	No	N/A	No	No
X-6614-H	Sewage Lift Station	No	N/A	No	No
X-6614-J	Sewage Lift Station	No	N/A	No	No
X-6619	Sewage Treatment Facility	Yes	N/A	Yes	Yes
X-6643	Fire Water Storage Tanks (Tanks I and II)	No	N/A	No	No
X-6644	Fire Water Pumphouse	No	N/A	No	No
X-700	Converter Shop and Cleaning Building (Includes X-721)	Yes	Category 2	Yes	Yes
X-700-A	Air Conditioning Equipment Building	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-701-A	Lime House	No	N/A	No	No
X-701-D	Water Deionization Facility	No	N/A	No	No
X-705	Decontamination Building	Yes	Category 2	Yes	Yes
X-705-D	Heating Booster Pump Building	No	N/A	No	No
X-710	Technical Services Building	Yes	Category 2	Yes	Yes
X-710-A	Technical Services Gas Manifold Shed	No	N/A	No	No
X-710-B	Explosion Test Facility	No	N/A	No	No
X-720	Maintenance and Stores Building	Yes	Category 2	Yes	Yes
X-720-A	Maint. & Stores Building Gas Manifold Shed	No	N/A	No	No
X-720-B	Radio Base Station Building	No	N/A	No	No
X-720-C	Paint and Oil Storage Building	No	N/A	No	No
X-721	Radiation Calibration Facility	See X-700 Building			
X-741	Oil Drum Storage Facility	No	N/A	No	No
X-742	Gas Cylinder Storage Facility	Yes	N/A	Yes	Yes
X-743	Lumber Storage Facility	No	N/A	No	No
X-744B	Salt Storage Building	No	N/A	No	No
X-744-H	Bulk Storage Building	No	N/A	No	No
X-744-J	Bulk Storage Building	Yes	N/A	Yes	Yes
X-744-L	Stores and Maintenance Warehouse	No	N/A	No	No
X-744-W	Surplus and Salvage Warehouse	No	N/A	No	No
X-745-B	Toll Enrichment Process Gas Yard - UEA	Yes	Category 2	Yes	Yes
X-745-D	Cylinder Storage Yard	Yes	Category 2	Yes	Yes
X-745-F	North Process Gas Stockpile Yard - UEA	Yes	Category 2	Yes	Yes
X-745-G	Cylinder Storage Yard	Yes	Category 2	Yes	Yes
X-745-H	Northwest Surplus and Scrap Yard	No	N/A	No	No
X-746	Materials Receiving and Inspection	No	N/A	No	No
X-747-A	Material Storage Yard	No	N/A	No	No
X-747-B	Material Storage Yard	No	N/A	No	No
X-747-C	Material Storage Yard	Yes	Radiological	No	No
X-747-D	Material Storage Yard	Yes	Radiological	No	No
X-747-E	Material Storage Yard	No	N/A	No	No

Table 4.2-7. Facilities Included in the SAR Review.

Facility	Name	PHS screen in?	Nuclear hazard category	PrHA required?	PSOA required?
X-747-F	Miscellaneous Material Storage Yard	No	N/A	No	No
X-747-J	Decontamination Storage Yard	No	N/A	No	No
X-748	Truck Scale Facility	No	N/A	No	No
X-750	Mobile Equipment Maintenance Shop	No	N/A	No	No
X-750-A	Garage Storage Building	No	N/A	No	No
X-760	Chemical Engineering Building	No	N/A	No	No
X-7721	Maintenance Stores Training Building	No	N/A	No	No
XT-801	Construction Manager Administration Building/South Offices Building	No	N/A	No	No
XT-847	Waste Management Staging Facility	Yes	Category 2	Yes	Yes

Table 4.2-8. Facilities Documented by Analysis Statement.

Facility	Name
X-103	Auxiliary Office Building
X-104	Guard Headquarters
X-105	Electronic Maintenance Building
X-334	Transformer Storage and Cleaning Building
X-600	Steam Plant
X-617	South pH Control Facility
X-630-3	Acid Handling Station
X-747-C	Material Storage Yard
X-747-D	Material Storage Yard

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities

Cascade facilities

Enrichment cascade process

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Light cascade gases (ClF_3, F_2, R-114, O_2, N_2)

Facilities associated with process

X-232-C1	Tie Line No. 1; X-342 to X-330
X-232-C2	Tie Line No. 2; X-330 to X-326
X-232-C3	Tie Line No. 3; X-330 to X-333
X-232-C4	Tie Line No. 4; X-326 to X-770
X-232-C5	Tie Line No. 5; X-343 to X-333
X-326	Process Building
X-330	Process Building
X-333	Process Building

Freezer/Sublimer process

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Facilities associated with process

X-333	Process Building

Freon degrader process

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Light cascade gases (ClF_3, F_2, R-114, O_2, N_2)

Facilities associated with process

X-326	Process Building

Cold Recovery Process

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Light cascade gases (ClF_3, F_2, R-114, O_2, N_2)

Facilities associated with process

X-330	Process Building
X-333	Process Building

Storage Process

Hazards exceeding the PrHA threshold

UNX - Uranyl Nitrate Crystals

Facilities associated with process

X-330	Process Building

Continued.

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities

Toxic gas storage and distribution processes

Hazards exceeding the PrHA threshold

Fluorine (F_2)

Chlorine trifluoride (ClF_3)

Facilities associated with process

X-326	Process Building
X-330	Process Building
X-333	Process Building

Purge cascade process

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Light cascade gases (ClF_3, F_2, R-114, O_2, N_2)

Technetium (Tc_{99})

Facilities associated with process

X-326	Process Building

Withdrawal processes (ERP, LAW, and Tails)

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Facilities associated with process

X-326	Process Building
X-330	Process Building
X-333	Process Building

UF_6 Handling Facilities

Feed vaporization and sampling processes (X-342-A and X-343)

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Facilities associated with process

X-342-A	Feed Vaporization & Fluorine Generation Building
X-343	Feed Vaporization and Sampling Facility

Toll sampling and transfer processes (X-344-A)

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Facilities associated with process

X-344-A	Toll Enrichment Services Facility

Cylinder handling/storage processes for leased facilities

Hazards exceeding the PrHA threshold

UF_6 - Uranium hexafluoride

Facilities associated with process

X-745-B	Toll Enrichment Process Gas Yard - UEA
X-745-D	Feed Storage Yard
X-745-F	North Process Gas Stockpile Yard - UEA
X-745-G	Cylinder Storagea Lot

Continued.

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities

Chemical facilities

Toxic gas storage and distribution process

Hazards exceeding the PrHA threshold

Fluorine (F_2)
Sulfuric acid (Fire Only)
Hydrofluoric acid
Chlorine
Chlorine trifluoride (ClF_3)
Sulfur dioxide

Facilities associated with process

X-342-A	Feed Vaporization and Fluorine Generation Building
X-342-B	Fluorine Storage Building
X-6000	GCEP Cooling Tower Pump House
X-611	Water Treatment Plant and Appurtenances
X-616	Liquid Effluent Control Facility
X-626-1	Recirculating Water Pump House
X-630-1	Recirculating Water Pump House
X-633-1	Recirculating Water Pump House
X-6619	Sewage Treatment Facility
X-742	Gas Cylinder Storage Facility

All processes for the X-342-B Fluorine storage building

Hazards exceeding the PrHA threshold

Hydrofluoric acid
Fluorine (F_2)
Hydrogen

Facilities associated with process

X-342-A	Feed Vaporization and Fluorine Generation Building
X-342-B	Fluorine Storage Building

All processes for X-611 series buildings

Hazards exceeding the PrHA threshold

Chlorine
Hydroxyacetic acid

Facilities associated with process

X-611	Water Treatment Plant and Appurtenances
X-611-B	Sludge Lagoon
X-611-C	Filter Building
X-611-D	Recarbonization Instrument Building
X-611-E	Chlorine Treatment Facility

Continued.

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities	
All processes for the X-616 chromate reduction facility	
Hazards exceeding the PrHA threshold	
Sulfur dioxide	
Facilities associated with process	
X-616	Liquid Effluent Control Facility
All processes for the RCW pump houses	
Hazards exceeding the PrHA threshold	
Sulfuric acid	
Chlorine	
Bromine	
Facilities associated with process	
X-6000	GCEP Cooling Tower Pump House
X-626-1	Recirculating Water Pump House
X-630-1	Recirculating Water Pump House
X-633-1	Recirculating Water Pump House
All processes for the X-6619 sewage treatment facility	
Hazards exceeding the PrHA threshold	
Chlorine	
Sulfur dioxide	
Facilities associated with process	
X-6619	Sewage Treatment Facility
Miscellaneous waste storage and handling facilities	
All processes for the X-744-J bulk storage building	
Hazards exceeding the PrHA threshold	
Bulk quantities of dry and wet chemicals	
Facilities associated with process	
X-744-J	Bulk Storage Building
All processes for the XT-847 Waste Management Staging Facility	
Hazards exceeding the PrHA threshold	
Radioactive waste	
Facilities associated with process	
XT-847	Waste Management Staging Facility

Continued.

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities

Waste storage/handling processes

Hazards exceeding the PrHA threshold

RCRA Hazardous waste
Low-level radioactive waste
Uranium-bearing waste (>1 WT % ^{235}U)
TSCA Hazardous waste
Mixed waste

Facilities associated with process

XT-847
XT-847 Waste Management Staging Facility

Miscellaneous support facilities

All processes for the X-621 coal pile runoff treatment facility

Hazards exceeding the PrHA threshold

Sodium hydroxide

Facilities associated with process

X-621 Coal Pile Runoff Treatment Facility

All processes for the X-700 converter shop and cleaning building

Hazards exceeding the PrHA threshold

Sodium hydroxide
Sulfuric acid
Fluorine (F_2)
Uranium-bearing solutions
Methanol
Acid cleaning solutions
Caustic cleaning solutions
Detergent cleaning solutions

Facilities associated with process

X-700 Converter Shop and Cleaning Building

All processes for the X-705 decontamination building

Hazards exceeding the PrHA threshold

Sodium hydroxide
Hydrofluoric acid
Uranium oxide
Fluorine (F_2)
Various analytical chemicals
Radionuclides (including Technetium)
Uranium-bearing solutions
Citric acid

Facilities associated with process

X-705 Decontamination Building

Continued.

Table 4.2-9. Hazards in Facilities Exceeding PrHA Thresholds.

Facility group/processes evaluated/hazards/facilities	
All processes for the X-710 technical services building	
Hazards exceeding the PrHA threshold	
UF_6 - Uranium hexafluoride	
Hydrofluoric acid	
Chlorine	
Chlorine trifluoride (ClF_3)	
Fluorine (F_2)	
Various analytical chemicals	
Uranium-bearing solutions	
Facilities associated with process	
X-710	Technical Services Building
All processes for the X-720 maintenance and stores building	
Hazards exceeding the PrHA threshold	
UF_6 - Uranium hexafluoride	
Sulfuric acid	
Uranium oxide	
Flammable liquids (e.g., varnish)	
Phosphoric acid	
Facilities associated with process	
X-720	Maintenance and Stores Building

Table 4.2-10. Hazard Categorization of Facilities.

Facility	Name
Radiological	
X-103	Auxiliary Office Building
X-105	Electronic Maintenance Building
X-342-B	Fluorine Storage Building
X-747-C	Material Storage Yard
X-747-D	Material Storage Yard
Category 2	
X-232-C1	Tie Line No. 1; X-342 to X-330
X-232-C2	Tie Line No. 2; X-330 to X-326
X-232-C3	Tie Line No. 3; X-330 too X-333
X-232-C4	Tie Line No. 4; X-326 to X-770
X-232-C5	Tie Line No. 5; X-343 to X-333
X-326	Process Building
X-330	Process Building
X-333	Process Building
X-342-A	Feed Vaporization and Fluorine Generation Building
X-343	Feed Vaporization and Sampling Facility
X-344-A	Toll Enrichment Services Facility
X-700	Converter Shop and Cleaning Building
X-705	Decontamination Building
X-710	Technical Services Building
X-720	Maintenance and Stores Building
X-745-B	Toll Enrichment Process Gas Yard - UEA
X-745-D	Feed Storage Yard
X-745-F	North Process Gas Stockpile Yard - UEA
X-745-G	Cylinder Storage Yard
XT-847	Waste Management Staging Facility

Table 4.2-11 Initiating Events

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
Cascade facilities			
Loss of Criticality Controls			
CRITICALITY			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	Yes	Yes
Cold recovery process	Evaluation basis event	Yes	Yes
Purge cascade process	Evaluation basis event	Yes	Yes
External Event			
EARTHQUAKE			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Toxic gas storage and distribution processes	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
EVACUATION OF CASCADE PROCESS BUILDING			
Enrichment cascade process	Anticipated event	Yes	Yes
Freezer/sublimer process	Anticipated event	Yes	Yes
Freon degrader process	Anticipated event	Yes	Yes
Cold recovery process	Anticipated event	Yes	Yes
Toxic gas storage and distribution processes	Anticipated event	Yes	Yes
Purge cascade process	Anticipated event	Yes	Yes

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
FLOOD			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Toxic gas storage and distribution processes	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
HIGH WIND			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Toxic gas storage and distribution processes	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
LARGE FIRE			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Toxic gas storage and distribution processes	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
Pressure Increase			
B-STREAM BLOCK VALVE CLOSURE			
Enrichment cascade process	Anticipated event	Yes	Yes
Purge cascade process	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
COOLANT TUBE RUPTURE INTO PRIMARY SYSTEM			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
COOLANT/OXIDANTS - VIOLENT REACTION			
Enrichment cascade process	Evaluation basis event	No	No
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
OVERPRESSURE OF PRIMARY SYSTEM WITH PLANT AIR			
Enrichment cascade process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
STAGE CONTROL VALVE CLOSURE			
Enrichment cascade process	Anticipated event	Yes	No
Purge cascade process	Anticipated event	No	No
STRESS RUPTURE OF F/S VESSEL			
Freezer/sublimer process	Evaluation basis event	No	No
Primary System Integrity			
COMPRESSOR SEAL FAILURE			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
HEAVY EQUIPMENT DROP			
Enrichment cascade process	Evaluation basis event	Yes	Yes
Freezer/sublimer process	Evaluation basis event	Yes	Yes
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
LARGE UF_6 RELEASE TO ATMOSPHERE			
Enrichment cascade process	Evaluation basis event	Yes	Yes
LIMITED UF_6 RELEASE TO ATMOSPHERE			
Enrichment cascade process	Anticipated event	Yes	Yes
MINOR UF_6 RELEASE TO ATMOSPHERE			
Purge cascade process	Anticipated event	No	No
MISVALVING (OPENING PRIMARY SYSTEM TO ATMOSPHERE)			
Enrichment cascade process	Evaluation basis event	No	No
Freezer/sublimer process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
MOTOR-COMPRESSOR COUPLING FAILURE			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
OPENING OF PRIMARY SYSTEM W/O PURGING			
Enrichment cascade process	Evaluation basis event	No	No
Freezer/sublimer process	Evaluation basis event	No	No
Freon degrader process	Evaluation basis event	No	No
Cold recovery process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
PRIMARY SYSTEM FAILURE DUE TO VEHICLE IMPACT			
Enrichment cascade process	Evaluation basis event	No	No
Freezer/sublimer process	Evaluation basis event	No	No
Freon degrader process	Evaluation basis event	No	No
Purge cascade process	Evaluation basis event	No	No
STORAGE/DISTRIBUTION SYSTEM BREACHES			
Toxic gas storage and distribution processes	Evaluation basis event	No	No
Support System Loss			
LOSS OF ELECTRICAL POWER			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No
LOSS OF LUBE OIL SUPPLY			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No
LOSS OF PLANT AIR			
Enrichment cascade process	Anticipated event	No	No
Freezer/sublimer process	Anticipated event	No	No
Cold recovery process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
Temperature Decrease			
ClF_3 ROOM TEMPERATURE DECREASE			
Toxic gas storage and distribution processes	Anticipated event	No	No
Temperature Increase			
LOSS OF COOLING TO FREEZER/SUBLIMER			
Freezer/sublimer process	Anticipated event	No	No
APPLYING EXCESSIVE HEAT TO A LINE PLUGGED WITH UF_6			
Cold recovery process	Evaluation basis event	No	No
COMPRESSOR FAILURE - STARVING FLOW IN THE A-STREAM			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No
COMPRESSOR FAILURE - UF_6 /HOT METAL REACTION			
Enrichment cascade process	Anticipated event	Yes	Yes
Purge cascade process	Anticipated event	No	No
LOSS OF COOLANT			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No
LOSS OF RCW TO COOLANT SYSTEM			
Enrichment cascade process	Anticipated event	No	No
Purge cascade process	Anticipated event	No	No
RCW TEMPERATURE INCREASE			
Freezer/sublimer process	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
UF$_6$ handling and storage facilities			
Loss of Criticality Controls			
CRITICALITY			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
Cylinder handling/storage processes	Beyond evaluation basis event	No	No
External Event			
EARTHQUAKE			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
Cylinder handling/storage processes	Evaluation basis event	No	No
EVACUATION OF FACILITY			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Anticipated event	Yes	Yes
FLOOD			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
Cylinder handling/storage processes	Evaluation basis event	No	No
HIGH WIND			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
Cylinder handling/storage processes	Evaluation basis event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
LARGE FIRE			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A)	Evaluation basis event	No	No
Feed vaporization and sampling processes (X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	No	No
Cylinder handling/storage processes	Evaluation basis event	Yes	Yes
Pressure Increase			
AUTOCLAVE STEAM CONTROL VALVE FAILS OPEN			
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	Yes	Yes
Toll sampling and transfer processes (X-344-A)		Yes	Yes
COOLANT TUBE RUPTURE INTO PRIMARY SYSTEM			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	No	No
HEATING OF A CYLINDER WITH EXCESSIVE UF_6			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
HEATING OF CYLINDER WITH EXCESSIVE NONCONDENSIBLES			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
LOSS OF UF_6 QUALITY CONTROL IN UF_6 CYLINDER			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	No	No
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	No	No
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	No	No
COOLANT/OXIDANTS - VIOLENT REACTION			
Sampling process venting Cold Trapping (X-343)	Evaluation basis event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
PLUGGED CYLINDER VALVE/PIGTAIL			
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	No	No
Toll sampling and transfer processes (X-344-A)	Anticipated event	No	No
PLUGGED/BLOCKED PROCESS LINE			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
Primary System Integrity			
COMPRESSOR SEAL FAILURE			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
CYLINDER FAILURE			
Cylinder handling/storage processes	Evaluation basis event	No	No
CYLINDER FAILURE INSIDE AUTOCLAVE			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
CYLINDER FAILURE OUTSIDE AUTOCLAVE			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
DAMAGED CYLINDER			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
Cylinder handling/storage processes	Anticipated event	No	No
HEAVY EQUIPMENT DROP			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
LIMITED UF_6 RELEASE TO ATMOSPHERE			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	Yes	Yes
MINOR LEAKS OF UF_6 INSIDE AN AUTOCLAVE			
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	No	No
Toll sampling and transfer processes (X-344-A)	Anticipated event	No	No
MINOR LEAKS OF UF_6 TO ATMOSPHERE			
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	No	No
Toll sampling and transfer processes (X-344-A)	Anticipated event	No	No
MOTOR–COMPRESSOR COUPLING FAILURE			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
OPENING OF PRIMARY SYSTEM W/O PURGING			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	No	No
Sampling processes - Cold trapping (X-343, X-344)	Evaluation basis event	No	No
PIGTAIL FAILURE AT WITHDRAWAL POSITION			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes
PIGTAIL LINE FAILURE INSIDE AUTOCLAVE			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	No
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	No
PIGTAIL LINE FAILURE OUTSIDE AUTOCLAVE			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	Yes	Yes
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	Yes	Yes
PROCESS LINE FAILURE AT COMPRESSOR DISCHARGE			
Withdrawal processes (ERP, LAW, and Tails)	Evaluation basis event	Yes	Yes

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
PROCESS LINE FAILURE OTHER THAN PIGTAIL OR COMPRESSOR DISCHARGE			
Withdrawal processes (ERP, LAW, and Tails)	Beyond Evaluation basis event	No	No
MISVALVING (OPENING PRIMARY SYSTEM TO ATMOSPHERE)			
Sampling-Venting-Cold Trapping	Evaluation basis event	No	No
RELEASES OF SOLID/GASEOUS UF_6 TO ATMOSPHERE			
Cylinder handling/storage processes	Anticipated event	No	No
Support System Loss			
LOSS OF ELECTRICAL POWER			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	No	No
Toll sampling and transfer processes (X-344-A)	Anticipated event	No	No
LOSS OF LUBE OIL SUPPLY			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
LOSS OF PLANT AIR			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
Feed vaporization and sampling processes (X-342-A and X-343)	Anticipated event	No	No
Toll sampling and transfer processes (X-344-A)	Anticipated event	No	No
Temperature Increase			
APPLYING EXCESSIVE HEAT TO A LINE PLUGGED WITH UF_6			
Feed vaporization and sampling processes (X-342-A and X-343)	Evaluation basis event	No	No
Toll sampling and transfer processes (X-344-A)	Evaluation basis event	No	No
COMPRESSOR FAILURE - STARVING FLOW TO THE COMPRESSOR			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
COMPRESSOR FAILURE - UF_6/HOT METAL REACTION			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	Yes	Yes

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
LOSS OF COOLANT			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
LOSS OF RCW TO COOLANT SYSTEM			
Withdrawal processes (ERP, LAW, and Tails)	Anticipated event	No	No
Chemical facilities			
Concentration Increase			
WHAT IF CONTAMINANTS ENTER THE FLUORINE TANK			
All processes for the X-342-B fluorine storage building	Evaluation basis event	No	No
WHAT IF FLUORINE CONTAMINATES THE PLANT AIR SYSTEM			
All processes for the X-342-B fluorine storage building	Evaluation basis event	No	No
External Event			
WHAT IF THERE IS A LARGE FIRE			
Toxic gas storage and distribution process	Evaluation basis event	Yes	Yes
All processes for the X-342-B fluorine storage building		Yes	Yes
All processes for the X-611 series buildings		Yes	Yes
All processes for the RCW pump houses		Yes	Yes
All processes for the X-6619 sewage treatment facility		Yes	Yes
Pressure Increase			
WHAT IF THE PRESSURE IS HIGH IN ONE OR MORE OF THE FLUORINE TANKS			
All processes for the X-342-B fluorine storage building	Evaluation basis event	No	No
Primary System Integrity			
LARGE RELEASE OF CHLORINE			
Toxic gas storage and distribution process	Evaluation basis event	Yes	Yes
All processes for the X-611 series buildings		Yes	Yes
All processes for the RCW pump houses		Yes	Yes

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
LARGE RELEASE OF SULFUR DIOXIDE			
Toxic gas storage and distribution process	Evaluation basis event	Yes	No
RELEASE OF FLUORINE FROM A LINE AT THE STORAGE TANK			
Toxic gas storage and distribution process	Evaluation basis event	Yes	Yes
All processes for the X-342-B fluorine storage building		Yes	Yes
RELEASE OF HF FROM DAMAGED PIGTAIL			
Toxic gas storage and distribution process	Evaluation basis event	Yes	Yes
All processes for the X-342-B fluorine storage building		Yes	Yes
WHAT IF FLUORINE IS DISCHARGED THROUGH THE RUPTURE DISK VENT LINE			
All processes for the X-342-B fluorine storage building	Evaluation basis event	Yes	No
WHAT IF HYDROCHLORIC ACID OR HYDROXYACETIC ACID IS SPILLED DURING WELL REDEVELOPING			
All processes for the X-611 series buildings	Anticipated event	No	No
WHAT IF HYDROGEN ACCUMULATES INSIDE THE X-342-A BUILDING			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THE PRESSURE IS HIGH IN ONE OR MORE OF THE FLUORINE TANKS			
Toxic gas storage and distribution process	Evaluation basis event	No	No
WHAT IF THERE IS A LEAK IN AN ELECTROLYTIC CELL			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE CHLORINE OR SULFUR DIOXIDE EQUIPMENT			
All processes for the X-6619 sewage treatment facility	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A LEAK IN THE CHLORINE SYSTEM			
All processes for the X-611 series buildings	Anticipated event	No	No
All processes for the RCW pump houses		No	No
WHAT IF THERE IS A LEAK IN THE CURTAIN SEPARATING THE HYDROGEN AND FLUORINE IN THE ELECTROLYTIC CELLS			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE DISTRIBUTION SYSTEM OUTSIDE OF THE X-342-B BUILDING			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE SYSTEM INSIDE A BUILDING			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE HF SYSTEM			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE SULFURIC ACID SYSTEM			
All processes for the RCW pump houses	Anticipated event	No	No
WHAT IF THERE IS A RUPTURE IN THE CHLORINE OR SULFUR DIOXIDE EQUIPMENT			
All processes for the X-6619 sewage treatment facility	Evaluation basis event	Yes	Yes
WHAT IF THERE IS A RUPTURE IN THE FLUORINE DISTRIBUTION SYSTEM OUTSIDE THE X-342-B BUILDING			
Toxic gas storage and distribution process	Evaluation basis event	Yes	No
All processes for the X-342-B fluorine storage building		Yes	No
WHAT IF THERE IS A RUPTURE IN THE SULFURIC ACID SYSTEM (EXCLUDING THE TANK)			
All processes for the RCW pump houses	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF AN ELECTROLYTIC CELL			
All processes for the X-342-B fluorine storage building	Evaluation basis event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A RUPTURE OF AN HF CYLINDER			
All processes for the X-342-B fluorine storage building	Beyond Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF THE SULFURIC ACID TANK			
All processes for the RCW pump houses	Evaluation basis event	No	No
Temperature Increase			
WHAT IF THERE IS A HIGH TEMPERATURE IN THE CYLINDER HEATING CABINET			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
WHAT IF THERE IS A HIGH TEMPERATURE IN THE NAF TRAPS DURING REGENERATION			
All processes for the X-342-B fluorine storage building	Anticipated event	No	No
Miscellaneous waste storage and handling facilities			
Loss of Criticality Controls			
WHAT IF THERE IS A CRITICALITY			
All processes for the XT-847 construction warehouses	Evaluation basis event	Yes	Yes
Waste storage/handling processes	Evaluation basis event	Yes	Yes
External Event			
WHAT IF THERE IS A LARGE FIRE			
All processes in the X-744-J bulk storage building	Evaluation basis event	Yes	Yes
All processes for the XT-847 construction warehouses	Evaluation basis event	No	No
Waste storage/handling processes		Yes	Yes
Excessive Exposure to Radiation			
WHAT IF THERE IS A BUILDUP OF EXCESS RADIONUCLIDES (E.G., " Tc)			
Waste storage/handling processes	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
Primary System Integrity			
WHAT IF THERE IS A LEAK IN ONE OR MORE OF THE STORAGE CONTAINERS			
All processes in the X-744-J bulk storage building	Anticipated event	No	No
All processes for the XT-847 Waste Management Staging Facility		No	No
WHAT IF THERE IS A RUPTURE OF ONE OR MORE OF THE STORAGE CONTAINERS			
All processes for the XT-847 Waste Management Staging Facility	Evaluation basis event	No	No
Waste storage/handling processes	Evaluation basis event	No	No
Miscellaneous support facilities			
Loss of Criticality Controls			
WHAT IF THERE IS A CRITICALITY			
All processes for the X-700 converter shop and cleaning building	Evaluation basis event	Yes	Yes
All processes for the X-705 decontamination building	Evaluation basis event	Yes	Yes
All processes in the X-710 technical services building	Evaluation basis event	Yes	Yes
All processes in the X-720 maintenance and stores building	Evaluation basis event	Yes	Yes
Concentration Increase			
WHAT IF A LARGE QUANTITY OF PERCHLORIC ACID ACCUMULATES IN THE HOOD			
All processes in the X-710 technical services building	Anticipated event	No	No
External Event			
WHAT IF THERE IS A LARGE FIRE			
All processes for the X-621 coal pile runoff treatment facility	Anticipated event	No	No
All processes for the X-700 converter shop and cleaning building	Evaluation basis event	Yes	Yes
All processes for the X-705 decontamination building	Evaluation basis event	Yes	Yes
All processes in the X-710 technical services building	Evaluation basis event	Yes	Yes
All processes in the X-720 maintenance and stores building	Evaluation basis event	No	No
WHAT IF THERE IS AN EARTHQUAKE			
All processes in the X-710 technical services building	Evaluation basis event	Yes	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
Excessive Exposure to Radiation			
WHAT IF THERE IS A BUILDUP OF TECHNETIUM			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS A RELEASE OF RADIOACTIVE MATERIALS			
All processes in the X-710 technical services building	Anticipated event	No	No
Level Increase			
WHAT IF A TANK OR COLUMN OVERFLOWS			
All processes for the X-705 decontamination building	Anticipated event	No	No
Pressure Increase			
WHAT IF THE UF_6 CYLINDER IS OVERHEATED WHILE IT IS CONNECTED TO THE MANIFOLD			
All processes in the X-710 technical services building	Anticipated event	No	No
Primary System Integrity			
WHAT IF A 2S CYLINDER OF LIQUID UF_6 CYLINDER LEAKS			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A 2S CYLINDER OF LIQUID UF_6 RUPTURES DURING MIXING OR WHILE ATTACHING IT TO THE MANIFOLD			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF A 2S CYLINDER RUPTURES IN THE WATER BATH			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A CLEANING TANK LEAKS			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF A CLEANING TANK RUPTURES			
All processes for the X-700 converter shop and cleaning building	Evaluation basis event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF A CYLINDER OF SOLID UF_6 RUPTURES			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF A MANIFOLD LINE LEAKS			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A MANIFOLD LINE RUPTURES			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF A POLYBOTTLE LEAKS OR RUPTURES			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A UF_6 CYLINDER LEAKS OR RUPTURES			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A UF_6 CYLINDER LEAKS WHILE BEING HEATED IN THE WATER BATH			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF A URANIUM-BEARING SOLUTION STORAGE VESSEL LEAKS			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF A URANIUM-BEARING SOLUTION STORAGE VESSEL RUPTURES			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF DANGEROUS VAPORS ARE EXHAUSTED WHILE SOMEONE IS ON THE ROOF			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF COMBUSTIBLE GAS LEAKS IN THE ROOM			
All processes in the X-710 technical services building	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF ONE OR MORE 2S CYLINDERS OF LIQUID UF_6 RUPTURE IN THE WATER BATH			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF ONE OR MORE CONTAINERS OF ANALYTICAL CHEMICALS IN THIS AREA LEAK OR RUPTURE			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF ONE OR MORE CYLINDERS OF LIQUID UF_6 RUPTURE			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF ONE OR MORE OF THE CORROSIVE GAS CYLINDERS (ClF_3, HF, OR Cl_2) LEAK			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF OPERATOR OPENS THE SAMPLE CONNECTION WITHOUT HAVING A SAMPLE TUBE CONNECTED TO THE MANIFOLD			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THE CORROSIVE GAS MANIFOLD LEAKS			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THE CORROSIVE GAS MANIFOLD RUPTURES			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THE FLUORINE SUPPLY CABINET OR LINES OUTSIDE X-710 LEAK			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THE FLUORINE SUPPLY CABINET OR LINES OUTSIDE X-710 RUPTURE			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THE OPERATOR DROPS THE LIQUID UF_6 CYLINDER DURING MIXING OR WHILE ATTACHING IT TO THE MANIFOLD			
All processes in the X-710 technical services building	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THE OPERATOR OPENS THE SPRAY TANK LID TOO SOON			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THE TANK IS OPEN WHILE THE ACID PUMP IS ON			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THE UF_6 CYLINDER WASH EQUIPMENT LEAKS OR RUPTURES			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS ClF_3 LEAK			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A FLUORINE LEAK IN THE ROOM			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS FLUORINE RUPTURE IN THE ROOM			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THERE IS A LEAK			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN A ClF_3 CYLINDER			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN A GLOVE BOX			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE CAUSTIC STORAGE TANKS			
All processes for the X-705 decontamination building	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A LEAK IN THE CAUSTIC SYSTEM			
All processes for the X-621 coal pile runoff treatment facility	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE ClF_3/F_2 CYLINDER			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE CYLINDER CONDITIONING EQUIPMENT			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE DISTRIBUTION LINES AT THE X-700 BUILDING			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE DISTRIBUTION LINES AT THE X-705 BUILDING			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE SUPPLY SYSTEM			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE FLUORINE SYSTEM			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE METHANOL TANK			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE NITRIC ACID SYSTEM			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK IN THE SPRAY BOOTH			
All processes for the X-705 decontamination building	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A LEAK IN THE VARNISHER			
All processes for the X-720 maintenance and stores building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE AT A HANDTABLE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A CAUSTIC SYSTEM DRUM			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A PHOSPHORIC ACID DRUM			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A POLYBOTTLE			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A SOLVENT SOLUTION VESSEL OR LINE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A STORAGE CONTAINER			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN A SULFURIC ACID DRUM			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN AN AQUEOUS SOLUTION VESSEL OR LINE			
All processes for the X-705 decontamination building	Anticipated event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS LEAK OR RUPTURE IN THE BIODENITRIFICATION SYSTEM			
All processes for the X-700 converter shop and cleaning building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN THE CALCINER SYSTEM			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE IN THE HEAVY METALS PRECIPITATION OR TECHNETIUM ION EXCHANGE SYSTEM			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE OF ONE OF THE NITRIC ACID DAY TANKS			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A LEAK OR RUPTURE OF ONE OF THE STORAGE CONTAINERS			
All processes in the X-710 technical services building	Anticipated event	No	No
WHAT IF THERE IS A RUPTURE IN THE CAUSTIC STORAGE TANK			
All processes for the X-621 coal pile runoff treatment facility	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE CAUSTIC SYSTEM (EXCLUDING THE STORAGE TANKS)			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE CAUSTIC SYSTEM (EXCLUDING THE TANK)			
All processes for the X-621 coal pile runoff treatment facility	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE CYLINDER CONDITIONING EQUIPMENT			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE FLUORINE DISTRIBUTION LINES AT THE X-700 BUILDING			
All processes for the X-700 converter shop and cleaning building	Evaluation basis event	Yes	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A RUPTURE IN THE FLUORINE DISTRIBUTION LINES AT THE X-705 BUILDING			
All processes for the X-705 decontamination building	Evaluation basis event	Yes	No
WHAT IF THERE IS A RUPTURE IN THE FLUORINE LINE PASSING THROUGH THIS LAB			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE FLUORINE SYSTEM			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE NITRIC ACID SYSTEM (EXCLUDING THE OUTSIDE STORAGE TANKS)			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE IN THE SPRAY BOOTH			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF A CAUSTIC STORAGE TANK			
All processes for the X-705 decontamination building	Evaluation basis event	No	No
WHAT IF THERE IS RUPTURE OF A CORROSIVE GAS CYLINDER (ClF_3, HF, Cl_2)			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF THE ClF_3 / F_2 CYLINDER			
All processes in the X-710 technical services building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF THE METHANOL TANK			
All processes for the X-700 converter shop and cleaning building	Evaluation basis event	No	No
WHAT IF THERE IS A RUPTURE OF THE OUTSIDE STORAGE TANK			
All processes for the X-705 decontamination building	Evaluation basis event	No	No

Continued.

Table 4.2-11 Initiating Events (Continued)

Facility group/parameter/event/applicable process descriptions	Event frequency	Exceeds PSOA threshold?	Limiting event?
WHAT IF THERE IS A RUPTURE OF THE VARNISHER			
All processes for the X-720 maintenance and stores building	Evaluation basis event	No	No
WHAT IF THERE IS A SPILL OR RUPTURE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A SPILL OR SPLASH AT A FILTER TABLE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THERE IS A UF_6 RELEASE			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF UF_6 IS EXPOSED DURING DISASSEMBLY OPERATIONS			
All processes for the X-705 decontamination building	Anticipated event	No	No
Temperature Increase			
WHAT IF THE CHAMBER OVERHEATS			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THE NITRIC ACID HEATER FAILS HIGH			
All processes for the X-705 decontamination building	Anticipated event	No	No
WHAT IF THE TEMPERATURE IN THE PRE-EVAPORATOR AND STRIPPER EXTRACTOR IS TOO HIGH			
All processes for the X-705 decontamination building	Anticipated event	No	No

Table 4.2-12. Threshold Analysis for PrHA.

Case no.	Description	Release duration/ quantity (s/lb)	Radiation dose (rem)	U uptake (mg)	HF exposure (ppm)
2	Open valve on a liquid-filled cylinder, 6 o'clock position	N/A 225/3304 75/1106	< 5 rem	30.2	20.0
3	Open valve on a liquid-filled cylinder, 12 o'clock position—liquid/vapor	N/A 428/2183 233/1466	Negligible	30.1	19.9
	Open valve on a liquid-filled cylinder, 12 o'clock position—vapor only	N/A 405/1544 195/779	Negligible	29.8	19.9
4	Broken pigtail during parent–daughter transfer	N/A 285/1677 120/720	Negligible	29.8	20.3
5	Broken pigtail during withdrawal—full release	N/A 1050/4163 1800/7009	Negligible	30.0	19.7
	Broken pigtail during withdrawal— accumulator isolation after 1 min	N/A 3600/3096 1800/1880	Negligible	29.4	13.5
6	Broken withdrawal compressor discharge	3120/25080	Negligible	8.6	5.3
7	B-line break at maximum power	N/A 110/32200 78/22900	Negligible	30	20
8	Release from isolated cell	150/11000	Negligible	9.7	8.5
9	Interbuilding tie-line failure	8/1151	Negligible	30	196[a]

[a] This value is derived by assuming the peak concentration throughout a 1-hr exposure. This method is a different analysis technique than that used for the other HF exposure values which are derived from a more realistic averaging technique.

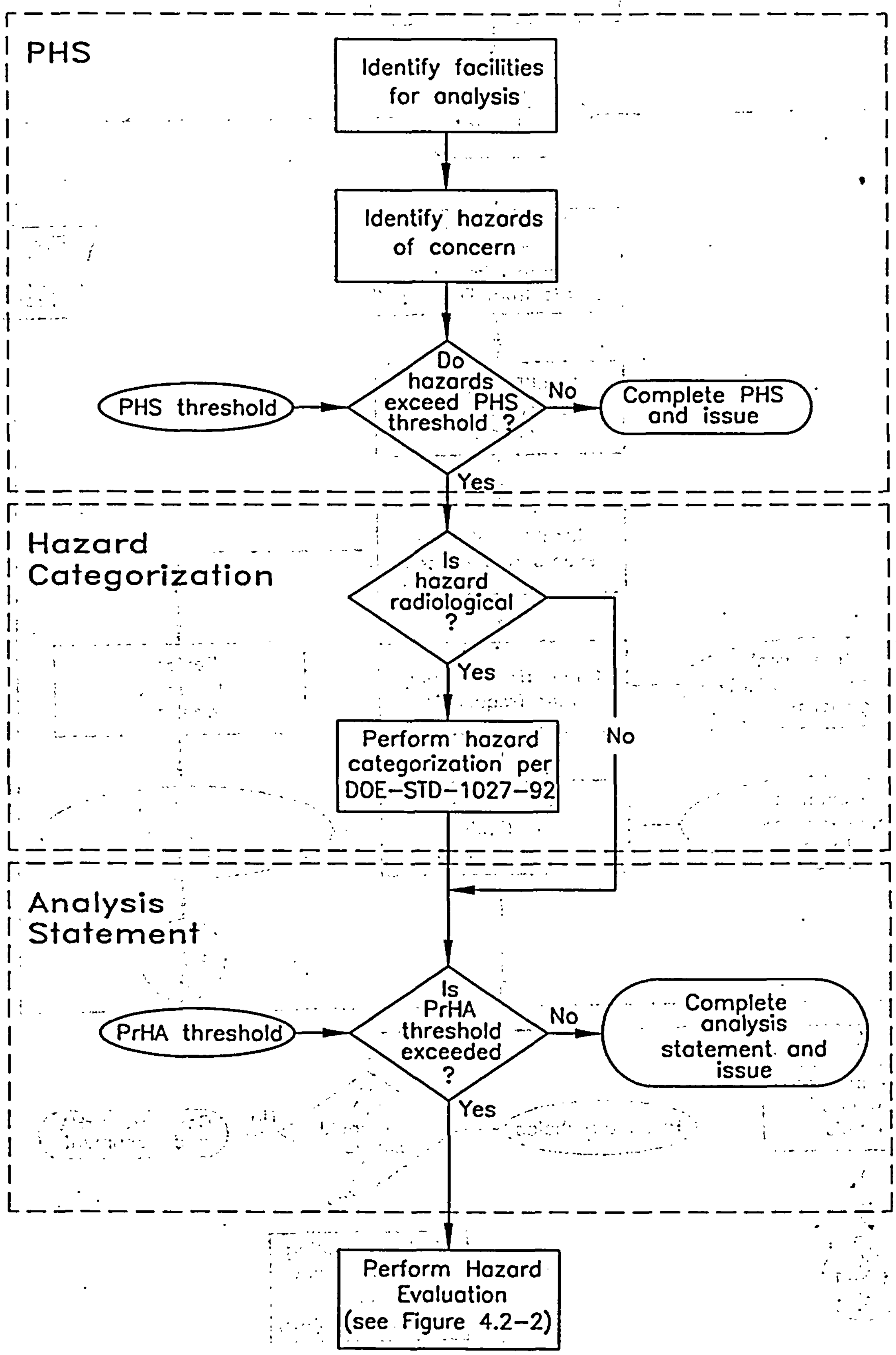

Figure 4.2-1
Hazard Identification

AUTOCAD/GSD
3/27/03
4.2-1

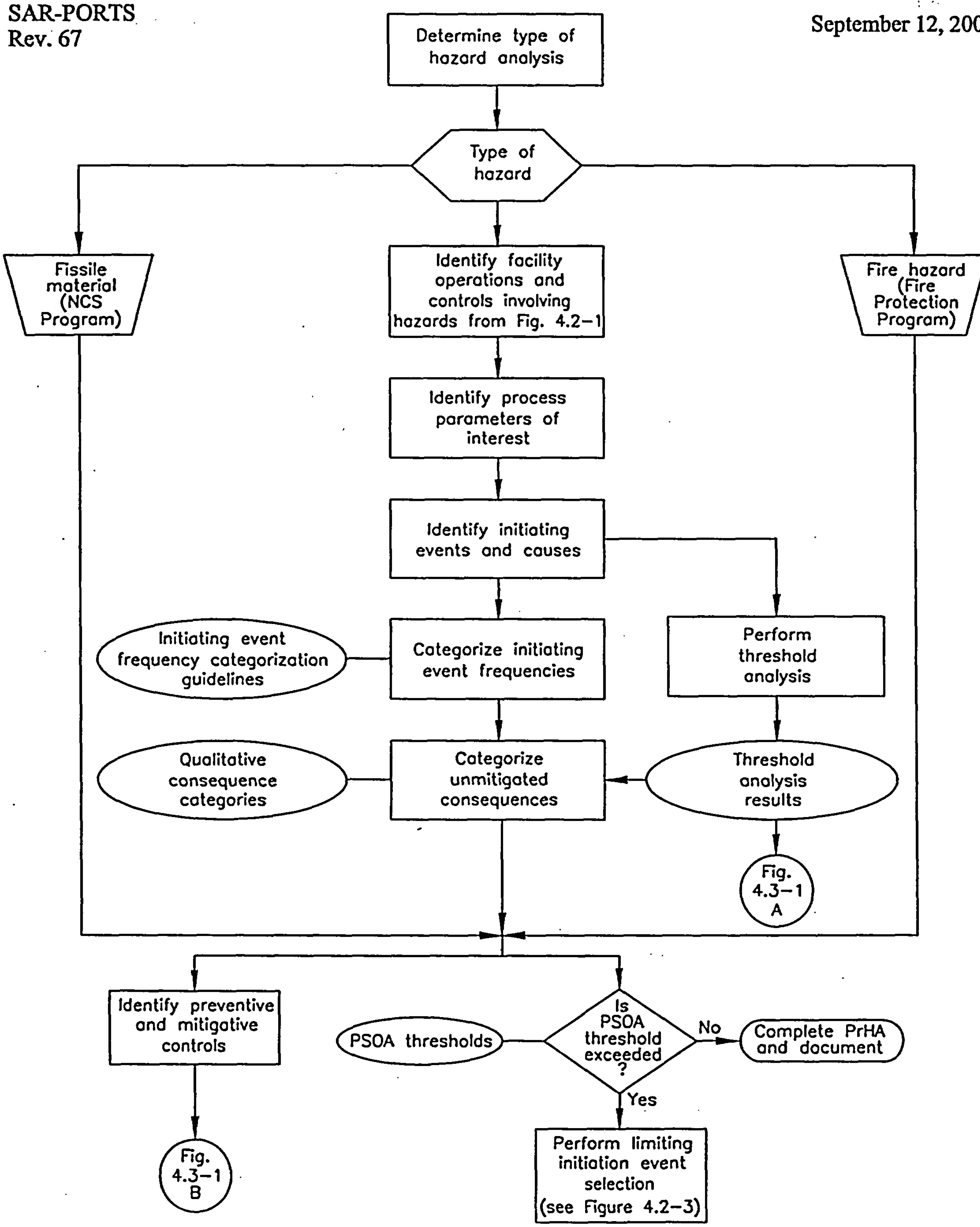

Figure 4.2-2
Hazard Evaluation

AUTOCAD/GSD
8/27/03
4.2-2

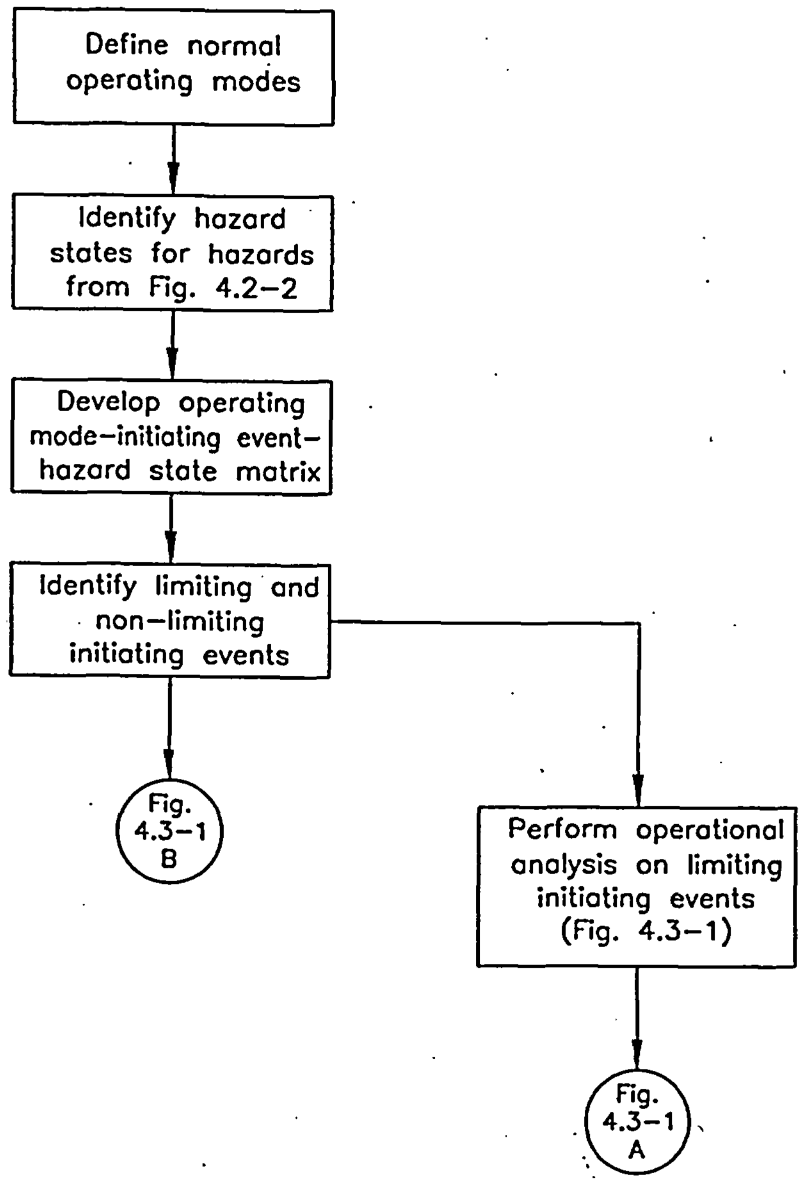

Figure 4.2-3
Limiting Initiating Event Selection

AUTOCAD/CSD
8/27/03
4.2-3

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4.3 ACCIDENT ANALYSIS

This section presents the development of the potential accidents identified in the accident selection portion of Section 4.2.6. Each limiting initiating event was evaluated to identify the essential safety actions and controls to support the EGs. For the limiting initiating events identified in Section 4.2.6, the accident analysis documents the most limiting scenario associated with the initiating event, operating mode, and hazard state. Additionally, the controls that require TSRs were also identified as a result of the analysis.

4.3.1 Accident Analysis Methodology

The accident analysis methodology used the operational analysis (OA) outlined in Figure 4.3-1 to develop the scenarios presented in this section. The OA was applied to each limiting initiating event, operating mode, and hazard state as identified in Section 4.2.6 of the hazard analysis to develop the scenarios. Once the OA was accomplished, the controls selected in the PrHA and OA were classified as described in Section 4.2.2. The methods used for developing source-term modeling and consequence analysis are described in Section 4.3.1.2.

4.3.1.1 Operational Analysis

Each of the limiting initiating events was reviewed in detail to determine the required safety actions (Table 4.3-1) and controls necessary to support the Evaluation Guidelines (see Section 4.2.1). The objectives of the Operational Analysis were as follows:

- Evaluate normal operation and unmitigated initiating events to identify essential safety actions.
- Identify essential systems, structures, or components required to perform safety actions.
- Evaluate essential system capabilities and supporting system requirements (i.e., air, electrical).
- Develop operating limits [i.e., safety limits (SLs), limiting condition settings (LCSs), limiting conditions of operation (LCOs), and surveillance requirements (SRs)] and appropriate technical bases.

4.3.1.1.1 Essential Safety Actions

Safety actions are defined as the actions required to prevent exceeding the Evaluation Guidelines (EGs) for initiating events that could exceed the PSOA threshold. Table 4.3-1 lists typical safety actions used for the GDPs. Each safety action has a description of the function it provides for mitigation or prevention of a potential initiating event.

The first objective of Operational Analysis–identification of essential safety actions–involved evaluating each limiting initiating event combination identified in the hazard analysis. Only safety actions required to prevent exceeding the EGs were identified. This evaluation used the EGs given in Table 4.2-2, a consequence screening threshold analysis, and engineering judgment to determine whether a safety action is required to prevent exceeding the EGs.

Each limiting initiating event combination, along with its associated unmitigated consequences, was compared with the EGs for the same frequency category to determine whether the EG could be exceeded. If no EG could be exceeded, justification is provided, and no additional analysis is required for that particular combination. For each combination that requires a safety action to prevent exceeding an EG, a safety action was selected, and appropriate justification is provided. The combinations requiring safety actions are considered in the evaluation described in Section 4.3.1.1.2.

4.3.1.1.2 Essential Controls

The second objective of Operational Analysis–identification of essential systems, structures, or components required to perform safety actions–was accomplished by using the results of the evaluation described in Section 4.3.1.1.1. The identified set of essential controls is the minimum set of controls necessary to support meeting the EGs, and thus it provides the primary input for Technical Safety Requirement (TSR) selection. The analysis addressed each combination of safety action, initiating event, operating mode, and hazard state. For each safety action, the minimum set of controls required to accomplish it was selected. The essential controls that were selected during the evaluation were listed along with their respective safety functions. The scope of each control associated with performing the associated safety function was explicitly defined to support subsequent analyses of the system and to establish functional requirements.

4.3.1.1.3 Essential System Capabilities and Support Requirements

When a system, structure, or component was selected as essential as described in Section 4.3.1.1.2, the installed configuration of the control is typically subjected to a more detailed review to verify the capability of the control to accomplish the required safety action(s)as follows:

- Active controls selected that require TSRs were evaluated to identify the required components, their positions (e.g., valve positions), and the support systems required to accomplish the safety action (the analysis performed should be centered on the hardware only, with operator interface being the initiator for manually initiated systems).

- Controls selected that were assumed to perform a safety function during events related to natural phenomena were evaluated as described in Section 4.3.1.3.

The discussion of results for essential system capabilities and support requirements is presented in Section 3.8.

4.3.1.1.4 Operating Limits

The final objective of the Operational Analysis—development of operating limits and appropriate technical bases—was accomplished using a three-step process: (1) Limiting Conditions for Operation (LCO) development, (2) Surveillance Requirements (SR) development, and (3) Safety Limits (SL) and Limiting Control Settings (LCS) development.

LCO development. The first step, LCO development, used the identified essential controls described in Section 4.3.1.1.2. LCOs were derived by requiring essential active controls meeting the TSR selection guidelines (Section 4.2.3) to be operable in each operating mode and hazard state combination for which a safety action is required. This established the applicability statement and LCO statement for each control.

SR development. The second step, SR development, used the qualitative analyses required by Section 4.3.1.1.3 to establish SRs to verify operability of the required control. SRs include appropriate testing requirements to ensure that each portion of the control can accomplish its required safety action. Surveillance intervals are based on industry standards and on current testing intervals described for the GDPs for similar SRs. Current testing intervals are based on historical information for the type of equipment being used in the GDPs. Where historical evidence was not available, the current testing interval was used with a recommendation to trend any failures for potential changes to the testing intervals.

SL and LCS development. The final step, operating limit development, established the appropriate SLs and LCSs (if applicable) for each essential control. This step requires evaluation of each initiating event, operating mode, and hazard state to determine which combination results in the most stringent demand on the control. For systems requiring SLs and LCSs, an analysis of the limiting transient is performed and the results are used to establish the SL, LCS, and the associated technical bases. This may require specific transient response calculations to characterize system response to the initiating challenge and to provide a basis for any SL and LCS. Only controls selected to prevent an EBE, which could exceed the off-site EGs, were typically considered for establishing an SL and LCS.

Operating limits for essential systems are presented in the TSRs.

4.3.1.2 Consequence Analysis Methodology

This section summarizes the methods used to quantify the consequences of operational accidents, natural phenomena events, and external events selected in Section 4.2.6.1.3. This section discusses the development and application of computer models that provided estimates of (1) source terms (Section 4.3.1.2.1), (2) in-building transport (Section 4.3.1.2.2), and (3) outdoor atmospheric transport (Section 4.3.1.2.3).

4.3.1.2.1 Source-Term Methodology

This section discusses the source-term methodology used in the SAR. Two models are described in this section: (1) the PIPELEAK code, which was used to estimate release rates from UF_6 cylinders, and (2) the Improved Multi-site Productivity Program (IMPP), which was used to predict pressures and interstage flow rates for each cell in the enrichment cascade.

4.3.1.2.1.1 PIPELEAK

The PIPELEAK code is a variant of the CYLIND code developed by the NRC to estimate release rates for UF_6 cylinders as detailed by NUREG/CR-4360 (Reference 1). The code simulates the release of UF_6 from a cylinder through either a breach in the cylinder itself or through a broken or misvalved transfer piping system. There have been some improvements to the original version of CYLIND. The primary modifications involve the PIPSYS subroutine, which evaluated releases through a piping system. The version of CYLIND documented in NUREG/CR-4360 would attempt to divide by zero in certain piping configurations. These errors have been corrected, and the modifications are documented in a letter from J. H. Clinton to R. W. Schmidt (Reference 2). The PIPELEAK code used for this analysis is documented in Reference 3 and overcomes the shortcomings that existed in the original CYLIND code.

Estimating releases from cylinders is complicated by UF_6 phase behavior. Two or three phases of UF_6 may be present inside the cylinder. As UF_6 moves along the release pathway (e.g., broken transfer piping or a cylinder breach), the material's phase composition is likely to change, and special considerations are needed if the flow at any point in the pathway approaches the UF_6 triple point (see Figure 3.1-1). The PIPELEAK code uses mass and energy balances around the cylinder and associated piping, along with detailed UF_6 physical property data, to track the cylinder pressure as well as the phase and temperature changes of both the UF_6 remaining in the cylinder and the UF_6 released to the atmosphere. Also, the code offers the choice of assuming isentropic (i.e., constant temperature) or isenthalpic (i.e., constant heat) flashing (i.e., rapid conversion of UF_6 liquid to the solid and vapor phases) modes.

To estimate release rates through a cylinder breach or transfer piping system, PIPELEAK first assumes a UF_6 velocity through the release path. The standard multiphase flow calculations are performed to determine the pressure drop across each segment of the release path. The UF_6 velocity is corrected until the calculated pressure drop across the release path equals the actual pressure difference between the cylinder and the ambient air. The release rates calculated by PIPELEAK are reasonably consistent with those calculated by other multiphase release models, although the pure vapor release rates generated by PIPELEAK are somewhat higher than rates calculated with standard equations for single-phase flow through an orifice.

Many of the potential releases modeled using PIPELEAK would involve cylinders with pressures above pure UF_6 vapor pressure at a specified temperature because of the presence of noncondensable gases. Because the PIPELEAK code is limited to handling pure UF_6 only, two model runs can be made to simulate the effects of noncondensable gas pressure. The first run (called the correct temperature run) is made at the scenario temperature, with the vapor pressure of liquid UF_6 at this temperature. The second run (called the correct pressure run) is made at a higher temperature, providing a pure UF_6 liquid vapor pressure at the desired scenario pressure. The correct pressure run is used to estimate the correct release rate while the liquid level in the cylinder is above the opening. Once the liquid level in the cylinder falls below the opening, the noncondensable gases would escape, and the release would continue as in the correct temperature run (the first run made). The amount of UF_6 release from a liquid source (e.g., a source with the liquid level in the cylinder above the opening) would be taken from the correct temperature run because the higher temperature in the correct pressure case would overestimate the height of the liquid in the cylinder because of the additional thermal expansion of liquid UF_6.

4.3.1.2.1.2 Improved Multi-site Productivity Program

The Improved Multi-site Productivity Program (IMPP) is a standard productivity code for use at the GDPs. This code was used to prepare flowsheet data for PORTS operating at its nameplate power level (2260 MW). The flowsheets provide pressures and interstage flow rates for each cell in the enrichment cascade. These data were used to estimate cell inventories and potential release rates from line ruptures in a cell due to closing of a B-line block valve while the A-line valve remains open. The following equation is a curve-fit to these flowsheet data:

$$INV = MSP\left[P_N N + (P_{max} - P_N)\frac{(N-1)}{\ln(N)}\right], \qquad (1)$$

where

INV is the mass of UF_6 in the involved stages (lb),
MSP is the mass per stage pressure equal to 65.3 lb UF_6 / stage psia,
P_N is the normal high-side pressure equal to 21.0 psia,
P_{max} is the maximum pressure at the closed block-valve (psia), and
N is the number of stages with elevated pressure.

4.3.1.2.2 In-Building Transport Methodology

This section discusses the in-building transport methodology used in the SAR. The methods described within this section are for UF_6 releases that occur inside the process buildings, specifically Building X-333 at PORTS. When UF_6 is released into the process building air, it will undergo an exothermic chemical reaction with water vapor to form UO_2F_2 and HF. The in-building transport methodology was used to estimate the amount of UO_2F_2 and HF retained in the building and, conversely, the amount of these materials released into the atmosphere that may be dispersed downwind.

4.3.1.2.2.1 Background on Previous Methods

For previous GDP safety studies, a lumped parameter model was developed by Williams (Reference 4) to evaluate in-building transport from releases of UF_6 inside a process building. The model included treatment of UF_6 in solid, liquid, and vapor phases, and treatment of HF and water in the liquid and vapor phases. Polymerization of HF was also employed in the Williams model, referred to as the cascade-summer (CSCDSM) model, because the model was developed to estimate in-building transport of UF_6 and its reaction products with summer ventilation rates in the process buildings.

The CSCDSM model solves mass and energy balance equations for a compartment with a single-volume representation. In CSCDSM, UF_6 released from process building piping is assumed to flash instantaneously to solid and vapor. The solid UF_6 is assumed to be dispersed uniformly throughout the mixing volume (i.e., the entire process building) and subjected to gravitational settling only, neglecting other mechanisms (e.g, agglomeration). The mass of solid UF_6 particles (Δm_d) that is removed from the in-building air over time (t) is calculated as:

$$\Delta m_d = \frac{m_c}{V} vA\Delta t , \qquad (2)$$

where

- m_c is the particle mass (g),
- V is the inside volume of the process building (m^3),
- v is the aerosol settling velocity (fixed at 0.01 m/s), and
- A is floor area (m^2).

The CSCDSM model assumes that process building volume is well represented by simple geometry (e.g., the process building is divided into control volumes equal to the size of one unit), thereby ignoring spatial effects of particle distribution and deposition on equipment and piping surfaces. Because of the limitations of the CSCDSM model (i.e., consideration of gravitational settling only with a constant settling velocity of 0.01 m/s and single-volume, simple-geometry representation of the process buildings), new computer modules were developed to simulate in-building transport. These new modules were linked to the MELCOR computer code (Reference 5) and are discussed in more detail in Section 4.3.1.2.2.2.

4.3.1.2.2.2 In-Building Transport Methods Used for this SAR

The MELCOR model computer code, developed by the NRC, is widely used for simulating severe accidents in nuclear reactor facilities. MELCOR is written in a highly modular fashion, in which modules may be changed or replaced, allowing the user to focus on their particular application. This modular nature facilitated the development of an in-building transport model for use for the PORTS X-333 process building. For the remainder of this section, the in-building transport model will be referred to simply as MELCOR; however, the remaining discussion will focus on the new modules incorporated into the model that deal specifically with transport of UF_6 in the X-333 process building. The following information is a summary from Kim et al. (Reference 6).

a. <u>Development and Features of MELCOR</u>

The MELCOR code was first used to develop a single-volume representation of the process building, and the results were used to benchmark the code with the CSCDSM. As with CSCDSM, the MELCOR model was developed for the summer ventilation configuration. During summer, the ventilation system works as a once-through system in which air is drawn into the operating floor of the process building and then forced to the cell floor by a large blower (as shown in Figure 4.3-2). The summer ventilation system results in the largest amount of material mass (e.g., UO_2F_2 and HF) to be released to the outside atmosphere after a potential accident. MELCOR estimates for the single-volume representation were found to be comparable to the CSCDSM model (Reference 6).

The next step examined the effect of finer nodalization by specifying the cell housing as a separate volume in order to observe spatial effects from multi-volume calculations on particle and vapor transport (e.g., three control volumes were used to simulate a single unit in the process building). This examination revealed that far fewer UO_2F_2 particles were estimated to be released to the outside atmosphere than were estimated for the single-volume representation (i.e., more particles settled in the building). However, the review neglected many of the spatial effects of air flow distribution and mixing behavior that would occur in the entire process building under the summer ventilation system. For the purpose of the SAR, the entire process building was divided into a much finer nodalized system, discussed in more detail in the next section.

b. MELCOR Nodalization of the Process Building

Figure 4.3-3 shows the control volume and unit layout of the process buildings at the GDPs, specifically Building X-333 at PORTS, containing eight units, and Building C-337 at PGDP, containing six units. Each unit is combined into a single control volume, except for Unit 4. Because the fifth cell in Unit 4 (note each unit contains ten cells) is the postulated location of the pipe break, the volume of this unit is finely nodalized to capture the temporal and spatial effects of the particle and vapor dispersion in the immediate vicinity of the source. Specifically, the cell floor area of Unit 4 is divided into three-story control volumes, as seen in Figure 4.3-4. The first floor consists of 20 control volumes because each cell at this level has 2 control volumes: (1) the cell housing and (2) the cell floor volume outside the cell housing. The second story was nodalized into ten control volumes, one corresponding to each cell, and the third-story volume is treated as a single large control volume. Several other control volumes serve to model the outside atmosphere and the released source term (i.e., the material released into the environment). Also, several flow paths connect the control volumes as described in detail in Kim et al. (Reference 6).

c. Modeling of Cell Housing Wall Leakage

The cell housing wall is constructed of steel framing with 0.4-in. (1-cm) thick transite siding bolted in place. Although the housing seams are tightly closed, the cell housing was not designed to provide confinement of released UF_6 in the event of a line rupture inside the housing. The air inside the housing will heat up due to heat (both convective and radiative) from equipment surfaces such as compressors. A significant temperature difference between inside and outside the housing develops buoyancy forces, convecting air naturally through the cracks in the housing, untightened seams, and other leak paths. As shown in Figure 4.3-5, three flow paths are assumed during steady-state conditions (i.e. normal operation) due to convection: (1) leak in at wall, (2) leak out at wall, and (3) leak out at ceiling. When UF_6 is released into the housing cell, a 7- by 3-ft (2.1- by 0.91-m) door is assumed to swing open to the outside because no restraint is installed to restrict the door from opening (Reference 6). Therefore, the door is assumed to stay open during the MELCOR simulations. This adds an additional flow path (Figure 4.3-5) out of the cell housing.

To obtain an appropriate size of the four cell housing flow paths, localized, three-dimensional flow simulations were performed using the Computational Fluid Dynamics (CFD) tool, CFDS-FLOW3D (a commercially available program developed by AEA Technology Engineering Software, Inc). For the CFDS-FLOW3D simulations, a single cell housing was divided into about 50,000 small control volumes (Reference 7). In the simulations, particles were uniformly sourced into the cell housing as tracers; however, particle deposition was not considered due to limitations of the code. A steady-state (i.e., normal cell operation) simulation was established, and then a transient (i.e., after a UF_6 release) simulation was performed. Results of the CFDS-FLOW3D steady-state simulation showed that 50% of the particles released into the cell housing are exhausted through the roof vents, and the remaining 50% exit through the motor exhaust or are passed on to an adjacent cell. The transient simulation was then run using the steady-state simulation as the initial conditions, and the results showed that 70% of the released particles would escape through the roof vent due to the increased convection caused by the exothermic heat generated by the UF_6 reactions. To produce results compatible with CFDS-FLOW3D, input into the MELCOR model that specified the four cell housing leakage flow paths (Figure 4.3-5) was calibrated to match the transient simulation results from CFDS-FLOW3D.

d. Sensible Energy and Chemical Reaction of Gaseous UF_6 Releases into the Cell Housing

As gaseous UF_6 is released, the cell housing is subjected not only to exothermic energy generated from the UF_6 hydrolysis reaction, but also to sensible energy carried by the UF_6 gas. The magnitude of the UF_6 gas sensible energy is a function of the temperature of the UF_6, T_U, at the release point. The enthalpy of gaseous UF_6, H_V, is obtained from Williams (Reference 4):

$$H_V = 43.2614 + 9.21307 \times 10^{-2} T_U + 6.26265 \times 10^{-6} T_U^2 + \frac{2951.71}{T_U} + 3.0939 \times 10^{-3} T_U (Z_{p,T} - Z_{14.7,T}) \quad , \tag{3}$$

where H_v is given in Btu/lb and T_U is given in °R. The compressibility factor, Z, is calculated as

$$Z = \frac{T_U^3}{T_U^3 + 4.8923 \times 10^5 p} \quad , \tag{4}$$

where p is the pressure (psia).

The gaseous UF_6 is assumed to mix instantaneously with the air in the control volume and undergoes an instantaneous chemical reaction:

$$UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF + 0.33\,\text{MJ/kg of } UF_6 \text{ reacted} \quad . \tag{5}$$

However, this chemical reaction is limited in magnitude by the availability of moisture in the air. MELCOR simulates the moisture-limited UF_6 reaction process through a series of control functions designed to monitor moisture content in each control volume atmosphere, to calculate the UF_6 reaction rate limited by the moisture content, and to determine the rate of moisture consumption in the control volume. Such amount of moisture consumption is used as input to the Control Volume Hydrodynamics (CVH) package of MELCOR as a mass sink in corresponding control volumes. Because each control volume is connected, the air flow path is updated by air being circulated into the control volume. Any unreacted UF_6 gas is subjected to convection and transport into neighboring control volumes and to chemical reactions with the moisture present in those neighboring volumes.

e. Particle Transport Model

The radionuclide package of MELCOR simulates many of the particle transport phenomena that may occur in the process buildings:

- Particle condensation, evaporation, agglomeration, deposition, and scavenging by engineering safety features (e.g., filter trapping, pool scrubbing, spray washout).
- Particle movement, as the particles grow by agglomeration, to larger-size bins through the use of multiple particle-size bins that are user-defined.
- Gravitational settling, Brownian diffusion, thermophoresis (i.e., a process causing migration of particles from higher to lower temperatures), and diffusiophoresis (i.e., deposition induced by condensation of water vapor onto structural surfaces) deposition mechanisms.

For simulations of accidental UF_6 releases, the effect of gravitational settling dominates other deposition processes (e.g., thermophoresis and diffusiophoresis) by 1 to 2 orders of magnitude (Reference 6).

For MELCOR calculations, UO_2F_2 is assumed always to be a solid, with initial particle size assumed to be a log-normal distribution between 0.4 and 2.5 μm. This particle-size range is based on guidance from the uranium particle-size distribution measurements taken at Sequoyah Nuclear Fuel Plant (Reference 8). According to these air filter measurements, most of the uranium particles fell in the size range between 0.4 and 2.5 μm, with a peak between 1.3 and 1.6 μm. Experiments by Pickrell (Reference 9) and Lux (Reference 10) corroborate the data obtained from the Sequoyah measurements.

For the deposition calculations, the surfaces of equipment and piping are included in addition to the floor surfaces. The gravitational settling model of MELCOR calculates particle mass settled on heat structure surfaces (e.g., floors, equipment, walls) based on a settling velocity that accounts for various indoor atmospheric conditions (e.g., temperature and relative humidity). However, the model does not track individual particle paths for settling. Consequently, the model does not acknowledge the relative altitude of various structures in the particle-settling calculation (i.e., particle-settling length is not factored into the calculation). Therefore, to account for the particle-settling length, equipment and piping surface measurements were increased to twice what would actually be in the cell housing. This change has the effect of uniformly distributing the surfaces throughout the different elevations in the control housing volume.

4.3.1.2.3 Atmospheric Transport Methodology

This section discusses the atmospheric transport methodology used in the SAR. Potential accidental releases of UF_6 to the atmosphere are a more likely threat to human health and safety than other potential, but unlikely, environmental transport pathways (i.e., water and soil). Four topics important in the development of the atmospheric transport methodology are summarized: (1) historical accidental atmospheric releases of UF_6, (2) reactions and dispersion of UF_6 in the atmosphere, (3) background on previous methods used to assess releases of UF_6, and (4) atmospheric transport methods used for this SAR.

4.3.1.2.3.1 Historical Accidental Atmospheric Releases of UF_6

This section discusses three historical accidental atmospheric releases of UF_6: the Comurhex plant release, the PORTS occurrence, and the Sequoyah Fuels Corporation occurrence. Because there have been virtually no controlled field data experiments for large releases of UF_6 to the atmosphere, these incidents helped provide an understanding of the potential downwind dispersion associated with an accidental release and were germane in formulating the accident analysis methodology.

4.3.1.2.3.1.1 Comurhex Plant Release

On July 1, 1977, a large release of UF_6 occurred at the Comurhex plant in Pierrelatte, France (Reference 11), in which a valve ruptured on a cylinder heated to 194–203°F (90–95°C). Liquid UF_6 was released for 10–15 min, until the liquid level in the container had fallen below the valve opening. After this, UF_6 escaped in the gas phase until the release was contained 15 min later. In the total release time of 30 min, 16,000 lb (7100 kg) of UF_6 was released into the atmosphere. The weather favored rapid dilution because the atmosphere was unstable (warm and sunny conditions), and the wind speed was 19 mph (9 m/s) (Reference 12).

Most of the uranium released was recovered within a distance of 2000 ft (600 m), suggesting that most of the solid uranium compounds settled in a relatively small area [about 0.25 acres (0.10 hectares)]. At 2000 ft (600 m) downwind of the release, ambient air monitoring showed that atmospheric concentrations of uranium were about 10 mg/m^3, and HF concentrations exceeded the French workplace limit of 2.4 mg/m^3 out to a distance of 3900 ft (1200 m) (Reference 13). About 7 percent of the uranium was not recovered and is believed to have dispersed into the atmosphere.

4.3.1.2.3.1.2 PORTS Occurrence

On March 7, 1978, a liquid-filled 14-ton UF_6 cylinder ruptured in a PORTS cylinder yard (Lot No. X-745-B) after being dropped about 9 in (23 cm). At the time of release, light snow and freezing rain were falling, and about 0.6 in (1.5 cm) of snow covered the ground in the cylinder yard. The ambient air temperature was about 32°F (0°C), with the wind blowing from the northeast at about 5 mph (2 m/s). The distance from the release point to the nearest site boundary in the direction of the wind was about 1.4 mi (2.2 km).

Within 1 h, about 21,100 lb (9500 kg) of UF_6 [14,300 lb (6400 kg) of uranium] was released from the ruptured cylinder. About 1200 lb (550 kg) of uranium was recovered from the snow in the cylinder yard. About 2500 lb (1130 kg) of uranium was carried by melted snow to the plant's west drainage ditch, of which 1500 lb (680 kg) was transported through the ditch and was released into the Scioto River and about 450 kg (1000 lb) was retained in the ditch impoundment. Therefore, 10,300 lb (4720 kg) (about 76 percent of the uranium released) left the area as an airborne plume and dispersed in the atmosphere (Reference 14).

Environmental sampling after the release showed that significant soil and water contamination were confined to distances of a few hundred meters from the release point (Reference 14). Five workers who drove through the plume on the perimeter road [about 7218 ft (2200 m) from the release point] showed no harmful amount of uranium in their urine samples and experienced only brief discomfort (e.g., eye irritation) from HF exposure. Because on-site aquatic and terrestrial biota were exposed to elevated uranium and HF concentrations for only a short time, environmental impacts were minimal. Also, no public exposure was reported (Reference 14).

Observers of this release indicate that the visible portion of the plume (i.e., solid UF_6 and UO_2F_2) hovered over the ground for the first few hundred meters, mixing very little in the vertical. At about 980–1300 ft (300–400 m) downwind (southwest) of the release point, the plume stretched vertically, and the plume centerline lifted off the ground (Reference 14). Observations of the deposition of solid UF_6 and UO_2F_2 within the first few hundred meters from the release point agree qualitatively with these observations. The snow and freezing rain that were falling at the time may have contributed significantly to the amount of uranium deposited.

4.3.1.2.3.1.3 Sequoyah Fuels Corporation Occurrence

On January 4, 1986, at Sequoyah Fuels Corporation in Gore, Oklahoma, 30,800 lb (14,000 kg) of UF_6 was released from a 14-ton cylinder that had ruptured because of overfilling. The rupture was about 4 ft (1.2 m) long, and most of the UF_6 was released in less than 1 min (Reference 12). At the time of release, winds were from the north-northwest at about 18 mph (8 m/s) with gusts to about 30 mph (14 m/s). Atmospheric stability, not measured on site, was assumed to be neutral due to the high wind speeds (Reference 8).

Estimates of uranium recovery ranged from 35 percent to 50 percent; most of the uranium was found on the ground near the release point as solid UF_6 and UO_2F_2. The amount of uranium that was transported offsite [i.e., at distances greater than about 980 ft (300 m)] in an atmospheric plume was between about 7300 and 10,000 lb (3300 and 4700 kg).

One worker died from HF exposure as a result of the release. Several other workers experienced reversible effects of acute HF exposure, including skin burns and irritation to the eyes, mucous membranes, and respiratory tract. No symptoms of kidney injury occurred from chemical exposure to uranium, although nine workers exceeded NRC's regulatory limit for uranium inhalation (10.0 mg over a 1-wk period) (Reference 12). An air monitor at the site boundary directly downwind of the release [about 984 ft (300 m) from the release] measured a maximum ground-level uranium concentration of 120 mg/m^3 (averaged over a 10-min period) (Reference 8). Another monitor, located about 5250 ft (1600 m) downwind of the release, recorded a maximum uranium concentration over the same averaging time of 12 mg/m^3 (Reference 8). This monitor was located about 1300 ft (400 m) from the projected plume centerline (Reference 8). Computer modeling performed by Lawrence Livermore National Laboratory estimated that maximum HF concentrations at receptors located off site were about 15 mg/m^3 (averaged over a 20-min period) (Reference 8).

The worker killed during this release was on a scrubbing tower 165 ft (50 m) from the release point. Observations of the plume indicated that he was quickly enveloped in a dense, white cloud. The process building (the largest structure at the Sequoyah plant), positioned just downwind of the release point, was also engulfed by the white plume (Reference 8).

4.3.1.2.3.2 Reactions and Dispersion of UF_6 in the Atmosphere

The following information on UF_6 reactions and dispersion in the atmosphere is summarized from References 15, 16, and 17. For more details, the reader is directed to these references, particularly Chapter 5 in Reference 17 and Chapter 2 in Reference 15.

At normal atmospheric temperatures and pressures, UF_6 exists only as a gas or solid (see Figure 3.1-1, UF_6 phase diagram). Liquid UF_6 exists at pressures exceeding about 1.6 atm (160 kPa) and temperatures exceeding 147°F (64°C). If exposed directly to atmospheric temperatures and pressures (e.g., during a breach of a heated 14-ton storage cylinder), liquid UF_6 will flash (i.e., immediately partition) to a mixture of vapor and solid particles. The solid UF_6 will sublimate to the vapor form within a few minutes after release. The UF_6 vapor, which is much denser than ambient air, reacts exothermically with atmospheric water vapor entrained into the plume, forming HF vapor and solid UO_2F_2:

$$UF_6(g) + 2H_2O(g) \rightarrow UO_2F_2(s) + 4HF(g) \quad . \tag{6}$$

This reaction releases about 25,000 Btu/lb-mol (58 kJ/g-mol) of H_2O, which heats the plume. At the same time, the sublimation of solid UF_6 to the vapor phase cools the plume. At normal atmospheric pressures, HF vapor is assumed to polymerize and depolymerize as an equilibrium mixture of the dimer, $(HF)_2$, hexamer $(HF)_6$, octamer $(HF)_8$, and the $HF \cdot H_2O$ compound as described by the following equations (Reference 18):

$$2HF = (HF)_2 \quad , \tag{7}$$

$$6HF = (HF)_6 \quad , \tag{8}$$

$$8HF = (HF)_8 \quad , \tag{9}$$

$$HF + H_2O = (HF \bullet H_2O) \quad . \tag{10}$$

Figure 4.3-6 (Reference 17) shows the two-phase mixture of chemical species that may be present in a plume resulting from an atmospheric release of UF_6. Because of this two-phase mixture and the heating and cooling effects of the reactions and phase changes, the plume may alternate between negative, neutral, and positive buoyancy caused by varying plume density. Figure 4.3-7 (Reference 15) is an example of the special complications (i.e., those complications caused by the varying plume density) in simulating dispersion. Figure 4.3-7 schematically represents a moderate-velocity, vertical release of UF_6 to the atmosphere. Although the plume is initially much denser than the ambient air, the momentum of the vertical release initially causes the plume to rise as it moves downwind, as shown in Region 1 of the figure. As the momentum slows, the plume may sink as shown in Region 2 of the figure, because the plume can be much denser than the surrounding air. If it sinks all the way to the ground, the plume is designated a ground-hovering plume, as shown in Region 3 of the figure. During (and before) this ground-hovering plume phase, UF_6 reactions with water vapor occur and release more heat than the heat removed by sublimation of solid UF_6 to the vapor phase. The net heat released and the entrainment of air may cause the plume to become less dense. In turn, the plume may rise, as shown in Region 4 of the figure. In Region 5, the plume becomes neutrally buoyant because concentrations of uranium and HF are small, reactions are essentially complete, and the temperature is close to ambient. The Gaussian plume methodology for passive, nonbouyant plumes is appropriate to model plume behavior in Region 5.

Many variations in plume trajectory shown may occur, as shown schematically in Figure 4.3-7. Depending on the release rate and mass flow of the mixture, rapid entrainment of ambient air may cause the plume to become neutrally buoyant (Region 5) very quickly. Alternatively, the UF_6 mixture may be released downward, causing a strong interaction with the ground and a direct transition into a ground-hovering plume, represented in Region 3. For a pure UF_6 gas release, the plume density may decrease by as much as a factor of 12 (the ratio, about 350:29, between the molecular weights of UF_6 and dry air) between the release point and a downwind distance of a few hundred meters.

Equations (6) through (10) are the basic chemical reactions equations used in UF_6 chemistry modules. Although included in the models, the tendency of HF polymers to form in plumes resulting from UF_6 releases [Eqs. (7) through (10)] is minimized because HF concentrations are generally far below the concentrations of about 10% required for significant polymerization (Reference 19). Because the chemical reaction of UF_6 with water vapor proceeds at an extremely high rate (Reference 20), the UF_6 hydrolysis reaction [Equation (6)] dominates the overall reaction sequence. In other words, water vapor entrained into the plume will first react with UF_6, which is restricted by a mass transfer-limited reaction rate (i.e., the limited mass transfer that occurs between the plume and ambient air at the edges of the plume) due to incomplete mixing (References 21 amd 22). Any remaining water vapor mixes into the plume and reacts with the HF created by the UF_6 hydrolysis reaction.

The mass transfer–limited reaction rate (hereafter called the turbulence-limited reaction rate to conform with previous conventions established in the literature, where turbulence indicates the turbulent edge of the plume, not atmospheric turbulence), (kmol/s^2), of UF_6 and entrained water vapor is assumed to be determined by the mixing properties of the expanding plume (Reference 15):

$$\dot{R} = \frac{3.6 v_e}{\Lambda} \left(\frac{M_w \times M_u}{2M_u + M_w} \right) , \tag{11}$$

where

v_e is the entrainment velocity (m/s),
Λ is the ratio of the plume cross-sectional area to plume circumference (m), and
M_w and M_u are the molar flow rates (kmole/s) for water vapor and UF_6 vapor, respectively.

The entrainment velocity, v_e, is on the order of 0.6 times the jet speed (m/s) or 0.6 times the ambient friction velocity (a reference velocity that depends on the nature of the surface over which the plume is traveling and the mean wind speed in a shallow layer above the ground surface) for a low-momentum, ground-hovering plume. The ratio Λ is half the plume radius for a circular cross section.

4.3.1.2.3.3 Background on Previous Methods

This subsection discusses the different methodologies employed in the atmospheric transport analyses after a release of UF_6. The purpose of this section is to establish a basis for selecting the methodology for this SAR. Three previous analyses are discussed: (1) the analysis used in the 1985 PORTS FSAR (Reference 23), (2) the analysis recommended by the NRC (Reference 12), and (3) the analysis used by Louisiana Energy Services for the Claiborne Enrichment Center SAR (Reference 24).

4.3.1.2.3.3.1 1985 PORTS FSAR

In 1978 existing atmospheric dispersion codes were surveyed to determine the availability of existing dispersion models that could be used to simulate atmospheric transport of a plume containing UF_6 and UF_6 hydrolysis products. At that time atmospheric plume dispersion was modeled almost exclusively by assuming a Gaussian distribution in both the vertical and cross-wind (perpendicular to the horizontal wind component) directions. Because the standard Gaussian methodology does not accurately simulate key elements of UF_6 plume dispersion, such as chemical reactivity, release of the heat of reaction, and the density variations of a UF_6 plume, DOE funded the development of a UF_6 dispersion model. The code developed and used in the 1985 PORTS FSAR was called PLUMEA. The methods used to model UF_6 dispersion and the development of the code are detailed in Reference 15, in which updates to the algorithm are included and the model is renamed PLM89A; the special aspects of UF_6 dispersion are incorporated into the model. The model incorporates the following:

- The exothermic reaction associated with the hydrolysis of UF_6 is taken into account.
- A plume containing a mixture of UF_6 and its hydrolysis products may be positively, negatively, or neutrally buoyant, depending on the density, composition, and temperature.
- A plume containing a mixture of UF_6 hydrolysis products may be either elevated or ground-hovering (gravity spreading).
- Phase changes, such as UF_6 sublimation and condensation of hydrofluoric acid (a condensed mixture of HF and water) and the associated consumption or release of heat are included.
- The plume density may decrease by more than a factor of 12 as the UF_6 reacts with ambient moisture and is diluted by air entrained into the plume.

In addition to simulating the dispersion of UF_6 and its hydrolysis products, PLM89A can simulate the dispersion and atmospheric chemical reactions associated with releases of ClF_3, F_2, and HF.

For the 1985 FSAR, uranium and HF concentrations were calculated for atmospheric releases of UF_6 associated with accidents occurring in the uranium enrichment cascade. For this analysis, the released UF_6 was assumed to pass immediately through the ventilation system into the outdoor atmosphere. Different release quantities of UF_6 were simulated. The results show that only a release of 20,000 lb (9000 kg) or more of UF_6 to the atmosphere would have toxic effects on personnel downwind of the large process buildings.

4.3.1.2.3.3.2 NUREG-1140

The purpose of NUREG-1140 is to evaluate emergency preparedness requirements for NRC material licensees possessing large quantities of radioactive materials (e.g., the GDPs) (Reference 12). NUREG-1140 establishes relatively simple calculations to determine radiation doses and chemical exposure that would occur after an accidental release at a fuel cycle facility. For the GDPs, NUREG-1140 recommends that a release of UF_6 from a hot [~250°F (120°C) or more] 14-ton cylinder be used to establish emergency preparedness guidelines. This release was chosen because it represents the largest release of UF_6 from many possible accidents that were analyzed in two studies (References 25 and 26). This release scenario is similar to accidents that occurred at PORTS, the Sequoyah conversion plant, and the Comurhex plant.

NUREG-1140 assumes that 21,000 lb (9500 kg) of UF_6 is released in 15 min due to the rupture outdoors of a heated 14-ton cylinder, in which 11,000 lb (4800 kg) of uranium and 3600 lb (1620 kg) of HF become airborne. These airborne masses were calculated by conservatively assuming that all hydrolysis reactions and agglomeration and deposition of solid UO_2F_2 particles occur at the moment of release. Also, NUREG-1140 assumes the plume centerline rises to a final height of 66 ft (20 m) within 660 ft (200 m) of the release because of the heat generated during the hydrolysis reactions. This plume height was chosen on the basis of PLM89A model estimates (Reference 12). With these assumptions, the mass of uranium inhaled, I (kg), is calculated as

$$I = q_U \times B \times \frac{\chi}{Q} , \tag{12}$$

where

q_U is the released quantity of uranium (4800 kg),
B is the breathing rate (2.66×10^{-4} m^3/s),
χ is the atmospheric concentration (g/m^3), and
Q is the release rate (g/s).

Values for the atmospheric dispersion term, χ/Q (s/m^3), were directly obtained from a standard Gaussian plume model.

For HF exposure, NUREG-1140 uses a similar calculation to calculate concentrations, χ (kg/m^3), downwind of the release:

$$I = q_{HF} \times t^{-1} \times \frac{\chi}{Q} \tag{13}$$

where

q_{HF} is the released quantity of HF (1620 kg), and
t is the release time (assumed to be 900 s).

Based on these equations, fixed values of downwind exposure were calculated for (1) very adverse meteorological conditions (i.e., atmospheric stability equal to F with a wind speed equal to 1 m/s) and (2) more typical (but not particularly favorable) meteorological conditions (atmospheric stability equal to D with a wind speed equal to 4.5 m/s) (Reference 12). From these calculations, NUREG-1140 concludes that consequences from chemical exposure of uranium and HF are similar in severity. Additionally, the consequences of chemical exposure are much greater than consequences resulting from radioactive dose received from uranium exposure. Thus, a uranium enrichment plant can be considered more of a potential chemical hazard than a radiation hazard. The assumptions used the NUREG-1140 analysis (e.g., maximum quantity released, minimum atmospheric dilution, receptor at the plume centerline) to provide an extreme consequence estimate (i.e., estimates that result in the absolute maximum downwind exposure to the public) from the many types of releases that could occur at PORTS.

4.3.1.2.3.3.3 Louisiana Energy Services SAR

In the Louisiana Energy Services SAR (Reference 24), two "worst case" UF_6 release scenarios were identified that resulted in off-site impact. The first scenario was a storage yard fire, which was analyzed following NUREG-1140 (described in Section 4.3.1.2.3.3.2). The second scenario was an autoclave heater malfunction for which three different release cases were analyzed to determine offsite impacts: (1) plume dispersion for which there is no building confinement (i.e., the release occurs in an open field); (2) plume dispersion from the facility stack (i.e., an elevated release) after the released material has mixed, reacted, and settled within the building; and (3) plume dispersion from the doors and other openings on the sides of the building (i.e., a ground-level release) after the released material has mixed, reacted, and settled within the building.

The three cases were simulated using (1) the NUREG-1140 modeling method (as described above), (2) a modified version of the NUREG-1140 modeling method where χ/Q values are obtained from NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, and (3) the TRIAD UF_6 atmospheric dispersion model (Reference 26). Estimates from the TRIAD model are much lower than those from the other two methods because TRIAD includes the effects of exothermic/endothermic chemical reactions on plume buoyancy as well as particle deposition and settling. Plume rise estimates among the three modeling methods were found to be especially significant in estimating downwind concentrations; a higher final plume height resulted in a lower ground-level concentration.

4.3.1.2.3.4 Atmospheric Transport Methods Used in this SAR

In 1992, then Martin Marietta Energy Systems, Inc. (MMES), sponsored a review of existing atmospheric dispersion models to determine the most appropriate basis for development of a model for predicting the consequences of an accidental UF_6 release. The review was conducted by the Aeronautical Research Associates Princeton (ARAP) Group and summarized in a report by Sykes and Lewellen (Reference 27). Five models were examined in detail by Sykes and Lewellen.

- PLM89A—a UF_6 dispersion model developed by Lockheed Martin Energy Systems, Inc. (LMES, formerly Martin Marietta Energy Systems, Inc.) (Reference 15).
- TRIAD—a UF_6 model developed by the Nation Oceanic and Atmospheric Administration's (NOAA's) Air Resource Laboratory (Reference 26).
- HGSYSTEM—a suite of codes that model dense-gas dispersion and HF chemical and thermodynamic processes developed by Witlox et al. (Reference 28) of Shell Research Ltd. and available through the American Petroleum Institute (API).
- ADAM—a dense-gas model developed by Raj and Morris (Reference 29) for the United States Air Force.
- SLAB—a dense-gas model developed by Ermak (Reference 30) and available from Lawrence Livermore National Laboratory.

Sykes and Lewellen recommended the following two possible model development and modification options because none of the five candidate models completely met the eleven requirements listed as relevant to safety analysis application:

- Revise PLM89A's dense-gas dispersion algorithms but retain its sophisticated treatment of UF_6 chemistry and thermodynamics, or
- Revise HGSYSTEM—because it is widely accepted and includes HF chemistry—to include the UF_6 chemistry and thermodynamic modules employed by the PLM89A.

Sykes and Lewellen reported that the basis for selecting HGSYSTEM over SLAB and ADAM was not overly compelling. HGSYSTEM and ADAM had existing HF chemistry modules that made them favorable to SLAB; however, HGSYSTEM has a more modular construction than ADAM, which would ease import of UF_6 and chemistry modules. Furthermore, the main module in HGSYSTEM, HEGADAS, has undergone more extensive testing as a dense-gas model than ADAM and therefore is more widely accepted.

After the ARAP review, MMES decided that the best course of action would be to revise HGSYSTEM on the basis of the model's existing heavy-gas treatment, acceptance in the community, and the amount of work required to update PLM89A. The new HGSYSTEM/UF_6 model, developed by Hanna et al. (Reference 17) of Earth Technology Corporation under the sponsorship of LMES, is a hybrid model containing the best attributes of the HGSYSTEM and PLM89A models. Figure 4.3-8 shows a schematic of the development of HGSYSTEM/UF_6.

The following sections discuss the development, major features, evaluation, and limitations of HGSYSTEM/UF_6. See References 16, 17, 31, and 32 for more detailed information.

4.3.1.2.3.4.1 Development of HGSYSTEM/UF_6

HGSYSTEM was originally developed by Shell Research, Ltd., in the mid-to-late 1980s to simulate a wide variety of hazardous gas releases, including two-phase aerosol jets of HF resulting from ruptures of valves and pipelines on pressurized HF tanks (References 28 and 33). The first version of HGSYSTEM, released in 1990, incorporated the dense-gas dispersion model HEGADAS, which was developed in the late 1970s to simulate liquid spills and subsequent evaporation of liquefied natural gas (LNG) and liquefied petroleum gas (LPG) (Reference 34). By the time it was incorporated into HGSYSTEM, HEGADAS had already undergone extensive evaluation and been approved by the U.S. Environmental Protection Agency (EPA) as an alternative regulatory model (40 CFR 51, App. W).

In 1994 an updated version of HGSYSTEM (Version 3.0) was released by Shell Research Ltd., with several enhancements sponsored by API. Like HEGADAS, HGSYSTEM Version 3.0 was approved by the EPA as an alternative regulatory model (40 CFR 51, App. W). Development of HGSYSTEM Version 3.0 was closely coordinated with development of HGSYSTEM/UF_6 (Reference 17). All improvements to the Shell HGSYSTEM model have been incorporated into HGSYSTEM/UF_6. The final Shell technical documentation and user's guide contain descriptions of the UF_6 modules.

As shown in Figure 4.3-8, the UF_6 modeling system is divided into three, interrelated subprocesses: (1) plume dispersion and entrainment, (2) UF_6 chemistry, and (3) UF_6/HF thermodynamics. The key component in the plume dispersion subprocess is the calculation of entrainment rate. In turn, the entrainment rate determines the mixing-limited chemical reaction rate, which provides values for the amounts of entrained dry air and water vapor. Calculation of chemical reactions provides the heats of reaction for the thermodynamics module and determines the changes of the amounts of the UF_6, HF, water vapor, and UO_2F_2 in the plume. In the thermodynamics equilibrium routine, partitioning of phases (which affect the chemical reaction) leads to the calculation of plume density and buoyancy (which drive the plume dispersion). The numerical method and the implementation of these three interrelated subprocesses are described in detail in Chapter 5 of Reference 17.

Several enhancements were incorporated into HGSYSTEM/UF_6, including (1) effects of buildings on plume dispersion, (2) lift-off of the plume centerline from ground level as buoyancy changes from negative to positive as a result of heat input due to chemical reactions, (3) removal of gases and particles by wet and dry deposition, (4) parameterization of some meteorological variables using recent boundary-layer theory, and (5) accounting for variations in concentration with averaging time. The development of the UF_6 chemistry and thermodynamics modules and some key enhancements pertinent to this SAR are discussed immediately below.

a. <u>Effects of Buildings on Plume Dispersion</u>

In the development of HGSYSTEM/UF_6, enhancements were made to the model to account for the influence of buildings on dispersion. Because of the turbulent eddies that form around buildings, algorithms to model the effect of buildings on downwind concentrations, such as trapping of emissions from vents flush with the roof or with the side of a building, were incorporated into HGSYSTEM/UF_6. However, these algorithms are only applicable for nonbuoyant releases.

Two additional models have been developed for HGSYSTEM/UF_6 that simulate the influence of buildings on warm plumes (e.g., those plumes associated with a release of UF_6 from buildings at the GDPs). The first model, called WAKE, simulates a positively buoyant plume released from vents flush with the roofs of the large process buildings (Building X-333). Although the WAKE model was developed with the large PORTS process building in mind, the formulations are sufficiently general that they can be applied to a broad range of warm plumes emitted from industrial buildings.

Figure 4.3-9 is a schematic of the complex flow that develops around large buildings. As the wind field impacts the upwind face of the building, streamlines will split, with a significant fraction of the flow ascending over the roof of the building. Downwind of the building, streamlines descend toward the ground surface. As the flow is split and streamlines ascend and descend over the building, many turbulent zones are created. A positively buoyant plume emitted at roof level may be affected by one or more of these turbulent zones as the rising plume passes through the region of the building wake. For instance, if a vent is located within the roof recirculation region near the upwind edge of the building, much of the plume may be recirculated toward the roof level, and relatively high concentrations would be expected (Reference 35). Also, as a positively buoyant plume rises through the roof recirculation cavity or the high-turbulence zone, it will be rapidly diluted (to ambient density), causing the height of final plume rise to be shorter, and the plume vertical width to be larger, than that of a plume released in the absence of a building (Reference 36).

On the lee side of the building, a recirculation cavity may form. (This region is also called the near wake.) Any fraction of the positively buoyant plume captured in the near wake would be rapidly brought to ground level along recirculation streamlines. The remaining fraction of the positively buoyant plume not captured in the recirculation cavity would be influenced by the turbulent wake zone, where streamlines descend near the lee side of the building (downwash). Recent wind tunnel studies conducted by EPA (References 37 and 38) show that the actual trajectory of a rising plume is substantially affected by building downwash. With certain combinations of wind speed and direction, Scire et al. (Reference 39) report that a positively buoyant plume may actually descend to the ground surface because streamline descent overcomes the effects of buoyancy.

A primary assumption in the development of the WAKE model, as applied to the PGDP process buildings, is that all chemical reactions are completed inside the building before release to the atmosphere. Therefore, the reaction products (UO_2F_2 and $HF{\cdot}H_2O$) are dispersed as nonreactive but warm gases, and atmospheric chemical reactions can be ignored. Following ASHRAE (Reference 40), Schulman and Scire (Reference 41), and Wilson (Reference 42), the WAKE model splits the plume into two components: (1) the fraction, f_c, of the plume captured in the near wake and then transported into the far wake region and (2) the remaining fraction, $1\text{-}f_c$, of the plume that rises through the turbulent wake directly above the building. The total ground-level concentration, C_{total}, at downwind distances from the release point is the sum of the ground-level concentrations from these two components (Reference 43):

$$C_{total} = C_c + C_a , \qquad (14)$$

where

C_c is the ground-level concentration (mg/m³) from the component of the plume caught in the wake (f_c), and

C_a is the ground-level concentration (mg/m³) from the component of the plume that rises above the wake ($1 - f_c$).

The development of equations used to calculate C_c are summarized in Hanna and Chang (Reference 43). In the near wake, C_c is calculated using formulations empirically derived from recent wind tunnel data (Reference 42):

$$C_c = \frac{Q_c}{V_o\left[1 + 13\left(\dfrac{T_a}{T_s}\right)^{1/2}\dfrac{w_o}{u_H}\right] + \dfrac{u_H x_s^2}{16}} , \qquad (15)$$

where

Q_c is equal to the $f_c \times Q$, and Q is the mass flux (kg/s) of the plume constituent (either UO_2F_2 or HF),

V_o is the plume volume flux at the vent (m³/s),

T_a is the temperature of the ambient air (K),

T_s is the temperature of the plume at the vent (K),

w_o is the initial plume speed (m/s),
u_H is the wind speed at the top of the building (m/s), and
x_s is the "stretched string" distance from the source to the receptor (m).

In the denominator of Equation (15), V_o is included to make sure that the predicted concentrations do not exceed the initial concentration in the vent plume. The second term, the one with T_a/T_s, takes into account reductions in concentrations due to the initial rise of the plume out of the jet. This term should be set equal to zero for capped roof vents (Reference 41). The third term calculates the concentrations on the roof and downwind sides of the buildings, similar to previous zero-momentum release algorithms incorporated in HGSYSTEM/UF_6 (Reference 17).

Equation (15) applies until the plume grows to the point that the estimated concentrations drop to the concentrations calculated using a model for a well-mixed building wake. The well-mixed building model is used to calculate concentrations at downwind distances beyond this point and is given as

$$C_c = \left(\frac{Q_c}{u_H R^2}\right) \frac{B_{LO}}{\left[0.037 + 0.03\left(\frac{x}{H_B}\right)^2 + F_{**}^2\left(\frac{x}{H_B}\right)^4 + \left(\pi\frac{\sigma_y\sigma_z}{R^2}\right)^3\right]^{1/3}} , \qquad (16)$$

where

R^2 is the scaling area in the wake as defined by Wilson (Reference 42) (m^2), with R being the representative scaling length of the building (m),
B_{LO} is the nondimensional buoyant lift-off term,
x is the downwind distance from the source to the receptor (m),
H_B is the height of the building (m),
F_{**} is the nondimensional buoyancy flux, described below, and
σ_y and σ_z are the Gaussian horizontal and vertical dispersion parameters, respectively (m).

Equation (16), an empirical formula derived by Briggs (Reference 44), provides a conservative best fit to wind tunnel data gathered by Hall and Waters (Reference 45) and Hall et al. (Reference 46). Both wind tunnel experiments focused on buoyant plumes affected by building wakes. The latter set of wind tunnel experiments (Reference 46) involved relatively complicated release simulations for a variety of vent configurations, building shapes, and wind angles. More details on the derivation of Equation (16) are detailed in Hanna and Chang (Reference 43).

In Equation (16), B_{LO}, describes the decrease in ground-level concentration due to buoyant lifting of the plume, which is determined by

$$B_{LO} = \exp\left(-6F_{**}^{0.4}\right) . \qquad (17)$$

In Equation (17), F_{**} is the nondimensional buoyancy flux of the term, calculated as

$$F_{**} = \frac{F_o}{u_H^3 W_B} , \qquad (18)$$

where F_o is the buoyancy flux calculated using the standard Briggs plume rise equations (m^4/s^3) (References 47 and 48).

The first three bracketed terms in the denominator of Equation (16) correspond to (1) plume dilution across the building face and recirculation cavity, (2) plume diluation due to expansion with downwind distance, and (3) plume dilution due to growth caused by buoyancy. The fourth term accounts for dispersion of the plume due to ambient turbulence not related to the presence of the building, where the Gaussian plume model is applicable. Each of the four terms is consistent with fundamental physical relations developed and verified over the past two decades (Reference 43).

To estimate ground-level concentrations resulting from the part of the plume that rises through the building wake, C_a [Equation (14)], the Industrial Source Complex—Version 3 (ISC3) (Reference 49) dispersion model is used. In calculating C_a, ISC3 is run as with building wake parameters, because the buoyant plume would be affected by the wake when rising. The source term for the part of the plume above the wake, Q_a, is calculated as:

$$Q_a = (1 - f_c)Q \ . \qquad (19)$$

The total downwind concentration, C_{total}, is calculated using Equation (14).

The second model to simulate the influence of buildings on warm plumes, called UF_6MIXER, simulates the drifting of plumes in the horizontal direction out of a building into the lee-side recirculation cavity [i.e., the movement of an accidental release of pressurized UF_6, caused by a valve or pipe rupture during transfer operations, moving out of the large bay doors of the X-334-A transfer building]. The jet of UF_6 released in such a scenario would mix with air in the transfer building as it flows around various obstacles (e.g., tanks and pipes). This in-building mixing is taken into account by assuming that the area of the plume when it exits the building is a fraction, f_A, of the area of the downwind face of the building (equal to the building width, W_B, multiplied by the building height, H_B). As a maximum, f_A equals the ratio of the area of the open doors to the area of the downwind face of the building. The value of f_A is a key input into the model, such that with increasing f_A values, the amount of UF_6 that reacts in the building increases.

The UF_6MIXER model first calculates the amount of UF_6 that has reacted to form UO_2F_2 and HF in the building. Ambient air is introduced incrementally, and all available water vapor introduced during that step is assumed to react with UF_6 completely according to Equation (6). These incremental reactions continue until the plume grows to the specified size in the building as determined by f_A.

From this point, two cases are calculated by UF_6MIXER and compared. Case I assumes that all the UF_6 has reacted in the building. Equations (15) and (16) are used to calculate ground-level concentrations in the wake. Equation (17) is used to calculate B_{LO}, which is applied to take into account any plume lift-off that may occur. When using Equation (17), F_{**} is calculated using the temperature of the plume at the end of the chemical reactions (i.e., buoyancy flux is assumed to be conserved once UF_6 hydrolysis reactions have ceased).

Case II assumes that a significant fraction of the plume is unreacted as it leaves the building and that the plume is relatively dense as it enters the recirculation cavity. As the plume exits the building, a complete description of the plume state is input into a modified form of HEGADAS/UF_6. In the recirculation cavity, the HEGADAS/UF_6 model is run using stability class B (unstable), which is intended to characterize the turbulence in the near wake. The selection of stability class B as representative of turbulent conditions in the recirculation cavity is consistent with Wilson's (Reference 42) solution [i.e., the term $u_h x_r^2/16$ in Equation (15)] when made equivalent to the Gaussian plume method. At the end of the recirculation cavity, HEGADAS/UF_6 is applied using the original stability class (i.e., the atmospheric stability class appropriate for a given scenario). The calculation of F_{**} is made with plume variables calculated in HEGADAS/UF_6 at downwind increments because buoyancy flux is not conserved if UF_6 hydrolysis reactions are occurring. (This use of F_{**} with HEGADAS is discussed in more detail in the next section.)

The results of Case I and II are compared in the final phase of the UF_6MIXER simulation. In the recirculation cavity, the higher of the predicted concentrations is selected to estimate impacts. To maintain consistency, concentrations for the far wake are selected from the method having the highest concentration estimated in the near wake.

b. Lift-Off of Ground-Level Buoyant Plumes

If the UF_6 plume centerline is on the ground (or very near the ground), either because it was initially released at ground-level or because it slumped due to the high plume density, it may eventually lift off the ground. Lift-off occurs if the buoyancy forces, which lift the plume, exceed the turbulent forces in the ambient boundary layer, which spreads the plume laterally (Reference 19).

Reductions in ground-level concentrations due to lift-off of the plume centerline may be taken into account by applying the buoyant lift-off term, B_{LO} [Equation (17)]. Originally, B_{LO} was suggested by Briggs (Reference 44) for use with buoyant plumes that conserve their buoyancy flux, F_o (i.e., the buoyancy flux would be determined by release conditions and/or building dimensions). However, Hanna and Chang (Reference 43) applied B_{LO} to plumes with buoyancy fluxes that vary with time and distance, such as a reactive UF_6 plume. In this application, the u_H and W_B terms in Equation (18) are the local plume advection speed and local plume width output by the HEGADAS/UF_6 model at a particular downwind distance. The assumption made by Hanna and Chang (Reference 43) is that B_{LO} is applicable to a wide range of initially ground-based, buoyant plumes. Based on this assumption, the application of B_{LO} to HEGADAS/UF_6 is appropriate to determine the reduction of ground-level concentrations that would occur as a warm UF_6 plume lifts off of the ground. The plume lift-off calculations are applied as a postprocessor to HEGADAS/UF_6.

c. <u>Wet and Dry Deposition of Particles, Aerosols, and Gas from the Plume</u>

As the UF_6 plume is transported downwind, it will be composed of a mixture of gases, solid particles, and aerosols. To estimate the effects of deposition from an accidental UF_6 release, dry and wet deposition algorithms are applied as postprocessors to HGSYSTEM/UF_6. For both wet and dry removal, there is no feedback mechanism between plume chemistry and thermodynamics and deposition. In running HGSYSTEM/UF_6, all of the UF_6 in the plume is assumed to react to form HF and UO_2F_2; however, some UF_6 may actually be removed via deposition. This assumption results in upper-bound estimates of airborne uranium and HF concentrations received by a downwind receptor and, consequently, provides a conservative estimate of impact to human health.

For small particles, drops, and gases (i.e., those with aerodynamic diameters less than about 50 μm), the dry deposition modules in the ISC3 (Reference 49) dispersion model have been adopted for use in the HGSYSTEM/UF_6 postprocessor. ISC3 estimates dry deposition by assuming that the dry deposition flux, F_d (g/m^2-s), is linearly proportional to the air concentration, C:

$$F_d = C \times v_d \, , \tag{20}$$

where v_d is the deposition velocity (m/s), which is calculated using the resistance analog technique (Reference 50). The equations for deposition velocity are described in detail in the *ISC3 User's Manual* (Reference 49).

The initial flashing process may result in the formation of large aerosols and particles with diameters of thousands of micrometers (i.e., a few millimeters). Particles and aerosols with aerodynamic diameters of about 1 mm or greater have a gravitational settling speed greater than 1 m/s (Reference 16), and simple gravitational settling (as described by Stoke's Law) can be used to estimate v_d:

$$v_d = (\rho_p - \rho_a)\frac{g D_p S_{CF}}{18\mu} \, , \tag{21}$$

where

ρ_p is the particle or aerosol density (g/m^3),
ρ_a is the air density (g/m^3),
g is the gravitational constant (9.802 m/s^2),
D_p is the aerodynamic diameter of the particle (m),
μ is the dynamic viscosity of air (g/m^2-s), and
S_{CF} is the slip correction factor.

The slip correction factor, S_{CF}, is applied to account for particles with aerodynamic diameters of 50–1000 μm and is given by the empirical formula

$$S_{CF} = 1 + 0.13[1.257 + 0.4\exp(-8.5D_p)] \, . \tag{22}$$

Concentration values from HGSYSTEM/UF_6 are applied to Equation (20) using deposition velocities calculated using Equation (21) or the ISC3 resistance model. A percentage of the concentration is applied to fixed-particle-size diameters that vary as a function of distance. In other words, the percentage of particles with large D_p decreases with downwind distance because these particles will rapidly settle out of the plume.

HGSYSTEM/UF_6 estimates wet deposition flux, F_w, using a below-cloud scavenging mechanism (i.e., raindrops scrub plume gases and solids from the plume) employed by PLM89A and Ramsdell et al. (Reference 51). In-cloud scavenging (i.e., removal of plume gases and solids by impact with fog droplets) is neglected by the current version of HGSYSTEM/UF_6 because it is insignificant for short plume-travel times (Reference 17).

4.3.1.2.3.4.2 Major Features of HGSYSTEM/UF_6

The HGSYSTEM/UF_6 dispersion code suite consists of the following models applied to various stages of the plume or puff:

a. <u>AEROPLUME/RK</u>

This model estimates near-field (i.e., downwind distances ranging from tens to hundreds of meters) dispersion of elevated, two-phase (aerosol and vapor) momentum jets of UF_6 and its reaction products. This model applies to releases from pressurized tanks or cylinders at the point of release to the time when they either (1) strongly interact with the ground and become a dense ground-based plume or (2) become passive (i.e., the density approaches ambient air density and chemical reactions cease). The initials RK stand for the inclusion of a robust Runge-Kutta numerical solver that enables the user to model situations in which the plume angle changes rapidly with time, such as UF_6 releases with steep jet angles (between -10 and -45° from the horizontal) pointing toward the ground. The RK numerical solver replaces the SPRINT numerical solver employed in HGSYSTEM Version 3, which could not consistently simulate UF_6 releases with steep jet angles (Reference 43). The UF_6 chemistry and thermodynamics modules used in this model are the same as those used by HEGADAS/UF_6 (discussed below).

b. <u>HEGADAS/UF_6</u>

This model applies to continuous, ground-hovering plumes. The model is used for either (1) area source releases (i.e., spills) or (2) the point where AEROPLUME predicts that the dense plume will be in direct contact with the ground. Steady-state (HEGADAS-S) and transient (HEGADAS-T) modules are incorporated into the model. The transient module is used for finite duration releases (<~2 min). HEGADAS/UF_6 uses the same UF_6 modules as AEROPLUME/RK.

c. <u>PGPLUME</u>

This model is used in the final passive phase of the plume, in which the Gaussian plume methodology is applicable. The Gaussian plume methodology is a well documented industry standard that incorporates emission, downwind, crosswind, and vertical factors. No chemical reactions or thermodynamic processes are modeled in PGPLUME. AEROPLUME/RK will transition to PGPLUME if the plume becomes passive (neutral buoyancy/non-reactive). This would simulate the plume dynamics of region five from Figure 4.3-7.

d. WAKE

This model is used to simulate releases from roof vents and stacks on the GDP process buildings. WAKE determines the dimensions of the recirculation cavity, and calculates the plume rise to estimate the fraction of the plume captured in the cavity. It calculates the concentration for the part of the plume captured in the cavity based on the Wilson/Briggs model and estimates the correction to the concentrations for the part of the plume captured in the cavity due to possible plume lift-off based on the Briggs model. WAKE then creates all of the necessary input files for the ISC3 model for the part of the plume that escapes the cavity. A postprocessor merges the results from (1) the WAKE model for the part of the plume captured in the cavity and (2) the ISC3 model for the part of the plume that escapes the cavity.

e. ISC3

The basis of the ISC3 model is the straight-line, steady-state Gaussian plume equation, which is used with some modifications to model simple point source emissions from stacks, emissions from stacks that experience the effects of aerodynamic downwash due to nearby buildings, isolated vents, or multiple vents. It uses meteorological data to define the conditions for plume rise, transport, diffusion, and deposition. The model estimates the concentration or deposition value for each source and receptor combination. ISC3 is used in conjunction with WAKE and its postprocessors to model releases from roof vents and stacks on the GDP process buildings.

f. UF_6MIXER

This model and its postprocessors are used to simulate releases from the open bay doors of the GDP transfer buildings. UF_6MIXER determines the dimensions of the recirculation cavity and estimates the plume states (e.g., the total plume mass emission rate, the plume composition, the plume temperature, etc.) after the assumed in-building dilution and associated chemical reactions. It then estimates the plume buoyancy flux and the equivalent mass emission rates for UO_2F_2, HF, U, and F when all chemical reactions have been completed (the buoyancy flux and the mass emission rates are required by the Wilson/Briggs model). Using the Wilson/Briggs model, it calculates the concentrations and prepares the required input files for the modified version of HEGADAS/UF_6. This modified version of HEGADAS/UF_6 assumes a B stability class in the cavity to account for the observed effects of enhanced dilution in building wakes, regardless of the stability class specified by the user for the ambient atmosphere.

g. POSTMIX

This UF_6MIXER postprocessor retrieves the plume geometry and density information from the HEGADAS/UF_6 predictions to estimate the downwind distribution of the plume buoyancy flux, which in turn is used to estimate the correction to concentrations predicted by HEGADAS/UF_6 due to possible plume lift-off based on the Briggs model. The postprocessor will then select the UO_2F_2, HF, U, and F concentrations predicted by the Wilson/Briggs model at downwind distances that are (1) less than the length of the cavity based on which model gives higher predicted concentrations for U, and (2) greater than the length of the cavity based on which model gives higher predicted concentrations for U at the end of the cavity.

4.3.1.2.3.4.3 Evaluation of HGSYSTEM/UF_6

Three types of evaluations were made to assess the performance of HGSYSTEM/UF_6, as detailed in Chapter 8 of Reference 17. The first evaluation compared results from HGSYSTEM/UF_6 with data from seven field tests reported by Hanna et al. (Reference 52). These field tests involved releases of nonreactive dense gases (e.g., LNG, LPG, and Freon) and aerosols (e.g., ammonium and polymerized HF). In essence, this evaluation assessed the performance of dense gas dispersion algorithms in HGSYSTEM/UF_6 without the use of the UF_6 chemistry and thermodynamic modules. Thirteen other hazardous gas models were considered in the comparisons, including an earlier (1990) version of HGSYSTEM. The comparison showed that (1) HGSYSTEM/UF_6 produced results that are very similar to the 1990 version of HGSYSTEM, (2) the HEGABOX model, developed for instantaneous dense-gas releases, produced results that are in good agreement with the Thorney Island field data (i.e., data from an instantaneous release of dense gas), and (3) the performance measures (e.g., fractional mean bias and normalized mean square error) for the HGSYSTEM/UF_6 concentration estimates were consistently at the level of the six best-performing models.

The second evaluation compared concentration and lateral plume with observations from three French UF_6 field experiments with calculations using HGSYSTEM/UF_6 (References 53, 54, 55, and 56). The release rate in the French field experiment was about 0.2 lb/s (0.08 kg/s), about two orders of magnitude less than a potential 14-ton cylinder rupture. Also, because UF_6 was released entirely in the gas phase, UF_6 particle sublimation was not a factor. When HGSYSTEM/UF_6 is applied to these release conditions, the model quickly transitions from AEROPLUME/UF_6, the dense gas jet model, to PGPLUME, the passive gas model. Therefore, the French field data represent a passive gas release and are not adequate for assessing the performance of the UF_6 chemistry and thermodynamics modules or the dense gas dispersion. However, results from PGPLUME were compared with the ISC model (a standard Gaussian plume model) and field data. Both PGPLUME and ISC showed fair agreement with the field data. PGPLUME tended to show slight (15 percent to 50 percent) underpredictions in lateral dispersion (Reference 17).

The third evaluation compared the UF_6 chemistry and thermodynamics modules in HGSYSTEM/UF_6 with equilibrium analytical solutions calculated by Rodean (Reference 57). Rodean assumed that the initial temperature of the UF_6 release was 180°F (82°C) and that the initial release mixture was 50 percent gas and 50 percent solid. The ambient temperature was assumed to be 77°F (25°C), and the ambient relative humidity was assumed to be 100 percent. The AEROPLUME/UF_6 model was applied using input values that simulated Rodean's release conditions (Reference 16). As shown in Figure 4.3-10, results of the two solutions agree well. Differences between the two arise because the AEROPLUME/UF_6 model assumes turbulence-limited reaction rates (i.e., the solution is not in equilibrium).

An independent peer review panel (Reference 58) met in August 1996 to evaluate HGSYSTEM/UF_6 in general, and to evaluate in detail the building wake models (i.e., WAKE and UF_6MIXER) and the plume-lift algorithms incorporated in HGSYSTEM/UF_6. The review panel found in general that the models were "reasonable and scientifically dependable . . . for complex problems in an area where scientific understanding was still improving." Additionally, the peer reviewers found that "the desire for conservative predictions was apparent; if a modeling uncertainty arose, a reasonable, conservative option was followed." The building wake equations used in WAKE and UF_6MIXER were developed from fundamental physical principles and were calibrated with wind tunnel observations by Hall and Waters (Reference 45) and Hall et al. (Reference 46). The equations in these models were shown by Hanna and Chang (Reference 43) to be conservative with respect to laboratory observations, and were designed to be conservative for building geometries typical of the GDPs (i.e., building widths much greater than building heights).

4.3.1.2.3.4.4 Limitations of HGSYSTEM/UF_6

The following list of model limitations is summarized from Reference 19:

- As with all models, HGSYSTEM/UF_6 was developed with certain release scenarios and meteorological conditions in mind. For example, a release from a nozzle on a pressurized 14-ton cylinder has been a primary test case. Similarly, the meteorological input conditions of interest have emphasized light-to-moderate wind speeds, neutral-to-stable conditions, and small-to-moderate surface roughness conditions.
- Primary concern has been for dense (negatively buoyant), neutral, or slightly positively buoyant plumes. The entrainment relations have not been fully tested for strongly positively buoyant plumes.
- The meteorological parameterizations for the ambient atmospheric boundary layer are valid primarily for heights less than about 160 ft (50 m).
- Distances of interest range from the edge of the building to a few kilometers because the distances to the plant fence lines or to the point where concentrations drop below toxic levels are usually in that range.
- Releases of mixtures of two or more chemicals (i.e., multicomponents) can be modeled only if the chemical and thermodynamic properties of the mixture can be represented by a "pseudo chemical" with molecular weight given by the weighted average of the components.

4.3.1.3 Natural Phenomena Methodology

The evaluation basis earthquake and wind events for the PORTS site have been established as 250-yr return period events, with a 0.05-g peak ground acceleration (PGA) and 78-mph fastest-mile wind speed, respectively (Reference 59). A probable maximum flood (PMF) was also considered. Four analyses (i.e., structural, equipment, piping system, and overhead crane analyses) were performed to address natural phenomena hazards. (See Chapter 2 for input to these analyses.) The structural analysis was performed first, and the results of this analysis were then used as input to the remaining analyses. The following sections describe the methods used for each type of analysis.

4.3.1.3.1 Structural Analysis

The seismic provisions of UCRL-15910 (Reference 60) were used for buildings analyzed prior to the issuance of DOE-STD-1020-94 (Reference 61). After the issuance, DOE-STD-1020-94 was used to determine seismic load levels on the buildings.

Two of the major differences between UCRL-15910 and DOE-STD-1020-94 are as follows:

- DOE-STD-1020-94 includes a seismic load factor for brittle failure modes. This factor is 1.0 for PC3 facilities, which equates to UCRL-15910 "moderate hazard" category criteria because UCRL-15910 does not use a seismic load factor.

- UCRL-15910 uses different inelastic energy absorption factors for different categories of structures. With the exception of in-plane shear walls, factors from UCRL-15910 moderate hazard facilities closely match the factors in DOE-STD-1020-94. For shear walls, UCRL-15910 uses a factor of 1.7 for moderate hazard facilities, whereas DOE-STD-1020-94 specifies a value of 1.5, resulting in slightly higher demands.

For the analyses performed here, either UCRL-15910 moderate hazard or DOE-STD-1020-94 PC3 procedures were followed, and there is little difference between the two.

Computer models of the buildings were developed to obtain response to loads resulting from natural phenomena events acting in conjunction with existing in-place loads. For all but very simple structures, three-dimensional models were used.

Design drawings, design specifications, and walkdown packages were used to model, as closely as possible, existing conditions of the structures. Design drawings and specifications were used to define geometry and material properties. Walkdown packages were used to establish changes to geometry, structural changes (e.g., added or removed walls), and in-place loads.

The walkdown packages were detailed studies that identified major configuration changes, in-place loads, reference document lists, and member sampling data, which established relevance of existing design drawings.

Where detailed three-dimensional models were used, all primary structural elements, including mezzanines, were incorporated into the model. Roof trusses either were modeled discretely or were represented by equivalent beam elements. For simpler structures, three-dimensional stick models were used by hand-calculating global stiffness and mass properties.

4.3.1.3.1.1 Earthquake

The structural analysis proceeded generally as follows :

- The site-specific spectra and the mathematical model of the structure were used and an elastic dynamic analysis was performed to determine the elastic seismic demand.
- The inelastic earthquake demand was evaluated as the elastic demand divided by the inelastic demand-capacity ratio, F.
- The total demand for the components was evaluated by adding the gravity demand and the inelastic seismic demand.
- Member capacities were evaluated from code ultimate or yield values.
- Demand was compared with capacity. If the demand was less than the capacity, the member satisfied the seismic requirements. If the demand was greater than the capacity, the capacity was expressed in terms of a threshold PGA.
- Story drifts were evaluated.
- Peer review of the analysis was implemented.

For demand calculations, a 250-yr return period earthquake was used as the EBE. For PORTS, the 250-yr earthquake has a PGA of 0.05 g (see Chapter 2).

Dynamic analyses were used to determine building responses to earthquake input. In general, masses were taken from walkdown packages supplemented by information found on the original design drawings.

Two analyses were performed for each structure evaluated. First, a dynamic response spectrum analysis using mode superposition was used to determine the evaluation basis response of the structural elements. Second, a mode superposition dynamic time history analysis was performed to generate amplified, in-structure response spectra to be used for the analysis of equipment within the buildings. Site-specific input (response spectra and time histories) was used.

In the analysis, the best estimates of in-place loads were used. Included in the loads and masses on the buildings were slabs, framing, walls, equipment, and miscellaneous loads identified from walkdowns.

Masses were lumped at nodes. Enough natural frequencies were calculated and retained in the analysis that no less than 90 percent of the total mass in each direction considered (north–south, east–west, and vertical) was accounted for in the retained modes. This is in accordance with ASCE 4-86 (Reference 62) as referenced in DOE-STD-1020-94. The mass not explicitly included in the calculated modes was not ignored, but results were scaled up to approximate the effects of missing modes.

For large two-dimensional and three-dimensional models, the computer program GTSTRUDL (Reference 63) was used.

Where fewer than 50 modes were required for the analysis, modal combinations were made using either the complete quadratic combination (CQC) method or the NRC 10 percent method. When more than 50 modes were required, the NRC 10 percent method was used exclusively because of the increased computational effort required in the CQC method. The two horizontal seismic components (north–south and east–west) were always combined using the square root-sum of squares (SRSS) method. The NRC and CQC methods for modal combinations and the SRSS method for directional combination are in accordance with ASCE 4-86. The vertical contribution to seismic response was computed by including vertical modes in the modal superposition or as an equivalent static load. This static load was taken as 1.5 times the peak vertical ground acceleration times the structure gravity load. This vertical static load was combined with the horizontal seismic response and dead load.

In computing seismic demand, the inelastic energy absorption factor, *F*, was taken from DOE-STD-1020-94.

Load factors of unity were used in seismic load combinations. This is in agreement with DOE-STD-1020-94 when the EBE is for the safe shutdown condition, as is the case for the structures evaluated herein. Actual stresses were compared with code ultimate values to determine the adequacy of each member. In general, code checking of steel components was done internally by the computer programs, and concrete code checks were done by hand. Components were allowed to yield under the load combinations. The load combinations considered are shown in Table 4.3-2.

Beams, columns, walls, diaphragms, and footings were checked for the appropriate loads. Story drifts were compared with allowable levels. For in-structure spectra generation, the range of frequencies considered is shown in Table 4.3-3. These ranges are in accordance with ASCE 4-86 . In addition, the natural frequencies of the structure were included in the frequency envelope.

4.3.1.3.1.2 Wind

In the structural analysis, wind loads were applied in accordance with ASCE 7-88 (Reference 64) as referenced by UCRL-15910 and DOE-STD-1020-94. Static analyses were performed to determine the response of the buildings to wind loads in combination with gravity loads (i.e., walls, slabs, framing, equipment, miscellaneous loads).

The same models used for the dynamic seismic analyses were used for the static wind analyses. Beams, columns, walls, diaphragms, and footings were checked for the appropriate loads. Story drifts were compared with allowable levels.

A 250-yr return period straight wind was taken as the EBE. For PORTS, the 250-yr wind speed is 78 mph (see Chapter 2).

The north-south wind was assumed to act independently of the east-west wind. This is in accordance with ASCE 7-88.

Actual stresses were compared to code ultimate values to determine the adequacy of each member. For steel elements, these code checks were done internally by the computer software (Reference 63). Concrete elements were checked by hand.

4.3.1.3.1.3 Flood

The plant elevation is above the PMF (see Chapter 2). Therefore, river and stream flooding is not a hazard for the buildings. However, local ponding was investigated for the buildings. For typical buildings, the primary drainage system is roof drains. Some buildings have scuppers in the parapet. For ponding effects analysis, the primary drainage was considered to be completely blocked. In general, this meant that the roof structure had to be evaluated for a depth of rainwater up to the parapet height. This involves evaluating the roof beams, the deck, and the building columns for the load induced by standing water on the roof.

4.3.1.3.2 Equipment Analysis

The evaluation methodology for equipment analysis followed the general philosophy of the experience-based methods used by the commercial nuclear industry to evaluate equipment in older nuclear power plants for which documentation of seismic qualification was incomplete. The equipment evaluated was selected through the accident analysis process, which identified equipment whose failure from a natural phenomena event could release UF_6 or other hazardous materials. Therefore, the performance goal is defined as containment of hazardous materials or pressure boundary integrity. Continued operation of the diffusion equipment during or after a natural phenomena event is not required.

The equipment is located in two large process buildings, two feed facilities, two product withdrawal facilities, a tails withdrawal facility, a toll enrichment services facility, and tie-line structures connecting the various buildings. Because much of the equipment and connecting piping consists of similar components arrayed in repeated patterns, equipment capacities were determined on a representative sample. About 7 percent of the equipment in the process buildings and more than 10 percent in the other buildings or facilities was sampled.

A two-step process was used to evaluate the seismic capacity of equipment identified by the accident analysis process. First, a procedurally controlled walkdown inspection of the equipment was performed to determine existing conditions and to identify equipment attributes that may result in the vulnerability of the equipment to natural phenomena effects. Next, the capacity of equipment was determined by calculating the capacity of vulnerable elements or weak links. The capacity of the equipment was expressed in terms of PGA for the earthquake hazard and fastest-mile wind speed for the wind hazard, from which the annual probabilities of failure were calculated.

4.3.1.3.2.1 Earthquake

The equipment evaluation process, walkdown inspection, and structural assessment address two categories of equipment: that which is included in the 22 classes for which earthquake experience data are given in the DOE Electric Power Research Institute (EPRI) Seismic Qualification Utilities Group (SQUG) database and that which is not in the DOE EPRI/SQUG database (References 65 and 66). Comparisons were made between the equipment selected for evaluation and the equipment that the nuclear industry has found from experience to be seismically rugged in actual earthquakes. Equipment that is similar to the rugged equipment but does not possess all the attributes of the rugged equipment was called an outlier and was evaluated individually by analysis. The equipment not in the database was treated as an outlier and was evaluated by analysis. The EPRI/SQUG and outlier evaluation processes are described in References 65 and 67.

4.3.1.3.2.2 Wind

Equipment potentially exposed to wind effects was evaluated for fastest-mile wind pressures using the methodology described in DOE-STD-1020-94. Equipment located in buildings with siding or enclosures that were capable of withstanding the wind forces was not evaluated. In cases where the siding of the building had a low wind-speed capacity, the siding was assumed to fail, and the full pressure force from the wind was applied to exposed equipment. Wind- or tornado-driven missiles are not likely to occur for a 78-mph wind speed and were not considered.

4.3.1.3.2.3 Flood

The elevation of the ground floor slabs in buildings housing equipment identified by the accident analysis process was compared with the level of the PMF. In all cases the elevation of the ground floors of the buildings housing the equipment exceeded the water level associated with the PMF. Therefore, the effect of regional flooding was not considered further. The flood hazard for the PORTS site is described in Chapter 2.

Potential water inflow from ponding on roofs, from roof leaks, and from local flooding was determined not to affect the pressure boundary integrity function of equipment.

4.3.1.3.3 Piping Systems

The piping systems evaluated were selected through the accident analysis process, which identified piping whose failure from a natural phenomena event could release UF_6 or other potentially hazardous materials.

The performance goal is containment of hazardous materials. The equipment is located in two large process buildings, two feed facilities, two product withdrawal facilities, a tails withdrawal facility, a toll enrichment services facility, and tie-line structures connecting the various buildings. Because much of the piping, pipe supports, and pipe-supported components are similar and are arrayed in repeated patterns, capacities of piping systems were determined from a representative sample. Approximately 7 percent of the piping systems in the process buildings and more than 10 percent in the other buildings or facilities were sampled.

4.3.1.3.3.1 Earthquake

The evaluation methodology of piping systems for natural phenomena hazards generally follows the philosophy of experience-based methods. Earthquake experience data for piping systems are not currently included in the DOE's 22 EPRI/SQUG equipment classes, although there are considerable experience data on piping systems in earthquakes. The evaluation process focused on identifying weak links that could result in loss of pressure boundary integrity in the piping system during a seismic event.

The experience-based method for piping systems developed by Lockheed Martin Energy Systems (LMES) for use in the evaluations of piping systems at PORTS is described in References 68 and 69. Subsequent to developing these guidelines, DOE also developed similar guidelines for trial use in evaluating piping systems in existing DOE facilities (Reference 70). Both DOE and LMES utilize a two-step process consisting of a walkdown inspection and screening procedure followed by a structural assessment for piping systems that are not screened as rugged. Piping and piping supports judged to be rugged were assumed to have a capacity defined by the reference spectrum (Reference 65). The two methods are judged to give approximately the same results.

As stated previously, a two-step process was used to evaluate piping systems identified by the accident analyses. A procedurally controlled walkdown inspection of the pipe, pipe supports, and in-line components such as valves, expansion joints, and reducers was conducted to determine existing conditions and identify attributes that may make the equipment vulnerable in a seismic event. The capacity of the piping system was determined by assessing the capacity of the vulnerable features or weak links. Only certain types of valves from the GDP piping systems are included in the DOE EPRI/SQUG database. These valves were evaluated by comparing them with the database valves. All other piping system components were evaluated by analysis in accordance with guidance documents (Refernces 68 and 69). The capacities of the piping system components are expressed in terms of the PGA, from which an annual probability of failure was calculated.

4.3.1.3.3.2 Wind

Piping systems exposed to wind effects were evaluated for the wind-induced pressure forces. The wind pressure forces are calculated by the method described in DOE-STD-1020-94. In cases where the building's siding had a low wind speed capacity, the siding was assumed to fail, and the full wind pressure force was applied to the exposed piping.

4.3.1.3.3.3 Flood

The elevations of the piping systems were compared with the level of the PMF (see Chapter 2). The elevations of the ground floors of the buildings housing the piping systems are above the water level from a PMF. Therefore, regional flooding was not considered further.

Potential water inflow from ponding on the building roof, from roof leaks, and from local flooding was determined not to adversely affect the pressure boundary integrity of piping systems components.

4.3.1.3.4 Overhead Cranes

Cranes are used throughout PORTS to lift and transport equipment and materials. During operations and while in their parked position, cranes frequently are located above equipment, piping, and components containing hazardous materials. Those cranes whose failure could potentially result in a release of hazardous materials when they are subjected to the natural phenomena hazards (e.g., earthquake and wind) were evaluated. Failure was considered to occur when either the hook load is dropped or the overhead crane falls from its support structure. Therefore, the performance objective was position retention of both the crane and hook load.

4.3.1.3.4.1 Earthquake

Cranes and crane support structures were evaluated for the evaluation basis earthquake using the methods given in Reference 61. Because the performance objective was simply position retention, in contrast to continuing operation during and after an earthquake, stress levels and deflections in the crane support structure defined in Reference 61 were relaxed.

4.3.1.3.4.2 Wind

Cranes and their support structures exposed to wind effects were evaluated for the pressure forces from a 78-mph fastest-mile wind speed. The evaluation methodology used is given in Reference 61.

4.3.2 ACCIDENT ANALYSIS RESULTS

This section presents the results of the accident analysis for the limiting initiating event combinations identified in Section 4.2.6 and the consequence analysis of potential accidents resulting from these combinations. Accidents resulting from the limiting initiating events identified in Section 4.2.6 bound all other initiating events by consequence for each combination of initiating event, operating mode, hazard state, and preventive/mitigative measures. They form the set of unique and representative evaluation basis accidents that are needed to assess the bounding consequences of facility operations.

The operational analysis determines necessary controls (i.e., equipment and administrative controls) to prevent the occurrence of initiating events or mitigate the consequences of resulting accidents. The goal is to identify controls that are necessary to prevent the EGs from being exceeded. Each of the limiting initiating events identified in Section 4.2.6 was evaluated and is described in the following sections to document the scenario, indicate the essential controls, and compare the consequences to the EGs.

The results identify safety actions and the essential controls necessary to prevent exceeding the EGs or to minimize the impact. Detailed information about the essential system capabilities and support requirements is discussed in Section 3.8. Operating limits for the essential controls are presented in the TSRs.

4.3.2.1 Cascade Facilities

Table 4.2-11 documents the results of the hazard analysis for each of the cascade facility processes. In addition to the processes that were evaluated directly inside the cascade facilities, various waste storage/handling operations may also be present inside the facilities. These operations and their analyses are addressed in Section 4.3.2.3.

As noted earlier in Chapter 4, the shutdown of enrichment operations has reduced the probability and consequences of accidents described in this section. While the various accident initiators discussed could be present on cells running for deposit removal treatments, the inventory of uranium and other hazardous materials in the cell would not pose a threat to public health and safety. The protection of onsite worker from releases of toxic materials is accomplished by evacuation according to site "see and flee" procedures.

4.3.2.1.1 Compressor Failure–UF_6/Hot Metal Reaction (Temperature Increase)

a. Scenario Description

UF_6 oxidizes most metals producing a metal fluoride and solid uranium compounds, but at moderate temperatures the reaction is mild and the reaction rate is inhibited by the layer of reaction products formed on the surface of the metal. However, if aluminum is heated above the solidus temperature [about 1100°F (593°C)], the protective metal fluoride layer is disturbed and a more vigorous exothermic reaction can occur. The reaction will continue as long as UF_6 and aluminum are available, and the heat generated by this reaction is sufficient to maintain the aluminum above the solidus temperature.

Any mechanism capable of heating the aluminum to temperatures above the solidus temperature when UF_6 is present can initiate the UF_6/aluminum reaction. However, the most probable and most historically common initiating mechanism is friction associated with component rubbing after axial compressor failure/deblade which generates sufficient heat to raise aluminum temperatures above the solidus temperature. While all axial compressors have aluminum blades, the "00" compressors have the greatest potential for UF_6/hot metal reactions because they have aluminum rotors that tend to expand more than the "000" compressor steel rotor. This expansion results in decreased rotor blade tip clearances and a greater probability of blade rubbing and deblade. Friction or rubbing of aluminum components or fragments after a deblade has the potential to provide sufficient heat to reach the solidus temperature of the aluminum and create an exothermic UF_6/hot metal reaction. The reaction will result in increased temperatures and decreased pressures locally as the UF_6 is reacted to produce solid compounds. If the reaction occurs in a vulnerable location and is not mitigated, it can damage the pressure boundary and cause a breach of the primary system. A breach would result in a release of UF_6 if the process pressure were above atmospheric pressure. In addition, under certain conditions, the heat from an exothermic reaction in the compressor can be transmitted to the cooler. If this occurs, and sufficient heat is provided to melt the aluminum components in the stage cooler, the R-114 coolant would leak into and pressurize the process system. If the R-114 coolant system is breached in a cell that is isolated from the cascade, this could result in overpressure and breach of the primary system due to the limited expansion volume available. Coolant system ruptures into the primary system are addressed in Section 4.3.2.1.6.

During the modes of operation for the enrichment cascade where the compressors are running, a number of causal factors may result in compressor failure in a cell or booster station operating either on-stream or off-stream including (1) compressor flow starvation or compressor overload, (2) catastrophic seal or bearing failure that results in wet air inleakage and subsequent rotor imbalance (excessive vibration) due to uranium deposition, (3) enrichment cascade disturbances which result in compressor surging, and (4) overheating the process gas stream due to coolant system malfunctions. These factors can cause the progressive effects of (1) compressor surging or overload, (2) overheating, and (3) if unmitigated, a compressor deblade. Direct compressor failure can also be caused by (1) a foreign object in the compressor suction or (2) blade fatigue. When a compressor deblades, the possibility of heat build up exists due to rubbing/friction of aluminum components or fragments sufficient to initiate a UF_6/hot metal exothermic reaction, and burn a hole in the primary system boundary and/or the R-114 coolant system boundary.

This event is an AE because a single active failure of a compressor, left unmitigated, could result in a UF_6/hot metal reaction that could lead to a breach in the process system and a release. Operational history indicates that only a small percentage of compressor failure events result in a UF_6/hot metal reaction.

A UF_6/hot metal reaction event was evaluated in the PrHA, and it was determined that the consequences could include significant on-site impact while operating above atmosphere if no mitigation were provided.

The primary concerns associated with this event are (1) the primary system temperature increase, and (2) controlling the UF_6 release if the primary system should fail. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 4 is addressed by the NCS Program (see Section 5.2). The first safety action required to meet the other EGs would be to maintain the primary system temperature within EG 3. This action will prevent primary system failure, protect on-site personnel, and maintain habitability of the required control area by preventing a release of UF_6. If primary system temperature cannot be maintained within EG 3, a breach of the primary system could conceivably occur. The safety actions for above atmospheric systems of (1) primary system leakage detection, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), (3) building holdup, and (4) emergency response by on-site personnel would be required to maintain the effects of a UF_6 release within EGs 1, 2, and 6. These actions protect on-site personnel and will maintain habitability of the required control area in accordance with EG 6 as well.

Primary system temperature control is required to meet EG 3. The primary means of accomplishing this safety action is to minimize the potential for the event to occur. Typically, when one of the causal factors that could lead to a compressor deblade is identified by an abnormal motor load and confirmed by examining other process parameters, operators will initiate appropriate actions (e.g., reduce the operating pressure, take the cell off-stream, or trip the cell(s) and take off-stream) to prevent a deblade. However, once a deblade is confirmed the essential method for preventing the reaction is to trip the cell(s) from the area control room (ACR) to shut down the motors to eliminate any heat generation due to rubbing parts. If this control fails to stop the transient in sufficient time to prevent the failure of the primary system, a release is assumed to occur if the system is above atmospheric pressure. The release of UF_6 to the atmosphere could exceed EGs 1, 2, and 6 if no mitigation is accomplished. The compressor failure-UF_6/hot metal reaction produces the most limiting temperature transient event in the AE category for the operating and standby operating modes.

b. Source-Term Analysis

In order for a UF_6/hot metal reaction event to produce a significant release of UF_6 to the atmosphere, the event must be in cells or equipment operating above atmospheric pressure. Therefore, the source-term associated with the UF6/hot metal reaction event is addressed for cells operating above atmospheric pressure.

When a cell is off-stream, the system is isolated from the cascade, thus limiting the amount of UF_6 available for continued reaction (versus the operating mode). Based on the stoichiometry of the UF_6/aluminum reaction, enough aluminum is available in one "00" stage to consume the entire UF_6 inventory of a "00" cell at maximum power level. Consumption of UF_6 during the reaction reduces the amount of UF_6 available for dispersion to the atmosphere, and it causes the primary system pressure in the cell to decrease.

When a cell is on-stream, the system is operating at normal cascade operating pressures. The potential source term due to a breach in the primary system while the cell is operating above atmospheric pressure is bounded by the source term for the B-stream block valve closure event (Section 4.3.2.1.3). This is because UF_6 is consumed during the reaction, the compressor at the point of the breach will be pumping inefficiently if it is pumping at all, and the pressure would not significantly increase due to the temperature increase. In addition, if the breach occurs while the cell is on-stream, operator action would be taken to trip the cell in response to the UF_6 release and/or the surging of compressors in this cell and adjacent cells. Tripping the cell compressors significantly reduces primary system pressure due to a loss of compression.

Based on the potential source term described above, this event is bounded by the B-stream block valve closure event (Section 4.3.2.1.3).

c. Consequence Analysis

The consequence analysis for the UF_6/hot metal reaction event is subdivided to address the on-site receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — The analysis for the B-stream block valve closure event (Section 4.3.2.1.3) concluded that adequate time is available for operational personnel to accomplish the essential safety actions (leakage detection and mitigation). Because the UF_6/hot metal reaction source term is bounded by the B-stream block valve closure event, adequate time would also be available for operational personnel to detect and mitigate this event prior to any need to evacuate the ACR. However, once these essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) detection of the release, (2) minimization of the release by tripping applicable cells, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is to detect the release of UF_6. As stated previously, the motor load indicators provide an indication of abnormal compressor operation that could lead to failure (i.e, surging and/or loss of load). Typically, this indication will be detected, and corrective action will be taken prior to the initiation of a UF_6/hot metal reaction, or prior to a UF_6/hot metal reaction progressing to the point of a primary system breach. However, should a release occur, the equipment that has the potential for causing a large release (i.e., "00" or "000" building compressors which are intended to operate above atmospheric pressure) are equipped with UF_6 release detection that alarms in the applicable ACR. Other portions of the cascade do not have operating pressures or inventories sufficient to result in any significant consequences outside the building, and this receptor would not be applicable (see Section 4.2.6.4). The second essential control, is for operators to trip the appropriate cell(s) to reduce the pressure and minimize the release of UF_6. The shutdown of a cell(s) will decrease the cell(s) high side pressure to about one-half the normal operating pressure, which will bring the cell uniformly below atmospheric pressure. Pressure at an interbuilding booster comperssor can be reduced, if needed, by tripping the compressor motor or by tripping adjacent enrichment cell compressor motors. Once the pressure has dropped to atmospheric pressure or below, the release of material is effectively terminated for any potential exposure outside the process building. Sufficient time is then available to perform any necessary valve evolutions to isolate the cell. The third essential control, process building holdup, is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

d. <u>Comparison With Guidelines</u>

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. The EG associated with preventing overtemperature (EG 3) cannot be ensured based on operational history. However, operational history also indicates that the source term associated with this event is typically minimal. If EG 3 is not met, the other EGs for protection against releases are applicable to the event. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the ACR were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, cell trip, building holdup, and evacuation of areas upon detection of a release) and the analysis presented for the B-stream block valve closure event (bounding AE event), EGs 1 and 2 would be met for workers outside the process building.

e. <u>Summary of SSCs and TSR Controls</u>

The essential controls for the UF_6/hot metal reaction event associated with meeting EG 3 are to minimize the potential for failing the primary system due to temperature increase. These controls include detection of the compressor failure and minimizing the source of heat/friction that could lead to the elevated temperatures that allow the UF_6/hot metal reaction. For equipment operating above atmospheric pressure, the essential controls for this event are summarized as follows:

- Motor load indicators in ACR—indication of abnormal compressor operation (i.e., surging and/or loss of load) (EG 3 only); and
- Compressor motor manual trip in ACR—elimination of heat/friction (EG 3 only).

For equipment operating above atmospheric pressure, essential mitigation of any UF_6 releases associated with this event (EGs 1, 2, and 6) are the same as those described for the B-stream block valve closure event (Section 4.3.2.1.3) for on-site receptors and are summarized as follows:

- Compressor motor manual trip in ACR—minimize release to workers outside the process building (EGs 1, 2, and 6);
- UF_6 release detection system—workers outside the process building (EGs 1, 2, and 6);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators, compressor motor manual trip system, UF_6 release detection system, and process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.

- TSRs are provided for the motor load indicators; compressor motor manual trip system; UF_6 release detection system; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.2 Stage Control Valve Closure (Pressure Increase)

a. <u>Scenario Description</u>

The stage control valve is used to control the pressure in a stage automatically or manually. The inadvertent closure of the stage control valve in a cell will cause a pressure increase in the stages above the closed control valve. Inadvertent closure of a stage control valve could be caused by initiators such as (1) an operator error, (2) a failure in the valve controls, (3) a mechanical failure in the valve mechanism (e.g., valve disk failure), (4) a freeze-out of UF_6 in the high side instrument line, or (5) a rupture of the high-side instrument line. The valve closure(s) could cause an increase in pressure, surging, and possibly motor overload. The pressure increase is limited due to the fact that the shift in inventory required to increase the pressure will cause the stage compressor to go into surge. The pressure increase is further limited if the cell is operating off-stream because the inventory available to cause the pressure increase is fixed. Once the stage compressor goes into surge, the compressor will stop pumping additional inventory above the closed valve and the pressure will stop increasing. The pressure transient associated with closure of a stage control valve would be no higher than the pressure transient associated with the closure of a B-stream block valve when the recycle valve does not open. In a B-stream block valve closure scenario where the recycle valve does not open as designed, the maximum pressure attained in a "000" stage initially running at maximum steady state pressure would be about 30 psia. For equipment operating at a lower initial pressure, inadvertent closure would result in a lower maximum pressure (e.g., if the starting pressure was 14.4 psia the maximum pressure would be limited to 20 psia). In addition, stage control valves equipped with trimmer vanes and stops allow a limited amount of process gas flow to pass through the valve when it is closed. In the event of a stage control valve closure, this design feature would limit the maximum achievable pressure in the affected cell even further since a closed B-stream block valve allows virtually no flow through when closed.

This event is an AE because a single active failure or a single operator error could cause the inadvertent closure of a stage control valve or valves. Primary system failure is not expected at the maximum pressures associated with this event; however, it is assumed for the purpose of this evaluation that a primary system breach is possible.

Closure of a stage control valve was evaluated in the PrHA, and it was determined that the unmitigated consequences could include significant on-site impact in the operating mode. The evaluation determined that no significant consequences beyond the immediate area are expected if the event occurs in a cell in other modes.

The primary concerns associated with this event are (1) the primary system pressure increase, and (2) controlling the UF_6 release if the primary system should fail. The applicable EGs (see Table 4.3-1) associated with this event are all the EGs for the AE frequency range. EG 4 is addressed by the NCS Program (see Section 5.2). The first safety action required to meet the other EGs would be to maintain primary system pressure control within EG 3. This action will prevent primary system failure, protect on-site personnel, and maintain habitability of the required control area by preventing a release of UF_6. If primary system pressure cannot be maintained within EG 3, a breach of the primary system is assumed to occur. The safety actions of (1) primary system leakage detection, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), (3) building holdup, and (4) emergency response by on-site personnel would be required to maintain the effects of the UF_6 release within EGs 1, 2, and 6. These actions protect on-site personnel and will maintain habitability of the required control area in accordance with EG 6 as well.

Primary system pressure control is required to meet EG 3. The primary method of accomplishing this safety action is to detect the pressure increase and take actions to reduce the pressure. The essential method of detecting a pressure increase in the cascade equipment is through monitoring the motor load indicators. The motor load indicators (i.e., stage ammeter indications) will indicate a rise in current for the compressor motors above the point of valve closure that is proportional to the rise in pressure. Once the increased motor loads are detected by the operator, an operator response is needed to reduce the pressure. Typically, during normal operation, operators are likely to determine the cause of the rise in loads (e.g., through observing valve position indicators and compressor loads) and this will initiate routine actions to limit the pressure increase to meet EG 3. These routine actions could include tripping the cell and/or taking off-stream, establishing a split in the cascade to isolate flow to the cell, or placing the control valve in manual operating mode to regain pressure control. However, the essential method for limiting the pressure is to trip cell(s) from the ACR. Tripping the cell(s) will eliminate the compression source and limit the pressure increase. However, should the detection and/or cell trip not occur soon enough, a failure of the primary system is assumed to occur. The release of UF_6 to the atmosphere could exceed EGs 1, 2, and 6 if no mitigation is accomplished.

b. <u>Source-Term Analysis</u>

During the operating mode, the system is operating at normal cascade operating pressures. Operating experience indicates that this event has never resulted in a release of UF_6 due to overpressure. Therefore, failure of the primary system is not expected with this event at this frequency. However, for analysis purposes, a failure of the primary system is assumed to occur at this event frequency. A direct failure of the primary system is assumed to result because of the pressure increase associated with a stage control valve closure event. The maximum pressure would be significantly less than that evaluated for the B-stream block valve closure event (Section 4.3.2.1.3), and is therefore bounded by that analysis.

c. <u>Consequence Analysis</u>

The consequence analysis for the stage control valve closure event is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — The analysis for the B-stream block valve closure event (Section 4.3.2.1.3) concluded that adequate time is available for operational personnel to accomplish the essential safety actions (leakage detection and mitigation). Because the stage control valve closure event source term is bounded by the B-stream block valve closure event source term, adequate time would also be available for operational personnel to detect and mitigate this event prior to any need to evacuate the ACR. However, once these essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) detection of the release, (2) minimization of the release by tripping applicable cells, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is to detect the release of UF_6. As stated previously, the motor load indicators provide an indication of a pressure increase in the affected cell. Typically, this indication will be detected, and corrective action will be taken prior to any failure in the primary system. However, should a release occur, the equipment that has the potential for causing a large release (i.e., "00" or "000" building compressors which are intended to operate above atmospheric pressure) are equipped with UF_6 release detection that alarms in the applicable ACR. Other portions of the cascade do not have operating pressures or inventories sufficient to result in any significant consequences outside the building, and this receptor would not be applicable (see Section 4.2.6.4). The second essential control, is for operators to trip the appropriate cell(s) to reduce the pressure and minimize the release of UF_6. The shutdown of a cell(s) will decrease the cell(s) high side pressure to about one-half the normal operating pressure, which will bring the cell(s) uniformly below atmospheric pressure. Pressure at an interbuilding booster compressor can be reduced, if needed, by tripping the compressor motor or by tripping adjacent enrichment cell compressor motors. Once the pressure has dropped to atmospheric pressure or below, the release of material is effectively terminated for any potential exposure outside the process building. Sufficient time is then available to perform any necessary valve evolutions to isolate the cell. The third essential control, process building holdup, is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

d. <u>Comparison With Guidelines</u>

The EGs for the AE frequency category from Table 4.2-2 were compared to the consequences associated with the event scenario. The EG associated with preventing overpressure (EG 3) cannot be ensured because of the lack of automatic trips on high cascade pressures associated with existing cascade configurations. However, operational history indicates that this EG is likely to be met because no primary system failures have occurred from this transient. If EG 3 is not met, the other EGs for protection against releases are applicable to the event. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, equipment housings, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the ACR were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, cell trip, building holdup, and evacuation of areas upon detection of a release) and the analysis presented for the B-stream block valve closure event (bounding AE event), EGs 1 and 2 would be met for workers outside the process building.

e. <u>Summary of SSCs and TSR Controls</u>

The essential controls for the stage control valve closure event associated with meeting EG 3 are to minimize the potential for failing the primary system due to pressure increase. For equipment operating above atmospheric pressure, the essential controls associated with this EG are summarized as follows:

- Motor load indicators in ACR—indication of pressure increase (i.e., significant increase in motor load) (EG 3 only); and
- Compressor motor manual trip in ACR—decrease pressure (EG 3 only).

For equipment operating above atmospheric pressure, essential mitigation of any UF_6 releases associated with this event (EGs 1, 2, and 6) are the same as those described for the B-stream block valve closure event (Section 4.3.2.1.3) and are summarized as follows:

- Compressor motor manual trip in ACR—minimize release for all receptors except local worker (EGs 1, 2, and 6);
- UF_6 release detection system—all receptors except local worker (EGs 1, 2, and 6);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators, compressor motor manual trip system, UF_6 release detection system, and process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the motor load indicators; compressor motor manual trip system; UF_6 release detection system; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.3 B-Stream Block Valve Closure (Pressure Increase)

a. Scenario Description

Normal operation of the gaseous diffusion cascade requires a continuous A-stream (upstream) flow, and B-stream (downstream) flow, in order to complete the enrichment process. During the operation of the enrichment cascade, the B-stream block valves are generally operated only to take equipment off-stream or to establish cascade splits. These are operations that are typically performed at the local cell panel while the operator has an established communication link with the ACR. During these operations, the potential exists for the inadvertent closure or failure to open of the B-stream block valve by initiators such as (1) failure in the valve controls, or (2) operator error. A B-stream block valve closure that is caused by one of these initiating events is considered to be in the AE frequency category. It is also possible for the valve to mechanically fail (e.g., valve disk failure), however this initiator is considered to be in the EBE frequency category. This inadvertent "B" stream blockage will result in the A-upflow remaining near normal initially, with the B-downflow decreasing to zero as the B-stream block valve closes. Inventory would be pumped from stages below the closed B-stream block valve to the stages above the closed valve. If the recycle valve opens automatically as designed, the Stage 1 compressor will raise the inventory and pressure in the stage immediately above the closed B-stream valve. The inventory and pressures in stages above the closed valve are postulated to continue increasing until the pressure transient exceeds the rated pressure of a primary system component (e.g., expansion joint) and results in a UF_6 release to atmosphere. Routine actions would typically be taken by operators to mitigate the event prior to system breach (stopping or reversing the closure of the B block valve, or closing the appropriate A block valve to stop the A-stream flow if the B block valve fails to open).

There are other possible unmitigated end states associated with the B-stream block valve closure initiator, however these potential end states are not credited in this analysis. These other potential end states include:

- Compressors are automatically shut down on overload by the motor overload trip system.
- Compressors deblade due to overload.
- The expansion joint internal to a converter that separates the A & B stream ruptures (the pressure differential between the B-stream and the A-stream is greater than the pressure differential between the B-stream and the atmosphere).

An unmitigated closure of a B-stream block valve was evaluated in the PrHA and it was determined that the consequences of a release could include significant off-site and on-site impact in the operating mode if no mitigation were provided.

The primary concerns associated with this event are (1) the primary system pressure increase associated with the unmitigated inadvertent blockage of the B-stream, and (2) controlling the UF_6 release if the primary system should fail. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 4 is addressed by the NCS Program (see Section 5.2). The first safety action required to meet the other EGs is to maintain primary system pressure control within EG 3. This action will prevent primary system failure, protect both on-site personnel and the off-site public, and maintain habitability of the required control area by preventing a release of UF_6. If primary system pressure cannot be maintained within EG 3, a breach of the primary system could occur. The safety actions of (1) primary system leakage detection, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), (3) building/housing holdup, and (4) emergency response by on-site personnel would be required to maintain the effects of the UF_6 release within EGs 1, 2, and 6. These actions protect both on-site personnel and the off-site public and will maintain habitability of the required control area in accordance with EG 6 as well.

Primary system pressure control is required to meet EG 3. The primary method of accomplishing this safety action is to detect the pressure increase and take actions to reduce the pressure. The essential method of detecting a pressure increase in the cascade equipment is through monitoring the motor load indicators. The motor load indicators (i.e., stage ammeter indications) will indicate a rise in current for the compressor motors above the point of valve closure that is proportional to the rise in pressure. The pressure rise is not immediate. A bounding analysis was performed to determine the minimum time-frame to reach primary system failure. This analysis was based on a B-stream block valve closure occurring in a "000" cell while the cascade is operating at maximum power levels and at an area operating at maximum steady state pressure and maximum interstage flow rates. This analysis indicates that from the time that valve closure is initiated, the valve will completely close in approximately 2.5 min, primary system pressure would begin to significantly increase approximately 1.5 min after initiation of valve closure, and primary system failure is postulated to occur after approximately 3.5 min after initiation of valve closure. Rather than taking full credit for the expected closure time of the B-stream block valve, it is conservatively assumed for this analysis that the operator has 2.5 minutes from event initiation to detect the increased motor loads and to take actions to reduce pressure and prevent rupture and thus meet EG 3 for the worst case conditions. For lower cascade power levels, lower steady-state operating pressures, lower interstage flows, and smaller equipment, the time frame for reaction would typically be significantly longer.

Once the increased motor loads are detected by the operator, an operator response is needed to reduce the pressure. Typically, during normal operation, operators are likely to determine the cause of the rise in loads (e.g., through observing valve position indicators and compressor loads) and this will initiate routine actions to limit the pressure increase to meet EG 3. These routine actions could include stopping or reversing the closure of the B block valve, stopping or reversing the closure of the B bypass valve if the B block valve fails to open, or closing the appropriate A block valve to stop the A-stream flow. However, the essential method for limiting the pressure is to trip cell(s) from the ACR. Tripping the cell(s) will eliminate the compression source and limit the pressure increase. However, based on the minimum time-frame for operator action associated with the worst case conditions, detection or cell trip may not be accomplished in time to prevent exceeding EG 3. Consequently, a failure of the primary system is addressed. The release of UF_6 to the atmosphere could exceed EGs 1, 2, and 6 if no mitigation is accomplished.

The B-stream block valve closure produces the most limiting pressure increase event in the AE category for the case of a cell operating on-stream. Should the essential preventive actions fail to stop the transient in sufficient time to prevent a failure of the primary system, a release of UF_6 is assumed to occur. Operating experience indicates that this event has never resulted in a release of UF_6 due to overpressure. Therefore, failure of the primary system is not expected with this event at this frequency. However, for analysis purposes, a failure of the primary system is assumed to occur at this event frequency.

b. Source-Term Analysis

The B-stream block valve closure event is categorized as an AE because a single failure of equipment or a single operator error could initiate the event, and it is also based on operational history. There are many variables associated with this event that must be characterized to develop a source term. These variables include:

- The duration of the event prior to operator action;
- The size of the potential system failure;
- The location of the failure in the cascade (i.e., equipment associated with "00" or "000" cascade operations—other equipment is not considered credible due to lower pressures); and
- The initial pressures and associated flow rate of UF_6 at the break.

To characterize this scenario for consequence analysis, the objective was to determine the amount of material that can be released without exceeding the AE off-site EGs (i.e., 10 mg U and 5 rem) and evaluate the time frame to determine if sufficient operator time is available to mitigate the event prior to exceeding the EGs. The scenario assumes a conservative release rate equivalent to the B-stream line failure scenario release rate presented in the large UF_6 release to atmosphere event (see Section 4.3.2.1.7). The release rate is 130 lb/s (59 kg/s) of UF_6. Based on the analysis in Section 4.3.2.1.7, it would take approximately 90 s to release enough material [i.e., 11,700 lb (5307 kg)] to exceed 10 mg U at the nearest site boundary. Because of the various receptors of concern (i.e., personnel in the process building, operators, general on-site workers, and the off-site public), the EGs will be addressed based on these receptors.

c. Consequence Analysis

The consequence analysis for the B-stream block valve closure event is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — Operational personnel who are required to take mitigative action are located in the ACR, which typically would not be impacted by the event. However, during cold weather periods, the air on the cell floor is recirculated inside the building to minimize heat loss and maintain building temperatures. This mode of operation could result in elevated concentrations of HF in the ACR area, which would result in evacuation of the ACR. An evaluation of this potential concern concluded that adequate time is available for operators to perform the required actions prior to evacuation should the need arise. However, once these essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) detection of the release, (2) minimization of the release by tripping applicable cells, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is to detect the release of UF_6. As stated previously, the motor load indicators provide an indication of a pressure increase in the affected cell. Typically, this indication will be detected, and corrective action will be taken prior to any failure in the primary system. However, should a release occur, the equipment that has the potential for causing a large release (i.e., "00" or "000" building compressors which are intended to operate above atmospheric pressure) are equipped with UF_6 release detection that alarms in the applicable ACR. Other portions of the cascade do not have operating pressures or inventories sufficient to result in any significant consequences outside the building, and this receptor would not be applicable (see Section 4.2.6.4). The second essential control, is for operators to trip the appropriate cell(s) to reduce the pressure and minimize the release of UF_6. The shutdown of a cell(s) will decrease the cell(s) high side pressure to about one-half the normal operating pressure, which will bring the cell(s) uniformly below atmospheric pressure. Pressure at an interbuilding booster compressor can be reduced, if needed, by tripping the compressor motor or by tripping adjacent enrichment cell compressor motors. Once the pressure has dropped to atmospheric pressure or below, the release of material is effectively terminated for any potential exposure outside the process building. Sufficient time is then available to perform any necessary valve evolutions to isolate the cell. The third essential control, process building holdup, is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — Because this event, as described, could involve a significant UF_6 release, a scenario is presented that determines how much material must be released at the assumed conservative flow rate to result in a 10 mg U exposure at the nearest site boundary. This information is evaluated and described in the accident analysis for a large UF_6 release to atmosphere (Section 4.3.2.1.7). For the worst-case conditions, the results indicate that it takes 11,700 lb (5307 kg) of UF_6 to reach a 10 mg U exposure at the nearest site boundary. With the conservative release rate assumed, this would result in a release time of 1.5 min. Based on the minimum time-frame to breach the primary system, the operator would have to trip the cell(s) within 4 min (i.e., 2.5 min to reach failure and 1.5 min of release) to meet EGs 1 and 2. For portions of the cascade not operating at maximum pressures and for smaller equipment, more time would be available for the operator to take action to mitigate the event. This allows adequate time for the operators to act. This is based on operational history associated with typical cascade operating configurations (i.e., no breach has occurred from this initiator), the typical location of the operators when the event is initiated (i.e., at the ACR and cell panel), operator training, and the early indications available (i.e., motor load indicators and UF_6 release detectors).

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. The EG associated with preventing overpressure (EG 3) cannot be ensured because of the lack of automatic trips on high cascade pressures associated with existing cascade configurations. However, operational history associated with typical cascade operating configurations indicates that this EG is likely to be met because no failures have occurred from this transient. If EG 3 is not met, the other EGs for protection against releases are applicable to the event. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the ACR were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, cell trip, building holdup, and evacuation of areas upon detection of a release), EGs 1 and 2 would be met for workers outside the process building. Finally, an analysis was performed to determine the worst-case scenario at which an off-site exposure of 10 mg U would be reached at the nearest site boundary. Results of this analysis indicated that the operator action could be accomplished within the time frame to meet the EGs.

e. Summary of SSCs and TSR Controls

The essential controls for the B-stream block valve closure event associated with meeting EG 3 are to minimize the potential for failing the primary system due to pressure increase. Based on the results of this analysis, the essential controls associated with this EG are summarized as follows:

- Motor load indicators in ACR—indication of pressure increase (i.e., significant increase in motor load) (EG 3 only) and
- Compressor motor manual trip in ACR—decrease pressure (EG 3 only).

Essential mitigation of any UF_6 releases associated with this event (EGs 1, 2, and 6) are summarized as follows:

- Compressor motor manual trip in ACR—minimize release for all receptors except local worker (EG s 1, 2, and 6)
- UF_6 release detection system for cells operating above atmospheric pressure—all receptors except local worker (EGs 1, 2, and 6);
- Equipment housing holdup for compressors operating above atmospheric pressure—off-site public (EGs 1 and 2);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building and the off-site public (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators, compressor motor manual trip system, UF_6 release detection system, equipment housings, and process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the motor load indicators; compressor motor manual trip system; UF_6 release detection system; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.4 Limited UF_6 Release to Atmosphere (Primary System Integrity)

a. <u>Scenario Description</u>

During all the enrichment cascade operating modes, small passive failures in the primary system may result in limited releases of UF_6 into the process buildings. These could be caused by initiators such as failures of instrument lines, expansion joints, weld joints, etc., that could be caused by vibration, fatigue, or corrosion. These types of failures are expected frequently enough to place them in the AE category.

A limited UF_6 release event was evaluated in the PrHA, and it was determined that the consequences could include significant on-site impact in any cascade operating mode where the cell pressure is above atmosphere if no mitigation were provided.

The primary concern associated with this event is controlling the UF_6 release. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 3 is not addressed in this scenario because the primary system is assumed to fail, and EG 4 is addressed by the NCS Program (see Section 5.2). The safety actions of (1) building holdup, and (2) emergency response by local personnel would be required to maintain the effects of the UF_6 release within EGs 1, 2, and 6. Because of the limited size of the releases for this event, no additional action is required to keep the effects of the UF_6 release within EGs 1, 2, and 6 for areas outside the process buildings. These actions protect on-site personnel and will maintain habitability of the required control area in accordance with EG 6 as well. In addition, although it is not considered essential, termination of these releases would typically be accomplished via the means identified for other scenarios such as the B-line block valve failure event (Section 4.3.2.1.3).

The limited UF_6 release to atmosphere is the most limiting primary system integrity failure event for the AE category. For larger primary system integrity failures that could result in a large UF_6 release, the frequency is considered to be significantly lower. Such failures are addressed in the large UF_6 release to atmosphere event (see Section 4.3.2.1.7).

b. <u>Source-Term Analysis</u>

The limited UF_6 release to atmosphere event is considered to be an AE because minor passive failures of equipment or operator error can initiate the event and because of operational history. Many variables associated with this event must be characterized to develop a source term. These variables include:

- The duration of the release;
- The size of the potential system failure;
- The location of the failure in the cascade (i.e., X-326, "0", "00", "000", or auxiliary equipment); and
- The initial pressures and associated flow rate of UF_6 at the break.

For equipment operating below atmospheric pressure, the source term for this event would be minimal because of inleakage, and no additional consideration is warranted. However, for equipment operating above atmospheric pressure, some release of UF_6 would be expected although as indicated by operational history, the releases are typically very small. This event is associated with minor passive failures only. The size of the failure in the primary system is expected to be small and significantly less than that described for the B-stream block valve closure event (see Section 4.3.2.1.3). Based on the potential source term, this event is bounded by the B-stream block valve closure event (Section 4.3.2.1.3).

c. <u>Consequence Analysis</u>

The consequence analysis for the limited UF_6 release to atmosphere event is subdivided to address the on-site receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — Because of the minimal source term associated with this event, no essential actions are required of operational personnel in the ACR. However, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) temporary holdup of the release by the existing process building structure, and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. Process building holdup is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. There are no essential actions required of operational personnel in the ACR to meet EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., building holdup, and evacuation of areas upon detection of a release) and the minimal source term associated with this event, EGs 1 and 2 would be met for workers outside the process building.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential mitigative controls for the limited UF_6 release to atmosphere event associated with meeting EGs 1, 2, and 6 are a subset of those described for the B-stream block valve closure event (Section 4.3.2.1.3) and are summarized as follows:

- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.5 Evacuation of Cascade Process Buildings (External Events)

a. Scenario Description

The evacuation of cascade process buildings event is a special event to be evaluated for all operational areas with significant hazardous operations to ensure that evacuation does not result in consequences from process operations. The event scenario addresses any essential actions required by the operational staff prior to evacuation of the facility for all conditions except when a release of hazardous material within the facility is the initiating event. For a discussion of releases of hazardous material within the cascade process buildings and associated operator actions, refer to the appropriate sections of this chapter for required actions. The evacuation event is an AE because various types of events associated with plant operations could result in a required evacuation of a facility. Some of these events include spurious operation of the criticality accident alarm system, potential releases of hazardous material from another facility, or a fire within the facility.

The primary concern associated with this event is to prevent release of hazardous material (e.g., UF_6) as a result of an evacuation of the facility. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 4, is addressed by the NCS Program (see Section 5.2). EG 6 is addressed by this event scenario (i.e., determine what safety actions are required by the operational personnel and whether they can be accomplished for this event). The only safety action required to meet these EGs is to maintain primary system pressure control within EG 3. This action will prevent primary system failure as well as protect both on-site personnel and the off-site public.

The analysis for this scenario addressed each facility process and associated operating modes to determine the essential controls necessary to prevent failure of the primary system. The initial conditions associated with this event are assumed to be normal operations carried out within the facility.

The evacuation of cascade process buildings event is considered a limiting event because of the special nature of the analysis. All the applicable EGs are met by controlling the primary system pressure within EG 3. Both the on-site worker and the off-site public are protected in this event by controlling the primary system pressure so that it does not exceed EG 3 and the release of UF_6 is prevented.

b. <u>Source-Term Analysis</u>

The objective of this analysis is to prevent failure of the primary system in the event of an evacuation of a cascade process building. This would result in no source term for the event. Although this objective might not be accomplished completely, as indicated in the following analysis, the source term would be small in relation to the other anticipated events (Sections 4.3.2.1.1 through 4.3.2.1.4, and Section 4.3.2.1.6). Therefore, source-term analysis is not applicable to this event.

c. <u>Consequence Analysis</u>

Consequence analysis is not applicable to the evacuation of cascade process buildings event.

d. <u>Comparison With Guidelines</u>

For the evacuation of cascade process buildings event, a summary of each process and its associated controls is given to indicate how primary system pressure and temperature are controlled within EG 3.

The freezer/sublimer process is automatically controlled to prevent overfilling. However, even if overfilling were to occur, no change to the sublime mode would occur during the event. Therefore, overfilling is not a threat to primary system pressure and temperature values. During the sublime mode, insufficient heat is available to cause pressures greater than the capacity of the freezer/sublimer vessel. Therefore, no controls are required to ensure that this process will meet EG 3.

The Freon Degrader process is operated at subatmospheric pressures at all times and should primary system failure occur, only local consequences would be possible. With an evacuation already performed, these consequences would be negligible.

The cold recovery process is operated at subatmospheric pressures at all times and should primary system failure occur, only local consequences would be possible. With an evacuation already performed, these consequences would be negligible.

The purge cascade (Building X-326 only) and enrichment cascade cells in this building do not have sufficient hazards to cause significant on-site consequences beyond the immediate area, even if the primary system were to fail. Therefore, EG 3 is not applicable. However, explosive concentrations of cascade gases could potentially result in a failure of the primary system during this operating mode.

Should an explosion occur, only local consequences would be possible, and with an evacuation already performed, these consequences would be negligible.

The enrichment cascade was also evaluated for any actions required to protect primary system integrity should evacuation be necessary. The primary concerns associated with the enrichment cascade process include the dropping of heavy equipment and controlling primary system pressures and temperatures within EG 3.

Heavy equipment may be moved during any of the facility operating modes. If evacuation of the facility is required during movement of this equipment, the design of the transport devices must ensure that continued movement of the equipment is prevented when personnel are not present. The crane operator may be required to move the crane to a designated location to exit. Once the crane operator leaves the controls, no additional movement should occur. On the basis of this concern, the process building cranes are required to stay in their last position upon the operator's release of crane control. This requirement provides assurance that a heavy load will not be dropped as a result of evacuation.

The only other condition that could result in a failure of primary system integrity and in the subsequent release of UF_6 or another hazard in the enrichment cascade would be excessive pressures or temperatures in the operating modes where the compressors are normally operating. The essential controls for preventing overpressurization events (e.g., B-stream block valve closure event [Section 4.3.2.1.3]) and overtemperature (e.g., UF_6/hot metal reaction event [Section 4.3.2.1.1]) are accomplished via motor load indicators in the primary control facility (PCF) (one per cell, to detect compressor operating abnormalities) and associated manual trip capability in the PCF. This provides a comparable level of protection for controlling primary system pressure and temperature as compared to the ACR. Certain compressors are not provided with ammeters for motor load indication or trip capability in the PCF. Trip capability is not provided for top and side purge boosters, and motor load indicators are not provided for any auxiliary compressors. However, motor load indicators and trip capability are provided for all cells connected to these compressors. For those compressors without motor load indicators, large changes in auxiliary compressor loads would be detectable on these adjacent cell motor load indicators so that appropriate action (e.g., tripping compressors) could be initiated to meet EG3. For those compressors without trip capability, tripping of the connected cell would reduce the input pressure, which in turn reduces the pressure in the booster compressors to meet EG3. Therefore, EG 3 could be met should an evacuation event be required for various reasons.

e. <u>Summary of SSCs and TSR Controls</u>

The essential controls for the evacuation of cascade process buildings event are summarized as follows:

- Motor load indicators in PCF—indication of pressure increase (i.e., significant increase in motor load) (EGs 3 and 6);
- Compressor motor manual trip ("00" and "000" cells only) in PCF—decrease pressure and/or eliminate source of heat/friction from PCF (EGs 3 and 6);
- Crane design to prevent movement upon release of controls—prevent primary system failure due to load drop (EG 3)

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators in the PCF, compressor motor manual trip from the PCF, and the process building cranes are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the motor load indicators in the PCF; the process building cranes; and the compressor motor manual trip from the PCF.

4.3.2.1.6 Coolant Tube Rupture Into Primary System (Pressure Increase)

a. Scenario Description

A failure of coolant tube(s) in a cascade cell gas cooler could result in a significant pressure increase in the primary system if the cell was off-stream. If the coolant leak should occur when the cell is on-stream, sufficient volume is available within the cascade to allow for expansion of the coolant without causing any significant pressurization. Coolant tube failures could be caused by initiators such as fatigue cracks or ruptures, joint failures, corrosion pitting, a loss of RCW cooling coupled with a failure of the coolant high-pressure relief system, or a UF_6/hot metal reaction burning a hole in the gas cooler tubes. This event in a cell operating off-stream (limited volume for expansion) could result in a rapid pressure increase above the normal operating pressures within the primary system. The pressure transient may exceed the rated pressure of the converters and expansion joints, etc. This could lead to a UF_6 release regardless of whether the cell is operating above or below atmospheric pressure. This event is an AE based on operational history.

A rupture of coolant tubes into the primary system was evaluated in the PrHA, and it was determined that the consequences could include significant on-site impact if the cell was off-stream and no mitigation were provided. The threshold consequence analysis performed for the PrHA determined that off-site EGs would not be exceeded for this event.

The primary concern associated with this event is controlling the UF_6 release if the primary system fails. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 4 is addressed by the NCS program (see Section 5.2). EG 3 cannot be ensured for this event, therefore the safety actions of (1) building holdup, and (2) emergency response by on-site personnel are required to maintain the effects of a UF_6 release within EGs 1 and 2. No operator action is required for this event, therefore there are no actions required to meet EG 6.

The coolant tube rupture into the primary system produces a pressure transient event in the AE category for a cell operating off-stream in the enrichment cascade process.

b. Source-Term Analysis

The threshold source term analysis performed during the PrHA process determined that the maximum source term for the coolant tube rupture into the primary system event is about 11,000 lb for a "000" cell. This analysis assumes that no operator actions are taken to mitigate the event. No credit was taken for air in-leakage, nor for UF_6 remaining in the cell once it has reached atmospheric pressure. Therefore, the value given is a conservative upper bound on the maximum amount of UF_6 which could be released from a single isolated cell.

If an isolated cell running on recycle were breached, the flow rate would drop as the UF_6 is exhausted. The minimum release duration for this condition is conservatively estimated at 2.5 minutes, for an average release rate of 73 lb/sec which results in a smaller release rate than postulated for the B-stream block valve closure event (Section 4.3.2.1.3). Based on the smaller release rate and the smaller total amount of material released, this event is bounded by the analysis performed for the B-stream block valve closure event.

c. Consequence Analysis

The consequence analysis for the coolant tube rupture into the primary system event will be subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — No essential actions are required of operational personnel in the ACR. However, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) temporary holdup of the release by the existing process building structure, and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. Process building holdup is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the coolant tube rupture into the primary system event. The EG associated with preventing overpressure (EG 3) cannot be ensured if the event occurs when the cell is off-stream. If EG 3 is not met, the other EGs for protection against releases are applicable to the event. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. The operational personnel in the ACR were evaluated and it was determined that there are no required essential actions to meet EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., building holdup, and evacuation of areas upon detection of a release) and the analysis presented for the B-stream block valve closure event (bounding AE event), EGs 1 and 2 would be met for workers outside the process building.

e. Summary of SSCs and TSR Controls

Essential mitigation of any UF_6 releases associated with the coolant tube rupture into primary system event (EGs 1, 2, and 6) are a subset of those described for the B-stream block valve closure event (Section 4.3.2.1.3) and are summarized as follows:

- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.7 Large Release of UF_6 to Atmosphere (Primary System Integrity)

a. Scenario Description

While operating above atmospheric pressure, various primary system failures may result in a large release of UF_6 within the process buildings. These failures can be initiated by a pressure increase event (see Section 4.3.2.1.3) or a primary system integrity failure event (see Section 4.3.2.1.4). The frequency of the large UF_6 release to atmosphere event is an EBE. This categorization is based on cascade operating experience and the low frequency of an AE progressing to the point of a large release.

A large release of UF_6 event was evaluated in the PrHA, and it was determined that the consequences could include significant on-site and off-site impact while operating above atmospheric pressure if no mitigation were provided.

The primary concern associated with this event is controlling the UF_6 release. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the EBE frequency range. EG 3 is not evaluated because a primary system breach is assumed to occur. The safety actions of (1) primary system leakage detection, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), (3) building/housing holdup, and (4) emergency response by on-site personnel would be required to maintain the effects of the UF_6 release within EGs 1, and 2. These actions protect on-site personnel and the off-site public and will maintain habitability of the required control area in accordance with EG 6 as well.

The large UF_6 release to atmosphere produces the most limiting primary system integrity failure event in the EBE category for the cascade facilities. Therefore, this event is analyzed for detailed source terms and consequences. While the heavy equipment drop event (Section 4.3.2.1.8) has a higher initial release rate, a B-stream block valve closure event (Section 4.3.2.1.3) that progresses to the point of a primary system rupture would pose a greater threat to exceed off-site EGs based on a higher sustained release rate (see Section 4.3.2.1.8 source term discussion). Therefore, the analysis is based on the B-stream block valve closure event.

b. Source-Term Analysis

There are many variables associated with the large UF_6 release to atmosphere event that must be characterized to develop a source term. These variables include:

- The duration of the event prior to operator action,
- The size of the potential system failure,
- The location of the failure in the cascade (i.e., equipment associated with "00" or "000" cascade operations – other equipment is not considered credible due to lower pressures), and
- The initial pressures and associated flow rate of UF_6 at the break.

In characterizing this scenario for consequence analysis, the objective was to determine the amount of material that can be released without exceeding the EBE off-site EGs (i.e., 30 mg U and 25 rem) and evaluate the time frame to determine if sufficient operator time is available to mitigate the event prior to exceeding the EGs. This analysis simulates an accidental release of UF_6 from a rupture in the process equipment along a B-line. The largest potential single UF_6 source term in the process buildings would be associated with a "000" cell near the location where pressures and interstage flows are the highest while the cascade is operating at maximum power (2150 MW). The cause of the rupture is a B-line block valve closure event, allowing UF_6 [at a temperature of 290°F (143°C)] to accumulate just above the closed B-line valve so that pressure rises from 21 to 40 psia (0.14 to 0.27 MPa) in that part of the B-stream. The primary system pressure of 40 psia (0.27 MPa) is an assumed failure point that was chosen as a conservative value to minimize the time allowed for operator action considering the time for the pressure to rise and the time of release of material before the off-site EGs would be exceeded. The rupture is postulated to create a 0.667-ft^2 (0.062-m^2) hole [equivalent to a circular hole about 11 in. (28 cm) in diameter] at the point of highest pressure, just above the closed block valve. Hole sizes larger than this do not significantly increase the release rate. Through this hole, UF_6 escapes into the equipment housing. For the baseline case, the release is assumed to be terminated in 480 s (8 min). This is considered to be an upper bound response time. Other time frames are also evaluated (i.e., 1.5 and 4 min) to determine the time allowed for operator action before the EGs are exceeded. An average release rate of 130 lb/s (59 kg/s) was used for this source-term analysis. For the purposes of calculating radiological exposures, the released UF_6 is assumed to be 5.5 wt percent ^{235}U. The sensitivity of this enrichment is discussed in the consequence analysis section.

A modified version of the MELCOR computer code was used to simulate the transport of particles and vapor in the process buildings (see Section 4.3.1.2.2.2). MELCOR simulations show that the UF_6 released into the equipment housing quickly escapes (via cracks, untightened seams, and a door that is assumed to swing open to the outside) to the remainder of the unit and eventually to other units (mostly to the neighboring units). As the UF_6 escapes, it reacts with water vapor to form UO_2F_2 and HF, and it is assumed that all the UF_6 has reacted by the time of release from the "000" building to the outside atmosphere (i.e., no UF_6 is released to the atmosphere). Assuming that the release occurs during the summer, when the ventilation system is configured to work as a once through system [the ventilation configuration that results in the maximum mass of material released to the outside atmosphere], MELCOR simulations indicate that about 43 percent of the UO_2F_2 would settle on the equipment housing floor and on surfaces of equipment and piping within the building. The remaining 57 percent would escape to the outside atmosphere via the exhaust and roof vents flush with top of the building. The total mass of uranium released to the atmosphere for the baseline case would be about 24,045 lb (10,916 kg). Because HF is a gas, most (99.1 percent) of it would escape to the outside atmosphere, and the total mass of HF released for the baseline case would be about 14,165 lb (6431 kg).

Although the initial release into the equipment housing would last 8 min (baseline scenario), much of the UO_2F_2 and HF would be retained in the building for a longer time before being released to the outside atmosphere. The release of material to the outside atmosphere would occur over about 42 min. The release rate and temperature of the plume would vary substantially over this 42-min release period. Releases to the atmosphere would be expected to occur from all building vent locations (modeled as 12 roof vents and 6 motor vents for dispersion calculation purposes).

c. Consequence Analysis

This section presents a detailed quantitative discussion of the consequence calculations that were developed for the large UF_6 release to atmosphere event followed by a discussion of how the EGs are addressed for each receptor.

The detailed consequence calculations are divided into two sections: (1) baseline scenario and (2) effects on consequence estimates by varying scenario parameters.

Baseline scenario. The baseline scenario is as follows: (1) UF_6 is released into the equipment housing for 8 min prior to cell trip, (2) the release to the atmosphere occurs during early morning hours, when the atmosphere is stable, to minimize dispersion and maximize ground-level concentrations of uranium and HF, and (3) building wake effects are included. Parameters used in defining the baseline scenario are listed in Table 4.3-4. For this particular release (i.e., buoyant plumes emitted from vents flush with the tops of the large process building) under a very stable atmosphere (Class F), a higher wind speed of 7 mph (3 m/s), designated F3, provides higher consequence estimates than did a 2 mph (1 m/s) wind speed discussed in the dropped cylinder (Section 4.3.2.2.15) and parent/daughter transfer cases (Section 4.3.2.2.10). Because higher wind speeds are associated with lower final plume heights, the plume intersects the ground nearer the release site under F3 conditions than under F1 conditions. At lesser distances from the source, with correspondingly less dispersion of the plume, the maximum ground-level concentrations for this release are greater with higher wind speeds. F3 conditions occur slightly less than 1 percent of the time on an annual basis [averaged over a 1-yr period, 1993].

Because the ventilation system configuration during warm weather periods results in significantly larger masses of material being released to the atmosphere, the temperature for the baseline scenario was assumed to be 70°F (21°C), a value associated with F stability in the summer. Although lower temperatures are possible under F stability, 70°F (21°C) was chosen because a high temperature results in higher consequence estimates because the height of final plume rise decreases as the temperature difference between the plume and the atmosphere decreases.

Unlike the dropped cylinder (Section 4.3.2.2.15) and the parent/daughter transfer cases (Section 4.3.2.2.10), the released UF_6 is assumed to have completely reacted to UO_2F_2 and HF before being released into the atmosphere. Therefore, the relative humidity, used to determine atmospheric water vapor content, is not a parameter in the dispersion modeling because there are no UF_6 reactions occurring as the plume disperses downwind.

The WAKE model (see Section 4.3.1.2.3.4.2) was used to predict downwind concentrations of uranium and HF. Figures 4.3-11 through 4.3-13 show estimated downwind consequences associated with the baseline scenario. Note that the baseline scenario (F3) is represented by the top curve on these figures. The other two curves are for different meteorological conditions and are discussed below. Calculated values of the consequence parameters were compared to EBE guideline values for uranium (25 rem for U radiological toxicity, and 30 mg U uptake for U chemical toxicity), and to the Emergency Response Planning Guidelines (ERPG-2) for HF (20 ppm for 1 hour).

Table 4.3-5 lists specific consequence estimates at the nearest site boundary, 1 mi (1600 m), and 5 mi (8050 m) downwind of the release point. The nearest site boundary is located about 0.68 mi (1100 m) southeast of the eastern face of Building X-333. Consequence estimates for uranium chemical toxicity (30 mg of inhaled uranium) and HF exposure (20 ppm averaged over a 1-h period) exceed their respective comparison values at the nearest site boundary. The uranium chemical toxicity comparison value is exceeded just beyond 1.6 mi (2600 m), and the HF exposure comparison value is exceeded to about 1.7 mi (2700 m). The radioactive dose, which is sensitive to enrichment level, does not exceed the comparison value of 25 rem at downwind distances equal to or beyond 0.062 mi (100 m).

Effects on consequence estimates by varying scenario parameters. The following parameters were varied to obtain some uncertainty estimates and provide some characterization of the range of potential consequences: (1) the duration of release of UF_6 inside the building, (2) meteorological conditions, and (3) building wake effects. The results provide perspective for interpretation of the baseline scenario. The consequences presented in this section are more probable, providing a lower-bound estimate of potential consequences. For the duration of release and building wake discussions, consequence estimate comparisons are not shown for radioactive dose and HF exposure because these estimates display the same general trend as the uranium chemical toxicity dose. A discussion of the uncertainties in the analysis that have not been quantified is provided.

Duration of release into the building — The baseline case assumes that the compressors are tripped in 8 min to terminate the release. If the compressors are tripped in about 4 min (240 s) or 1.5 min (90 s), the corresponding amount of UF_6 released into the process building would be about 31,200 lb (14,165 kg) and 11,700 lb (5312 kg) respectively [assuming an average release rate of 130 lb/s (59 kg/s)]. For these comparisons, the percentage of UO_2F_2 deposited in the building (43 percent) was assumed to be the same as that used in the baseline scenario. For these cases, the release durations to the outside atmosphere were assumed to be about 23 min for the 4-min release into the building and 9 min for the 1.5-min release into the building, based on scaling calculations.

As shown in Fig. 4.3-14, consequence estimates for the 4-min and 1.5-min releases are lower than those for the 8-min release at all downwind distances. With a 4-min release into the building, the uranium chemical toxicity dose drops below 30 mg close to the nearest site boundary. With a 1.5-min release into the building, the uranium chemical toxicity dose drops below 10 mg close to the nearest site boundary.

Meteorological conditions — Consequence estimates were made for two additional meteorological conditions to compare with the baseline scenario (F3). These additional conditions are (1) a typical condition that does not provide low consequence estimates (D4) and (2) a typical condition that provides low consequence estimates (C4). For D4, the ambient air temperature was assumed to be 80°F (26.7°C). This temperature is a typical summer daytime temperature under neutral atmospheric conditions, consistent with the building ventilation condition used in the MELCOR modeling. For the C4 simulation, an ambient temperature of 80°F (26.7°C) is also used.

Figures 4.3-11 through 4.3-13 show consequence estimates for uranium chemical toxicity, radioactive dose, and HF toxicity exposure resulting during baseline (F3), D4, and C4 meteorological conditions. Consequence estimates under D4 conditions are slightly higher than under F3 conditions between downwind distances of 0.12 mi (200 m) and 0.25 mi (400 m). Although increased turbulent mixing associated with D stability can result in higher pollutant concentrations at ground-level close to the source, by the time the plume is about 0.25 mi (400 m) from the source, the general relationship of increased atmospheric turbulence producing decreased pollutant concentrations has established itself. Under D4 conditions, uranium chemical and HF toxicity estimates are below guideline values at distances of about 1 mi (1600 m) and greater. Under C4 conditions, uranium chemical and HF toxicity estimates are below guideline values at distances of about 0.43 mi (700 m) and greater.

Building wake effects,—Wake effects cause higher initial dispersion, which generally has the effect of reducing ground-level concentrations far from an elevated source. However, near the source, high initial mixing can lead to high pollutant concentrations being brought to ground level before the pollutants move very far from the elevated source and undergo much lateral dispersion. As distance from the source increases, this initial wake-induced dispersion becomes smaller and smaller relative to the normal lateral and vertical dispersion of the plume, which becomes increasingly larger. At large distances from the source, wake effects and the effects of normal dispersion begin to complement, rather than counteract, each other, so that concentrations under wake conditions become almost equal to the no-wake case. However, as shown in Fig. 4.3-15, wake effects for this release scenario lead to higher consequence estimates at distances beyond 5 mi (8050 m). Note that results from the two cases would converge at distances beyond 5 mi (8050 m). For the no-wake case, consequence estimates are below the uranium chemical toxicity dose guideline value for all downwind distances.

Uncertainties not quantified —Large air intakes are located at ground level on the outside of each process building. Any fraction of the plume captured into the building recirculation cavity may be caught by these air intakes, effectively preventing the captured plume mass from dispersing downwind. Air from the intakes enters the process buildings at the ground floor and is moved to the operating floor via large supply fans. This air would eventually be redirected to the cell floor, out the vents and motor exhaust ducts, thereby reentering the atmosphere. The fraction of the plume entering this intake circulation would be diluted, and retention time of the released material in the building would be increased. This would lower the emission rate of the released material to the atmosphere and also lower the temperature of the plume from the vents. Downwind consequence estimates would be less than those predicted for the base scenario because of the lower emission rate. Also, with a lower plume temperature, a larger fraction of the plume would enter the recirculation cavity, repeating the intake cycle and ultimately lowering downwind consequence estimates.

The following sections describe how the EGs are addressed for the different receptors.

Local workers in the immediate area—Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping are enclosed in housings to maintain normal operating temperatures.The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — Operational personnel who are required to take mitigative action are located in the ACR, which typically would not be impacted by the event. During cold weather periods, the air on the cell floor is recirculated inside the building to minimize heat loss and maintain building temperatures. This mode of operation could result in elevated concentrations of HF in the ACR area, which would result in evacuation of the ACR. However, an evaluation of this potential concern concluded that adequate time is available for operators perform the required actions (i.e., about 4 min) prior to any evacuation should the need arise. However, once these essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) detection of the release, (2) minimization of the release by tripping applicable cells, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is to detect the release of UF_6. Equipment that has the potential for causing a large release (i.e., "00" or "000" building compressors which are intended to operate above atmospheric pressure) are equipped with UF_6 release detection that alarms in the applicable ACR. Other portions of the cascade do not have operating pressures or inventories sufficient to result in any significant consequences outside the building, and this receptor would not be applicable (see Section 4.2.6.4). The second essential control, is for operators to trip the appropriate cell(s) to reduce the pressure and minimize the release of UF_6. The shutdown of a cell will decrease the cell high side pressure to about one-half the normal operating pressure, which will bring the cell uniformly below atmospheric pressure. Pressure at an interbuilding booster compressor can be reduced, if needed, by tripping the compressor motor or by tripping adjacent enrichment cell compressor motors. Once the pressure has dropped to atmospheric pressure or below, the release of material is effectively terminated for any potential exposure outside the process building. Sufficient time is then available to perform any necessary valve evolutions to isolate the cell. The third essential control, process building holdup, is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — Because this event, as described, could involve a significant UF_6 release, a scenario is presented that indicates how much material is required to be released at the assumed conservative flow rate to result in the 30 mg U exposure at the nearest site boundary. For the worst-case conditions, the results indicate that it takes about 31,200 lb (14,165 kg) of UF_6 to reach a 30 mg U exposure at the nearest site boundary. With the conservative release rate assumed, this would result in a release time of about 4 min. The large UF_6 release to atmosphere event is characterized by the B-stream block valve closure event. The large UF_6 release to atmosphere event ignores the time required to reach a 40-psia (0.27-MPa) cascade pressure, at which the primary system is assumed to fail (about 2.5 min, see Section 4.3.2.1.3). This extra time would allow the operator even more time to react to the event (i.e., about 6.5 min to trip the compressors for the worst case assumptions). There is sufficient time for operator response based on operator presence near the controls when this event is expected to occur. In addition, with any quicker response time, different wind conditions, ventilation system settings, or variations in the wake effects, the resulting consequences would be below the guidelines.

d. Comparison With Guidelines

For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the ACR were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, cell trip, building holdup, and evacuation of areas upon detection of a release), EGs 1 and 2 would be met for workers outside the process building. Finally, an analysis was performed to determine the worst-case scenario at which an off-site exposure of 30 mg U would be reached. Results of this analysis indicated that the operator action could be accomplished within the time frame to meet the EGs.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for the large UF_6 release to atmosphere event are summarized as follows:

- Compressor motor manual trip in ACR—minimize release for all receptors except local worker (EGs 1, 2, and 6);
- UF_6 release detection system for cells operating above atmospheric pressure—all receptors except local worker (EGs 1, 2, and 6);
- Equipment housing holdup for compressors operating above atmospheric pressure—off-site public (EGs 1 and 2);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building and the off-site public (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The compressor motor manual trip system, UF_6 release detection system, equipment housings, and process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the compressor motor manual trip system; UF_6 release detection system; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.1.8 Heavy Equipment Drop (Primary System Integrity)

a. Scenario Description

During process building operations, the change-out of cascade equipment for maintenance requires that heavy equipment (converters, compressors, valves, etc.) occasionally be moved over operating cells by overhead building cranes and lifting fixtures. If this equipment should be dropped because of a failure of the crane or lifting rig, the primary system could be breached, and UF_6 released if the cell is operating above atmospheric pressure. The fall of a crane itself is not considered a credible release initiator. A crane that is normally parked over cascade equipment has been shown to be seismically qualified in this position (see Section 3.8). The greatest potential for a UF_6 release would be from a drop of a converter on a B-bypass line operating at the maximum operating pressure. The heavy equipment drop event has been assigned to the EBE frequency category. The assignment is justified because there is no historical precedent for a release of UF_6 as a result of such an event, and controls such as design and inspections placed on the cranes and lifting fixtures and operating procedures are in place to prevent the event.

Dropping of heavy equipment was evaluated in the PrHA and it was determined that if no mitigation were provided, the potential consequences could include (1) significant off-site and on-site impact if the breached cascade process equipment were operating above atmospheric pressure and on-stream, or (2) significant on-site impact if the cascade process equipment were operating above atmospheric pressure and off-stream, and in the freeze, sublime, or hot standby modes for the freezer/sublimer process.

The primary concern associated with this event is controlling the UF_6 release. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the EBE frequency range. EG 3 is not addressed because a primary system breach is assumed to occur. The safety actions of (1) primary system leakage detection, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), and (3) building holdup would be required to maintain the effects of the UF_6 release within EGs 1 and 2. These actions protect on-site personnel and the off-site public and will maintain habitability of the required control area in accordance with EG 6 as well.

The heavy equipment drop event was chosen as a limiting event in the EBE category because of the different controls required to detect the potential release of UF_6 quickly.

b. Source-Term Analysis

In order for a heavy equipment drop event to produce a significant release of UF_6 to the atmosphere, the breaches must be in cells or equipment operating above atmospheric pressure. Breaches of this type at sub-atmospheric pressure will result in inleakage to the cascade with minimal loss of UF_6. If this event were to damage a cell operating off-stream, the resulting source term would be consistent with the source term presented for the coolant tube rupture into primary system event (Section 4.3.2.1.6). For the operating mode, this event has the potential to completely sever a B-line (or significantly damage other equipment), which could result in initial release rates exceeding those indicated for the large UF_6 release to atmosphere (Section 4.4.2.1.1.7) event. If the event were to damage a freezer/sublimer, the source term is bounded by the cascade operating mode case. Therefore, the remainder of the discussion will focus on the event affecting equipment operating in the cascade operating mode. If a B-line at maximum operating pressure were to be completely severed, the suction side of the break would initially depressurize to atmospheric pressure at which time air would be pulled into the suction side of the compressor. This will cause the compressors in the vicinity of the break to surge, thereby reducing their pumping ability and significantly reducing the ability of the compressors to continue operating or to sustain the high initial release rate. Also, as long as the compressors continue to operate, the air would be mixed with the UF_6 in the cascade in the vicinity of the break, reducing the release of UF_6 by diluting the released stream.

Because of the potential for a large initial release rate, the following administrative controls are required to ensure early detection and mitigation of the event. In process buildings containing equipment that is operating above atmospheric pressure:

- Only trained and qualified crane operators are allowed to operate the process building cranes.
- Crane equipment is inspected at appropriate intervals and for obvious defects before each use.
- ACR operating personnel are informed of time and travel path of equipment being moved overhead of cells prior to such movements.
- Personnel, other than the crane operator, are present during the movement, are in visual contact with the equipment being moved, and are able to contact ACR personnel should an event occur.

In the unlikely event of an equipment drop that damages the primary system, the personnel stationed at the lift site would inform the ACR operator, and if the ACR operator had not already taken actions to trip the affected cell in response to other indications (i.e., motor load indicators or UF_6 release detection system annunciation), the cell would be shut down, and the cell pressure would rapidly fall to below atmospheric pressure limiting the UF_6 release. The cell floor observer method of detection provides the essential control for detection of the release by the ACR. Based on this control, the fact that the B-line pressure at failure is less than that described in the large UF_6 release to atmosphere scenario, and the fact that the initial flow rate of a completely severed B-line cannot be sustained, this event is bounded by the large UF_6 release to atmosphere event (Section 4.3.2.1.7).

c. Consequence Analysis

The consequence analysis for the heavy equipment drop event is subdivided to address the various receptors. As stated previously, the event will only result in significant consequences if it occurs in equipment operating above atmospheric pressure. In addition, if the event occurs in a cell operating off-stream, the source term and consequences would be consistent with the coolant tube rupture into primary system event (Section 4.3.2.1.6).

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the cascade process buildings is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR — The analysis for the large UF_6 release to atmosphere event (Section 4.3.2.1.7) concluded that adequate time is available for operational personnel to accomplish the essential safety actions (leakage detection and mitigation). Because the heavy equipment drop event source term is bounded by the large UF_6 release to atmosphere event, and because of the administrative requirements related to crane movements to ensure early detection and mitigation of the event, adequate time would also be available for operational personnel to detect and mitigate this event prior to any need to evacuate the ACR. However, once these essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are (1) detection of the release, (2) minimization of the release by tripping applicable cells, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is to detect the release of UF_6. This control will be accomplished quickly based on the previously defined administrative controls. The second essential control, is for operators to trip the appropriate cell(s) to reduce the pressure and minimize the release of UF_6. The shutdown of a cell(s) will decrease the cell(s) high side pressure to about one-half the normal operating pressure, which will bring the cell(s) uniformly below atmospheric pressure. Pressure at an interbuilding booster compressor can be reduced, if needed, by tripping the compressor motor or by tripping adjacent enrichment cell compressor motors. Once the pressure has dropped to atmospheric pressure or below, the release of material is effectively terminated for any potential exposure outside the process building. Sufficient time is then available to perform any necessary valve evolutions to isolate the cell. The third essential control, process building holdup, is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released via the exhaust and roof vents flush with the top of the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — The source term for the heavy equipment drop event is bounded by the source term for the large UF_6 release to atmosphere event (Section 4.3.2.1.7). The essential controls for mitigating the heavy equipment drop event are the same as those described for the large UF_6 release to atmosphere event, with the addition of the controls associated with crane operation/inspection, and with the exception of the UF_6 release detection system and equipment housing hold-up. Based on these controls and the analysis presented for the large UF_6 release to atmosphere event, operator actions can be accomplished in sufficient time to preclude exceeding off-site EGs.

d. <u>Comparison With Guidelines</u>

For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the ACR were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the ACR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, cell trip, building holdup, and evacuation of areas upon detection of a release) and the analysis presented for the large UF_6 release to atmosphere event (Section 4.3.2.1.7), EGs 1 and 2 would be met for workers outside the process building. Finally, based on the analysis presented for the large UF_6 release to atmosphere event, the essential operator actions could be accomplished in sufficient time to preclude exceeding off-site EGs.

e. <u>Summary of SSCs and TSR Controls</u>

The essential controls for the heavy equipment drop event are the same as those described for the large UF_6 release to atmosphere event (Section 4.3.2.1.7), with the addition of the controls associated with crane operation/inspection, and with the exception of the UF_6 release detection system and equipment housings. The essential controls for the applicable receptors are summarized as follows:

- Crane equipment is inspected at appropriate intervals and for obvious defects before each use—initial condition (EG 5);
- In process buildings where equipment is operating above atmospheric pressure, ACR operating personnel informed of time and travel path of equipment being moved overhead of cells prior to such movements—pre-notification of potential operational problems (EGs 1, 2, and 6);
- In process buildings where equipment is operating above atmospheric pressure, personnel, other than the crane operator, are present during the movement, will be in visual contact with the equipment being moved, and will be able to contact ACR personnel should an event occur—notification to ACR personnel (EGs 1, 2 and 6);
- Compressor motor manual trip in ACR—minimize release for all receptors except local worker (EGs 1, 2, and 6);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building and the off-site public (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The compressor motor manual trip system, process building cranes, and process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the compressor motor manual trip system; and administrative requirements for procedures and training of workers for evacuation actions, for protective equipment/measures for crane operators, and for operations/inspections of process building cranes.

4.3.2.1.9 Large Fire (External Event)

a. <u>Scenario Description</u>

During any of the cascade facility processes and their associated operating modes, various types of fires could occur. The hazard analysis identified the enrichment cascade and the freezer/sublimer (F/S) processes as having the most potential for significant consequences. The withdrawal facilities located in the process buildings were also considered in this event. Other processes are limited in quantity of material and pressures such that no significant impact would occur, even if primary system integrity is lost. Other hazards of concern in a fire would be the potential for criticality due to the loss of primary system integrity and subsequent moderation from the fire protection system. Criticality concerns are addressed in Section 5.2 and in Section 4.3.2.6. The fire protection program is described in Section 5.4. The capabilities of the fixed fire suppression system and the onsite fire department provide a high degree of confidence that a postulated fire could be contained and extinguished prior to a breach of the primary system. However, for the purposes of this scenario, it is assumed that a large fire could occur that results in a failure of the primary system and a release of UF_6. Based on the installed fire suppression and on-site fire fighting capability, the large fire is categorized as an EBE.

A large fire was evaluated in the PrHA and it was determined that if no mitigation were provided, the consequences could include significant impacts beyond the immediate area in all enrichment cascade and freezer/sublimer operating modes.

The large amount of lube oil in the process buildings is an unavoidable fire hazard. The most likely cause of a large fire is the rupture of a compressor bearing lube oil supply line. This could cause compressor bearing overheating and a small localized fire. The fire would then have to spread to the point that it exceeded the capability of the fire protection systems as additional oil discharged. Another cause is an oil pump failure resulting in a release of oil and the friction heating of pump parts that could ignite the oil pool that would collect in the diked oil pit area. Other failures of oil piping will not typically result in a fire unless an ignition source is available (e.g., cutting, welding, electrical failures).

A large fire is considered to be a potential threat to primary system integrity either (1) directly from overtemperature or, (2) directly by weakening the support structures and causing failure due to falling debris. Another possibility is for a fire to indirectly cause primary system failure due to control system damage. For example, if the control system for an A valve were damaged and a cascade split were initiated, it would result in a similar scenario to the B-block valve closure event (Section 4.3.2.1.3). If the ACR is inhabited and an event such as this occurs, the essential controls presented for that scenario (Section 4.3.2.1.3 for this example) are applicable. In the event that the ACR were evacuated due to the fire, the essential controls presented for the evacuation of process building (Section 4.3.2.1.5) are applicable.

In order for this event to produce a release of UF_6 to atmosphere, the failure must be in the cascade cells or equipment piping. A large fire in the vicinity of the F/S vessel could potentially sublime the solid UF_6 in the vessel as well as cause a direct failure of primary system integrity. It is assumed in this analysis that the entire process building inventory is at risk, which includes the F/S vessel inventories.

The primary concerns associated with this event are (1) controlling the fire and (2) minimizing the effects of any UF_6 released should primary system integrity be lost. The applicable EGs associated with this event are all the EGs for the EBE frequency range. The safety actions of (1) building holdup, and (2) emergency response are the essential actions identified to maintain the effects of the UF_6 release within EGs 1 and 2. Habitability of the ACR per EG 6 cannot be ensured for this event, and is not required due to the expectation that the EGs 1 and 2 will be met regardless of actions taken in the ACR (see the consequence analysis section).

The large fire event produces the most limiting external event associated with fires in the EBE category.

b. <u>Source-Term Analysis</u>

The large fire event is categorized as an EBE because of the preventive/mitigative measures in place (i.e., fire protection program and fire protection system). Variables associated with this event that would be required to develop a source are as follows:

- The duration of the event,
- The size of the potential system failure (if any),
- The location of the potential failure in the cascade (e.g., "00" or "000" equipment), and
- The amount of fuel available for the fire.

Large fires could potentially result in significant consequences beyond the immediate area. However, the typical result of a large fire is a hot, buoyant plume giving rise to an elevated release of any hazardous material. With a significantly elevated release, minimal health effects would result off-site. This is consistent with the consequences for a cylinder fire event versus the release from a liquid-filled cylinder. The consequences for the cylinder fire event were evaluated (Section 4.3.2.2.16), and consequences exceeding 30 mg U were predicted out to less than 990 ft (300 m). Conversely, the release from a liquid-filled cylinder exceeds 30 mg U more than 3.4 mi (5500 m) downwind (see Section 4.3.2.2.15). Therefore, a specific source term was not developed for this event. However, a consequences analysis is provided to indicate the essential controls for minimizing the effects of this event.

c. <u>Consequence Analysis</u>

The consequence analysis for the large fire event will be subdivided to address the different receptors.

Local workers in the immediate area — Because of the time it would take for the primary system integrity to fail should a large fire occur, local workers in the area would have already evacuated the area due to the fire. Therefore, no specific requirements are identified for the local worker.

Operational personnel in the ACR — Depending on the timing of the event and the progression, operator action to trip operating oil pumps, compressors, or setup valving may be attempted to reduce lube oil available to the fire or to minimize UF_6 releases. Cell trips can also be performed from the PCF. Switchyard operators can trip cells or open breakers to de-energize oil pumps and other equipment as necessary. However, none of these actions are considered essential because in the event that the fire directly results in a primary system failure, none of these actions would significantly effect the quantity of UF_6 ultimately released. This is because of the extensive time required to reduce building inventory. The main concern is for operational personnel in the ACR to evacuate the facility when that decision is made.

Workers outside the process buildings —The essential controls for protecting on-site personnel outside the process buildings are (1) elevated dispersion of any release by the existing process building structure, and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The process building is expected to cause most of the UF_6 that escapes the building to be released at an elevated point. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public —As indicated in the source term discussion, this event is not likely to cause any off-site impact because of the extreme high temperatures generated from the fire and the rise of the plume from the heat of the fire that would occur. Therefore no off-site exposures exceeding the EGs are expected. However, the fire protection system and the fire protection program described in Section 5.4 are extremely important in preventing a small fire from becoming the large fire that could initiate this event.

d. Comparison With Guidelines

As indicated in the consequence analysis, no direct calculations of consequences were performed to provide a comparison to the EGs. However, the controls provided in the consequence analysis are expected to maintain the effects of the event within the applicable EGs.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for the large fire event are summarized as follows:

- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Process building structure providing elevated dispersion—on-site workers outside process building and the off-site public (EGs 1 and 2);
- Process building fixed fire protection system—minimize potential and mitigation of a large fire (EG 5); and
- Fire Protection Program—minimize potential for a large fire (normal operation, EG 5 only)

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The process buildings, and process building fixed fire suppression systems are identified as important to safety SSCs. See Section 3.8 for details including safety classification.

- TSRs are provided for the fire protection system and its associated water supply from the HPFWS, and administrative requirements for the Fire Protection Program, and for procedures and training of workers for evacuation actions.

4.3.2.2 UF_6 Handling and Storage Facilities

Table 4.2-11 documents the results of the hazards analysis for each of the UF_6 handling and storage facilities processes. The UF_6 handling and storage processes consist of feed vaporization, toll transfer and sampling, product and tails withdrawal, and cylinder storage. The principal hazard evaluated for this group is UF_6 and its reaction products. As noted earlier in Chapter 4, the shutdown of enrichment operations has reduced the probability and consequences of accidents described in this section related to the cascade product withdrawal systems. In addition, autoclave cascade feed related accidents are not applicable when enrichment operations are shutdown. The following summarizes the hazards and results of the accident analysis involving these facilities.

4.3.2.2.1 Compressor Failure–UF_6/Hot Metal Reaction (Temperature Increase)

a. Scenario Description

UF_6 reacts with most metals. Typically the reaction between UF_6 and the metals used to fabricate gaseous diffusion process equipment is relatively mild due to: (1) the relatively moderate temperatures associated with the gaseous diffusion processes, and (2) a reaction-inhibiting layer of reaction products that is formed on the metal surfaces. However, if the metal is heated above its solidus temperature (about 1100°F for aluminum) in the presence of UF_6, then the exothermic reaction is not inhibited and can become self-sustaining. Once the reaction becomes self-sustaining, it can continue as long as UF_6 and exposed metal are available for the reaction. Due to the localized nature of the event, there is no direct indication that a self-sustaining UF_6/hot metal reaction is occurring in the process. Therefore, a self-sustaining UF_6/hot metal reaction can cause a primary system failure that would result in a loss of primary system failure.

An event involving a UF_6/hot metal reaction is applicable for the centrifugal compressors used in the ERP, LAW and Tails withdrawal facilities.

The excessive heating required to start a UF_6/hot metal reaction can be generated in the centrifugal compressors due to various initiators such as frictional heating generated by misaligned compressor parts rubbing together, foreign objects in the compressor's suction, etc. A loss of physical integrity associated with a UF_6/hot metal reaction in the first stage centrifugal compressors would result in an air leakage into the withdrawal process since both the inlet and outlet sides of the first stage centrifugal compressors operate at sub-atmospheric pressures. However, should the second stage centrifugal compressors suffer a similar type of failure, a UF_6 gas release could be expected since the second stage compressors operate with discharge pressures that are above atmospheric pressure.

The UF_6/hot metal reaction event is classified in the AE frequency range because a single active failure or operator error could cause the event. The bounding compressor failure involves the UF_6/hot metal reaction. Past operating experience indicates that many compressor failures have occurred with a few resulting in a UF_6/hot metal reaction. This was typically discovered only when the compressor was removed and opened up for repair. Therefore, failure of the primary system is rarely experienced for this event. However, for purposes of this analysis, a compressor failure with an associated UF_6/hot metal reaction that results in failure of the primary system is assumed to occur in the AE frequency category.

The primary concerns associated with a UF_6/hot metal reaction event in the withdrawal facilities are (1) the primary system temperature increase associated with the reaction and (2) controlling the UF_6 release if the primary system should fail. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range, EG 4 is addressed by the NCS Program (See Section 5.2). The first safety action required to meet the other EGs would be to maintain primary system temperature within EG 3 limits. This action will prevent primary system failure, protect on-site personnel, and maintain habitability of the required control area by preventing a UF_6 release. If primary system temperature cannot be maintained within EG 3, a breach of the primary system integrity could conceivably occur. The safety actions of (1) visual/odor detection of primary leakage, (2) primary system pressure control (to reduce the primary system pressure and minimize the UF_6 release), (3) building holdup, and (4) emergency response by onsite personnel would be required to maintain the effects of a UF_6 release within EGs 1, 2, and 6. These actions protect on-site personnel and will maintain habitability of the required control area in accordance with EG 6 as well.

The expected primary system failure for a UF_6/hot metal reaction event in the withdrawal facilities would begin as a small hole in or near the centrifugal compressor. This hole would gradually enlarge as the event progressed. Due to the lack of direct indication that a UF_6/hot metal event is occurring, a failure of the primary system was assumed to occur for this analysis. It was determined that the consequences of the event could result in significant on-site impact if no mitigation were provided. The initiators, detection methods, EGs, safety actions, frequency, and mitigative actions associated with this event in the withdrawal facilities are similar to those described for a UF_6/hot metal reaction event for compressors used in cascade operations (see Section 4.3.2.1.1). Due to these similarities, only the differences unique to the withdrawal process event will be discussed in the following analyses.

b. <u>Source-Term Analysis</u>

The centrifugal compressors are subject to UF_6/hot metal reactions that could result in a primary system integrity failure. A primary system failure near the discharge of the second stage centrifugal compressors could result in a significant UF_6 release since the discharge of these compressors are above atmospheric pressure. The compressor failure-UF_6/hot metal reaction event is similar for both the withdrawal and cascade facilities (see Section 4.3.2.1.1). However, due to differences in equipment configuration, the source term associated with a UF_6/hot metal reaction in the withdrawal facilities is assumed to be similar to the source term developed for a process line failure at the compression discharge scenario (see Section 4.3.2.2.12).

A process line failure (i.e., breach) at the compressor discharge in the withdrawal facilities is expected to result primarily in a vapor phase release of UF_6. Process design considerations (i.e., height differences between the accumulator and condenser) would tend to preclude any significant liquid-phase releases at a physical integrity failure near the compression discharge. However, the source term analysis conservatively modeled the release assuming the compression source continues to pump vapor through the breach at 1.31 pounds per second at 30 psia while liquid UF_6 back flows through the breach at 6.73 pounds per second from other withdrawal process equipment. The gas-phase portion on the source term assumes the release is equivalent to the normal output of the compression source. The liquid-phase backflow portion of the source term was modeled as resulting from a one-inch diameter breach in the bottom of a vertical cylindrical tank 60 inches in diameter and 120 inches tall containing approximately 21,000 pounds of liquid UF_6. This tank is roughly modeled after a UF_6 accumulator process tank that is typically near empty with accumulations of UF_6 usually happening only during cylinder changes. The largest accumulator at Tails has a capacity of approximately 13,300 pounds of liquid UF_6 and the two connected ten inch diameter accumulators have a capacity of approximately 2,900 pounds of liquid UF_6; the four eight inch diameter accumulators at LAW are connected in pairs with each pair having a capacity of approximately 2,500 pounds of liquid UF_6; the four accumulators at ERP are connected in pairs with the eight inch diameter pair having a capacity of approximately 2,500 pounds liquid UF_6 and the four inch diameter pair having a capacity of approximately 700 pounds of liquid UF_6.

This liquid-phase back flow portion of the source term represents a much larger release than would be expected from a primary system failure at the compression discharge. Because the UF_6 accumulator and condenser are located at a lower elevation than the compressor discharge, it would not be possible for liquid UF_6 to flow upward and out of the compressor discharge line breach. The expected vapor flow from the top of the accumulator through the condenser and interconnecting piping and valves would be much less than the modeled 6.73 pounds per second (probably on the order of one pound per second). Therefore, the combined 8.04 pounds per second release rate developed by the source-term analysis represents a release that is much larger than the actual UF_6 release expected to occur from a UF_6/hot metal reaction event that causes a process line failure at the compression discharge.

c. <u>Consequence Analysis</u>

As discussed in the source-term analysis, it is unlikely that a UF_6/hot metal reaction would cause a line failure that would result in a 8.04 pounds per second release rate. However, the consequences associated with releasing UF_6 in the withdrawal facilities at a rate of 8.04 pounds per second have been evaluated. This consequence analysis determined that if no mitigation were provided, the hazardous material doses at a distance of 1000 meters (actual distance from the withdrawal stations to the nearest site boundary varies from 1300 to 1500 meters) for a 30-minute plume exposure associated with this release would be 9.8 mg of uranium and 5.4 ppm (one hour equivalent exposure) of hydrogen fluoride. The uranium exposure consequence would satisfy the EGs for the AE category. The consequences that this exposure level would have on different receptors are discussed below:

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the withdrawal buildings is: (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide adequate indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping that are common with the withdrawal facilities are enclosed in housings to maintain normal operating temperatures. The configuration of the housings required to maintain normal operating temperatures, and therefore to keep the UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g., emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR or LCR — Operating personnel who can take mitigative action (i.e., trip motors) in the event of a process gas release are located in the associated ACR (LAW & TAILS) or LCR (ERP). The ACR and LCR would not be affected by the release in the time frame required to take mitigative actions. However, if operating personnel must be evacuated from the ACR or LCR due to the release, then the required mitigative actions could be accomplished from the X-300 building or other locations.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the process buildings are: (1) detection of the release, (2) minimization of the release by tripping the second stage centrifugal compressors, (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. Motor load indicators provide an indication of abnormal compressor operations that could lead to failure (i.e, surging and/or loss of load). Typically, this indication will be detected and corrective action will be taken prior to the initiation of a UF_6/hot metal reaction or prior to a UF_6/hot metal reaction progressing to the point of a primary system breach. However, if a primary system failure does occur and a release is confirmed (e.g., operator visual/odor indications and/or UF_6 smoke detectors), then actions can be taken to trip the appropriate second stage compressor motors to minimize the release. Once the second stage compressors stop operating, the release of material from the compressor is effectively terminated since the associated first stage compressors operate at sub-atmospheric pressures. However, the release from the other process sources (i.e., accumulator and condenser) may continue until they are exhausted. Withdrawal process equipment housings outside of the cascade cells are not credited with providing a time delay between a release of UF_6 from the primary system to release from the building. The existing process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released at an elevated point. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — As indicated above, the postulated compressor failure-UF_6/hot metal reaction event will not result in consequences that would exceed the 10-mg EG for the AE frequency category with no mitigation other than building holdup. However, the smaller source term expected and the release mitigation actions identified for on-site personnel provide additional assurance that off-site consequences of this event will stay below the 10-mg U EG.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. The equipment configuration does not provide for automatic detection and trips on high temperatures, so compliance with EG 3 cannot be verified during normal operation. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operations personnel in the ACR or LCR were evaluated (i.e., tripping the second stage centrifugal compressors), and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects the habitability of the ACR or LCR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded and the necessary actions could be accomplished from the X-300 building or other locations. In addition, based on the controls identified, (i.e., release detection, second stage centrifugal compressor trip, building holdup, evacuation of areas upon detection of the release), EGs 1 and 2 would be met for workers outside the process building. Finally, an analysis was performed which determined that, if no mitigation were provided, off-site exposure would not exceed guidelines.

e. Summary of SSCs and TSR Controls

The essential controls for the UF_6/hot metal reaction event associated with meeting EG 3 are to minimize the potential for failing the UF_6 primary system due to a temperature increase. These controls include detection of the compressor failure and minimizing the source of heat/friction that could lead to the elevated temperatures that allow the UF_6/hot metal reaction. Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Motor load indicators in ACR (LAW & TAILS) or LCR (ERP) for second stage compressors—early detection of compressor failure (i.e., surging and/or loss of load) (EG 3 only); and
- Compressor motor manual trip in ACR (LAW & TAILS) or LCR (ERP) for second stage compressors—elimination of heat/friction (EG 3 only).

Essential mitigation of any UF_6 releases associated with this event (EGs 1, 2, and 6) are summarized as follows:

- Compressor motor manual trip for second stage compressors in ACR (LAW & TAILS) or LCR (ERP)—minimize release to workers outside the process building (EGs 1, 2, and 6)
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- UF_6 release detection associated with withdrawal compressors—workers outside process building (EGs 1 and 2);
- Process building holdup—workers outside process building (EGs 1 and 2); and
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators and compressor motor manual trip system for second stage compressors, UF_6 release detection, and the process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the motor load indicators and compressor motor manual trip system for second stage compressors; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.2.2 Autoclave Steam Control Valve Fails Open (Pressure Increase)

a. <u>**Scenario Description**</u>

During normal autoclave operations in X-342-A, X-343, and X-344-A, the autoclave is filled with steam to heat the UF_6 in cylinders to a liquid state. Once the UF_6 has reached the liquid state, a prolonged significant increase in steam pressure in the autoclave could result in a corresponding temperature and pressure increase inside the cylinder, increasing the potential for a UF_6 release. Controls are provided to limit the normal operating temperatures within initial conditions. The allowable temperature varies for different types of cylinders. The most limiting transient that will increase the primary system pressure is to allow excessive heat to be applied to the primary system; such heating could occur if the autoclave steam control valve were to fail in the open position. This event is an AE because a single active failure (i.e., the failure of a steam control valve in the open position) or operator error could allow a large amount of steam to enter the autoclave.

An evaluation of this event determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided. The consequences are based on a liquid UF_6 release with the valve in the 6 o'clock position. This is conservative for the feed activities since they always have the valve at 12 o'clock. The toll transfer and sampling activities utilize the 6, 3 or 9 and 12 o'clock position during transfer, sampling, and heating operations.

The most severe transient associated with this event would occur after the cylinder heating cycle is completed and the UF_6 is liquefied within the cylinder. At this point in the operating cycle, the peak normal operating temperature has been achieved. The primary system pressure increase could result in the loss of expansion volume (i.e., "ullage") and could over pressurize the cylinder as a result of expansion of the liquid UF_6, possibly leading to a leak or rupture.

Various sizes of cylinders with different allowable shipping values and ullage requirements can be heated in an autoclave. Each combination of allowable shipping weights and cylinder temperatures was evaluated to determine which combination would result in the most limiting pressure transient inside the primary system. The evaluation was based on maintaining a minimum of 5 percent ullage at the ANSI N14.1 allowed heating temperatures. The evaluation determined that a 14-ton, 48G thin-wall cylinders with an allowable shipping value of 28,000 lb. (12,701 kg) of UF_6 would reach its 5 percent ullage limit at the lowest temperature [i.e., 235°F (112°C)]. This same cylinder was also used to evaluate maximum temperatures of other cylinders that have a 5 percent ullage at 250°F (121°C). This is conservative because of the thin wall of the cylinder and its heat transfer characteristics.

The initial conditions assumed to ensure this event is controlled within EG 3 were as follows:

- Initial temperature in the cylinder is 225°F (107°C) for type B cylinders and 240°F (116°C) for type A cylinders;
- Cylinder does not exceed the allowable weight limits; and
- Cylinder does not contain excessive noncondensables.

The initial conditions are ensured respectively by the following controls:

- UF_6 cylinder high temperature autoclave steam shutoff system with a set point of less than or equal to the initial temperature limit;
- Administrative controls to verify cylinder weight is within allowable shipping values; and
- Administrative controls to verify cylinder pressure is less than or equal to 10 psia (69 kPa) prior to heating.

The most limiting transient will occur when the UF_6 within the cylinder is completely liquefied when the steam control valve fails open. The transient will result in a pressure increase inside the autoclave until the steam supply valve is closed. The UF_6 cylinder high temperature autoclave steam shutoff system will detect this event and close the steam block valves. However, in the event that this system fails to isolate the steam supply, the autoclave shell high-pressure containment shutdown system will detect the increase in autoclave pressure, and initiate closure of the steam supply isolation valves, stopping the transient. Once the steam isolation valves are closed, the temperature within the cylinder will continue to rise until an equilibrium temperature between that of the cylinder and that of the autoclave is reached. The final temperature within the cylinder will remain significantly less than 250°F (121°C) for type A cylinders and less than 235°F (112°C) for type B cylinders, preventing a failure of the cylinder pressure boundary. Based on the analysis, the autoclave shell high-pressure containment shutdown system will provide sufficient protection for all cylinders during the normal heating modes if the initial autoclave temperature is limited to less than the assumed initial temperature conditions.

In addition to these active systems and administrative controls, the passive features of the UF_6 cylinders, pigtails, primary system piping outside the autoclave, and autoclave shell and associated isolation valves would also be required. These components must be designed to withstand the transient conditions described without failure. This event is considered a limiting event for the pressure increase parameter and the AE frequency category.

The primary concern associated with this event is the primary system pressure increase associated with the increase in steam pressure inside the autoclave. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the AE frequency range and any initial conditions assumed (i.e., normal operation, EG 5). EG 4 is addressed by the NCS Program (Section 5.2). The only safety action required to meet these EGs would be to maintain primary system pressure control within the EG 3 limits. This action will prevent primary system failure and thus protect on-site personnel and the off-site public and maintain the habitability of the required control area by preventing a release of UF_6.

b. Source-Term Analysis

This is not applicable because adequate protection is available to prevent primary system failure.

c. Consequence Analysis

This is not applicable because adequate protection is available to prevent primary system failure.

d. Comparison With Guidelines

All of the applicable EGs are met by controlling the primary system pressure within acceptable limits as required by EG 3. Both on-site workers and the off-site public are protected in this event because the primary system pressure is prevented from exceeding acceptable limits, and the release of UF_6 is thereby prevented.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to verify cylinder weight is within allowable shipping values—maintain initial condition (normal operation, EG 5 only);
- Administrative controls to verify cylinder pressure is less than or equal to 10 psia (69 kPa) prior to heating—maintain initial condition (normal operation, EG 5 only);
- UF_6 cylinder high temperature autoclave steam shutoff system—maintain initial condition (normal operation, EG 5 only);
- Autoclave shell high pressure containment shutdown system—detection of high autoclave pressure and isolation of steam lines (EG 3 only); and
- UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves—maintain primary system integrity (EG 3 only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high temperature autoclave steam shutoff system, autoclave shell high pressure containment shutdown system, UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high temperature autoclave steam shutoff system, autoclave shell high pressure containment shutdown system; UF_6 cylinders; and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.3 Releases of Solid/Gaseous UF_6 to Atmosphere (Primary System Integrity)

a. Scenario Description

During routine cylinder lifting or moving operations within the various facilities as well as during on-site transportation, various initiators are present that could result in a loss of physical integrity involving a cylinder containing solidified UF_6. Loss of physical integrity involving cylinders filled with liquefied UF_6 outside of autoclaves is addressed in Section 4.3.2.2.15. Various design and administrative controls are identified to minimize the potential for loss of cylinder integrity in the hazards analysis results for the UF_6 handling and storage facilities (see Section 4.2.6.5). However, with the administrative controls in place, a single operator error or equipment failure could result in a cylinder valve failure and loss of cylinder integrity. Past operational history indicates that physical integrity failure events involving cylinders containing solidified UF_6 have occurred. Therefore, the solid/gaseous release of UF_6 to atmosphere event is categorized in the AE frequency range since a single operator error could result in a loss of cylinder integrity.

The most severe transient in the UF_6 handling and storage facilities associated with a solid/gaseous UF_6 release event would occur after a cylinder has been placed in a temporary storage area for its required cooldown period and has cooled to its triple point temperature [147.3°F]. At this point in the cooldown cycle, the amount of gaseous UF_6 within the ullage area is at its maximum for non-liquid conditions.

The primary concern associated with this event is the release of solid/gaseous UF_6 to the atmosphere. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the AE frequency range. EG 3 is not addressed in this scenario because the primary system is assumed to fail. EG 4 is addressed by the NCS Program (see Section 5.2). The safety action of emergency response (i.e., the plant see and flee policy which requires personnel to evacuate the area for their own protection) for local personnel is required to satisfy EGs 1, 2, and 6. Due to the limited size of the releases for this event, no additional action is required to satisfy EGs 1, 2, and 6. This action protects on-site personnel and will maintain the habitability of any of the required control areas in accordance with EG 6 as well. The release of solid/gaseous UF_6 to atmosphere is the most limiting primary system integrity failure event for the AE category involving a solid/gaseous release.

b. Source-Term Analysis

A source-term analysis was performed which simulated a valve failure (i.e., removed, broken, etc.) in the 12 o'clock position for a 48G cylinder containing 28,000 pounds of fully solidified UF_6 at the triple point temperature of 147.3°F. Under these conditions, a full cylinder will contain approximately 63 pounds of UF_6 vapor. The vapor pressure of UF_6 above 134°F is greater than one atmosphere. Upon the postulated valve failure, approximately one-third of this vapor (assuming ideal-gas relationships) will be quickly released before pressures equalize and significantly decrease the release rate. Once the initial vapor content of the cylinder escapes, little additional UF_6 vapor is expected to be released even though the cylinder contains enough heat to vaporize another 700 pounds of UF_6. The vaporization rate of the remaining material will be low because of the low thermal conductivity of solid

UF_6 (0.35 BTU/hr-ft-°F at 147°F) and the high thermal conductivity of the metal cylinder. The majority of the available heat will be lost through the cylinder wall to the atmosphere.

Once a UF_6 cylinder has cooled below 134°F, the vapor pressure of the material is less than one atmosphere. A broken cylinder or valve under these conditions would allow outside air to flow into the cylinder. The moisture in the air would react with the UF_6 in the cylinder. In time, the reaction products would generate a positive pressure enabling some reaction products to flow out of the cylinder.

A source term analysis was performed to characterize the release that would occur from a 48-inch cylinder initially containing UF_6 at the ambient conditions. This analysis assumed a valve failure on a 48-inch cylinder containing a typical heel weight of UF_6 (nominal 50 pounds) at the ambient conditions of 90°F and 60 percent relative humidity. Since water vapor is the limiting reactant inside the cylinder, a nearly empty cylinder was considered the bounding configuration for this analysis since it would maximize the volume available for wet air to enter the cylinder. The analysis also conservatively assumed that a UF_6/moisture reaction does not begin until enough air has entered the cylinder to pressurize it to atmospheric pressure. Under these conditions, the source term analysis determined that the release would include 2.5 pounds of UF_6, 0.1 pounds of UO_2F_2, and 0.03 pounds of HF.

c. <u>Consequence Analysis</u>

Although no specific dispersion analysis was performed for this event involving the release of UF_6 vapor from a solidified cylinder, the consequences would be below the EGs for an AE at the site boundary due to the relatively small size of the release. The consequence analysis is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release.

Operational personnel in the control area — There are no required operator actions for this event other than immediate evacuation as described for the local worker. The actions required for a general facility evacuation scenario are addressed separately (see Section 4.3.2.2.4).

Workers outside the process buildings — The essential controls for protecting on-site personnel beyond the immediate vicinity of the release are the same as the local worker.

Off-site public — As indicated above, this scenario would not result in any consequences that would exceed the 10-mg U EG for this event frequency with no mitigation.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared to the consequences associated with the solid/gaseous UF_6 release event scenario. Specific exposures were not calculated for on-site workers in the immediate area or workers outside the process building because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. Based on these actions, on-site workers would be able to evacuate the area of concern and maintain exposures within EGs 1 and 2 to the extent practical. The operational personnel in the control area were evaluated and no actions are required other than immediate evacuation; thus, EG 6 is satisfied. Finally, with no mitigation provided, off-site exposure would not exceed guidelines.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential control for the solid/gaseous release of UF_6 to the atmosphere event is summarized as follows:

- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1,2, and 6).

Based on the above essential control, TSRs are provided for administrative requirements for procedures and training of workers for evacuation actions in the event of a release.

4.3.2.2.4 Evacuation of the UF_6 Handling and Storage Facilities (External Event)

a. Scenario Description

The evacuation of the UF_6 handling and storage process buildings event is a special event to be evaluated for all operational areas with significant hazardous operations to ensure that evacuation does not result in consequences from process operations. The event scenario addresses any essential actions required by the operational staff prior to evacuation of the facility for all conditions except when a release of hazardous material within the specified facility (e.g., feed, withdrawal, etc.) is the initiating event. For a discussion of releases of hazardous material within the UF_6 handling and storage facilities and associated operator actions, refer to the appropriate sections of this chapter for required actions. The evacuation event is an AE because various types of events associated with plant operations could result in a required evacuation of a facility. Some of these events include spurious operation of the criticality accident alarm system, potential releases of hazardous material from another facility, or a fire within the facility.

The primary concern associated with this event is to prevent release of hazardous material (e.g., UF_6) as a result of an evacuation of the facility. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the AE frequency range. EG 4 is addressed by the NCS program (see Section 5.2). EG 6 is addressed by this event scenario (i.e., determine what safety actions are required by the operational personnel and if they can be accomplished for this event). The only safety action required to meet these EGs is to maintain primary system pressure control within EG 3. This action will prevent primary system failure as well as protect both on-site personnel and the off-site public.

The analysis for this scenario addressed each facility process and associated operating modes to determine the essential controls necessary to prevent failure of the primary system. The initial conditions associated with this event are assumed to be the normal operations carried out within the given facility.

The evacuation of the UF_6 handling and storage facilities event is considered a limiting event because of the special nature of the analysis. All the applicable EGs are met by controlling the primary system pressure within EG 3. Both the on-site worker and the off-site public are protected in this event by controlling the primary system pressure so that it does not exceed EG 3 and the release of UF_6 is prevented.

b. Source-Term Analysis

The objective of this analysis is to prevent failure of the primary system in the event of an evacuation of a UF_6 handling and storage facility. This would result in no source term for the event. Although this objective might not be accomplished completely, the source term would be small in relation to other anticipated events (Sections 4.3.2.2.1 through 4.3.2.2.5). Therefore, source-term analysis is not applicable to this event.

c. Consequence Analysis

Consequence analysis is not applicable to the evacuation of UF_6 handling and storage facilities event.

d. Comparison With Guidelines

Each process and associated controls are summarized below to describe how primary system pressure and temperature are controlled within EG 3 as applicable.

Feed and Toll Enrichment Services Facilities — During the cylinder handling/preparation mode of operation, the only identified concern is the movement of cylinders within the facility. If evacuation of the facility is required during the movement of cylinders, the design of the transport devices must ensure that no damage is incurred when an operator evacuates the area. Therefore, the following two controls were identified to accomplish this action:

- Cranes are designed so that when the controls are released, only small compensatory movements are allowed to occur to prevent the load from swinging, and
- Rail stops are provided to prevent cylinder transport cart movement beyond stops.

During all other facility operations, the only concern that could result in a loss of primary system integrity is that excessive temperatures during heating operations in the autoclave could result in a primary system pressure increase and potentially a subsequent release of UF_6. Control is provided by the UF_6 cylinder high temperature autoclave steam shutoff system for each of the autoclave heating modes.

In addition to these active systems, the passive features of the UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves would also be required.

Although the existing controls provide protection to prevent a release of UF_6 in the event that the facility is evacuated, other transient events could occur that may require operator presence inside the facility. Because of the potential for these events to occur independent of the evacuation, continued operation of the facility without operator presence should be limited to ensure that independent events do not result in a release of UF_6 within the facility. Therefore, the autoclaves must be placed in the autoclave shutdown or containment mode within 4 hours of the evacuation or when conditions permit entry, if continued presence of operations personnel cannot be reestablished. In the event hazardous conditions prevent reentry, the placement of the autoclaves in the autoclave shutdown or containment mode would be accomplished when conditions (as defined by the emergency response coordinator for the event) allow the action to be accomplished. The controls for this action may be any of the normal operational controls or autoclave isolation functions.

Four hours is considered a reasonable time frame to allow any external condition to be resolved and allow reentry of operational personnel. During this period of time, the probability of additional independent events occurring within the facility is extremely low, and continued feeding/transferring of the UF_6 would therefore be acceptable.

Withdrawal Facilities — Evacuation of the withdrawal facilities was evaluated and it was determined to be a special event that was categorized in the AE frequency range because of the various types of events associated with plant operations that could result in a required evacuation of the withdrawal facilities. The withdrawal operation poses the same concerns associated with cylinder handling as those described earlier for the feed and toll enrichment services facilities. The same controls are also applicable for the withdrawal facilities.

The only other concern that could result in a failure of the primary system integrity and subsequent release of UF_6 in the withdrawal operations is excessive pressures/temperatures in the modes during which the compressors are operating. Because of the potential for these events to occur independent of the evacuation, continued operation of the facility without operator presence should be limited to ensure that independent events do not result in a release of UF_6 within the facility. Remote tripping capability is provided for the withdrawal compressors in the PCF; however, limited monitoring information is provided to indicate any process upsets that may be occurring. Therefore, the compressors will be tripped if reestablishment of continued operation personnel presence cannot be accomplished within 4 hours of the evacuation. The controls for this action may be any of the normal operational controls. The UF_6 release detection system monitors the withdrawal compressors and would provide an alarm in the ACR and PCF if a release occurred.

The withdrawal facility is equipped with automatic detection and isolation systems for line withdrawal positions (pigtail line isolation system). This system provides adequate protection for line failures at the withdrawal positions. Therefore, continued operation of the withdrawal process in the event of an evacuation would be acceptable.

e. Summary of SSCs and TSR Controls

The essential controls for evacuation of the UF_6 handling and storage facilities event are summarized as follows:

Feed, Toll Enrichment, and Withdrawal Facilities

- Operator training for required actions–maintain primary system integrity (EG 3 only);
- UF_6 cylinders, pigtails, and primary system piping–maintain primary system integrity (EG 3 only);
- Crane design to prevent movement upon release of controls–maintain primary system integrity (EG 3 only);
- Liquid UF_6 handling cranes–maintain primary system integrity (EG 3 only);
- Liquid UF_6 cylinder handling equipment (scale carts)–maintain primary system integrity (EG 3 only);
- Rail stops to prevent cylinder transport cart movement beyond stops–maintain primary system integrity (EG 3 only);

Feed and Toll Enrichment Facilities

- Autoclave primary containment system–maintain primary system integrity (EG 3 only);
- Autoclave shell and associated isolation valves–maintain primary system integrity (EG 3 only);
- Pigtail line isolation systems–maintain primary system integrity (EG 3 only);

- UF_6 cylinder high temperature autoclave steam shutoff system–maintain primary system temperature/pressure below allowable values (EG 3 only);

Withdrawal Facilities

- Pigtail line isolation system–maintain primary system integrity (EG 3 only);
- Compressor motor manual trip for second stage compressors–maintain primary system temperature/pressure below allowable values (EG 3 only), and
- UF_6 release detection system–maintain primary system integrity after facility evacuation (EG 3 only.

Based upon the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- UF_6 cylinders, pigtails, primary system piping, liquid UF_6 cylinder handling equipment (cranes, scale carts), autoclave primary containment system, autoclave shell and associated isolation valves, pigtail line isolation systems (feed, transfer, withdrawal), UF_6 cylinder high temperature autoclave steam shutoff system, UF_6 release detection system, and compressor motor manual trip for second stage compressors are identified as important to safety SSCs. See Section 3.8 for details including safety classification.

- TSRs are provided for the UF_6 cylinders, liquid UF_6 handling cranes, scale carts, autoclave primary containment system, pigtail line isolation systems (feed, transfer, withdrawal), UF_6 cylinder high temperature autoclave steam shutoff system, compressor motor manual trip for second stage compressors, UF_6 release detection system, and administrative requirements for procedures and training of workers for evacuation actions and protective equipment/measures for crane operators.

4.3.2.2.5 Limited UF_6 Release to Atmosphere (Primary System Integrity)

a. Scenario Description

During the withdrawal operating modes, small passive failures in the primary system may result in limited releases of UF_6 into the process buildings. These could be caused by initiators such as failures of instrument lines, expansion joints, weld joints, etc., that could be caused by vibration, fatigue, or corrosion. These types of failures are expected frequently enough to place them in the AE category.

The limited UF_6 release to atmosphere event in the withdrawal facilities was evaluated in the PrHA and it was determined that the consequences could result in significant on-site impact in any operating mode if no mitigation were provided.

The primary concern associated with this event is controlling the UF_6 release. The applicable EGs (see Table 4.2-2) associated with this event are all the EGs for the AE frequency range. EG 3 is not addressed in this scenario because the primary system is assumed to fail, and EG 4 is addressed by the NCS Program (see Section 5.2). The safety actions of (1) building holdup, and (2) emergency response by local personnel would be required to maintain the effects of the UF_6 release within EGs 1, 2, and 6. Because of the limited size of the releases for this event, no additional action is required to keep the effects of the UF_6 release within the EGs 1, 2, and 6 for areas outside the process buildings. These actions protect on-site personnel and will maintain habitability of the required control area in accordance with EG 6 as well.

The limited UF_6 release to atmosphere event is the most limiting primary system integrity failure event for the AE category. Accident scenarios involving larger failures of the withdrawal system's physical integrity are addressed in the pigtail/line failure at withdrawal station scenario (see Section 4.3.2.2.11) and the process line failure at compression discharge scenario (see Section 4.3.2.2.12).

b. Source-Term Analysis

The limited UF_6 release to atmosphere event in the withdrawal facilities is categorized as an AE due to the various passive (i.e., fatigue-type) equipment failures and operator errors that could initiate this accident scenario. The UF_6 releases associated with this accident scenario are defined to originate from relatively small failures (i.e., hair-line cracks) in equipment operating above atmospheric pressure. These small physical integrity failures are expected to result in very small UF_6 release rates. However, as indicated in the scenario description, larger primary system failures can result in significantly larger release rates. There are many variables that must be characterized in order to develop a source term for this accident scenario. These variables include the following:

- The duration of the release;
- The size of the failure;
- The location of the failure in the withdrawal process (i.e., gaseous or liquid piping); and
- The process pressures, temperatures, UF_6 concentrations, and the amount of UF_6 available to leak out of the system at the break.

As indicated, the limited UF_6 release to atmosphere event in this accident scenario is associated with minor equipment failures involving the physical integrity of equipment used in the withdrawal facilities. However, a limited UF_6 release to atmosphere accident scenario is also evaluated for equipment used in the cascade facilities (see Section 4.3.2.1.4). Due to differences in operating parameters (e.g., flow rates), the release rates associated with small physical integrity failures would be larger in the cascade facilities. The source term associated with limited UF_6 release to atmosphere event in the withdrawal and cascade facilities would be bounded by the B-stream block valve closure event (see Section 4.3.2.1.3) which characterized the amount of UF_6 that can be released in cascade process buildings without exceeding AE off-site EGs (i.e., 10 mg U and 5 rem).

c. <u>Consequence Analysis</u>

This event is associated with only minor passive equipment failures. The size of the failure in the primary system is expected to be small and result in a release rate that is less than that described for the B-stream block valve closure event (see Section 4.3.2.1.3). The consequence analysis for the limited UF_6 release to atmosphere event is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential methods of detection for workers within the withdrawal buildings is: (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping that are common with the withdrawal facilities are enclosed in housings to maintain normal operating temperatures. The configuration of the housings required to maintain normal operating temperatures, and therefore to keep the UF_6 in the gaseous state, provides an inherent barrier against UF_6 releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g. emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the control area — Workers in the control area typically would not be affected by a limited UF_6 release to atmosphere event. Since the exact release mechanism is not defined for the limited UF_6 release to atmosphere event, no essential actions are required of operational personnel in the control area. However, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings—The essential controls for protecting on-site personnel outside the process buildings are (1) temporary holdup of the release by the existing process building structure, and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. Process building holdup is provided by the existing process building structure. The process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released at an elevated point. Withdrawal process equipment housings outside of the cascade cells are not credited with providing a time delay between a release of UF_6 from the primary system to release from the building. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — Based on the potential source term, the limited UF_6 release to atmosphere event in the withdrawal facilities is bounded by the B-stream block valve closure event (see Section 4.3.2.1.3). Therefore, no additional analysis is required for this event.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee, and PPE or other protective measures for crane operators) will maintain exposures within EGs 1 and 2 to the extent practical. EG 4 is addressed by the NCS Program (see Section 5.2). There are no essential actions required of operational personnel in the control area to meet EG 6. In the event that the release ultimately affects habitability of the control area, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., building holdup and evacuation of areas upon detection of a release) and the minimal source term associated with this event, EGs 1 and 2 would be met for workers outside the process building.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential mitigative controls for the limited UF_6 release to atmosphere event associated with meeting EGs 1, 2, and 6 are summarized as follows:

- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures is provided to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.2.6 Heating of a Cylinder with Excessive UF_6 (Pressure Increase)

a. Scenario Description

During autoclave heating modes, controls are provided to limit the normal operating temperatures and pressures to allowable values for preventing primary system failures that would result in a loss of physical integrity. One method of increasing the primary system pressure beyond acceptable limits is to heat a cylinder with excessive UF_6. This event could only occur as a result of multiple operator errors; therefore, this event is categorized as an EBE.

This event was evaluated, and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided.

The primary concern associated with this event is the primary system pressure increase associated with lack of expansion volume in the cylinder during normal heating. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the EBE frequency range. Only a significant failure of the primary system could cause the applicable EGs to be exceeded for this event. Significant failures of the primary system during autoclave operations are addressed separately in Sections 4.3.2.2.10, 13, 14, and 15. The required controls for mitigation of any primary system failures would be similar for the same failure location (i.e., inside or outside the autoclave). Therefore, only the measures in place to prevent this event from occurring and prevent a primary system failure once the event occurs are addressed in this scenario. The only safety action required to meet these EGs is primary system pressure control. This action will prevent primary system failure as well as protect on-site personnel.

ANSI N14.1 places weight limits on the amount of UF_6 that can be in UF_6 cylinders when they are shipped. This standard is used at the GDPs and at the commercial vendors supplying UF_6 to the GDPs. When these weight limits are met, the normal heating cycles of the autoclaves may be used to liquefy the UF_6 as needed for operation. In addition, the following administrative control is in place for all autoclave operations:

- UF_6 cylinders to be heated in an autoclave have their weight verified prior to heating. (Cylinders that exceed the allowable shipping weight values may only be heated in the controlled feeding mode of operation that prevents liquefaction of the UF_6.)

In addition to this administrative control, the UF_6 cylinder high pressure autoclave steam shutoff system is available during heating modes of operation to detect high cylinder pressures and isolate the steam supply to stop the event prior to primary system failure. This action will minimize the potential for on-site personnel to be exposed to releases of material. In addition to this active system, the passive features of the UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves would also be required.

b. Source-Term Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

c. Consequence Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

d. Comparison With Guidelines

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to verify cylinder weight is within allowable shipping values—maintain initial condition (normal operation, EG 5 only);
- UF_6 cylinders, pigtails, and primary system piping outside the autoclave—maintain primary system integrity (EGs 1, 2, and 6 only);
- Autoclave shell and associated isolation valves—maintain primary system integrity (EG 3 only); and
- UF_6 cylinder high pressure autoclave steam shutoff system —minimize potential for primary system integrity failure (EGs 1, 2, and 6–on-site only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.7 Heating of a Cylinder with Excessive Noncondensables (Pressure Increase)

a. Scenario Description

During autoclave heating modes, controls are provided to limit the normal operating temperatures and pressures to allowable values for preventing primary system failures that would result in a loss of physical integrity. One method of increasing the primary system pressure beyond acceptable limits is to heat a cylinder with excessive noncondensables. This event could only occur as a result of multiple operator errors; therefore, this event is categorized as an EBE.

This event was evaluated, and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided.

This event is similar to the event described in Section 4.3.2.2.6. The only difference is that the event involves excessive noncondensables rather than excessive UF_6. Therefore, the only item addressed in this scenario is the difference in the controls to prevent heating a cylinder with excessive noncondensables.

The following administrative controls are in place for all autoclave operations:

- A cold pressure check, indicating less than or equal to 10 psia (69 kPa), is performed prior to initial heating. [Cylinders that exceed this pressure, and cannot be cold burped down to less than or equal to 10 psia (69 kPa), may be heated only in the controlled feeding mode of operation that prevents liquefaction of the UF_6.]

- Because of the accelerated cooling process employed for the "Russian cylinders", the normal heating process may produce pressures at the valve that exceed the cylinder high pressure settings. These readings are not due to noncondensable but rather to the decreased void space at the valve caused by "crusting" of solid UF_6 around the valve (a phenomena caused by the accelerated cooling methods employed in Russia). In this situation, there is no danger of hydraulic rupture with release of significant quantities of UF_6 since the pressure occurs within minutes of the initial heating - long before the cylinder contents have been liquefied. PORTS is employing a modified heating method for these cylinders to avoid generation of high pressure spikes.

b. Source-Term Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

c. Consequence Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

d. <u>Comparison With Guidelines</u>

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

e. <u>Summary of SSCs and TSR Controls</u>

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative control to verify cylinder pressure less than or equal to 10 psia (69 kPa) prior to heating—maintain initial condition (normal operation, EG 5 only);
- UF_6 cylinders, pigtails, and primary system piping outside the autoclave—maintain primary system integrity (EGs 1, 2, and 6 only);
- Autoclave shell and associated isolation valves—maintain primary system integrity (EG 3 only); and
- UF_6 cylinder high pressure autoclave steam shutoff system—minimize potential for primary system integrity failure (EGs 1, 2, and 6—on-site only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.8 Heavy Equipment Drop (Primary System Integrity)

The heavy equipment drop event is limited to the cell floor of the process building in the area of the withdrawal system equipment. Drops of heavy equipment in the cylinder handling and autoclave areas are discussed in other accident analysis scenarios. These scenarios include: (1) pigtail/line failure outside autoclave (see Section 4.3.2.2.10), (2) the pigtail/line failure at the withdrawal station (see Section 4.3.2.2.11), and (3) the cylinder failure outside the autoclave (see Section 4.3.2.2.15). The administrative controls, and frequencies of occurrence for the heavy equipment drop accident scenario in the withdrawal facilities are bounded by the discussion of the heavy equipment drop accident scenario for the cascade facilities (see Section 4.3.2.1.8). Any required engineering controls for mitigation are the same as those described for the process line failure at compressor discharge in the withdrawal facilities (see Section 4.3.2.2.12). Therefore, no additional analysis of this event is provided.

4.3.2.2.9 Heating a Damaged Cylinder (Primary System Integrity)

a. Scenario Description

During autoclave heating modes, controls are provided to ensure cylinders are free from obvious damage/leakage that could result in a loss of primary system integrity. This event could only occur as a result of multiple operator errors; therefore, this event is an EBE.

This event was evaluated, and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided.

This event is similar to the event described in Section 4.3.2.2.6. The main difference is that this event involves heating a damaged cylinder during normal autoclave heating modes. Other differences are that once the cylinder passes inspection, no additional controls would be required (i.e., normal operation is occurring). Therefore, the only item addressed in this scenario is the difference in the controls to prevent heating a damaged cylinder during normal autoclave heating modes.

The following administrative control is in place for all autoclave operations:

- Cylinders are inspected for obvious damage that could threaten their ability to withstand a normal heating cycle prior to heating. (Damaged cylinders that do not meet inspection restrictions may only be heated in the controlled feeding mode of operation, which prevents liquefaction of the UF_6.)

b. Source-Term Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

c. Consequence Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

d. Comparison With Guidelines

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to inspect for obvious cylinder damage that could threaten their ability to withstand a normal heating cycle prior to heating—maintain initial condition (normal operation, EG 5 only);
- UF_6 cylinders, pigtails, and primary system piping outside the autoclave—maintain primary system integrity (EGs 1, 2, and 6 only);
- Autoclave shell and associated isolation valves—maintain primary system integrity (EG 3 only); and
- UF_6 cylinder high pressure autoclave steam shutoff system—minimize potential for primary system integrity failure (EGs 1, 2, and 6—on-site only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high pressure autoclave steam shutoff system, UF_6 cylinders, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.10 Pigtail/Line Failure Outside Autoclave (Primary System Integrity)

a. Scenario Description

During autoclave operations, several manipulations of the cylinder and pigtail connections are made to accomplish the required tasks associated with the heating, sampling, feed, and transfer of UF_6. These operations include such activities as rolling the cylinder, connecting and disconnecting pigtails, and purging and evacuating pigtails. Due to faulty equipment (i.e., pigtail line, gaskets, etc.) or multiple inadvertent operator errors, it is possible that the pigtail line or its associated equipment connections could fail resulting in a UF_6 release. However, various administrative controls are used to prevent a pigtail/line failure including:

- UF_6 cylinders are not rolled unless visual contact is made with the pigtail during the operation to prevent breakage of a pigtail;
- UF_6 lines are purged and evacuated before the primary system is opened;
- Only cylinder pigtails that have been inspected and approved are used;
- UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced;
- Cylinder cleaning requirements conform to ANSI 14.1 for cylinder cleaning; and
- UF_6 cylinders are not filled with UF_6 when there is a >40 pound (18 kg) discrepancy between shipper UF_6 cylinder weight and received cylinder weight until the weight discrepancy is explained.

All of the potential causes for pigtail/line failure were reviewed, along with operational experience, to determine the frequency associated with this event. Although pigtail failures have occurred in the past, the administrative controls listed above were identified as a result of these failures and have been implemented to reduce the probability of occurrence of this event. Based on the operations and administrative controls, this event was classified in the EBE frequency category because of the low probability that a pigtail/line failure would be caused by deficient pigtails or by multiple operator errors.

This event was evaluated, and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided. These consequences are based on a liquid/vapor UF_6 release from the parent cylinder and a liquid/vapor release from the receiving cylinder.

The primary concern associated with this event is the loss of primary system integrity and the release of UF_6. The applicable EGs (see Table 4.2-2) associated with this event are EGs 1 and 2, as well as EG 6 in the EBE frequency range. No primary containment system exists for this type of event because the break is outside the autoclave. Therefore, EG 3 does not apply. The essential safety actions associated with meeting these EGs include (1) detection of the release, (2) isolation of the primary system to stop the release (where possible), and (3) emergency response to evacuate the immediate vicinity so that the exposure of on-site personnel is minimized.

Scenarios (i.e., causes, source terms, mitigation) associated with this event vary slightly between the feed and toll transfer autoclaves. Each variation is addressed, and the most limiting event is presented for the purpose of analysis.

All autoclaves in the autoclave cylinder/pigtail operations mode — During the autoclave cylinder/pigtail operations mode of operation, various pigtail connections, disconnections, and cylinder rolling operations are performed. During these operations, multiple operator errors or equipment malfunctions could occur that could result in a pigtail failure and release of UF_6. This event would result in significant consequences beyond the immediate vicinity only if the UF_6 is in the liquid/gaseous state. During this operating mode, there are no systems available that would isolate the cylinder should a failure of the pigtail occur at the cylinder connection. Therefore, the source term for this event would be an unmitigated release of the contents of a cylinder. If the cylinder is in a position where the level of UF_6 is below the valve, the release would be in the vapor state. If the liquid level is above the valve, liquid UF_6 would exit the opening and flash to solid and vapor. The release of vapor only for this condition is bounded by the release at a transfer station in the toll transfer facility (see below) where the receiving cylinder is not isolated. Therefore, no additional analysis of this condition is provided. The liquid release is bounded by a cylinder failure event outside the autoclave as described in Section 4.3.2.2.15. Therefore, no additional analysis of this condition is provided. Consequently, no specific source term and consequence analysis is provided for any modes where the autoclave is open.

Feed facilities — The X-343 and X-342-A feed facilities UF_6 primary system lines outside the autoclave exit the autoclave shells and are routed in heated housings or are individually heated and insulated to the tie-line that enters the process buildings. The routing of this piping prior to reaching the process buildings is exposed to external hazards that could cause a line failure to occur. Therefore, this event is applicable to both feed facilities in all autoclave modes where UF_6 is being processed outside the autoclave.

The source term for the autoclave operations in the feed facilities is based on cylinder orientation (12 o'clock) where the liquid UF_6 would be below or slightly above the cylinder valve. The release of a small amount of liquid and vapor for this condition is bounded by the baseline release at a transfer station in the toll transfer facility (see below) where the receiving cylinder is isolated. Therefore, no additional analysis of this condition is provided.

Toll enrichment services facility — The X-344-A toll transfer UF_6 primary system lines outside the autoclave are exposed to potential hazards (e.g., equipment failure, operator errors) that could cause a pigtail/line failure to occur during autoclave transfer modes of operation. The only remaining potential for failures outside the autoclave associated with X-344-A operations would be natural phenomena-initiated events, which are addressed in Section 4.3.2.5. A failure in the transfer line pigtail at the receiving cylinder interface was determined to be the limiting event for a line failure outside the autoclave for all autoclave operations. Slight variations in this scenario will bound any other pigtail/line failure associated with autoclave operations except for the liquid release in the autoclave cylinder/pigtail operations mode that is bounded by cylinder failure outside the autoclave (Section 4.3.2.2.15).

This scenario is a limiting event for the primary system failure and the EBE frequency category.

b. <u>Source-Term Analysis</u>

The analysis for a parent-daughter transfer release simulates an accidental release of UF_6 just after a daughter cylinder has been filled from a low-enriched uranium parent cylinder that was originally full to its allowable shipping value per ANSI N14.1. Initial temperature in both cylinders is 240°F (116°C), which is controlled by the UF_6 cylinder high temperature autoclave steam shutoff system. Liquid UF_6 exits the parent through a valve in the 6 o'clock position and moves through a pigtail pipe [1.0 in. (2.54 cm) inside diameter] to a 15-ft-long (4.6-m) transfer pipe [1 in. (2.54 cm) inside diameter] and then into another pigtail pipe [1.0 in (2.54 cm) inside diameter] before entering the valve at the 12 o'clock position of the daughter cylinder. The daughter has been filled to the maximum fill limit per ANSI N14.1, but no valves have been closed. At this point, the pigtail becomes disconnected from the valve on the daughter cylinder. This causes a release from the parent cylinder, via the transfer piping, that is assumed to last for 45 seconds before isolation (i.e., before the valve is closed by operator action). It also leads to a release from the valve connected to the daughter cylinder, which is assumed to last for 45 seconds before isolation by operator action.

Liquid UF_6 exits the parent cylinder at 240°F (116°C) and 87.9 psia (0.61 MPa), about 6 atm. The release rate from the end of the transfer piping is 7.26 lb/s (3.29 kg/s). The length of transfer piping between the parent cylinder and the release point has a noticeable effect on reducing the atmospheric release rate. Upon release, the liquid UF_6 flashes to a mixture of 62 percent vapor 4.50 lb/s (2.04 kg/s)] and 38 percent solid [2.76 lb/s (1.25 kg/s)], and the temperature is assumed to be lowered to 134°F (56.6°C), the temperature at which vapor and solid forms of UF_6 are in equilibrium at 1 atm.

Some liquid UF_6 exits the daughter cylinder through the valve in the 12 o'clock position and passes through the attached cylinder valve before being released. Because the level of liquid UF_6 is slightly above the valve opening of the daughter cylinder, releases from the daughter are initially in the liquid form and then in the vapor state. The liquid is released at an average rate of 8.58 lbs/s (3.89 kg/s) at an average temperature of 240°F (116°C) and a pressure of 87.9 psia (0.61 MPa). Total UF_6 released during the initial 45 seconds is 326.7 lb (148.2 kg) from the parent cylinder and 385.9 lb (175.5 kg) from the daughter cylinder.

Another variation in the above scenario is for the receiving cylinder not to be isolable because of disconnection from the pigtail at the cylinder connection. The parent cylinder will still be isolated within the 45 seconds, but the receiving cylinder will continue to release its contents until emergency personnel plug the cylinder or the amount is exhausted. This is further discussed below as variations of the baseline scenario.

c. <u>Consequence Analysis</u>

The consequence analysis is divided into three sections. The first subsection details the baseline scenario that estimates conservative (i.e., reasonable upper-bound) consequences from a UF_6 release associated with a postulated accident during transfer from a parent cylinder to a daughter cylinder, including release of material from both the parent and daughter cylinders for 45 seconds before isolation. After the baseline scenario, the second subsection discusses the effects of varying input parameters from those used in the baseline scenario. The final subsection discusses the uncertainties in the analysis that have not been quantified. Effects of varying surface roughness and initial deposition of solid UF_6 are the same as those discussed in Section 4.3.2.2.15.

Baseline scenario. Parameters that define the base scenario for the parent/daughter release are listed in Table 4.3-6. This scenario includes adverse meteorological conditions (i.e., conditions resulting in high-consequence estimates), consisting of a stable atmosphere and a low wind speed [Pasquill-Gifford stability class F and a wind speed of 1 m/s (2 mph), or simply F1]. These conditions occur at PORTS 3.4 percent of the time on an annual basis (averaged over the 1-yr period, 1993).

An ambient air temperature of 40°F (4.4°C) was selected for these simulations because that temperature results in relatively high consequence estimates compared to other temperatures that occur under F1 conditions. Lower ambient temperatures [to 30°F (-1°C)] were also evaluated and indicated marginally higher consequences. However, lower temperatures introduce condensation mechanisms for which there is less confidence in model results. Therefore, 40°F (4.4°C) is the lowest ambient temperature used in this analysis. During 1993, ambient temperatures were greater than 40°F (4.4°C) about 80 percent of the time.

An ambient relative humidity of 70 percent was selected for the baseline scenario because it is a typical relative humidity for a stable atmosphere with low wind speeds at PORTS. During 1993, the median relative humidity under F1 conditions was 80 percent. Higher relative humidities (e.g., 90 percent) would result in only minimally higher consequence estimates because the corresponding increase in specific humidity (the humidity expressed as the number of grams of water vapor per kilogram of moist air) at 40°F (4.4°C) is small. The maximum relative humidity under F1 in 1993 was 100 percent. The maximum specific humidity (100 percent relative humidity) associated with an ambient air temperature of 40°F (4.4°C) is 5.5 g of water vapor per kilogram of moist air. Twenty percent of that amount the difference between 70 percent and 90 percent relative humidity) is 1.1 g of water vapor per kilogram of air. This slight difference in water vapor available for UF_6 hydrolysis reactions would result in virtually no change in downwind consequence estimates.

The value of f_A accounts for the in-building mixing of the released UF_6 in the transfer building, and with increasing f_A values, the amount of UF_6 that reacts in the building increases (see Section 4.3.2.3.4). Values of f_A were calculated using the plume cross-sectional area at the point when all of the solid UF_6 in the plume has completely sublimated to UF_6. The cross-sectional area of the plume is a function of the release and meteorological conditions. For the baseline scenario, in-building mixing is assumed to be minimal, with a low f_A value calculated to be 0.055.

The UF_6 MIXER model was used to predict downwind consequences from the parent-daughter transfer release. Figures 4.3-17 through 4.3-19 show estimated downwind consequences associated with the baseline scenario. Note that the baseline scenario (stable atmosphere and a low wind speed [Pasquill-Gifford stability class F and wind speed of 1 m/s, or simply F1]) is represented by the top curve in these figures. The other two curves are for different meteorological conditions and are discussed below. Calculated values of the consequence parameters were compared to EBE guideline values for uranium (25 rem for U radiological toxicity, and 30 mg U intake for U chemical toxicity), and to the Emergency Response Planning Guidelines (ERPG-2) for HF (20 ppm for 1-hour).

Table 4.3-7 lists specific consequence estimates at 0.62 mile (1000 m), 0.93 mile (1500 m), and 5.3 miles (8500 m) downwind from the postulated release point. The postulated release point is assumed to be located outside the western entrance of the toll transfer building (Building X-344-A). The nearest site boundary is located about 0.68 mile (1100 m) to the northwest of the postulated release point. Consequence estimates are less than their respective guidelines at the nearest site boundary. These consequences are significantly less than those for the dropped cylinder event (see Section 4.3.2.2.15).

Effects of varying scenario parameters on consequence estimates. The following parameters were varied to obtain some uncertainty estimates and provide some characterization of the range of potential consequences: (1) the duration of release from the daughter cylinder, (2) meteorological conditions, (3) the initial in-building mixing [indicated by the fractional area of the leeward side of building that is covered by the exiting plume (f_A)], and (4) the building wake effects on plume dispersion. The results provide perspective for interpreting the baseline scenario. The consequences presented in this section are either more probable, providing a lower-bound estimate of potential consequences, or less probable, providing a worst-case estimate of potential consequences. For the duration of release, fractional area, and building wake discussions, consequence estimate comparisons are not shown for radioactive dose and HF exposure because these estimates display the same general trend as the uranium chemical toxicity dose and are generally less than their respective guideline values.

Duration of release from the daughter cylinder — The baseline scenario assumes that the daughter cylinder valve would be isolated (closed) in 45 seconds. If the daughter cylinder valve does not isolate, then the release duration may be as long as 30 min (1800 s). In Figure 4.3-20, consequence estimates are higher with the longer duration release from the daughter cylinder. The uranium chemical toxicity dose exceeds the guidelines up to about 2.9 miles (4700 m), while the HF toxicity dose exceeds the guideline up to about 3 miles (5000 m).

Meteorological conditions — Consequence estimates were made for two additional meteorological conditions to compare with the baseline scenario. The compared meteorological conditions included: (1) typical conditions that do not provide favorable or unfavorable consequence estimates [represented by neutral atmospheric stability (Pasquill-Gifford stability class equal to D) and moderate wind speeds (4 m/s = 9 mph)] and (2) typical conditions that provide relatively low-consequence estimates [represented by a slightly unstable atmosphere (Pasquill-Gifford stability class equal to C) with moderate wind speeds (4 m/s)]. These representative meteorological conditions were chosen based on a screening analysis performed using the simple Gaussian plume equation.

Table 4.3-10 shows the results of this screening analysis, where normalized concentration values (concentration, χ, divided by the source term, Q, therefore called χ/Q values) were calculated at a downwind distance of 0.62 mile (1 km), assuming that the source was at ground level and that plume constituents were not reactive. The values of χ/Q in Table 4.3-10 are ordered such that values near the top of the table represent more favorable dispersion conditions and values near the bottom represent less favorable dispersion conditions.

The most frequently occurring meteorological condition at PORTS is D4 (stability class D, neutral, and wind speed of 4 m/s), which occurred 8.4 percent of the time on an annual basis. As shown in Table 4.3-10, meteorological conditions that would result in equal or lesser consequences than those produced by D4 conditions occur 57 percent of the time. An additional criterion for selecting D4 is the historical use of similar meteorological conditions in regulatory applications. The U.S. Department of Transportation has used D4.5 to calculate evacuation distances along transportation corridors for accidents involving toxic chemicals (see References 71 and 72) and the U.S. Army has used D3 as the default value for "conservative-most-likely" meteorological conditions for assessing hazards associated with accidental releases of chemical warfare agent (see References 73 and 74). Based on the selections of similar atmospheric conditions and the frequency of occurrence at PORTS, D4 was chosen to represent typical conditions that do not bias the result toward favorable or unfavorable consequence estimates. The temperature of 40°F (4.4°C) and relative humidity (70 percent) were not varied from the baseline scenario [which used F1 (stability class F, stable, and a wind speed of 1 m/s) meteorological conditions].

The C4 meteorological condition occurs about 4.1 percent of the time. As shown in Table 4.3-10, consequence estimates would be more favorable or equal to C4 about 32 percent of the time. Other meteorological conditions such as A1, A2, and B2 occur more frequently, but these scenarios are considered too propitious for the purpose of this comparative analysis. Therefore, C4 was selected to represent a typical condition that results in relatively low consequence estimates. The temperature and relative humidity for this scenario were selected to represent typical summer, daytime conditions when C stability is likely to occur. The temperature used for this comparative scenario was 80°F (27°C) and the relative humidity was 50 percent.

Figures 4.3-17 and 4.3-18 show consequence estimates for uranium chemical toxicity exposure and radioactive dose resulting from a parent-daughter transfer release during F1, D4, and C4 meteorological conditions. Turbulent mixing can increase ground-level concentrations (and associated consequences) close to the source such that unstable (C4) conditions produce the greatest consequences at very small downwind distances. However, by the time the plume is 165 ft (50 m) from the source, the expected relationship of increased atmospheric turbulence producing decreased pollutant concentrations and consequences has established itself and becomes increasingly apparent as distance from the source increases. Simulated consequence estimates are below guideline values at distances of 2210 ft (675 m) or greater.

Figure 4.3-19 shows consequence estimates for HF exposure. At distances of 1.40 mile (2250 m) or less, the consequences are greatest for D4 conditions rather than for the baseline conditions. This apparently counterintuitive result is due to the way in which HF exposure is calculated; in particular, it is a result of the relatively rapid spreading caused by slumping of the dense plume under F1 conditions compared with much slower spreading of such a plume under D4 conditions, where turbulent mixing is more influential in determining the initial spreading. At distances beyond 1.40 mile (2250 m), the D4 plume has spread sufficiently for the higher wind speed and increased atmospheric dispersion associated with this meteorological condition to allow consequence estimates to fall below F1. Consequence estimates for D4 conditions are below the guidelines values at distances greater than about 2210 ft (675 m) from the source.

Initial mixing of the released UF_6 with air in the toll enrichment services facility — The fraction (f_A) of the leeward side of the building that is covered by the plume as it exits the toll transfer and sampling facility building is used to indicate the amount of initial mixing of the released UF_6 with air in the building. The value of f_A was varied from a very small fractional area ($f_A = 0.0001$) up to a value of 0.52. Values of f_A greater than 0.52 resulted in the plume becoming buoyant before reaching the 1000 m site boundary and therefore were not considered.

Larger values of f_A are associated with mixing a larger amount of air inside the building with the plume, and although expected to result in smaller consequence estimates, actually lead to similar smaller consequence estimates at all distances from the source until very large values of f_A are assumed. Figure 4.3-21 shows the comparative results for uranium chemical toxicity with values of f_A equal to 0.0001, 0.055 (used for the baseline case), 0.1, and 0.52. As can be seen, the three lower values of f_A result in nearly identical consequences at all downwind distances, while the largest f_A results in initially higher consequences within 2000 m. Beyond 2000 m, the largest f_A results in increasingly lower consequences. Concentrations are below the guideline value (30 mg of inhaled uranium) at distances equal to or greater than 2620 ft (800 m) for all values of f_A.

Building wake effects — Building wake effects cause higher initial dispersion, which generally has the effect of reducing consequences for ground-level sources. (Note that for elevated sources the opposite may be true because the building wake near the source may mix and direct the plume toward the ground, thereby increasing consequence estimates; see Section 4.3.2.1.7.) As distances from the source increase, dispersion of the plume becomes larger compared with the initial dispersion caused by the wake. These effects are seen in Figure 4.3-22, which compares the uranium chemical toxicity consequences for the simulated effects of building wake to those of no building wake. At 330 ft (100 m), consequence estimates for the no-wake case are about 2.5 times higher than that for the building wake case. With increasing distance, the difference between consequence estimates decreases. At 0.62 mile (1000 m), consequence estimates for the no-wake case are about 1.6 times higher than the wake case, and at 1.2 miles (2000 m), consequence estimates for the no-wake case are about 1.4 times higher than the wake case. Estimated consequences become even closer at a distance of 5.3 miles (8500 m). Simulated uranium chemical toxicity consequences exceed guideline values at distances up to 2460 ft (750m) for the case of no building wake effects.

Uncertainties not quantified. The baseline scenario simulates dispersion of a dense, ground-hovering plume under common meteorological conditions during the early morning (stable atmosphere and light wind speeds). Such a plume would flow much like water, seeking low spots and being deflected around rises. The plume would tend to pool in low-lying areas, capturing a significant fraction of the plume mass and leading to the formation of small local areas of high concentrations. Pooling would tend to occur at downwind distances close to the release point where the plume is most dense and could possibly limit concentrations further downwind. A dense plume would tend to flow into and pool in low areas near the release point, which would essentially act as retaining basins for the released UF_6 and reaction products. Pooling would act to effectively reduce the uranium concentrations in the plume and extend the reaction time. As a result, exposures would be reduced.

The following sections describe how the consequences are addressed for the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the autoclave facilities is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the ocurrence of a release and (2) the need for the workers to evacuate the area of the release.

Operational personnel in the control area —Operational personnel who are required to take mitigative action could be located in any of the general areas of the facility but would detect the event quickly because of the large release. As indicated for the local worker, immediate evacuation is required for operational personnel. During exit, the pigtail line isolation system (for Building X-344-A) and the pigtail line isolation system (for Buildings X-343 and X-342-A) will be activated to initiate valve closure.

Workers outside the process buildings —The essential controls for protecting on-site personnel outside the facilities are (1) detection of the release, (2) minimization of the release by initiating isolation, and (3) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential action is to detect the release of UF_6. For the feed and toll enrichment services facilities, a release is detected visually or by smelling the HF, and operator action would be taken to initiate the pigtail line isolation system. The second essential action is accomplished by the manual isolation to terminate the release. If workers outside of the process buildings have not received other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — As indicated in the consequences for the 45 second release from both parent and daughter, the consequence at the site boundary is about 12.3 mg U for the baseline scenario, while that for the f_A of 0.52 is 21.2 mg uranium. This allows for some extra time for detection and isolation prior to reaching the 30 mg U guideline. The time frame allowed for initiation of the isolation systems is about 109 sec for the baseline scenario and about 62 sec for the f_A of 0.52 scenario, before the evaluation guidelines are exceeded. This provides adequate time for personnel to evacuate and actuate the system as they leave.

For the scenario in which the parent release is terminated at 45 sec and the daughter continues beyond 45 sec and the liquid/vapor release from a cylinder in an open autoclave, the off-site EGs could be exceeded.

d. Comparison With Guidelines

For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However the controls identified (i.e., see and flee) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operational personnel in the control area were evaluated, and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects habitability of the control area, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded. In addition, based on the controls identified (i.e., release detection, process isolation, and evacuation of areas upon detection of a release), EGs 1 and 2 would be met for workers outside the process building. Finally, an analysis was performed to determine the worst case scenario at which an off-site exposure of 30 mg U would be reached.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to prevent pigtail/line failure—maintain initial condition (normal operation, EG 5 only);
    1. UF_6 cylinders are not rolled unless visual contact is made with the pigtail during the operation to prevent breakage of a pigtail;
    2. UF_6 lines are purged and evacuated before the primary system is opened;
    3. Only cylinder pigtails that have been inspected and approved are used;
    4. UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced;
    5. Cylinder cleaning requirements conform to ANSI N14.1 for cylinder cleaning; and
    6. UF_6 cylinders are not filled with UF_6 when there is a >40 lb (18 kg) discrepancy between shipper UF_6 cylinder weight and received cylinder weight until the weight discrepancy is explained (toll transfer facility only).
- UF_6 cylinder high temperature autoclave steam shutoff system—maintain initial condition (normal operation, EG 5 only);
- Pigtail line isolation systems (feed and transfer)—closure of isolation valves to terminate release (EGs 1, 2, and 6 only);
- UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves — maintain primary system integrity (EGs 1, 2, and 6 only); and
- Operator training for required actions—closure of isolation valves to terminate release and evacuation of the area (EGs 1, 2, and 6 only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high temperature autoclave steam shutoff system, pigtail line isolation systems (feed and transfer), UF_6 cylinders, pigtails, primary system piping outside the autoclave, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high temperature autoclave steam shutoff system, pigtail line isolation systems (feed and transfer), UF_6 cylinders, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.11 Pigtail/Line Failure at the Withdrawal Station (Primary System Integrity)

a. <u>Scenario Description</u>

Liquefied UF_6 is removed from the cascade in the withdrawal facilities and transferred into a cylinder through a flexible pipe or "pigtail." During withdrawal operations, several manipulations of the cylinder, pigtail, and associated mechanical connections are required in order to accomplish the tasks needed to withdraw UF_6. These operations include tasks such as connecting and disconnecting the pigtails, and purging and evacuating pigtails. Due to faulty equipment (i.e, pigtail line, gaskets, etc.) or multiple inadvertent operator errors, it is possible that the pigtail line or its associated equipment connections could fail resulting in a UF_6 release. In the event of a pigtail/line failure, the pigtail line isolation system will minimize the amount of UF_6 released by isolating the withdrawal stations. However, various administrative controls are used to prevent a pigtail/line failure. These administrative controls include:

- UF_6 lines are purged and evacuated before the primary system is opened;
- Only cylinder pigtails that have been inspected and approved are used;
- UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced;
- Cylinder cleaning requirements conform to ANSI N14.1 for cylinder cleaning;
- Operators disable the scale cart's air supply and place the air supply key holder on the cylinder valve on the pigtail prior to pigtail connection. This prevents anyone from reconnecting the air supply and ensures that no inadvertent movement of the scale cart occurs while a cylinder is connected to the pigtail; and
- UF_6 cylinders are not filled with UF_6 when there is a >40 lb (18 kg) discrepancy between shipper UF_6 cylinder weight and received cylinder weight until the weight discrepancy is explained.

All of the potential causes for pigtail/line failure were reviewed, along with operational experience, to determine the frequency associated with this event. Although pigtail failures have occurred in the past, the administrative controls listed above were identified as a result of these failures and have been implemented to reduce the probability of occurrence of this event. Based on the operations and administrative controls, this event was classified in the EBE frequency category because of the low probability that a pigtail/line failure would be caused by deficient pigtails or by multiple operator errors.

This event was evaluated and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation were provided. These consequences are based on a liquid/vapor UF_6 release from the cylinder feed manifold and a liquid/vapor release from the receiving cylinder.

The primary concern associated with this event is the loss of primary system integrity and the release of UF_6. The applicable EGs (see Table 4.2-2) associated with this event are EGs 1and 2, as well as EG 6 in the EBE frequency range. EG 3 does not apply since the primary system is assumed to fail. The essential safety actions associated with meeting these EGs include (1) detection of the release, (2) isolation of the primary system to stop the release (where possible), and (3) emergency response to evacuate the immediate vicinity so that the exposure of on-site personnel is minimized.

b. Source-Term Analysis

The initiators, source terms, and mitigation associated with a pigtail/line failure event at the withdrawal station vary only slightly from that described for a pigtail/line failure outside autoclave event (see Section 4.3.2.2.10). Only the variations from the autoclave scenarios are presented for the purpose of withdrawal scenario analysis.

This analysis assumes that the pigtail line isolation system will significantly limit the amount of UF_6 released due to a pigtail/line failure by automatically closing isolation valves within 30 seconds after detection of a UF_6 release. Since large quantities of "white smoke" are produced when relatively small quantities of UF_6 react with atmospheric moisture, it is assumed for the purpose of this analysis that the UF_6 detectors used in the withdrawal facilities will sense a significant UF_6 release in 15 seconds. Thus, the UF_6 release associated with a pigtail/line failure in the withdrawal facilities is assumed to last for a 45-second duration before closure of the isolation valves terminating the release.

The source term for the pigtail/line failure scenario in the withdrawal facilities is generally a function of the estimated release rate over the expected release duration. However, the release rate for this failure would be larger in the toll enrichment services facility than in the withdrawal facilities due to the higher operating temperatures. The initial conditions for the autoclave pigtail/line failure event scenario (Section 4.3.2.2.10) assumed that the initial temperature in the cylinder was 240°F (116°C). The temperature at the withdrawal stations is typically less than 180°F. Assuming all other conditions are constant, the vapor pressure of UF_6 associated with these operating temperatures would result in the toll transfer facility having a larger release rate than the withdrawal facilities for a pigtail/line failure event. Due to the larger release rate, the total amount of UF_6 released in the toll transfer facilities would be larger than the total amount released in the withdrawal facilities for the maximum 45 second release duration expected for a pigtail/line failure event.

c. Consequence Analysis

Based on the source term analysis, the consequences and mitigative controls associated with a pigtail/line failure event in the withdrawal facilities are bounded by the source terms and consequences associated with a pigtail/line failure event outside of the autoclave in the toll enrichment services facilities (see Section 4.3.2.2.10); thus no additional analysis is required for the pigtail/line failure event in the withdrawal facilities. Also, the withdrawal facilities have greater distance to the site boundary (> 1300 m) than the toll enrichment facility (1100 m).

d. <u>Comparison With Guidelines</u>

The comparison with guidelines is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the autoclave facilities is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release.

Operational personnel in the LCR or ACR — Operational personnel who can take mitigative action in the event of a UF_6 release associated with a pigtail/line failure in the withdrawal facilities are located in the LCR or ACR. In the event of a pigtail/line failure, LCR or ACR operator action will generally not be required because of the automated actions of the pigtail line isolation system. However, if the UF_6 detectors associated with this system are out of service (e.g., for maintenance, etc.), then manual actuation of the isolation system is required to minimize the release. Adequate time is available for operators to perform the required actions prior to any evacuation should the need arise. However, once the essential actions have been accomplished, the essential control to protect these personnel is evacuation, if required, upon detection of the release by sight or by odor.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the facilities are (1) detection of the release, (2) minimization of the release by initiating isolation, and (3) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential action is to detect the release of UF_6. The second essential action is accomplished by the manual or automatic isolation to terminate the release. For the withdrawal facility, the pigtail line isolation system will automatically detect the release and initiate primary system isolation. If workers outside of the process buildings have not received other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — The off-site consequences of a pigtail/line failure in the withdrawal station are bounded by the pigtail/line failure outside the autoclave scenario (see Section 4.3.2.2.10). The essential control for protecting the off-site public is isolation of the breach to minimize the UF_6 release.

e. <u>Summary of SSCs and TSR Controls</u>

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to prevent pigtail/line failure—maintain initial condition (normal operation, EG 5 only);
  1. UF_6 lines are purged and evacuated before the primary system is opened;
  2. Only cylinder pigtails that have been inspected and approved are used;
  3. UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced;
  4. Cylinder cleaning requirements conform to ANSI N14.1 for cylinder cleaning; and
  5. Operators disable the scale cart's air supply and place the air supply key holder on the cylinder valve on the pigtail prior to pigtail connection. This prevents anyone from reconnecting the air supply and ensures that no inadvertent movement of the scale cart occurs while a cylinder is connected to the pigtail; and
  6. UF_6 cylinders are not filled with UF_6 when there is a >40 lb (18 kg) discrepancy between shipper UF_6 cylinder weight and received cylinder weight until the weight discrepancy is explained.
- Pigtail line isolation system — closes isolation valves to terminate release (EGs 1, 2, and 6 only);
- UF_6 cylinders, pigtails, and primary system piping and associated isolation valves — maintain primary system integrity (EGs 1, 2, and 6 only); and
- Operator training for required actions — closure of isolation valves to terminate release and evacuation of the area (EGs 1, 2, and 6 only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The pigtail line isolation system, UF_6 cylinders, pigtails, and primary system piping and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the pigtail line isolation system, UF_6 cylinders, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.12 Process Line Failure at Compression Discharge (Primary System Integrity)

a. <u>Scenario Description</u>

During compression loop operation in the withdrawal facilities, a process line failure at the compression source discharge (i.e. centrifugal compressor) could result due to various initiators including: (1) UF_6/hot metal reaction (see Section 4.3.2.2.1) or (2) heavy equipment drop (see Section 4.3.2.2.8). The compression discharge line failure event was categorized in the EBE frequency category based on the likelihood of the identified initiating events progressing to a significant failure of the primary system before corrective action is taken.

This event was evaluated and it was determined that the consequences of the event could result in significant on-site impact if no mitigation were provided. These consequences are based upon a vapor UF_6 release from the compression source and a liquid/vapor UF_6 release resulting from backflow from the withdrawal equipment.

The primary concern associated with this event is the loss of primary system integrity and the release of UF_6. The applicable EGs (see Table 4.2-2) associated with this event are EGs 1 and 2, as well as EG 6 in the EBE frequency range. EG 3 does not apply since the primary system is assumed to fail. The essential safety actions associated with meeting these EGs include (1) visual/odor detection of the release, (2) tripping the compression source to minimize the amount of UF released, (3) building holdup, and (4) emergency response to evacuate the immediate vicinity so that the exposure of on-site personnel is minimized. These actions protect on-site personnel and maintain habitability of the required control area in accordance with EG 6 as well. The analysis for this event is similar to the compressor failure–UF_6/hot metal reaction (see Section 4.3.2.2.1).

b. Source-Term Analysis

A process line failure (i.e., breach) at the compression discharge in the withdrawal facilities would result primarily in a vapor phase release of UF_6. Process design considerations (i.e., height differences between the accumulator and condenser) would preclude any significant liquid-phase releases at a physical integrity failure near the compression discharge. However, the source-term analysis conservatively modeled the release assuming the compression source continues to pump vapor through the breach at 1.31 pounds per second at 30 psia while liquid UF_6 back flows through the breach at 6.73 pounds per second from other withdrawal process equipment. The gas-phase portion on the source term assumes the release is equivalent to the normal output of the compression source. The liquid-phase backflow portion of the source term was modeled as resulting from a one-inch diameter breach in the bottom of a vertical cylindrical tank 60 inches in diameter and 120 inches tall containing 21,000 pounds of liquid UF_6. This tank is roughly modeled after a UF_6 accumulator process tank that is typically near empty with accumulations of UF_6 usually happening only during cylinder changes. The largest accumulator at Tails has a capacity of approximately 13,300 pounds of liquid UF_6 and the two connected ten inch diameter accumulators have a capacity of approximately 2,900 pounds of liquid UF_6; the four eight inch diameter accumulators at LAW are connected in pairs with each pair having a capacity of approximately 2,500 pounds of liquid UF_6; the four accumulators at ERP are connected in pairs with the eight inch diameter pair having a capacity of approximately 2,500 pounds liquid UF_6 and the four inch diameter pair having a capacity of approximately 700 pounds of liquid UF_6.

The liquid-phase back flow portion of the source term represents a much larger release than would be expected from a primary system failure at the compression discharge. Because the UF_6 accumulator and condenser are located at a lower elevation than the compressor discharge, it would not be possible for liquid UF_6 to flow upward and out of the compressor discharge line breach. The expected vapor flow from the top of the accumulator through the condenser and interconnecting piping and valves would be much less than the modeled 6.73 pounds per second (probably on the order of one pound per second). Therefore, the combined 8.04 pounds per second release rate developed by the source-term analysis represents a release that is much larger than the actual UF_6 release expected to occur from a process line failure at the compression discharge.

c. Consequence Analysis

As discussed in the source-term analysis, it is unlikely that a process line failure at the compression discharge event would result in a 8.04 pounds per second release rate. However, the consequences associated with releasing UF_6 in the withdrawal facilities at rate of 8.04 pounds per second have been evaluated. This consequence analysis determined that if no mitigation were provided, the hazardous material doses at a distance of 1000 meters (actual distance from the withdrawal stations to the nearest site boundary varies from 1300 to 1500 meters) for a 30-minute plume exposure associated with this release would be 9.8 mg of uranium and 5.4 ppm (one hour equivalent exposure) of hydrogen fluoride. The uranium exposure consequence would satisfy the EGs for the EBE category. The consequences that this exposure level would have on different receptors are discussed below.

Local workers in the immediate area —Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within the withdrawal buildings is: (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide an indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release. All the cascade UF_6 processing equipment and major piping that are common with the withdrawal facilities are enclosed in housings to maintain normal operating temperatures. The configuration of the housings required to maintain normal operating temperatures, and therefore to keep UF_6 in the gaseous state, provides an inherent barrier against UF releases within the housing. Although the housings provide the local worker with additional time to detect the release and evacuate the area, the housings are not considered an essential control for this receptor rather they provide further assurance that workers will be able to evacuate the area in accordance with the plant see and flee policy. Personnel protective equipment (PPE) or other protective measures (e.g., emergency egress capability) must be available for personnel operating process building cranes.

Operational personnel in the ACR or LCR —Operating personnel who can take mitigative action (i.e., trip motors) in the event of a process gas release are located in the associated ACR (LAW & TAILS) or LCR (ERP). The ACR or LCR would not be affected by the release in the time frame required to take mitigative actions. However, if operating personnel must be evacuated from the ACR or LCR due to the release, then the required mitigative actions could be accomplished from the X-300 building or other locations.

Workers outside the process buildings —The essential controls for protecting on-site personnel outside the process buildings are: (1) detection of the release, (2) minimization of the release by tripping the compression source (e.g., centrifugal motor manual trip for second stage compressors), (3) temporary holdup of the release by the existing process building structure, and (4) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential control is detection of the release of UF_6. Motor load indicators provide an indication of abnormal compressor operations that could lead to failure (i.e., surging and/or loss of load). Typically, this indication will be detected and corrective action will be taken prior to primary system failure. However, if a primary system failure does occur and a release is confirmed (e.g., UF_6 release detection alarms, operator visual/odor indications), then actions can be taken to trip the appropriate motors to minimize the release. The compressor motors (for either the withdrawal compressor or the cell feeding the withdrawal station) can be manually tripped from several locations (i.e., LCR, ACR and PCF). Once the motor stops operating, the release of material from the compression source is effectively terminated. However, the release from the other process sources (i.e., accumulator and condenser) may continue until they are exhausted. Withdrawal process equipment housings outside of the cascade cells are not credited with providing a time delay between a release of UF_6 from the primary system to release from the building. The existing process building structure is expected to reduce the potential hazardous material concentrations to receptors outside of the building by holdup of a portion of the UF_6 released, and by causing most of the UF_6 that escapes the building to be released at an elevated point. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — As indicated above, this scenario event will not result in consequences that would exceed the 30-mg U guideline for the EBE frequency category with no mitigation other than building holdup. However, the smaller source term expected and the release mitigation actions identified for on-site personnel provide additional assurance that off-site consequences of this event will be minimized.

d. Comparison With Guidelines

The EGs for the AE frequency category from Table 4.2-2 were compared with the consequences associated with the event scenario. The equipment configuration does not provide for automatic detection and trips on process line failure at compressor discharge, so compliance with EG 3 cannot be verified during normal operation. For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However, the controls identified (i.e., see and flee) will maintain exposures within EGs 1 and 2 to the extent practical. Actions required of operations personnel in the ACR or LCR were evaluated (i.e. tripping the second stage centrifugal compressors), and they can be accomplished to meet the requirement for EG 6. In the event that the release ultimately affects the habitability of the ACR or LCR, this receptor would be able to evacuate the area before EGs 1 and 2 are exceeded and the necessary actions could be accomplished from the X-300 building or other locations. In addition, based on the controls identified, (i.e., release detection, second stage centrifugal compressor trip, building holdup, evacuation of areas upon detection of the release), EGs 1 and 2 would be met for workers outside the process building. Finally, an analysis was performed which determined that, if no mitigation were provided, off-site exposure would not exceed guidelines.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Motor load indicators in ACR (LAW & TAILS) or LCR (ERP) for second stage compressors— early detection of compressor failure (i.e., surging and/or loss of load) (EG 3 only); and

- Compressor motor manual trip in ACR (LAW & TAILS) or LCR (ERP) for second stage compressors — elimination of heat/friction (EG 3 only).

Essential mitigation of any UF_6 releases associated with this event (EGs 1, 2, and 6) are summarized as follows:

- Compressor motor manual trip in ACR (LAW & TAILS) or LCR (ERP) for second stage compressors — minimize release to workers outside the process building (EGs 1, 2, and 6)
- UF_6 release detection associated with withdrawal compressors — minimize release to workers outside the process building (EGs 1, 2, and 6);
- Visual/odor detection of release, worker training, and evacuation of affected area—all on-site workers (EGs 1 and 2);
- Administrative control—personal protective equipment (PPE) or other protective measures shall be available to personnel operating process building cranes (EGs 1 and 2); and
- Process building holdup—workers outside process building (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The motor load indicators and compressor motor manual trip system for second stage compressors, UF_6 release detection, and the process buildings are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the motor load indicators and the compressor motor manual trip system for second stage compressors; UF_6 release detection; and administrative requirements for procedures and training of workers for evacuation actions, and for protective equipment/measures for crane operators.

4.3.2.2.13 Pigtail Failure Inside Autoclave (Primary System Integrity)

a. <u>Scenario Description</u>

During autoclave operations, several manipulations of the cylinder and pigtail connections are made to accomplish the required tasks associated with the heating, sampling, feed, and transfer of UF_6. These operations include such activities as rolling the cylinder, connecting and disconnecting pigtails, and purging and evacuating pigtails. All pigtail operations take place in the autoclave cylinder/pigtail operations mode of operation, which greatly reduces the potential frequency of this event. In addition, administrative controls are required to leak-test pigtails after each connection ensuring proper connections as well as only using inspected and approved pigtails. However, with multiple operator errors, it is postulated that a pigtail failure could occur after the autoclave is closed. This event is an EBE because of the low probability that a pigtail failure will be caused by a deficient pigtail or multiple operator errors during autoclave operations.

This event was evaluated and it was determined that the consequences could result in significant off-site and on-site impact if no mitigation is provided. These consequences are based on a liquid UF_6 release.

The primary concern associated with this event is the loss of primary system integrity and the release of liquid UF_6. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the EBE frequency range. The only safety action required to meet these EGs is to establish primary containment. This action will prevent any significant release of material to the immediate area (i.e., protecting on-site personnel and maintaining habitability of the ACR) as well as limiting off-site public exposure within the EGs.

The initial conditions assumed in the analysis of this event were as follows:

- Initial cylinder temperature is conservatively 240°F (116°C), which is controlled by the UF_6 cylinder high temperature autoclave steam shutoff system.
- Condensate level within the autoclave is below the shell at the condensate drain, which is controlled by the autoclave high condensate level shutoff system.
- Administrative controls in place to prevent pigtail failure are:
  1. Only cylinder pigtails that have been inspected and approved are used.
  2. UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced.
  3. UF_6 cylinders are not rolled unless visual contact is made with the pigtail during the operation to prevent breakage of a pigtail.

Should these controls fail, it is postulated that a complete failure of a pigtail connection (or cylinder valve, pigtail, or line down stream of any installed MgF_2 traps) could occur within the autoclave while connected to a 14-ton cylinder filled with liquid UF_6. Analysis has shown that the release of the UF_6 would increase the autoclave pressure proportional to the rate the UF_6 is released. The initial conditions (except for cylinder administrative controls) for this scenario are identical to the event described in Section 4.3.2.2.14, cylinder failure inside autoclave. Since the cylinder failure scenario has a greater release rate of UF_6, the source-terms, consequences, and comparison with guidelines for this scenario are bounded by Section 4.3.2.2.14. Therefore, further analysis for this scenario is not necessary.

b. Source-Term Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

c. Consequence Analysis

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

d. Comparison With Guidelines

Further analysis is not required because this event is bounded by the cylinder failure inside autoclave event, Section 4.3.2.2.14.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to prevent pigtail failure during autoclave operations — maintain initial condition (normal operation, EG 5 only);
  1. Only cylinder pigtails that have been inspected and approved are used.
  2. UF_6 pigtails, when connected for use, are leak-tested before UF_6 is introduced.
  3. UF_6 cylinders are not rolled unless visual contact is made with the pigtail during the operation to prevent breakage of a pigtail.
- UF_6 cylinder high temperature autoclave steam shutoff system — maintain initial condition (normal operation, EG 5 only);
- Autoclave high condensate level shutoff system — maintain initial condition (normal operation, EG 5 only);
- Autoclave shell high pressure containment shutdown system—detection of high autoclave pressure and isolation of autoclave (EGs 1 and 2);
- Autoclave shell and associated isolation valves — minimize exposures to on-site and off-site personnel (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high temperature autoclave steam shutoff system, autoclave high condensate level shutoff system, autoclave shell high pressure containment shutdown system, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high temperature autoclave steam shutoff system, autoclave high condensate level shutoff system, autoclave shell high pressure containment shutdown system, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.14 Cylinder Failure Inside Autoclave (Primary System Integrity)

a. Scenario Description

During autoclave operations, the heating of cylinders inside the autoclaves is a normal operation. During these operations, the potential exists for cylinder failures inside the autoclave. A loss of the primary system integrity of a cylinder in an autoclave can result in a large release within the autoclave. Cylinder failure can be caused by pressure increases from heating (at normal operating temperatures) a cylinder containing abnormal contents [e.g., excessive UF_6 or excessive noncondensables (Sections 4.3.2.2.6 and 7)] or a damaged cylinder (Section 4.3.2.2.9). However, because of the autoclave controls and the administrative controls in place preventing these events from occurring, this event is an EBE.

This event was evaluated, and it was determined that the consequences could result in significant off-site/on-site impact if no mitigation were provided. These consequences are based on a liquid UF_6 release.

The primary concern associated with this event is the loss of primary system integrity and the release of liquid UF_6. The applicable EGs (see Table 4.2-2) associated with this event are all of the EGs for the EBE frequency range. The only safety action required to meet these EGs is to establish primary containment. This action will prevent any significant release of material to the immediate area (i.e., protecting on-site personnel and maintaining habitability of the ACR) as well as limiting off-site public exposure within the EGs.

The initial conditions assumed in the analysis for this event are as follows:

- Initial temperature in the cylinder is conservatively 240°F (116°C), which is controlled by the UF_6 cylinder high temperature autoclave steam shutoff system.
- The amount of water available for reaction with UF_6 is limited to the amount of water that is normally present inside the autoclave during heating conditions. This source of water includes (1) the steam supply for heating the autoclave; and (2) condensate collecting inside the autoclave. The autoclave high condensate level shutoff system provides additional assurance that condensate does not accumulate in the autoclave.
- Administrative controls in place to prevent cylinder failure are as follows:
  1. A cold pressure check, indicating less than or equal to 10 psia (69 kPa), is performed prior to initial heating [Cylinders that exceed this pressure and cannot be cold-burped down to less than or equal to 10 psia (69 kPa) may be heated only in the controlled feeding mode of operation that prevents liquefaction of the UF_6.]
  2. Initial heat up of cylinders (2.5-, 10-, and 14-ton) is performed only with the cylinder valve in the 12 o'clock position.
  3. Cylinders are inspected for obvious damage that could threaten their ability to withstand a normal heating cycle prior to heating. (Damaged cylinders that do not meet inspection restrictions may be heated only in the controlled feeding mode of operation, which prevents liquefaction of the UF_6.)
  4. UF_6 cylinders to be heated in an autoclave have their weight verified (by comparison of two cylinder weight determinations) prior to heating. (Cylinders that exceed the shipping weight values are heated under controls specified in the TSRs.)

However, even with these controls in place, a significant release of UF_6 could occur if the administrative controls/design controls fail to prevent a loss of the primary system integrity. This scenario is considered a limiting event for the primary system integrity failure and the EBE frequency category.

b. <u>Source-Term Analysis</u>

The limiting event for a loss of primary system integrity inside the autoclave is represented by the assumption that a 14-ton cylinder containing liquid UF_6 fails during a heating cycle inside the autoclave. During the heating cycle, the UF_6 expands. Ullage is lost when a cylinder is heated to an excessive temperature in relation to the amount of UF_6 in the cylinder. A cylinder is assumed to fail at some point above its hydrostatic test pressure limit. Once the primary system fails, the release of UF_6 material into the autoclave environment of saturated steam initiates the exothermic UF_6 and H_2O reaction, which generates HF and UO_2F_2 and causes a pressure increase inside the autoclave. The source term for this event will address the amount of material that could be released prior to autoclave isolation and subsequent leakages/relief paths once isolation is completed.

During operations in which the autoclave is closed for heating purposes, the only autoclave penetration that would allow release of material to the atmosphere is the condensate drain line. Any releases through this line would react with the condensate to form UO_2F_2 and HF. Both of these compounds are sufficiently soluble in water to allow very little, if any, release to the atmosphere. Once isolation of the autoclave is accomplished (typically less than 35 seconds for any significant release), the inflow of steam will be terminated to prevent additional moisture from entering the autoclave and reacting with the UF_6. The pressure inside the autoclave will continue to rise until the limiting reactant (i.e., the moisture) is consumed. An analysis indicates that the pressure inside the autoclave will not reach the maximum allowable working pressure (MAWP) for any of the autoclaves given any of the autoclave/cylinder configurations. Therefore, no release due to autoclave over pressurization is considered.

Subsequent leakage of released material from the autoclave as a result of leakage past valve seats and the autoclave shell seals is also considered. This leakage was quantified by assuming that the autoclave is functionally tested at 90 psig (0.72 MPa) with no more than 10 psi/h (69 kPa)/hr) or 12 scfm loss. Two cases were considered. The first case assumed that the leakage occurs at the autoclave shell seal toward the top of the autoclave resulting in a UF_6 vapor release. The release rate for this case was determined to be 3.5 lb/min (1.6 kg/min). The second case assumed that the leakage occurs at the autoclave shell seal toward the bottom of the autoclave resulting in a liquid UF_6 release. The release rate for this case was determined to be 8.3 lb/min (3.8 kg/min). These release rates are extremely low relative to the rates evaluated in Section 4.3.2.2.10, pigtail/line failure outside autoclave. Additional leakage through the autoclave seal may also be experienced if some degradation occurs due to the environment inside the autoclave. However, the leak rate would have to be significant to result in any significant consequences beyond the immediate vicinity. This is not expected because less than 200 lb (91 kg) of HF is generated from the reaction with UF_6. Therefore, the releases from a closed autoclave would be maintained below the EGs for the EBE frequency category.

c. <u>Consequence Analysis</u>

This is not applicable because the amount of release is bounded by the event evaluated in Section 4.3.2.2.10.

d. <u>Comparison With Guidelines</u>

The comparison with guidelines is subdivided to address the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within these facilities is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release.

Operational personnel in the control area — There are no required operator actions for this event. Therefore, the actions for this area are no different than those for the local worker.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the facilities are (1) establish primary containment, (2) detection of the release, and (3) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential action is to establish primary containment by initiation of the autoclave high pressure containment shutdown system. This minimizes release of material for all receptors. The second action is to detect the release of UF_6. If workers outside of the process buildings have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public —The consequences of this event will be bounded by the releases described in Section 4.3.2.2.10, pigtail/line failure outside autoclave, for the cases where isolation is accomplished. Therefore, off-site consequences will not exceed the EGs.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls in place to prevent cylinder failure are as follows:
  1. A cold pressure check, indicating less than or equal to 10 psia (69 kPa), is performed prior to initial heating. [Cylinders that exceed this pressure and cannot be cold burped down to less than or equal to 10 psia (69 kPa) may be heated only in the controlled feeding mode of operation that prevents liquefaction of the UF_6.]
  2. Initial heat up of cylinders (2.5-, 10-, and 14-ton) is performed only with the cylinder valve in the 12 o'clock position.
  3. Cylinders are inspected for obvious damage that could threaten their ability to withstand a normal heating cycle prior to heating. (Damaged cylinders that to not meet inspection restrictions may be heated only in the controlled feeding mode of operation, which prevents liquefaction of the UF_6.)
  4. UF_6 cylinders to be heated in an autoclave have their weight verified (by comparison of two weight determinations) prior to heating. (Cylinders that exceed the shipping weight values are heated under controls specified in the TSRs.)
- UF_6 cylinder high temperature autoclave steam shutoff system—maintain initial condition (normal operation, EG 5 only);
- Autoclave high condensate level shutoff system—maintain initial condition (normal operation, EG 5 only);
- Autoclave shell high pressure containment shutdown system—detection of high autoclave pressure and isolation of autoclave (EGs 1 and 2); and

- Autoclave shell and associated isolation valves—minimize exposures to on-site and off-site personnel (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinders, UF_6 cylinder high temperature autoclave steam shutoff system, autoclave high condensate level shutoff system, autoclave shell high pressure containment shutdown system, and the autoclave shell and associated isolation valves are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinders, UF_6 cylinder high temperature autoclave steam shutoff system, autoclave high condensate level shutoff system, autoclave shell high pressure containment shutdown system, and administrative requirements for procedures and training of workers for evacuation actions.

4.3.2.2.15 Cylinder Failure Outside Autoclave (Primary System Integrity)

a. <u>Scenario Description</u>

During feed, transfer, sampling, and withdrawal operations, handling and moving liquid- and solid-filled cylinders is a normal operation. During cylinder moving operations outside of the autoclaves, it is possible that the cylinder could suffer a physical integrity failure that could result in a large UF_6 release. The physical integrity failure can be caused by initiators such as dropping a liquid-filled cylinder, dropping a heavy component onto a liquid-filled cylinder, filling a cylinder contaminated with hydrocarbons, or impact from a vehicle. After an accidental drop of a liquid-filled cylinder at PORTS (see Section 4.3.1.2.3.1.2), various preventive controls (operator training, crane design and inspections, etc.) were instituted at both GDPs to reduce the probability of occurrence for this event. Based upon these preventive controls, an integrity failure event of a liquid-filled cylinder (i.e., liquid cylinder drop) occurring outside of an autoclave is classified in the EBE frequency category.

This scenario evaluates a physical integrity failure of a liquid-filled cylinder outside of an autoclave (specifically dropping a liquid-filled cylinder). The initial conditions assumed in the analysis of this event are as follows:

- Initial temperature in the cylinder is conservatively 240°F (116°C), which is controlled by the UF_6 cylinder high temperature autoclave steam shutoff system for autoclave facilities (withdrawal facilities operate at much lower temperatures and no control is required);
- The following administrative controls are in place:
  1. Liquid UF_6 cylinder handling cranes are inspected daily (prior to first use) for obvious defects associated with the lifting system;
  2. No cylinder or similar weight load is moved over a cylinder containing liquid UF_6;
  3. Only approved cylinder handling equipment is used by qualified operators for maneuvering cylinders and other heavy loads;
  4. Cylinder cleaning requirements conform to ANSI N14.1 for cylinder cleaning;
  5. Cylinders to be filled with UF_6 are verified as passing a current (within 5 years) hydrostatic pressure test;

6. Cylinders containing liquid UF_6 are staged in a designated area until solidified (this area is restricted so that routine vehicle traffic is not allowed - vehicles are required to support certain maintenance evolutions); and
7. UF_6 cylinders to be filled or heated are inspected for obvious damage that could threaten their ability to withstand normal filling, heating and moving.

The physical integrity failure event of a liquid-filled cylinder outside of an autoclave was previously evaluated for the withdrawal facilities, the feed facilities, and the toll enrichment services facility. These evaluations determined that a significant release of UF_6 could occur if the administrative controls/design controls fail to prevent a failure of the cylinder's primary system integrity. The liquid-filled cylinder drop scenario is considered a limiting event for the primary system integrity failure and the EBE frequency category.

The primary concern associated with this event is the release of liquid UF_6. The applicable EGs (see Table 4.2-2) associated with this event are EGs 1 and 2, as well as EG 6 in the EBE frequency range. EG 3 would not apply since the cylinder's integrity is defined to fail in the scenario description and no other containment is provided for this type of event. The essential safety actions associated with meeting these EGs for a cylinder failure outside an autoclave include detection of the release and emergency response to evacuate the immediate vicinity and downwind locations to minimize on-site/off-site personnel exposure.

b. <u>Source-Term Analysis</u>

The source-term analysis simulated dropping of a type 48G thin-wall cylinder containing the maximum permissible quantity of 28,000 lb (12,700 kg) of liquid UF_6 at 240°F (116°C) [as specified in ANSI N14.1]. The cylinder is assumed to be dropped as it is being moved outdoors which results in a physical integrity breach developing at the bottom of the cylinder. The liquid UF_6 inside the cylinder is assumed to be at 240°F (116°C) with an associated vapor pressure about 6 times atmospheric [88 psia (0.61 Mpa)]. The release duration is assumed to be fixed at 5 min (300 s). The average liquid UF_6 release rate is approximately 93.3 pounds per second (42.3 kg/s). To obtain this release rate with 88 psia (0.61 MPa) internal pressure, the breach would have an effective diameter of 2.75 in. (0.07 m). The presence or absence of noncondensable gases is not significant in this case because the breach diameter is calculated from a fixed release duration (i.e., 300 s), not vice versa.

As the liquid UF_6 is released, 62.5 percent [17,500 lb (7900 kg)] would be flashed to vapor, and the remaining 37.5 percent [10,500 lb (4800 kg)] is assumed to become entrained solid UF_6. Both the vapor and the solid are approximated to be at the equilibrium temperature of 133.8°F (56.6°C) at 1 atm (0.101 MPa). The release is assumed to be just above ground level and pointed directly toward the ground (i.e., the released UF_6 would have no net horizontal velocity). The released UF_6 is assumed to be 5.5 percent ^{235}U, by weight.

c. <u>Consequence Analysis</u>

The atmospheric dispersion of UF_6 associated with dropping a liquid-filled cylinder has been evaluated. The following discussion of the consequence analysis is broken into five sections. The first subsection details a baseline scenario that estimates conservative (i.e. reasonable upper-bound) consequences from a liquid UF_6 release from a dropped cylinder. The second subsection discusses the effect on consequence estimates of varying input parameters from those used in the baseline scenario. The third subsection describes maximum estimates of downwind uranium deposition that would occur with the baseline scenario. The fourth subsection compares the consequence estimates from the baseline scenario developed using the HGSYSTEM/UF_6 model with the more widely used Gaussian plume method. The final subsection discusses uncertainties in the analysis that have not been quantified.

Baseline scenario. Parameters that define the base scenario are listed in Table 4.3-8 . This scenario includes adverse meteorological conditions (i.e., conditions resulting in high-consequence estimates), consisting of a stable atmosphere and a low wind speed [Pasquill-Gifford stability class F and a wind speed of 1 m/s (2 mph), or simply F1]. These conditions occur at PORTS 3.4 percent of the time on an annual basis (averaged over the 1-yr period, 1993).

An ambient air temperature of 40°F (4.4°C) was selected for these simulations because that temperature results in relatively high consequence estimates compared to other temperatures that occur under F1 conditions. Lower ambient temperatures [to 30°F (-1°C)] were also evaluated and indicated marginally higher consequences. However, lower temperatures introduce condensation mechanisms for which there is less confidence in model results. Therefore, 40°F (4.4°C) is the lowest ambient temperature used in this analysis. During 1993, ambient temperatures were greater than 40°F (4.4°C) about 80 percent of the time.

An ambient relative humidity of 70 percent was selected for the baseline scenario because it is a typical relative humidity for a stable atmosphere with low wind speeds at PORTS. During 1993, the median relative humidity under F1 conditions was 80 percent. Higher relative humidities (e.g., 90 percent) would result in only minimally higher consequence estimates because the corresponding increase in specific humidity (the humidity expressed as the number of grams of water vapor per kilogram of moist air) at 40°F (4.4°C) is very small. The maximum relative humidity under F1 in 1993 was 100 percent. The maximum specific humidity (100 percent relative humidity) associated with an ambient air temperature of 40°F (4.4°C) is 5.5 g of water vapor per kilogram of moist air. Twenty percent of that amount (the difference between 70 percent and 90 percent relative humidity) is 1.1 g of water vapor per kilogram of air. This slight difference in water vapor available for UF_6 hydrolysis reactions would result in virtually no change in downwind consequence estimates.

Because the released UF_6 would impact with ground directly, all of its momentum would be transferred to the ground surface, and the plume would initially mix with the ambient air. The degree to which mixing with the ambient air would occur is unknown. Previous dispersion studies have used an initial mixing factor (ratio of the volume of ambient dry air to the volume of released UF_6) of 10. For this analysis, 50 was selected as the volume mixing ratio because 50 results in slightly higher consequence estimates than 10 does for downwind distances greater than 980 ft (300 m).

Although about 40 percent of the UF_6 is initially solid at the release point, the baseline scenario assumes that all of the solid is entrained in the airborne plume and that none of the UF_6 deposits near the release point. The entrained solid would quickly sublimate to UF_6 vapor while it is airborne; then it would react with atmospheric water vapor and be dispersed downwind. This assumption results in maximum health consequence estimates downwind of the release point because a larger mass of UF_6 is dispersed downwind. On the basis of historical accidental UF_6 releases (see Section 4.3.1.2.3.1), some initial deposition would be expected to occur near the release point.

As the UF_6 plume disperses downwind, objects projecting vertically (e.g., grass, trees, buildings) will cause mechanical turbulence, which could affect the dispersion characteristics where a greater amount of mechanical turbulence is generated by taller objects. The surface roughness is typically about one-tenth of the mean height of these objects and is a parameter used in calculating mechanical turbulence in the lower atmosphere. Surface roughness may be calculated rather than estimated from the typical height of objects for a given area, but this calculation requires detailed wind measurements that are not usually available. Normally, roughness is estimated from a limited number of field experiments that have occurred over a variety of terrains (see Reference 4.5). On the basis of these field experiments and the resulting roughness classifications, a surface roughness height of 1 in. (0.03 m) was selected because of site characteristics (i.e., long flat buildings located at and near the facility) for the baseline scenario. A roughness of 1 in. (0.03 m) is typical of low grass areas that would be found in a rural environment or a large parking lot found in an urban environment and results in relatively high downwind consequence estimates.

HEGADAS/UF_6 (see Section 4.3.1.2.3.4) was used to predict downwind concentrations of uranium and HF. Figures 4.3-23 through 4.3-25 show estimated downwind consequences associated with the baseline scenario. Note that the baseline scenario (F1) is represented by the top curve in these figures (the other two curves are for different meteorological conditions and are discussed below). Consequence estimates are expressed in terms of uranium chemical toxicity dose (see Figure 4.3-23), radioactive toxicity dose (see Figure 4.3-24), and equivalent HF chemical exposure concentration (see Figure 4.3-25). Calculation of these consequence values are made using concentration estimates from HEGADAS/UF_6. The exposure time from a passing plume was limited to 30 minutes. Exposures greater than 30 minutes would result in slightly higher consequence estimates.

Table 4.3-9 lists specific consequence estimates at the nearest site boundary, 1 mile (1600 m), and 5 miles (8050 m) downwind from the potential release point. The potential release point is assumed to be located outside the western entrance of the cylinder transfer building (Building X-344-A). This point was chosen because it represents a potential release location which would result in maximum consequences at the site boundary. The nearest site boundary is located about 0.68 mile (1100 m) to the northwest of the potential release point. Calculated values of the consequence parameters were compared to EBE guideline values for uranium (25 rem for U radiological toxicity, and 30 mg U intake for U chemical toxicity), and to the Emergency Response Planning Guidelines (ERPG-2) for HF (20 ppm for 1-hour).

As shown in Figures 4.3-23 through 4.3-25, for F1 atmospheric conditions, the guideline value of 30 mg inhaled uranium is exceeded to a downwind distance of about 3.4 miles (5500 m), the 25 rem radiological toxicity dose is exceeded out to about 0.3 miles (500 m), and the 20 ppm 1-h equivalent HF exposure is exceeded to a downwind distance of about 2.3 miles (3750 m).

Effects of varying scenario parameters on consequence estimates. The following parameters were varied to parameterize some of the uncertainty estimates: (1) meteorological conditions (specifically, atmospheric stability, wind speed, temperature, and relative humidity), (2) initial mixing of the released UF_6 with ambient air, (3) initial deposition of solid UF_6 at the release point, (4) surrounding surface roughness, and (5) plume lift-off. The difference in consequence estimates that result by varying these parameters are presented in this analysis to contribute to the understanding of baseline scenario results (as a reminder, the results from the baseline scenario are considered to provide upper-bound estimates resulting from atmospheric release of UF_6 associated with dropping a single, liquid-filled cylinder). The consequences presented in this section are less than the baseline scenario but are more probable and/or provide a lower-bound estimate of consequences; therefore, they are used to establish a range of potential consequences. For the initial mixing, initial deposition, and surface roughness sensitivity discussions, consequence estimates comparisons are not shown for radiological toxicity dose and HF exposure because these estimates display the same general trend as the uranium chemical toxicity dose.

Meteorological conditions — Consequence estimates were made for two additional meteorological conditions to compare with the baseline scenario: (1) typical conditions that do not provide favorable or unfavorable consequence estimates [represented by neutral atmospheric stability (Pasquill-Gifford stability class equal to D) and moderate wind speeds (4 m/s = 9 mph)] and (2) typical conditions that provide relatively low-consequence estimates [represented by a slightly unstable atmosphere (Pasquill-Gifford stability class equal to C) with moderate wind speeds (4 m/s)]. These representative meteorological conditions were chosen based on a screening analysis performed using the simple Gaussian plume equation.

Table 4.3-10 shows the results of this screening analysis, where normalized concentration values (concentration, χ, divided by the source term, Q, therefore called χ/Q values) were calculated at a downwind distance of 0.62 mile (1 km), assuming that the source was at ground level and that plume constituents were not reactive. The values of χ/Q in Table 4.3-10 are ordered such that values near the top of the table represent more favorable dispersion conditions and values near the bottom represent less favorable dispersion conditions.

The most frequently occurring meteorological condition at PORTS is D4 (stability class D, neutral, and wind speed of 4 m/s), which occurred 8.4 percent of the time on an annual basis. As shown in Table 4.3-10, meteorological conditions that would result in equal or lesser consequences than those produced by D4 conditions would occur 57 percent of the time. Therefore, D4 provides bounding estimates (i.e., relatively conservative) for more frequently occurring meteorological conditions. An additional criterion for selecting D4 is the historical use of similar meteorological conditions in regulatory applications. The U.S. Department of Transportation has used D4.5 to calculate evacuation distances along transportation corridors for accidents involving toxic chemicals (see References 71 and 72) and the U.S. Army has used D3 as the default value for "conservative-most-likely" meteorological conditions for assessing hazards associated with accidental releases of chemical warfare agent (see References 73 and 74). Based on the selections of similar atmospheric conditions and the frequency of occurrence at PORTS, D4 was chosen to represent typical conditions that do not bias the result toward favorable or unfavorable consequence estimates. The temperature of 40°F (4.4°C) and relative humidity (70 percent) were not varied from the baseline scenario [which used F1 (stability class F, stable, and a wind speed of 1 m/s) meteorological conditions].

The C4 meteorological condition occurs about 4.1 percent of the time. As shown in Table 4.3-10, consequence estimates would be more favorable or equal to C4 about 32 percent of the time. Other meteorological conditions, such as A1, A2, and B2 occur more frequently, but these scenarios are considered too propitious for the purpose of this comparative analysis. Therefore, C4 was selected to represent a typical condition that results in relatively low consequence estimates. The temperature and relative humidity for this scenario were selected to represent typical summer, daytime conditions when C stability is likely to occur. The temperature used for this comparative scenario was 80°F (27°C), and the relative humidity was 50 percent.

Figures 4.3-23 through 4.3-25 show consequence estimates for C4 and D4 meteorological conditions. For D4, consequence estimates exceed guideline values downwind to about 2.2 miles (3500 m), 0.2 mile (300 m), and 2.2 miles (3500 m) for uranium chemical toxicity dose (30 mg), radiological toxicity dose (25 rem), and HF exposure (20 ppm), respectively. Although D4 conditions result in lower downwind consequences when compared with those estimated for F1, all of the guideline values are exceeded at the nearest site boundary, which is about 0.68 mile (1100 m) from the release point. For C4, consequence estimates exceed guideline values downwind to about 0.59 mile (960 m), 0.12 mile (200 m), and 0.68 mile (1100 m) for uranium chemical toxicity dose, radiological toxicity dose, and HF exposure, respectively. Under C4 conditions, estimated consequences are at or below guideline values at the nearest site boundary.

Initial mixing with the ambient air — Figure 4.3-26 shows the comparison of consequence estimates (specifically, consequence estimates for uranium chemical toxicity dose) between two different mixing ratios of the volume of ambient dry air to the volume of released UF_6. For the baseline scenario, a value of 50 was used for the mixing ratio and was compared with a value of 10, which has been used in previous dispersion analyses. The results show virtually no difference between consequence estimates. A mixing value of 50 results in slightly higher downwind consequence estimates at distances beyond 984 ft (300 m) because the initial dilution with ambient air causes the plume to be cooler, and therefore the plume would have dispersed less in the vertical direction at a particular downwind distance. At distances less than or equal to 984 ft (300 m), plume concentrations would be slightly higher with a lower mixing ratio (i.e., lower initial dilution) even though the plume temperature is higher. At these close distances, sufficient vertical spreading has not occurred to reduce ground-level concentrations appreciably. It is expected that higher initial mixing ratios would also result in virtually the same downwind consequence estimates.

Initial deposition of solid UF_6 — Figure 4.3-27 shows the comparison of consequence estimates between no initial deposition of solid UF_6 and 40 percent initial deposition of solid UF_6 [the maximum initial deposition expected because about 37.5 percent of the UF_6 flashes to solid at the time of atmospheric release]. In calculating 40 percent initial deposition of UF_6, the solid UF_6 was assumed to be mixed initially with the ambient air using a mixing ratio of fifty (as detailed above) and then allowed to settle. Although 60 percent of the UF_6 used in the baseline scenario was input into the HEGADAS/UF_6 model, downwind consequence estimates are about 63 percent of those predicted with the baseline scenario at a downwind distance of 1 mile (1600 m). This 3 percent difference results from a lower estimated plume temperature associated with the lower mass of UF_6 dispersed into the atmosphere. Because the plume temperature is lower, the plume disperses less in the vertical direction at a particular downwind distance, thus increasing ground-level concentrations. If a greater amount of solid UF_6 could initially deposit, then this effect would be somewhat more prominent.

Surface roughness — Figure 4.3-28 shows the comparison of consequence estimates between the two roughness heights, 1 in. (0.03 m) used in the baseline scenario and 3.3 ft (1.0 m). A roughness height of 3.3 ft (1.0 m) is typically associated with an urban or heavily forested area, where mechanical mixing is high and resulting ground-level concentrations are generally lower than rural areas. Very close to the release point [i.e., within 160 ft (50 m)] there is little difference in consequence estimates because this is the downwind region where the plume is very dense relative to air and is rapidly spreading horizontally due to gravitational slumping. From 160 to 1300 ft (50 to 400 m), the difference in consequence estimates increases, so that at 1300 ft (400 m) consequence estimates from 1 in. (0.03 m) roughness are about 8 times that of 3.3 ft (1.0 m) roughness. For this downwind distance range, mechanical turbulence has the greatest effect on dispersion because the plume is closest to the ground and has not yet spread appreciably in the vertical direction. At farther downwind distances, the plume begins to disperse in the vertical direction, and the difference between consequence estimates decreases. At 0.68 mile (1100 m) (the downwind distance to the nearest site boundary), consequence estimates from 1 in. (0.03 m) roughness are about 6 times that of 3.3 ft (1.0 m) roughness. At 1 mile (1600 m), 2 miles (3200 m), and 5 miles (8050 m), consequence estimates from 1 in. (0.03 m) roughness are about 5, 4, and 3.5 times higher than the 3.3 ft (1.0 m) roughness, respectively.

Because roughness at the site is not known, the baseline scenario value of 1 in. (0.03 m) was selected to provide upper-bound consequence estimates, and the 3.3 ft (1.0 m) urban roughness value was selected to provide lower-bound estimates. Actual roughness at the site would be a composite of many terrain types and would vary as the plume moves downwind. Therefore, consequence estimates for actual site roughness would probably fall somewhere between the two curves shown on Figure 4.3-28.

Plume lift-off — Lift-off of the plume centerline was simulated by allowing the UF_6 in the plume to fully react to UO_2F_2 and HF before dispersing downwind, thereby raising the plume temperature sufficiently to induce buoyancy. An initial volume mixing ratio (ambient air to released UF_6) of approximately 300 was needed to provide enough water vapor for full reaction assuming an instantaneous reaction rate . This high initial mixing ratio and instantaneous reaction rate simulate a very turbulent condition at the release point, bringing in enough water vapor to rapidly react with the released UF_6 or a situation in which there was a very high amount of water vapor present per unit volume of air [e.g., during a drizzle episode similar to the precipitation that occurred during the PORTS occurrence in 1978 (see Section 4.3.1.2.3.1.2)].

The WAKE model, developed to simulate dispersion of buoyant, fully reacted plumes, was used to predict downwind consequence estimates for the plume lift-off case. Although WAKE is primarily for releases from or nearby buildings, it may be used for releases outside of a building wake by assuming no building dimensions. Figure 4.3-29 shows the comparison of consequence estimates between the plume lift-off case and the baseline case (no plume lift-off). For the lift-off case, the plume centerline reaches a height of approximately 410 ft (125 m) due to buoyant rise. Because concentrations are assumed to be highest at the plume centerline, ground-level concentrations are much lower with plume lift-off case because of the high plume centerline height. At 1 mile (1600 m), 2 miles (3200 m), and 5 miles (8050 m), consequence estimates from the plume lift-off case are about 118, 32, and 10 times less than the baseline case, respectively. With plume lift-off, the 30 mg uranium uptake guideline value is not exceeded at any downwind distance.

Downwind uranium deposition. A postprocessor in HGSYSTEM/UF_6 is used to estimate deposition of uranium downwind of the release point. Deposition depletes material from the plume, but there is no feedback mechanism in the model between deposition and plume dispersion, chemistry, and thermodynamics (see Section. 4.3.1.2.3.4). Consequently, the deposition estimates presented in this section are considered to overpredict actual mass of deposited material per unit area.

The mass of uranium deposited along the ground, averaged over the area passed by the plume, was calculated from results obtained using the postprocessor. The potential concentration of uranium in the soil, C_s (milligrams of uranium per gram of dry soil), is approximated as:

$$C_s = \frac{m_U}{A d \rho_s}, \tag{23}$$

where

m_U is the mass of uranium deposited at a particular downwind distance (mg),
A is the area of the plume passage (m^2)
d is the depth of the surface soil, assumed to be 0.01 m (0.4 in.), and
ρ_s is the density of the surface soil, assumed to 1×10^6 g/m^3.

The potential surface soil contamination, AC_s (picocuries per gram of dry soil) is calculated as:

$$AC_s = C_s \times SA_U, \tag{24}$$

where SA_U is the specific activity of uranium enriched to 5.5% ^{235}U (3820 pCi/mg).

Figure 4.3-30 shows AC_s vs downwind distance for baseline scenario conditions. Because of the large inaccuracies in the calculation method at long downwind distances (i.e., unrealistically high surface contamination estimates), values of AC_s are plotted out only to 0.62 mile (1000 m). As a comparison with these estimated values, the NRC has established a soil contamination limit of 35 pCi/g that allows for unrestricted use of sites that have been contaminated with uranium (see Reference 75). The predicted surface contamination estimates from a breach in a liquid-filled cylinder exceed this unrestricted use limit by several orders of magnitude.

Figure 4.3-31 shows rough estimates of cumulative percent uranium removed from the plume for downwind distances to 3300 ft (1000 m). At 3300 ft (1000 m), about 17 percent of the uranium is estimated to have deposited.

Comparison of results with those from the Gaussian plume method. The Gaussian plume method was one of the earliest approaches used to estimate downwind hazards from accidental releases for regulatory applications. In the Gaussian method, concentration profiles at any downwind distance in the horizontal crosswind direction (perpendicular to the transport direction) and vertical direction are represented by Gaussian (normal) distributions. Because standard Gaussian models assume that plume constituents are nonreactive and neutrally buoyant, all UF_6 hydrolysis reactions are assumed to occur prior to downwind dispersion, similar to the methodology outlined in NUREG-1140 (see Reference 72 and Section 4.3.1.2.3.3.2). For this comparison, the NUREG-1140 methodology was applied to calculate steady-state uranium concentrations [see Eq. (12), Section 4.3.1.2.3.3.2]. Some changes were made in applying the NUREG-1140 method to maintain a consistency for comparison with HEGADAS/UF_6 and to simulate the baseline release scenario: (1) the breathing rate was not applied in the equation because only steady-state concentrations were calculated, (2) the source term, Q, is the quantity of uranium released [18,900 lb (8600 kg)] rather than UF_6, and (3) the normalized concentration, χ/Q (s/m^3), was obtained using the Gaussian plume equation, assuming the release was at ground-level with no buoyant plume lift-off.

Figure 4.3-32 shows the results of the comparison of results between HEGADAS/UF_6 and the Gaussian plume method. The Gaussian plume method estimates higher consequence estimates (represented by steady-state uranium concentration in the figure but also higher for radiological dose and HF exposure) for all downwind distances. Differences in consequence estimates are roughly proportional to differences in plume cross-sectional areas predicted by the two models. HEGADAS/UF_6 predicts a larger plume cross-sectional area for all downwind distances due to initially rapid dense gas plume spreading. Because the pollutant mass is distributed over a larger horizontal area, the resulting plume concentration is less. The treatment of UF_6 chemistry and thermodynamics and the calculation of transient exposure also contribute to the difference in estimates, but to a smaller degree.

Uncertainties not quantified. The baseline scenario simulates dispersion of a dense, ground-hovering plume under common meteorological conditions during the early morning (stable atmosphere and light wind speeds). Such a plume would flow much like water, seeking low spots and being deflected around rises. The plume would tend to pool in low-lying areas capturing a significant fraction of the plume mass and leading to the formation of small local areas of high concentrations. Pooling would tend to occur at downwind distances close to the release point where the plume is most dense and could possibly limit concentrations further downwind. A dense plume would tend to flow into and pool in low areas near the release point, essentially acting as retaining basins for the released UF_6 and reaction products. Pooling would act to effectively reduce the uranium concentrations in the plume and extend the release time. As a result, exposures would be reduced.

This analysis assumes that the release would occur outdoors and not be affected by a building wake. However, most of the operations with liquid-filled cylinders occur indoors. An indoor release would result in lower consequence estimates because the plume would be diluted with air inside the building. Also, the building would tend to retain the released UF_6, lowering the release rate to the atmosphere and reducing downwind consequence estimates.

The following sections describe how the consequences are addressed by the different receptors.

Local workers in the immediate area — Workers in the immediate area of the release could be exposed to a significant uranium dose and/or HF exposure. In the event of a release, the plant see and flee policy requires personnel to evacuate the area for their own protection. The essential method of detection for workers within these facilities is (1) visual indication of a "white smoke" (i.e., reaction products of UF_6 and moisture) or (2) the odor of HF, which is a product of the reaction of UF_6 and moisture. The visual indication or the odor of HF will provide indication of (1) the occurrence of a release and (2) the need for the workers to evacuate the area of the release.

Operational personnel in the control room — There are no required operator actions for this event. Therefore, the actions for this area are no different than those for the local worker.

Workers outside the process buildings — The essential controls for protecting on-site personnel outside the facilities are (1) detection of the release and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor.

Off-site public — As indicated in the consequence analysis, this event could exceed the off-site EGs out to 3.4 miles (5500 m) assuming worst case conditions and no mitigative action. If the event does occur, the plant's Emergency Plan identifies contingency actions that can be taken to minimize off-site public exposure to the release. Reviewing the variations on the parameters for the analysis indicates that the consequences of the event could vary significantly depending on whether the plume rises or stays low to the ground. Additionally, the consequences are based on a 30-minute exposure at the centerline of the plume (which are conservative based on the HF concentration) Anticipated response (i.e., to HF odor) would tend toward immediate movement to avoid the plume which would also reduce the consequences of the event.

d. <u>Comparison With Guidelines</u>

For workers in the immediate area, specific exposures were not calculated because of variables and uncertainties associated with the calculations and because of obvious evacuation actions that would be taken by the worker. However the controls identified (i.e., see and flee) will maintain exposures to within EGs 1 and 2 to the extent practical. No actions are required of operational personnel in the control area; therefore, EG 6 is not applicable to this scenario. In addition, based on the controls identified (i.e., release detection, and evacuation of areas upon detection of a release), EGs 1 and 2 would be met for workers outside the process buildings. Finally, the analysis performed determined that the worst case scenario would result in off-site exposures exceeding the EBE EGs for uranium (30 mg U).

e. <u>Summary of SSC's and TSR Controls</u>

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to prevent cylinder failure—maintain initial condition (normal operation, EG 5 only);
  1. Liquid UF_6 cylinder handling cranes are inspected daily (prior to first use) for obvious defects associated with the lifting system;
  2. No cylinder or similar weight load is moved over a cylinder containing liquid UF_6;
  3. Only approved cylinder handling equipment is used by qualified operators for maneuvering cylinders and other heavy loads;

4. Cylinder cleaning requirements conform to ANSI N14.1 for cylinder cleaning;
5. Cylinders to be filled with UF_6 are verified as passing a current (within 5 years) hydrostatic pressure test;
6. Cylinders containing liquid UF_6 are staged in a designated area until solidified (this area is restricted so that routine vehicle traffic is not allowed - vehicles are allowed for certain maintenance evolutions); and
7. UF_6 cylinders to be filled or heated are inspected for obvious damage that could threaten their ability to withstand normal filling, heating and moving.

- UF_6 cylinder high temperature autoclave steam shutoff system — maintain initial condition (normal operation, EG 5 only);
- Liquid UF_6 handling cranes — maintain primary system integrity (EGs 1 and 2); and
- Operator training for required actions — evacuate area of releases (EGs 1 and 2 only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The UF_6 cylinder high temperature autoclave steam shutoff system and liquid UF_6 handling equipment (cranes, scale carts) are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the UF_6 cylinder high temperature autoclave steam shutoff system, liquid UF_6 handling cranes, scale carts, and administrative requirements for procedures and training of workers for cylinder handling requirements and evacuation actions.

4.3.2.2.16 Large Fire (External Event)

a. Scenario Description

During operations associated with withdrawal, feed, toll transfer, sampling, and cylinder handling and storage operations, the potential exists for fires to occur. Small fires can be caused by welding and burning operations, electrical failures, vehicle accidents, etc. The withdrawal operations are performed in the process buildings that house lube oil and the associated fire-related concerns are addressed in the large fire scenario for the cascade facilities (see Section 4.3.2.1.9).

The X-343 facility does not contain any significant quantities of flammable or combustible materials. Additionally, this facility is provided with a fixed fire suppression system to prevent a fire large enough to threaten primary system integrity. Therefore, the hazards analysis did not consider a large fire to be credible for the X-343 facility.

The X-342-A and X-344-A facilities do not contain any significant quantities of flammable or combustible materials. An assessment of these facilities concluded than an unmitigated fire would not compromise primary system integrity or result in a release of UF_6. In addition, an unmitigated fire will not threaten the structural steel or the steel roof decking to cause collapse of these buildings. The assessment did not credit the sprinkler systems or manual fire fighting capabilities for these facilities.

The cylinders in storage yards are exposed to combustible materials (i.e., fuel) from the equipment used in the cylinder handling/storage operations. If a large fire occurs in the cylinder storage yards, it has the potential to liquefy the contents of a cylinder to the point where the cylinder could hydraulically rupture. This cylinder rupture due to a large fire could result in a significant UF_6 release. The only mitigation source provided for large fire event in the cylinder storage yards is the on-site fire department. The plant Fire Protection Program (which includes the on-site fire department) is described in Section 5.4 and provides a high degree of protection against fires that could occur within the cylinder storage yards. The following preventive controls are used to minimize the potential for a large fire occurring during cylinder handling/storage operations:

- The presence and introduction of flammable and combustible materials in the cylinder yards are controlled by approved procedures.
  1. The following sources of flammable and combustible materials, as a minimum, are considered in the development of these procedures: cylinder handling equipment, adjacent vehicle traffic (including fuel trucks), any potential refueling operations, etc.;
  2. The following protections schemes, as a minimum, are considered in the development of these procedures: passive barriers, spatial separation, inspections, and other standard fire prevention practices;
- Daily inspection (when used) of cylinder handling equipment for obvious visual defects associated with the lifting system and potential fuel/hydraulic leaks;
- Communication capability between the cylinder handling operators and with the fire department/emergency response personnel is available; and
- Only approved cylinder handling equipment is used by qualified operators for maneuvering UF_6 cylinders or other heavy loads.

Should all of these measures fail, it is assumed that a fire could be initiated during cylinder handling operations, or due to vehicle accidents and sufficient heat added such that the integrity of the cylinders could be compromised from the fire. The scenario during handling operations is the most likely method because of the proximity of the handling equipment to the cylinders (i.e., administrative controls are in place to control the presence of any other significant fuel source). Cylinder handling equipment is made like other large industrial equipment (e.g., cranes), and failure modes leading to fires would be similar. It is assumed that a line containing combustible fuel (i.e., fuel, hydraulic, lube oil) fails and releases fuel onto a hot surface, causing ignition of the fuel. Although some of the fuel would be burned up as it comes out of the line, it is assumed the remainder of the fuel also catches fire as well and starts to form a pool or flows in such a way that an entire cylinder is engulfed in the fire long enough to cause cylinder failure as a result of the hydraulic pressures generated. Operator response to the event (i.e., evacuate immediate area and contact emergency response personnel) will occur quickly, and emergency response personnel will respond quickly. If emergency response is not sufficient to prevent cylinder failure, it is assumed for analysis purposes that a cylinder will fail due to liquefaction of the UF_6 and hydraulic pressures generated.

This event was evaluated, and it was determined that the consequences could result in significant on-site impact if no mitigation were provided. These consequences are based on a liquid UF_6 release from a cylinder breach caused by a large fire in the storage yards. Due to preventive measures in place, this event is classified in the EBE frequency category.

The primary concern associated with this event is the loss of primary system integrity and the release of liquid UF_6. The applicable EGs associated with this event are EGs 1 and 2, as well as EG 6 in the EBE frequency range. Since there is no primary containment system for cylinder failures, EG 3 does not apply. The essential safety actions associated with meeting these EGs for a large fire that could result in a loss of cylinder physical integrity include (1) detection of the release, (2) notification of emergency response personnel, and (3) emergency response to evacuate the immediate vicinity and downwind locations so that exposure of on-site personnel is minimized.

b. Source-Term Analysis

It is assumed that a fire could be initiated during cylinder handling operations (e.g., due to vehicle accidents, etc.) and sufficient heat could be added to the cylinders such that the physical integrity of the cylinders could be compromised. Cylinder handling equipment are equipped with large fuel tanks [approximately 450 gal (1703 L) of diesel fuel for the largest equipment] and some of this equipment also contains large amounts of hydraulic fluid [approximately 350 gal (1324 L)] as well as some lube oil. For purposes of this analysis, the cylinder haulers were assumed to carry a maximum of 800 gal (3027 L) of flammable or combustible liquids. Depending on the cylinder type, thickness, size, and amount of UF_6 present, analyses have been completed indicating that this amount of fuel could rupture a cylinder in less than 15 min if optimum conditions are present. Based on this analysis, a scenario for a fire event is presented as a limiting event for the cylinder yards.

Uncertainties in the source term resulting from a fire induced UF_6 cylinder rupture result from uncertainties in fire characteristics, the portion of a cylinder or cylinders immersed in a fire, the effects of fire fighting activities, the conditions inside the cylinder at the time of rupture, and the cylinder condition after rupture.

The thermal environment associated with a fire depends on fire characteristics including the flame temperature, flame emissivity, flame height, and fire duration. These fire characteristics depend on the amount of fuel released, the fire dimensions and shape, and ambient conditions such as temperature and wind speed. The literature indicates a significant variation in thermal environments associated with fires.

10 CFR 71 provides guidance associated with hypothetical transportation accident conditions. Section 71.73 provides the following guidance for the hypothetical thermal environment:

> Exposure of the specimen fully engulfed, except for a simple support system, in a hydrocarbon fuel/air fire of sufficient extent, and in sufficiently quiescent ambient conditions, to provide an average emissivity coefficient of at least 0.9, with an average flame temperature of at least 800°C (1475°F) for a period of 30 minutes, or any other thermal test that provides the equivalent total heat input to the package and which provides a time averaged environmental temperature of 800°C. The fuel source must extend horizontally at least 1 m (40 in), but may not extend more than 3 m (10 ft), beyond any external surface of the specimen, and the specimen must be positioned 1 m (40 in) above the surface of the fuel source. For purposes of calculation, the surface absorptivity coefficient must be either that value which the package may be expected to possess if exposed to the fire specified or 0.8, whichever is greater; and the convective coefficient must be that value which may be demonstrated to exist if the package were exposed to the fire specified. Artificial cooling may not be applied after cessation of external heat input, and any combustion of materials of construction, must be allowed to proceed until it terminates naturally.

10 CFR 71 provides an appropriate basis for evaluating and licensing containers of radiological materials. The 10 CFR 71 thermal environment was therefore selected as a reasonable basis for conducting the SAR analysis.

Based upon 10 CFR 71, the analysis of postulated fires in the UF_6 cylinder yards will be based on the following assumptions:

- The UF_6 cylinder is fully engulfed in the fire,
- A fire emissivity of 0.9,
- An average flame temperature of 1475°F,
- A surface absorptivity of 0.8,
- Simulation of convective heat transfer, and
- A 30-minute fire duration.

The convective heat transfer was calculated based on the methodology described in Reference 4.7. The analysis assumed that the cylinders are at their fill values [i.e., the mass of 28,000 lb (12,700 kg) UF_6 for a 48G; a 48Y would have slightly less but was assumed to also have 28,000 lb (12,700 kg)] and the cylinders are fully engulfed in a 1475°F fire. The analysis indicates that there is a significant variation in the conditions at the time of failure and in the post failure release conditions. An additional range of possible source term conditions exists because of uncertainties that include the fire duration, the fire temperature, the portion of a cylinder or cylinders immersed in a fire, the effects of fire fighting activities. Because of the considerable uncertainty in the source term, dispersion analyses varied the initial amount of liquid UF_6 released from 400 lb (181 kg), 4000 lb (1811 kg), and 8000 lb (3629 kg) for this event.

c. <u>Consequence Analysis</u>

The results for the release are relatively insensitive to the amount of UF_6 released. For example, the 400-lb (181-kg) release provides the maximum downwind consequences for Class D stability with a 13.1 ft/s (4 m/s) wind velocity between 400 and 800 m (varying from 17.1 mg U intake at 400 m, to 8.4 mg at 800 m). For 1000 to 2000 m downwind, the 400-lb (181-kg) release in D4 conditions provides 6.9 and 3.0 mg U intake respectively. For the 8000-lb (3629 kg) release for F1 conditions, the U intake at 400 m is 2.6 mg, while at 1000 m is 9.5 mg. From 1000 to 2000 m, the 8000-lb (3629 kg) release for F1 conditions remains in the range of 9.5 to 10.6 mg U intake and represents the highest off-site consequences for the releases for all three release amounts for both meteorological conditions. The highest on-site consequences are represented by the D4 conditions for a 8000 lb initial release, falling to 30 mg U intake at about 275 m.

After the fire has been extinguished, UF_6 can continue to be released from a failed cylinder due to sublimation and cool down. If the fire is terminated within 15 minutes and no additional means of cooling the cylinder is used (i.e., continued water spray), the sublimation and cool down period where UF_6 will continue to be released from a failed cylinder can last from 1 ½ to 3 hours. However, the UF_6 vapor released during this period is less than the liquid and vapor UF_6 released upon initial failure of the cylinder. The 8000-lb (3629 kg) initial release is used to bound the creditable cylinder failure scenarios, and it is sufficient to include the amount released even with no forced cool-down for the cylinder after rupture. The scenario for this event is low probability due to the preventive measures in place, the potential on-site resources for mitigation, and the fact that operational personnel would typically be in the area when the event occurred for quick detection and fire department response. Based on these conditions, the probability of this event is significantly lower than the cylinder failure outside autoclave event addressed in Section 4.3.2.2.15. The consequences are bounded by the cylinder failure event. The essential controls for this event are no different with the added requirement for the on-site fire department. Therefore, no additional consequences are addressed.

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d. Comparison With Guidelines

The comparison with guidelines will be subdivided to address the different receptors.

Local workers in the immediate area —Because of the time that lapses before a fire becomes large, workers in the immediate area of the release could easily evacuate the area prior to being exposed to any release. Therefore, no specific requirements are associated with the local worker.

Workers outside the process buildings —The essential controls for protecting on-site personnel outside the facilities are (1) detection of the fire and/or release (both worker and operator) and (2) training of on-site personnel to evacuate areas upon detection by sight or odor. The first essential action is to detect the fire and/or release of UF_6. If workers outside of the process building have received no other instructions for action to be taken (i.e., shelter in place or take cover), then the essential control for these receptors is to evacuate their areas if a release is detected by sight or by odor. As indicated in the consequence analysis, on-site consequences could exceed 30 mg U out to about 900 ft (275 m) for the initial release if no mitigative actions were taken.

Off-site public —As indicated in the consequences section, the consequences for this event could vary over a wide range due to the various parameters. The essential controls for mitigation of this event are bounded by the cylinder failure outside autoclave scenario described in Section 4.3.2.2.15 with the added control of the on-site fire department.

e. Summary of SSC and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Administrative controls to prevent a large fire—maintain initial condition (normal operation, EG 5 only);
  1. Presence and introduction of flammable and combustible materials in the cylinder yards is controlled by approved procedures;
  2. Daily inspection (when used) of cylinder handling equipment for obvious visual defects associated with the lifting system and potential fuel/hydraulic leaks;
  3. Communication capability between the cylinder handling operators and with the fire department/emergency response personnel is available;
  4. Only approved cylinder handling equipment is used by qualified operators for maneuvering UF_6 cylinders or other heavy loads;
  5. Operator training for required actions;
  6. Fire Protection Program (which includes on-site fire department).
- Fixed fire suppression systems in withdrawal facilities and the X-343 facility—prevent large fires (initial condition assumption, EG 5 only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The fixed fire suppression systems in withdrawal facilities and the X-343 facility are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the fixed fire suppression systems in withdrawal facilities and the X-343 facility; and administrative requirements for the Fire Protection Program and for procedures and training of workers for actions to be taken.

4.3.2.3 Miscellaneous Waste Storage and Handling Facilities

The miscellaneous waste handling and storage facilities are listed in Table 4.2-9.

4.3.2.3.1 Large Fire (External Event)

a. <u>Scenario Description</u>

The miscellaneous waste storage and handling facilities primarily handle and store RCRA waste as well as uranium bearing compounds. The most significant hazard associated with a fire is the RCRA waste. Fires can be caused by welding and burning operations, electrical failures, vehicle accidents, etc. The Fire Protection Program (see Section 5.4) provides a high degree of protection from fires that could occur within the miscellaneous waste storage and handling facilities (see Table 4.2-9). The protection provided is both preventive and mitigative. Some facilities contain fixed fire protection systems, (e.g., sprinklers and fire extinguishers) which provide additional mitigation for fires. Preventive measures (administrative practices) reduce the likelihood of any significant fires within facilities by controlling the amount of combustible materials allowed and by maintaining good housekeeping practices. Therefore, a large fire is categorized as an EBE.

This event was evaluated, and it was determined that the consequences could result in significant on-site impact if no mitigation were provided. These consequences are based on a release of toxic material.

The primary concern associated with this event is the loss of primary system integrity and the release of toxic material. The applicable EGs associated with this event are EGs 1 and 2, as well as EG 6 in the EBE frequency range. Since there is no primary containment system for this type of event, EG 3 does not apply. The essential safety actions associated with meeting these EGs for a large fire include (1) detection of the release, (2) notification of emergency response personnel, and (3) emergency response to evacuate the immediate vicinity and downwind locations so the exposure of on-site personnel is minimized.

This event is considered to result in the worst consequences for the miscellaneous storage and handling facilities, and is therefore, a limiting event for these facilities.

b. Source-Term Analysis

A realistic source term for a large fire is difficult to model. This is compounded in the waste storage facilities due to potential reactions of the various wastes during a high temperature fire. Therefore a specific source term has not been developed for these facilities. However, the analysis addresses the essential preventive and mitigative controls necessary to control this event. The controls are the same regardless of the consequences, since automatic fixed suppression systems are not credited for these facilities.

c. Consequence Analysis

A large fire could potentially result in significant on-site consequences. This is based on the vicinity of on-site personnel and the amount of toxic material present in these facilities. As indicated in the scenario, the Fire Protection Program (Section 5.4) plays an important role in preventing a large fire in these facilities. A conservative analysis for these facilities (i.e., all of the material released from the waste is dispersed along the ground) could possibly result in some off-site consequences depending on the location of the facility relative to the site boundary and the amount of waste present. However, should a large fire occur, the typical result of a large fire is a hot, buoyant plume giving rise to an elevated dispersion of most of the hazardous material. With a significant elevated release, the health effects would be greatly minimized. Therefore, no consequence analysis calculations are provided for this type of event.

The following sections describe how the consequences are addressed by the different receptors.

Local workers in the immediate area—Because of the time that lapses before a fire becomes large, workers in the immediate area of the release could evacuate the area prior to being exposed to any release. Therefore, no specific requirements are associated with the local worker.

Workers outside the process buildings—The essential control for protecting on-site personnel outside the facilities is (1) detection of the fire and/or release and (2) training of on-site personnel to evacuate areas upon detection of a release by sight or by odor. The first essential action is to detect the fire and/or release of toxic material. On-site workers are trained to flee an area if a release is detected by sight and/or smell. As indicated in the consequence analysis, on-site consequences could result in irreversible health effects if no mitigative action was taken.

Off-site public—As indicated in the consequences section, the consequences for this event could vary over a wide range due to the various parameters. The essential controls for mitigation of this event are the notification of emergency response personnel including the on-site fire department.

d. Comparison With Guidelines

As indicated in the consequence analysis, no direct calculations of consequences were performed to provide a comparison to the EGs. There are no EGs for comparison to toxic effects with the exception of uranium. However, the essential controls identified in the consequence analysis are expected to minimize the potential consequences for this event.

e. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for the large fire are summarized as follows:

- Administrative controls to minimize impact of a large fire (i.e., emergency response and evacuation)—maintain initial condition (normal operation, EG 5 only) and minimize consequences (EGs 1 and 2); and
- Fire Protection Program (which includes an on-site fire department)—maintain initial conditions (EG 5) and to provide mitigation of the fire (EGs 1, 2, and 6).

Based on the above essential controls, TSRs are provided for the Fire Protection Program and administrative requirements for procedures and training of workers for actions to be taken.

4.3.2.4 Miscellaneous Support Facilities

The miscellaneous support facilities are listed in Table 4.2-9.

4.3.2.4.1 Large Fire (External Event)

a. Scenario Description

The large fire event would be similar to that described in Section 4.3.2.3.1 with the exception of the hazards involved. The miscellaneous support facilities mainly contain UF_6 and associated compounds. The uncertainties that apply to these facilities are the same as those described in Section 4.3.2.3.1. The analysis and resulting essential controls are the same. Based on the similarity in the analysis and in the essential controls, no additional analysis of this scenario is provided.

b. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for the large fire event are summarized as follows:

- Administrative controls to minimize the impact of a large fire (i.e., emergency response and evacuation)--maintain initial condition (normal operation, EG 5 only) and minimize consequences (EGs 1 and 2; and
- Fire Protection Program (which includes an on-site fire department)--maintain initial conditions (EG 5) and to provide mitigation of the fire (EGs 1, 2, and 6).

Based on the above essential controls, TSRs are provided for the Fire Protection Program and administrative requirements for procedures and training of workers for actions to be taken.

4.3.2.5 Natural Phenomena

A review of facilities having a Hazard Category of 2 or 3 in accordance with DOE-STD-1027-92 was performed to determine the capacity of essential structures and equipment to withstand natural phenomena-induced failures. The evaluation basis natural phenomena events are identified in Section 2.7. Two types of analyses were performed: (1) structural analysis and (2) equipment/piping analysis. Based on Table 4.2-10, X-326, X-330, X-333, X-343, X-342-A, X-344-A, X-705, X-710, X-720, XT-847, cylinder storage yards, and the process building tie-lines were identified for analysis. In addition, Building X-300 was analyzed even though it is not identified as a Hazard Category 2 or 3 structure. The equipment and piping selected for analysis were identified as described in Section 4.3.1.1.3.

The structural analyses were performed as described in Section 4.3.1.3.1. Table 3.8-6 provides a summary of the results of the structural analyses. The cylinder yards are outdoor storage facilities with no structure to be analyzed. The results of the analyses are addressed in the applicable subsections below for the different initiators.

Equipment and piping selected for analysis were evaluated as described in Sections 4.3.1.3.2, 4.3.1.3.3, and 4.3.1.3.4. The equipment and piping selected for analysis were primarily associated with the liquid UF_6 systems and the large cascade piping systems. Either of these systems could result in a significant release of UF_6 if the primary system were to fail during a natural phenomena-initiated event. The results of the equipment and piping system are also presented in Section 3.8 for the various processes. As indicated in Tables 3.8-4 and 3.8-5, parts of the primary system piping and equipment do not satisfy the seismic and wind capacity goals, but all meet the requirements for flood. The following sections summarize the potential consequences due to the structures, equipment, or piping not satisfying the capacity goals.

4.3.2.5.1 Flood and Local Intense Storm (External Event)

All of the facilities are above the maximum flood elevation, and no damage would be experienced from a flood at the site. However, as indicated in Table 3.8-6, Buildings X-326, X-330, X-333 and X-705 could experience some inleakage of water that may develop because of local ponding on the roof from heavy rainfall events (10,000-yr event). The analysis assumed all of the normal drainage paths were clogged, allowing no draining except over the parapets. The event would occur over a period of time, which allows for additional operator intervention prior to any inleakage occurring. The impact of water inleakage in a typical process building was reviewed (see appropriate equipment discussions in Section 3.8), and no adverse impacts (i.e., loss of primary system integrity) were identified. Any inleakage to the cell floor would typically run to the open stairwells and floor drains, which would drain to the lower elevations. Some electrical equipment may be affected because of the water flow path. However, the likelihood of the combination of a heavy rainfall, all drainage paths being clogged, no operator intervention, and multiple electrical failures was not considered credible for these large buildings. It should be noted that compressor trip capability could also be accomplished from the switchyard if necessary to mitigate the effects of this event if it were to occur. Therefore, this concern was not addressed further in the analysis. (For X-705, the only concern associated with inleakage would be a potential moderator source for criticality. Criticality is addressed in Section 4.3.2.6. Therefore, this concern is not addressed further in this analysis.) Based on this analysis, this event was not identified as causing any impact on the leased facilities.

4.3.2.5.2 High Wind (External Event)

All of the facilities' Main Wind Force Resisting Systems (MWFRS) meet the requirements for high winds (see Table 3.8-5). Other types of structural damage associated with X-330, X-333, X-344-A, X-342-A, X-343, and X-705 due to high wind were identified, but were associated with loss of siding only and limited roof displacement in X-343, and not the buildings' MWFRS. The evaluation indicated that some of the siding for these buildings could be pulled from the building, which would have no effect on the equipment inside the buildings, except for wind impact. The limited roof displacement in X-343 would have no effect on the equipment inside the building. Piping and equipment were reviewed in several facilities at the plant site as indicated in Section 3.8, and no failures were identified because of wind loading. Therefore, these facilities were determined to be capable of withstanding the EBE high wind.

a. <u>Scenario Description</u>

Natural phenomena evaluations included consideration of evaluation basis wind loads on the major UF_6 facilities. As indicated previously, the facilities that were analyzed satisfy the 250-year return interval EBE of 75 mph (121 km/hr). Based on this analysis, this event was not identified as causing a release of radioactive material (primarily UF_6) in the leased facilities.

(Text Deleted)

b. <u>Source-Term Analysis</u>

Since no release of radioactive material is postulated, no source term analysis is required.

c. <u>Consequence Analysis</u>

Since no release of radioactive material is postulated, no off-site consequence analysis is required.

d. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for this event are summarized as follows

- Design and structural capacity of required facilities and equipment--maintain initial condition (normal operation, EG 5 only);
- Pigtail line isolation system (transfer) (if operable)--minimizes release to atmosphere (EGs 1 and 2);
- Pigtail line isolation system (withdrawal) (if operable)--minimizes release to atmosphere (EGs 1 and 2); and
- Administrative controls for reentry into areas with potential for criticality--minimize potential exposure to on-site personnel (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- Buildings X-326, X-300, X-330, X-333, X-343, X-344-A, X-342-A, X-705, X-710, X-720, XT-847, the process building tie-lines, the pigtail line isolation system (transfer), and the pigtail line isolation system (withdrawal) are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the pigtail line isolation system (transfer), pigtail line isolation system (withdrawal), and administrative requirements for procedures and training of workers on actions to be taken.

4.3.2.5.3 Earthquake (External Event)

a. Scenario Description

Structural and equipment evaluations were performed to estimate potential damage to UF_6 systems from an evaluation basis earthquake, as defined in Section 2.7.1. These evaluations identified potential weaknesses in facility structure. All operations were assumed to be normal for this scenario. Therefore, waste storage operations are potentially at risk in the seismic event.

This event was evaluated, and it was determined that the consequences could result in significant on-site impacts if no mitigation were provided. The consequence estimate is based on the results of other scenarios including the loss of NCS controls.

All facilities that process or store significant quantities of UF_6 were analyzed for seismic effects up to the evaluation basis earthquake. All facilities have structural capacities at least equal to this peak ground acceleration with the exception of non-leased facility X-744-G. This facility stores waste which may contain fissionable material such that inadvertent criticality would be the potential consequence of interest from structural failure.

Equipment whose failure could directly result in a release of UF_6 was also analyzed. This equipment includes supporting equipment not directly containing UF_6, such as overhead cranes, scale carts, and autoclaves, that if not retained in position, could impact UF_6 systems. This evaluation determined that a small number of components have less than the evaluation basis capacity (Table 3.8-4). Cascade components that were evaluated were found to meet or exceed the evaluation basis capacity criterion.

b. <u>Cascade Process System Confinement Failure</u>

Given the low peak ground acceleration for the evaluation basis earthquake, major UF_6 confinement systems within the cascade buildings were analyzed and determined not to result in a direct UF_6 release. While it is possible that some small leaks could develop (e.g., equipment seals), any release would be bounded by the "limited release" scenarios.

c. Source-Term Analysis

No source term analysis is required since no direct release of UF_6 is expected due to the evaluation basis earthquake.

d. Consequence Analysis

No off-site consequence analysis is required since no direct release of UF_6 is expected due to the evaluation basis earthquake.

Potential for Inadvertent Criticality. Water systems are not designed for seismic loads and could present a ready moderator. However, the size of the buildings, the leakage area between floors, and the barriers between the UF_6 and the fire suppression systems make criticality a remote possibility. Nevertheless, emergency procedures require that appropriate conditions be established for reentry to an evacuated facility. Consequences from an inadvertent criticality would be similar to the consequences described in the criticality event scenario (Section 4.3.2.6).

Lube Oil Impact. The evaluation basis seismic event may cause release of lubricating oil used to service the compressor motors. The tanks and lines connecting to the compressors have been evaluated as part of the equipment evaluations. The storage tank located on the roof has weak anchors. Failure of this anchorage would not result in complete loss of restraint of the lube oil tanks. Failure of the attached piping is possible, however. Failure of this piping could allow oil to leak onto the roof or in the diked area and drain from the dike to the ground floor. Some of this material could spread out on the operating floor. Failure of equipment and non-structural support components could lead to electrical shorting, creating potential ignition sources. In the absence of power, however, either as a direct result of the event or through operator action to shut down the power in the switchyard, the potential for a ready ignition source is significantly reduced. The only possible source would then be heat from mechanical components. Note that the lube oil is a low flammability blend with a high flash point and is, therefore, hard to ignite. Further, the potential for water system breaks is present, and if they do occur, such breaks would also serve to abate any fire potential from failure of the lube oil system. Therefore, a large fire in the process building following a seismic event is unlikely.

Overall Seismic Conclusions. The results of the analyses show that the evaluation guidelines would not be exceeded beyond the site boundary.

The applicable EGs associated with this event are all of the EGs for the EBE frequency range and any initial conditions assumed (i.e., normal operation, EG 5). The essential safety actions associated with meeting these EGs include (1) primary system pressure control to prevent, mitigate, or minimize any UF_6 release and (2) emergency response to evacuate the immediate vicinity so that the exposure of on-site personnel to UF_6, its reaction products, or ionizing radiation is minimized.

e. <u>Summary of SSCs and TSR Controls</u>

Based on the results of this analysis, the essential controls for this event are summarized as follows:

- Design and structural capacity of required facilities and equipment--maintain initial condition (normal operation, EG 5 only)
- Compressor trip capability (if power is available)--primary system pressure control to minimize UF_6 releases (EGs 1 and 2).
- Administrative controls for reentry into areas with potential for criticality--minimize potential exposure to on-site personnel (EGs 1 and 2).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- Buildings X-300, X-326, X-330, X-333, X-342-A, X-343, X-344-A, X-705, X-710, and XT-847; the process building tie-lines; process building cranes; and compressor motor trip systems are identified as important to safety SSCs. See Section 3.8 for details including safety classification.
- TSRs are provided for the compressor motor trip system, process building cranes, and for administrative requirements for procedures and training of workers on actions to be taken.

4.3.2.6 Criticality Events

a. <u>Scenario Description</u>

A criticality accident results in the uncontrolled release of energy from an assemblage of fissile material. The primary control for preventing an accidental criticality is the implementation of the NCS Program as described in Section 5.2. Preventing criticality is a central and very prominent objective of all fissile material activities at PORTS. Operations and equipment modifications are conducted in accordance with peer-reviewed criticality assessments that provide the limits and conditions that must be followed to ensure that criticality does not occur. The double contingency principle, a basic principle of criticality safety, applies to most operations. As described in ANSI/ANS-8.1 (Reference 76), the double-contingency principle requires a degree of safety such that two or more unlikely independent events would have to occur simultaneously before criticality could occur. Consequently, the actual frequency of accidental criticality is probably well below the 10^{-2}/yr threshold for EBEs. Furthermore, considering the three diffusion plants located in the United States, there have been more than 100 years of diffusion plant operation without a criticality accident.

This section uses conservative methodology to demonstrate that the potential consequences of accidental criticality, although possibly severe to workers in the immediate vicinity, would be mild to negligible for other workers on the plant site and negligible for the general public. The approach used is that outlined by NRC Regulatory Guide 3.34 (Reference 77). The potential consequences are, as a practical matter, dominated by radiological exposure. For example, a criticality event could, if it occurred inside a closed vessel, lead to a sudden pressure relief or vessel failure, but that would be less hazardous to a worker located nearby than the associated radiation exposure. For consequences from the release of the hazard to the atmosphere, refer to the appropriate release scenarios described in Sections 4.3.2.1 and 4.3.2.2. The radiological consequences are dominated by direct exposure to fission neutrons and gamma rays (prompt radiation), but the evaluation also considers the gamma radiation emitted by fission products and the exposure pathway provided by the airborne release of volatile fission products. The consequence evaluation includes both on-site and off-site exposures.

The potential radiological consequences to close-in workers in a criticality event are decided by deterministic effects, which are experienced by most individuals within hours or days after an exposure above the threshold for any given effect. Deterministic biological effects of radiation exposure imparted within a brief period are a function of the amount and quality of exposure. The quality refers to whether the exposure is to gamma or neutron radiation or to a mixture; it also depends on the energy of the rays or particles that make up the exposure. In addition, response varies considerably from one individual to another. The deterministic effects of whole-body gamma irradiation can best be characterized by grouping them in ranges (Reference 78):

- 0–25 rem—no effects.
- 25–100 rem—mostly no effects, though a few persons may exhibit mild symptoms such as nausea and anorexia, with prognosis for recovery excellent.
- 100–300 rem—mild to severe nausea, malaise, anorexia, and infection, with recovery probable, though not assured.

- 300–600 rem—as above, plus hemorrhaging, infection, diarrhea, epilation, and temporary sterility, with guarded recovery prognosis; exposure of about 400 rem is fatal to 50 percent of individuals without medical treatment.
- 600 rem—above symptoms plus impairment of central nervous system and incapacitation for doses above 1000 rem, with death expected.

The preceding list of ranges and thresholds, as stated, is derived from data on gamma radiation. However, the results can be extended to mixtures of gamma and neutron exposure because the limits are given in units of rem, which take into account the relatively higher biological efficiency of neutron irradiation (i.e., neutron radiation is generally more harmful than gamma radiation per unit of absorbed energy). In high doses and high dose rate situations, the determination of a "quality factor" is very difficult because of complex dosimetry and radiation biology interactions. Quality factors for neutron exposure also vary significantly based on the energy of the interacting neutrons. As a result, estimation of neutron radiation dose is usually done using units of "rad". However, in this analysis, the formulas from Reg. Guide 3.34 were used to provide estimates of neutron exposure and these are reported in the Reg. Guide in rem. In the consequence evaluations below, a mixed (gamma plus neutron) exposure of 400 rem is taken conservatively to define the zone of potential lethality.

b. <u>Historical Record of Accidental Criticality Events</u>

Accidental criticality, with uncontrolled power level, has occurred on 37 known occasions (according to data available up to 1988) (References 79 and 80). All but eight of these have occurred in facilities such as critical experiments facilities or reactor facilities and are thus of some interest but of limited applicability to the industrial processing activities that go on at a gaseous diffusion plant. The total yields for these events ranged from 3×10^{15} to 1.2×10^{20} fissions, with a median of about 1.3×10^{17} fissions. For the 27 events that were not terminated by automatic shutdown systems, the criticality was terminated by the negative reactivity effects of the energy released by the unintended fissions. The shutdown mechanisms can be summarized as follows:

- Density reduction, either via microbubble formation or thermal expansion.
- Loss of water moderation by boiling.
- Expulsion of part of the mass.
- Mixing of light and dense layers (dilution).
- Geometry change.

In the history of fissile material processing, eight accidental criticality events have occurred in processing plants and are therefore relevant to the industrial setting of a gaseous diffusion plant. Table 4.3-11, taken from References 80 and 81, summarizes important facts about these events. Most of the events can be characterized by an initial main pulse followed by other, smaller pulses and, in some cases, featuring a plateau of apparently steady criticality at a low level for an extended period. The magnitude of these accidents has ranged from about 10^{15} to about 6×10^{17} fissions in the initial pulse. The largest total yield is estimated to have been about 4×10^{19} fissions accumulated as a result of an extended period of small pulses. The likelihood of an extended period of criticality provides a firm basis for prompt evacuation of process areas to minimize the radiation exposure of workers. Another significant lesson is that all eight of the processing plant criticality accidents involved solutions rather than solids.

This is not surprising when it is considered that solution systems can have much smaller critical masses and are quite mobile, thus inviting criticality in unexpected locations. By contrast, solids typically are nonmobile or at least do not generally move except by deliberate action of operational personnel, and the masses required for undermoderated solids are large compared with those of well-moderated solution systems.

c. Possible Criticality Events at PORTS

Criticality accidents that may be possible at a gaseous diffusion plant are either similar to or not worse than those that might be encountered at a fuel fabrication plant. A gaseous diffusion plant and a fuel fabrication plant share many qualitatively similar operations involving analogous forms of fissile material:

- Gaseous and solid UF_6.
- Uranium solutions.
- Slurries of low-density uranium compounds.
- Low-density dry forms of uranium compounds, with and without moderation control for criticality safety purposes.

A gaseous diffusion plant lacks the high-density forms of uranium, such as pressed and sintered UO_2, that must be handled at a fuel fabrication plant to manufacture reactor fuel.

Considering the range of activities at PORTS, as well as industry experience, it is reasonable to conclude that the most likely type of criticality would be one involving uranium solution. Solution processing is most common in the Decontamination and Uranium Recovery Facility (Building X-705); however, solutions are routinely handled in several other facilities (e.g., the X-710 laboratory), and accidents could theoretically occur (e.g., in conjunction with a nonroutine cleanup or maintenance operation) in any facility on-site where significant quantities of fissile material are being processed.

In defining a second-most-likely type of criticality event, one would have to look to the sheer size of the cascade operations (>50 acres under roof) and the large number of UF_6 gas processing units. UF_6 gas is inherently safe against criticality for conditions possible in the cascade. The possibility of criticality is introduced by the chance that a buildup of solid uranium compound in large-diameter pipes or other large equipment (i.e., equipment for which size exceeds geometrically favorable dimensions) could become sufficiently moderated to go critical. It should be pointed out that inherent as well as intentionally maintained safety features make such an event a very unlikely and hypothetical postulate. In the cascade, the UF_6 must be kept in gaseous form, and except in the freezer/sublimer vessels, any buildup of solid forms must be avoided for the gaseous diffusion process to work properly. The deposits surveillance program (described in Section 5.2) is performed in addition to the normal cascade controls to detect buildup within the cascade. Nevertheless, buildup of solids does occur, and the buildup must be periodically cleaned out via chemical treatment or by equipment removal and decontamination.

Enrichment operations were terminated in 2001 by USEC. Enrichment cascade equipment is either in shutdown or standby condition, except when undergoing chemical treatments for removal of deposits. The RCW has been isolated from the cell cooling systems; the lube oil has been drained from the cells; the cells are buffered with dry gas at slightly above atmospheric pressure. With these conditions, the probability of a criticality is lower for the enrichment cascade when in a shutdown/standby condition than for an operating enrichment cascade. Uranium deposits have been identified and quantified and are handled based on the deposit size according to TSRs and NCS requirements.

Defining whether a solids-buildup-related criticality event warrants consideration in addition to that to be given to solution criticality requires consideration of the rate at which the hypothetical, potentially critical mass becomes moderated. If the rate of moderation were rapid (e.g., through actuation of fire sprinklers during disassembly of an equipment item with an excessive accumulation of fissile solids), then one might expect that the characteristics of the event could be similar to those of a solution criticality event. However, it is plausible that a poorly moderated critical mass could be achieved with what could be described as a damp or wet solid instead of a solution or with a mixture of damp solid and solution. Such an event is designated for consideration in the analyses presented below.

Another possibility deserves consideration: the case in which it is postulated that fissile material builds up so slowly that when it becomes critical, it achieves a quasi-steady equilibrium power level (i.e., a "slow-cooker" event with no power excursion) that does not trip the plant criticality alarm system. Such an event has not occurred at PORTS or anywhere else. Buildups of fissile material in process equipment have occurred but have been detected before they have exceeded a critical mass. Solid deposits would be of greatest concern in the part of the cascade that handles the highest enrichments (i.e., Building X-326). The probability of a "slow-cooker" event escaping detection is low because the criticality alarm system is designed to detect the minimum accident of concern defined in ANSI/ANS 8.3 (Reference 82) (see Section 3.8.7.1). Having the "slow cooker" event escape coverage is tantamount to assuming that the criticality occurs near an edge or boundary in criticality alarm system coverage. Radiation-monitoring instrumentation and programs (see Section 5.3) are in place and would be likely to alert workers before significant harm to individual workers occurs. Nevertheless, a "slow-cooker" criticality event, more properly referred to as "an event less than the ANSI standard minimum criticality accident of concern," is designated for further consideration because of its clear-cut qualitative difference from excursion-type events.

In summary, three types of accidental criticality events are considered in this section:

- Solution criticality.
- Moderated solids criticality.
- an event less than the ANSI standard minimum criticality accident of concern ("slow-cooker").

The first two of these are power excursion events that occur over short periods and would be detected rapidly, whereas the last could conceivably avoid detection for hours, depending on specific factors such as the location, rate, and geometry of fissile material buildup.

d. <u>Consequence Estimation Methodology and Assumptions</u>

This subsection primarily addresses methodology in the context of solution criticalities. In the consequence evaluation subsections that follow, it is shown that potential consequences of the moderated solids and the slow-cooker events are adequately bracketed by the consequences of solution criticality events, analyzed as described below.

NRC Regulatory Guide 3.34 (Reference 77) not only provides important assumptions for consequence estimation but also defines the magnitude and time phasing of the accident to be considered. The NRC definition is patterned after a hypothetical solution criticality event, as explained in the regulatory guide:

An excursion is assumed to occur in a vented vessel of unfavorable geometry containing a solution of 400 g/l of uranium enriched in ^{235}U. The excursion produces an initial burst of 10^{18} fissions in 0.5 second followed successively at 10-minute intervals by 47 bursts of 1.9 x 10^{17} fissions for a total of 10^{19} fissions in 8 hours. The excursion is assumed to be terminated by evaporation of 100 liters of solution.

Referring back to the historical processing plant criticality accidents summarized in Table 4.3-11, we see that the Reg. Guide 3.34 definition of a solution criticality event—in initial burst as well as accumulated total—is qualitatively similar to most of the actual criticality accidents, but that its fission yield is at least a factor of 3 or more in excess of that seen in any of them (except for the October 15, 1959, event at the ICPP fuel reprocessing plant). Reference 80 shows that an initial burst of 10^{18} fissions has a factor of conservatism of at least about 2, based on an estimated maximum potential rate of highly enriched solution transfer of 30 gallons/minute (114 L/min).

Accurate estimation of radiation exposures due to criticality events requires quantification of three potential components, listed here in descending order of importance: prompt neutron and gamma exposure (occurring at the time of the critical power excursion), gamma exposure due to decay of fission products (during and after termination of the criticality event), and exposure due to immersion in the plume of any volatile fission products released (applicable only to downwind locations). Reg. Guide 3.34 provides easily used formulas for the prompt gamma and neutron doses:

$$D_{gamma} = 2.1 \times 10^{-20} N d^{-2} e^{-3.4d},$$
$$D_{neutron} = 7.0 \times 10^{-20} N d^{-2} e^{-5.2d},$$

where,

D_{gamma} = gamma exposure (rem),
$D_{neutron}$ = neutron exposure (rem),
N = number of fissions, and
d = distance from the source (km).

Dose reduction factors are specified by Reg. Guide 3.34 to allow convenient estimation of the benefit of intervening concrete. For gamma dose, a reduction factor of 2.5 for the first 8 inches (20 cm) of concrete and a factor of 5 for the first 1 foot (30 cm) are specified; for neutrons, factors of 2.3 for the first 8 inches (20 cm) and 4.6 for the first 1 foot (30 cm) are specified. These formulas are used directly in the consequence calculations reported below.

Reg. Guide 3.34 recommends that delayed gamma radiation due to decay of fission products be included in the total-event exposure determination. The delayed gamma exposure values reported by Reference 83 are used here, but they are in basic agreement with those applied earlier to consequence evaluation at PORTS (Reference 84). In the consequence estimates reported below, delayed gamma exposure is for the total event but not for the first pulse, because the regulatory guide states that the formula for prompt gamma exposure (above) has an adequate allowance for the delayed gammas that would be emitted during the first minute after an excursion.

Reg. Guide 3.34 specifies the amount of volatile fission products (100% of noble gases, 25% of radioiodines) that should be assumed to be released to the environment as a result of an accidental criticality. In addition, F stability and 1-meter/second wind speed meteorological conditions are specified for the plume transport calculations. As shown in Table 4.3-10, conditions more favorable than F stability (i.e., more dispersion of airborne plumes and lower plume exposures) are in effect more than 96 percent of the time at Portsmouth. The calculated plume exposures include internal (via inhalation) and external (cloud and ground shine) plume exposures reported by Reference 85 in an implementation of Reg. Guide 3.34 for the Y-12 plant. Reference 86 conservatively does not take credit for decay of fission products before, during, or after a release. In the consequence estimates given below, plume exposure is not reported for the first-pulse exposures (Table 4.3-12) because of the unlikelihood that fission products could be released from the process vessel into the building, and from the building to the environment, during the short time scale of interest for first-pulse evaluations. Only the total-event exposures include plume exposures.

e. Consequence Estimate—Solution Criticality

Table 4.3-12 reports the radiation exposures for a first pulse of 10^{18} fissions, as recommended by Reg. Guide 3.34. Values are reported for air attenuation (no shielding) as well as for 1 foot (0.3 meter) of concrete to show the sensitivity to the amount of intervening shielding (or other structure). The radius inside which exposures could exceed a potentially lethal exposure of 400 rem or greater varies from 48 feet (14.5 meters) without shielding to 23 feet (6.9 meters) for 1 foot (0.3 meter) of intervening concrete. As shown in Figure 4.3-33, first-pulse exposures at the site boundary are negligible.

Table 4.3-13 reports the radiation exposures for the entire accident, and Figure 4.3-33 plots total radiation exposures as a function of distance from the critical mass, without consideration of any intervening shielding, for both the entire event and the first pulse. As prescribed by Reg. Guide 3.34, the entire accident fission yield is assumed to be 10^{19} fissions, occurring over a period of 8 hours. Prompt neutron and gamma, delayed gamma, and plume exposures are included in the calculations. Note that the exposure calculations do not take credit for the definition of the event as being spread over 8 hours. The total exposure is given with and without plume exposure because it is doubtful that one individual would be situated at the centerline of the plume for the entire plume passage, as assumed by the plume exposure calculation.

Because of the conservative meteorological conditions assumed, the downwind plume exposures are dominant for distances exceeding about 660 feet (200 meters); thus, the total exposures shown in Figure 4.3-33 for distances exceeding about 490 feet (150 meters) are applicable only to the downwind direction. The radius inside which exposures could exceed a potentially lethal level of 400 rem varies from about 72 feet (22 meters) with 12 inches (0.3 meter) of intervening concrete shielding to about 148 feet (45 meters) with no shielding.

Because 90 percent of the dose from this event is accumulated over an 8-hour period, there is no reason why any worker would necessarily experience more than about 10 percent of the calculated full-event exposure prior to evacuation. The total-event site boundary exposure, assuming the event occurs in the building closest to the site boundary [approximately 1940 feet (590 meters) south from Building XT-847], including plume exposure, is 1.94 rem—well below the 25 rem EG for off-site exposures resulting from EBEs (per Table 4.2-2). A total-event off-site exposure of 0.66 rem (plume exposure included), occurring at 3280 feet (1 kilometer), would be more representative of most of the major processing buildings [e.g., X-333 at 3250 feet (990 m), X-343 at 3300 feet (1005 m), X-344-A at 3580 feet (1090 m), X-330 at 3900 feet (1190 m), and X-326 at 3630 feet (1107 m) from the site boundary].

f. Consequence Estimate—Damp/Wet Solids Criticality

Damp/wet solids criticality events are not as well understood as solution criticality events because there have been no actual criticality events in this category. Computer analysis studies of damp/wet low-enriched UO_2 excursions and one study of dry high-enriched UO_2 powder criticality events have been completed (References 86, 87, 88). Note that low-enriched UO_2 will not go critical unless it is at least partially moderated. PORTS does not produce or handle UO_2, but it does handle and produce uranium compounds (e.g., U_3O_8 in Building X-705) or uranium oxyfluoride deposits in the cascade that could possibly become moderated. The lesson from the UO_2 studies is that the thermal effects of the power excursion are sufficient to terminate the criticality before the energy release significantly exceeds the total-event release of Reg. Guide 3.34. The results of the UO_2 studies predict total-event fission yields of between about 10^{18} and 10^{19} fissions. The time for the power deposition to occur would depend on the rate of reactivity addition. With credible rates of reactivity insertion (< 1¢/s), the simulation for low-enriched UO_2 predicted an initial pulse of about 0.9×10^{18} fissions, and with continuing broad, lower pulses, the total yield reached about 0.9×10^{19} fissions over about 10 min (Reference 86).

A calculational study specific to a postulated criticality excursion in diffusion plant freezer/sublimers (Reference 89) is of interest in this category. The postulated mechanism for criticality is water inleakage via simultaneous tube breaks in the freezer/sublimer and in the condenser/reboiler during a cold standby (the mode needed to maintain the UF_6 in solid form after freezing). This defines the postulated accident as a very improbable one. For the calculations, the analyst assigned a value at the upper end of the plausible range for the nominal water ingress rate, but ran cases at 50 percent of that nominal value. Responses for both a 10-MW and a 20-MW freezer/sublimer were calculated. The calculations predict a total-event yield of about 5×10^{18} fissions over about 20–40 seconds for the 10-MW unit and between about 0.8×10^{17} and 4×10^{18} fissions over about 30–60 seconds for the 20-MW unit.

The consequences of events in this category are adequately bracketed by the Reg. Guide 3.34–based solution criticality results, presented in the previous subsection and in Tables 4.3-12 and 4.3-13, with one important stipulation—the time scale for the total-event release may be significantly different from the 8-hour period prescribed by Reg. Guide 3.34. The time scale, of course, depends on the rate of criticality addition. A total-event fission yield between about 10^{18} and 10^{19} fissions should be regarded as physically possible, with the energy release able to take place over periods as short as 1–10 minutes. Even though the time scale for releases may be accelerated as compared with the regulatory guide, worker evacuation provides much potential for avoidance of exposure.

The on- and off-site exposures presented in Table 4.3-13 can be scaled to apply to events in this category because the calculations for Table 4.3-13 did not take credit for the 8-hour total-event duration prescribed by Reg. Guide 3.34. Accordingly, the maximum potential lethal range of this event would, depending on fission yield, be between about 49 feet (15 m) and 148 feet (45 m) without shielding and between about 26 feet (8 m) and 73 feet (22 m) with 1 foot (0.3 m) of concrete shielding. The nearest site boundary exposure would be between 0.19 and 1.9 rem, well below the 25 rem EG for EBEs in Table 4.2-2.

g. Consequence Estimate— Event Less Than the ANSI Standard Minimum Criticality Accident of Concern

A wide range of consequences is possible, depending on many parameters. The following analysis is intended to estimate the range of potential consequences.

ANSI/ANS 8.3 (Reference 82) defines the minimum criticality accident of concern as one that produces a dose rate (energy absorption in free air) of 20 rad/min at a point 6.6 feet (2 m) from the critical mass, and it requires that the system be capable of latching and initiating the alarm should that defined radiation level be sustained for as long as 0.5 second. This gives the system extraordinary sensitivity to pulse-type events. As discussed in Appendix A of the ANSI/ANS 8.3, a pulse-type event as small as about 3×10^{15} fissions occurring over 1 min or less would be detected. The consequences of such an event would be a factor of 333 lower than the consequences presented in Table 4.3-12 for the Reg. Guide 3.34–defined 10^{18} fissions for the first pulse. This would be a small criticality event, with very minor consequences for anyone more than a few meters away from the critical assembly. A small, pulse-type event would represent the most favorable outcome for this event, but there is no assurance that the increase in reactivity might not instead be very slow and essentially linear instead of exponential, as postulated by Reference 90. As a worst case, it will be assumed that a critical mass is stabilized at a power level infinitesimally lower than that corresponding to the minimum accident of concern. This is tantamount to assuming that the criticality occurs near an edge or boundary in criticality alarm system coverage. Studies (e.g., Reference 91) have shown that the system would alarm much more readily for a critical mass closer to a detector.

The steady power level that corresponds to the ANSI/ANS 8.3–specified constant of a 20-rad/min dose rate at 6.6 feet (2 m) is dependent on specific material and configuration parameters, including the enrichment and moderation ratio (H/U ratio). A recent Portsmouth calculational study (Reference 92) has provided a basis for defining the power levels of events that do not trip the criticality accident alarm system as a function of enrichment:

- 1280 W at 100 percent enrichment.
- 1720 W at 20 percent enrichment.
- 2880 W at 5 percent enrichment.

Using the conversion factor of (3.3×10^{10} fissions/s)/W given by Reference 93, we see that the corresponding fission rates would be, respectively, 4.23×10^{13}, 5.68×10^{13}, and 9.51×10^{13} fissions/s. The total number of fissions experienced during the event would then depend on how long the event goes on until detection and intervention or until unaided shutdown occurs. If we define the maximum period as 8 hours, then the magnitude of the total event would be as follows:

- 1.2×10^{18} fissions for a 100 percent enriched critical mass operating at 1280 W for 8 h.
- 1.6×10^{18} fissions for a 20 percent enriched critical mass operating at 1720 W for 8 h.
- 2.7×10^{18} fissions for a 5 percent enriched critical mass operating at 2880 W for 8 h.

It is reasonable to assume that such a worst-case "slow-cooker" criticality event would be detected within 8 hours because there are multiple ways—in addition to the criticality alarm system—for the presence of the critical mass to be detected, including room air monitors, stack monitors, and periodic surveys. Therefore, the consequences of a "slow-cooker" criticality event are bounded by the consequences presented above for the Reg. Guide 3.34 solution criticality event. The worst-case consequence threshold radii could therefore possibly be greater than the Table 4.3-12 data but less than the Table 4.3-13 data. The off-site exposures would, as with the solution criticality and the damp/wet solids criticality events analyzed above, be more than an order of magnitude below the 25 rem EG for EBEs in Table 4.2-2.

h. Comparison With Guidelines

For the criticality event, the comparison with guidelines is subdivided to address the different receptors.

Local workers in the immediate area. A criticality in the immediate vicinity of a local worker could result in significant exposure if no mitigative action is taken. The only action that can be taken is to immediately evacuate upon initiation of the CAAS.

On-site workers. The essential controls for protecting on-site personnel are the same as those for protecting the local worker.

Off-site public. As indicated in the consequence analysis, this event would not exceed the off-site EGs if no mitigative action were taken. Therefore, no controls are required for this receptor.

i. Summary of SSCs and TSR Controls

Based on the results of this analysis, the essential controls for the criticality event are summarized as follows:

- Administrative controls to prevent a criticality (see Section 5.2)—maintain initial condition (normal operation, EG 5 only).
- Criticality accident alarm system—detects and annunciates a criticality (EG 1 for on-site personnel only).

Based on the above essential controls, the resulting important to safety SSCs and TSRs are as follows:

- The criticality accident alarm system is identified as an important to safety SSC. See Section 3.8 for details including safety classification.
- TSRs are provided for the criticality accident alarm system.

Table 4.3-1. Safety Actions.

Safety action name	Safety action purpose
PRIMARY SYSTEM PRESSURE CONTROL	This safety action is required to maintain system (e.g., UF6 system) integrity during normal operation as well as during events. This safety action is also used to assure primary system integrity (passive).
CYLINDER HANDLING RESTRICTION	This safety action is required to support all normal operational cylinder handling restrictions.
INSPECTION/TESTING/ SURVEILLANCE	This safety action is required to support all inspections and testing performed during normal operations.
PRIMARY SYSTEM LEAKAGE DETECTION	This safety action is required to detect when the primary system integrity has failed and when leakage of the hazard has occurred. The detection of the leakage will be required to meet this safety action.
PRIMARY SYSTEM ISOLATION	This safety action is required to close the primary system isolation valves when a leak is detected outside primary containment.
ESTABLISH PRIMARY CONTAINMENT	This safety action is required to establish and maintain primary containment integrity during upset conditions.
AUTOCLAVE WATER INVENTORY CONTROL	This safety action is required to maintain conditions within primary containment autoclaves within predefined limits to assure autoclave integrity should a release of UF6 occur inside the autoclave.
CRITICALITY SAFETY CONTROL	This safety action is required to maintain essential criticality controls during normal operation and upset conditions.
ASSAY CONTROL	This safety action is required to maintain essential criticality controls during normal and upset conditions.
GEOMETRY CONTROL	This safety action is required to maintain essential criticality controls during normal and upset conditions.
EMERGENCY RESPONSE	This safety action is required to limit hazardous material releases to preestablished guidelines during upset conditions via administrative controls.
PRIMARY SYSTEM TEMPERATURE CONTROL	This safety action is required to limit temperature excursions within the primary system to prevent failures that will result in a loss of primary system integrity.
CRITICALITY NOTIFICATION	This safety action is required to provide alarms to area personnel of a criticality accident for emergency evacuation.
NO SAFETY ACTION IS REQUIRED	
FIRE PROTECTION	This safety action is required to provide fire protection systems to mitigate potential effects of the event.
OXIDANT CONCENTRA-TION CONTROL	This safety action is required to limit the amounts of oxidant concentration below acceptable amounts to preclude a violent reaction and subsequent loss of primary system integrity.
DENSITY CONTROL	This safety action is required to maintain essential criticality controls during normal operation and upset conditions.
BUILDING HOLDUP	This safety action is required to provide a temporary holdup of UF_6 released into the area and allow deposition within the facility. This will reduce the concentration of UF_6 leaving the building.
TOXIC GAS CONTROL	This safety action is required to prevent, detect, and/or mitigate the effects of a toxic material release.
HAZARDOUS MATERIAL INVENTORY CONTROL	This safety action is required to limit the amount of hazardous material to levels that will not require protection to meet the EGs should the material be released.
SAFE HANDLING PRACTICES FOR APPLICABLE HAZARD	This safety action is required to ensure that good safe handling practices are in place and are followed in accordance with an established program.

Table 4.3-2. Natural Phenomena Load Combinations.

$DL + Dl_{columns} + Dl_{walls} + EL + ML + E'$
$DL + Dl_{columns} + Dl_{walls} + EL + ML - E'$
$DL + Dl_{columns} + Dl_{walls} + EL + ML + WLNS$
$DL + Dl_{columns} + Dl_{walls} + EL + ML + WLEW$
$DL + Dl_{columns} + Dl_{walls} + EL + ML + 1.2F_p$

Notes: DL includes slabs, mezzanines, and supporting beams; EL includes equipment loads; ML includes miscellaneous supported loads; E' is the earthquake load; WLNS is the North/South wind load; WLEW is the East/West wind load; and F_p is the roof ponding load.

Table 4.3-3. ARS Frequency Array

From frequency	To frequency	Use interval
0.5 Hz	1.6 Hz	0.10 Hz
1.6 Hz	2.8 Hz	0.20 Hz
2.8 Hz	4.0 Hz	0.30 Hz
4.0 Hz	9.0 Hz	0.50 Hz
9.0 Hz	16.0 Hz	1.00 Hz
16.0 Hz	22.0 Hz	2.00 Hz
22.0 Hz	50.0 Hz	3.00 Hz

Table 4.3-4. Parameters Defining the Base Scenario for the Large Release of UF_6 to Atmosphere (B-line block valve closure release).

Parameter	Value
Atmospheric stability	Stable (Pasquill–Gifford stability class F)
Wind speed	7 mph (3 m/s)
Ambient air temperature[a]	70°F (21.1°C)
Release rate of UF_6 inside building	59 kg/s
Duration of release inside building	8 min (600 s)
Duration of release to the outside atmosphere[b]	42 min (2500 s)
Surface roughness[c]	Rural

[a]The ambient temperature for the baseline scenario differs from Cases A2 (A stability 2 m/s wind speed), A3 (A stability 4 m/s wind speed), and A5 (A stability 5 m/s wind speed) because Case A4 (A stability, 4 m/s wind speed) simulates releases from the process building during summer ventilation configuration. This ventilation results in a significantly larger mass of material being released.

[b]The duration of the release to the outside atmosphere is greater than that of the release in the building because of mixing that occurs inside the building during transport.

[c]The WAKE model (Hanna et al. 1997) allows only two roughness scales: rural and urban. A rural roughness length is relatively low (e.g., 0.03 m), and an urban roughness length is relatively high (1.0 m). Consequence estimates are higher with the rural roughness scale than with the urban roughness scale, due to greater atmospheric turbulence and resultant plume dilution in the latter.

Table 4.3-5. Estimated Consequences for the Base Scenario for the Large Release of UF_6 to Atmosphere (B-Lne Block Valve Closure Release Case; see Table 4.3-4 for Corresponding Source Conditions).

	Uranium Chemical Toxicity		Radiological Toxicity Dose		HF Chemical Exposure	
Receptor location	Estimated Consequence Value (mg)	Guideline Value (mg)	Estimated Consequence Value (rem)	Guideline Value (rem)	Estimated Consequence Value (ppm)	Comparison Value (ppm)
Site boundary[a]	53	30	0.56	25	40	20
1 mi (1600 m) downwind	41	30	0.42	25	29	20
5 mi (8050 m) downwind	9	30	0.09	25	6	20

a. Consequence estimates were made at the site boundary nearest to Building X-333 [0.56 mi (900 m) to the north].

Table 4.3-6. **Parameters Defining the Baseline Scenario for the Parent/Daughter Transfer Release.**

Parameter	Value
Atmospheric stability	stable (Pasquill-Gifford stability class F)
Wind speed	2 mph (1 m/s)
Ambient air temperature	40°F (4.4°C)
Ambient relative humidity	70 %
Initial mixing (volume ratio of ambient dry air to release UF_6)	50
f_A (fraction of area of leeward side of building that is open)	0.055
Surface roughness	1 inch (0.03 m)
Initial deposition of solid UF_6	0 %

Table 4.3-7. Estimated Consequences for the Parent/Daughter Transfer Release, Baseline Scenario.

	Uranium Chemical Toxicity		Radiological Toxicity Dose		HF Chemical Exposure[a]	
Receptor Location	Estimated Consequence Value (mg)	Guideline Value (mg)	Estimated Consequence Value (rem)	Guideline Value (rem)	Estimated Consequence Value (ppm)	ERPG-2 Comparison Value (ppm)
Site Boundary[b]	12.3	30	0.13	25	4.88	20
1 mile (1500 m)	7.8	30	0.08	25	2.92	20
5 miles (8050 m)	0.77	30	0.01	25	0.28	20

a. No guideline value is directly associated with hydrogen fluoride (HF) exposure. The guideline values for soluble uranium provide adequate control for HF exposure, since HF is produced in direct proportion with the amount of UO_2F_2 produced as a result of the UF_6 release. The Emergency Response Planning Guideline (ERPG-2) is shown for comparison.

b. Consequence estimates were made at the nearest site boundary from the potential release point [0.62 mile (1000 m)]. The site boundary nearest to the potential release point is 0.68 miles (1100 m) to the northwest.

Table 4.3-8 Parameters Defining the Baseline Scenario for the Dropped Liquid-Filled Cylinder Release

Parameter	Value
Atmospheric stability	stable (Pasquill-Gifford stability class F)
Wind speed	2 mph (1 m/s)
Ambient air temperature	40°F (4.4°C)
Ambient relative humidity	70 %
Initial mixing (volume ratio of ambient dry air to release UF_6)	50
Surface roughness	1 inch (0.03 m)
Initial deposition of solid UF_6	0 %

Table 4.3-9 Estimated Consequences for the Dropped Liquid-filled Cylinder Release, Baseline Scenario

	Uranium Chemical Toxicity		Radiological Toxicity Dose		HF Chemical Exposure[a]	
Receptor Location	Estimated Consequence Value (mg)	Guideline Value (mg)	Estimated Consequence Value (rem)	Guideline Value (rem)	Estimated Consequence Value (ppm)	ERPG-2 Comparison Value (ppm)
Site Boundary[b]	486	30	5.07	25	190	20
1 mile (1600 m)	250	30	2.61	25	92	20
5 miles (8050 m)	15	30	0.16	25	6	20

a. No guideline value is directly associated with hydrogen fluoride (HF) exposure. The guideline values for soluble uranium provide adequate control for HF exposure, since HF is produced in direct proportion with the amount of UO_2F_2 produced as a result of the UF_6 release. The Emergency Response Planning Guideline (ERPG-2) is shown for comparison.

b. Consequence estimates were made at the nearest site boundary from the potential release point [0.68 mile (1100 m) to the northwest].

Table 4.3-10 Gaussian Dispersion of a Nonreactive, Ground-Level Source at PGDP

Pasquill-Gifford Stability Class	Wind Speed[a] (m/s)	Normalized Concentration, χ/Q (s/m^3)[b] at 3300 ft (1000 m) downwind	Percent Occurrence	Cumulative Percent Occurrence for ≤ Identified Normalized Concentration
A	2	1.68×10^{-6}	6.6	6.6
A	1	3.36×10^{-6}	15.4	22.0
B	4	4.72×10^{-6}	1.2	23.2
C	7	7.21×10^{-6}	1.4	24.6
B	2	9.45×10^{-6}	3.5	28.1
C	4	1.26×10^{-5}	4.1	32.2
B	1	1.89×10^{-5}	5	37.2
D	7	2.08×10^{-5}	4.3	41.5
C	2	2.52×10^{-5}	7.4	48.9
D	4	3.64×10^{-5}	8.4	57.3
C	1	5.05×10^{-5}	6.3	63.6
E	4	7.22×10^{-5}	2.3	65.9
D	2	7.28×10^{-5}	13	78.9
E	2	1.44×10^{-4}	5.9	84.8
D	1	1.46×10^{-4}	7.3	92.1
E	1	2.89×10^{-4}	3.8	95.9
F	2	3.37×10^{-4}	0.7	96.6
F	1	6.73×10^{-4}	3	100.0

a. The discreet wind speed represent wind speed ranges (e.g., 1 m/s = < 2 m/s; 2 m/s = 2 - 4 m/s; 4 m/s = 4 - 6 m/s; 7 m/s > 6 m/s).

b. Estimates of χ/Q were obtained using the Gaussian plume equation.

Table 4.3-11. Criticality Accidents in Fuel Cycle Facilities.

Date	Location	Yield (Fissions) First Pulse	Yield (Fissions) Total	Duration	Cause	Personnel Exposures
6/16/58	Oak Ridge Y-12 Plant	1×10^{16}	1.2×10^{18}	20 min	Unsafe geometry; wash water added to $UO_2(NO_3)_2$ solution in 55-gal drum	8 people. Doses of 461, 418, 413, 341, 298, 87, and 29 rads. No fatalities.
12/30/58	Los Alamos National Laboratory	1.5×10^{17}	1.5×10^{17}	2 to 3 s	Liquid phases of plutonium separated out in unsafe geometry tank.	3 people. Doses of 12,000, 134, and 53 rads. One fatality.
10/16/59[b]	Idaho Chemical Processing Plant (ICPP)	1.0×10^{17}	4×10^{19}	20 min	Solution transferred to unsafe geometry (5000-gal tank).	19 people received modest beta doses. No direct gamma or neutron dose because tank was shielded.
1/25/61[b]	ICPP	No estimate	6 × 10	-1 s	Solution transferred to unsafe geometry tank	None. Highly shielded operation.
4/07/62[b]	Hanford Recuplex Plan	1.0×10^{16}	8.2×10^{17}	37 h	Plutonium solution incorrectly siphoned into unsafe geometry tank.	3 people. Doses of 110, 43, and 19 rads.
7/24/64	Wood River Junction	1.1 × 10 2.0×10^{16}	1.3×10^{17}	2 short pulses 1.5 h apart	Solution hand-poured into unsafe geometry tank.	3 people. Doses of 10,000, 100, and 60 rads. One fatality.
8/24/70[b]	UKAEA Windscale	No estimate	1 × 10	Short	Unsafe geometry process vessel.	Not available.
10/17/78[b]	ICPP	No estimate	3 × 10	18 min	Unsafe geometry process vessel.	< 0.13 rem (in shielded cell).

a. Exposures given in rad because that is how they were reported in the source document. One rad is equal to 1 rem for gamma radiation exposure; for neutron exposures, 1 rad can equal significantly more than 1 rem depending on the neutron energy.

b. Note that five of the eight criticality events occurred at fuel reprocessing plants. Personnel radiation exposures tend to be much smaller for these facilities because process vessels are located inside highly shielded hot cells. Neither of the two fatalities recorded occurred in a reprocessing plant.

Table 4.3-12. Solution Criticality Event — First Pulse Radiation Exposures (Reg. Guide 3.34 Assumption of 10^{18} Fissions in 0.5 s)

	Exposures (rem) With No Shielding (Air Only)			Exposures (rem) With 12 in. (0.3 m) of Concrete Shielding		
Distance[a] (m)	Prompt gamma[b]	Prompt neutron	Total	Prompt gamma[b]	Prompt neutron	Total
5	826.000	2730.0000	3560.000	165.0000	593.0000	758.0000
7	418.000	1380.0000	1800.000	83.0000	299.0000	382.0000
10	203.000	665.0000	868.000	41.0000	144.0000	185.0000
15	88.000	288.0000	376.000	18.0000	63.0000	81.0000
20	49.000	158.0000	207.000	9.8000	34.0000	44.0000
30	21.100	66.5000	87.600	4.2100	14.4000	18.7000
40	11.500	35.5000	47.000	2.3000	7.7000	10.0000
60	4.800	14.2000	19.000	0.9500	3.1000	4.1000
80	2.500	7.2000	9.700	0.5000	1.6000	2.1000
100	1.500	4.2000	5.900	0.3000	0.9000	1.2000
150	0.560	1.4300	1.990	0.1100	0.3100	0.4200
200	0.260	0.6200	0.880	0.0530	0.1300	0.1900
400	0.034	0.0550	0.089	0.0067	0.0120	0.0180
600	0.008	0.0086	0.016	0.0015	0.0019	0.0034
800	0.002	0.0020	0.004	0.0004	0.0004	0.0008
1000	7×10^{-4}	3.9×10^{-4}	1.1×10^{-3}	1.4×10^{-4}	8.4×10^{-5}	2.2×10^{-4}

a. 590 m (Building XT-847) is the smallest distance to the site boundary; other buildings are further (e.g., X-333 at 990 m, X-343 at 1005 m, X-344A at 1090 m, X-330 at 1190 m, and X-326 at 1110 m from the site boundary).

b. The prompt gamma numbers, as explained in Reg. Guide 3.34, include delayed gammas emitted during the first minute after the pulse.

Table 4.3-13. Solution Criticality Event — Total Accumulated Radiation (Reg. Guide 3.34 Assumption of 10^{19} Fissions Over 8h)

		Exposures (rem) With No Shielding (Air Only)					Total Exposures (rem) With 12 in. (0.3 m) of Concrete Shielding	
Distance[a] (m)	Plume exposures (rem)	Prompt Gamma	Delayed Gamma	Prompt Neutron	TOTAL No Plume	TOTAL With Plume[b]	TOTAL No Plume	TOTAL With Plume[b]
5	–[b]	8260.000	3138.000	27300.0000	38700.000	38700.00	8210.000	8210.00
10	–[b]	2030.000	771.000	6650.0000	9450.000	9450.00	2000.000	2000.00
15	–[b]	887.000	337.000	2880.0000	4100.000	4100.00	870.000	870.00
20	–[b]	490.000	186.000	1580.0000	2260.000	2260.00	478.000	478.00
30	–[b]	211.000	80.100	665.0000	956.000	956.00	203.000	203.00
40	–[b]	89.000	33.800	274.0000	396.000	396.00	84.000	84.00
60	–[b]	48.000	18.000	142.0000	208.000	208.00	44.000	44.00
80	–[b]	25.000	9.500	72.0000	107.000	107.00	22.600	22.60
100	–[b]	15.000	5.680	42.0000	62.000	62.00	13.200	13.20
150	9.25	5.600	2.100	14.0000	22.000	31.00	4.600	13.90
200	7.00	2.660	1.000	601.0000	9.900	16.90	2.100	9.10
400	2.90	0.340	0.130	0.5500	1.000	3.90	0.210	3.11
600	1.65	0.076	0.029	0.0860	0.190	1.84	0.040	1.69
800	1.10	0.022	0.0082	0.0170	0.046	1.15	0.010	1.11
1000	0.65	0.007	0.0027	0.0039	0.0135	0.66	0.003	0.65
1500	0.40	5.69 × 10	0.0002	1.27×10^{4}	9.1×10^{-4}	0.40	1.85 × 10	$^{-4}$ 0.40

a. 590 m (Building XT-847) is the smallest distance to the site boundary; other buildings are further (e.g., X-333 at 990 m, X-343 at 1005 m, X-344A at 1090 m, X-330 at 1190 m, and X-326 at 1110 m from the site boundary).
b. Plume exposures are not reported closer than 150 m because specialized modeling would be required for in-close dispersion calculations.

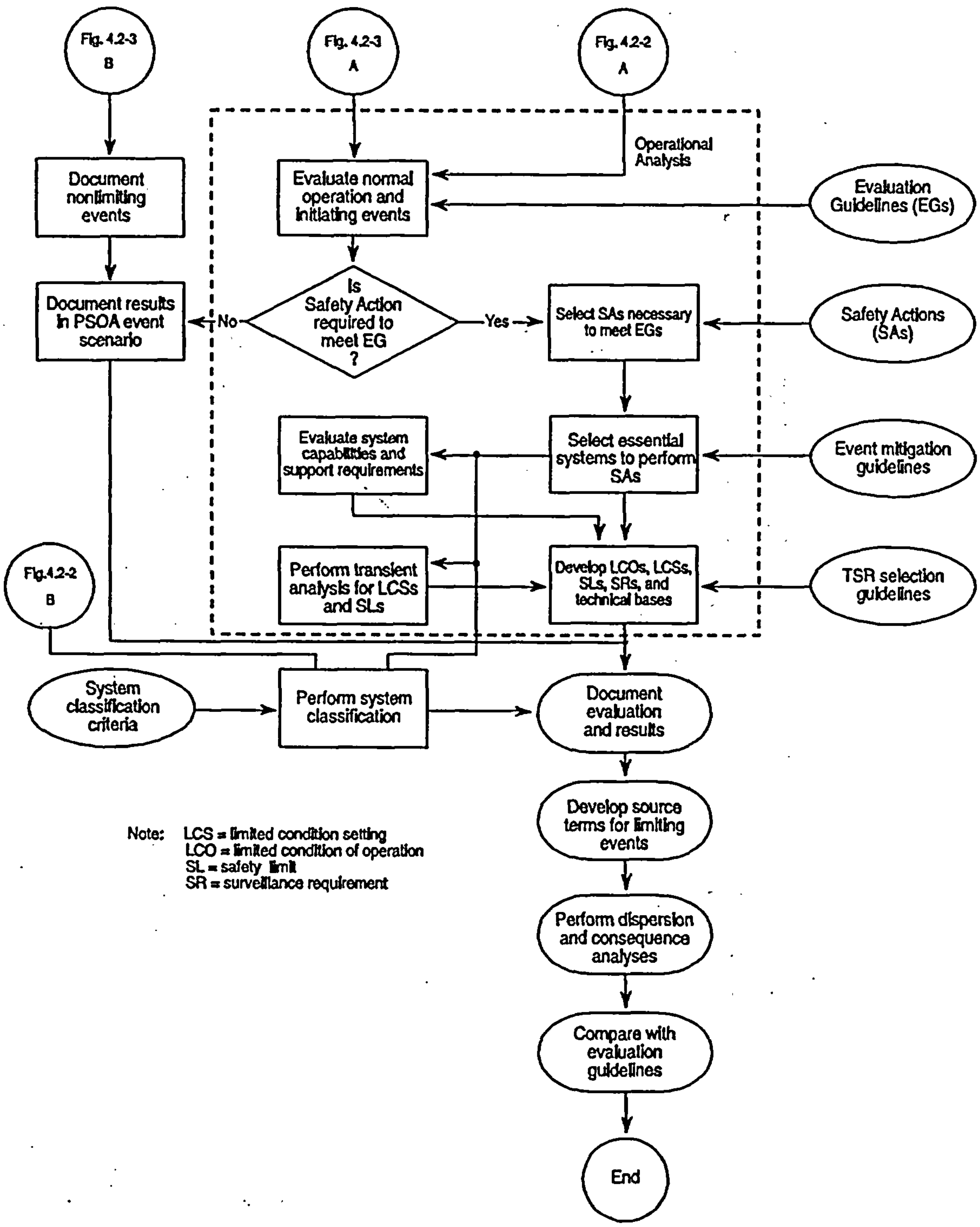


Figure 4.3-1. Operational Analysis

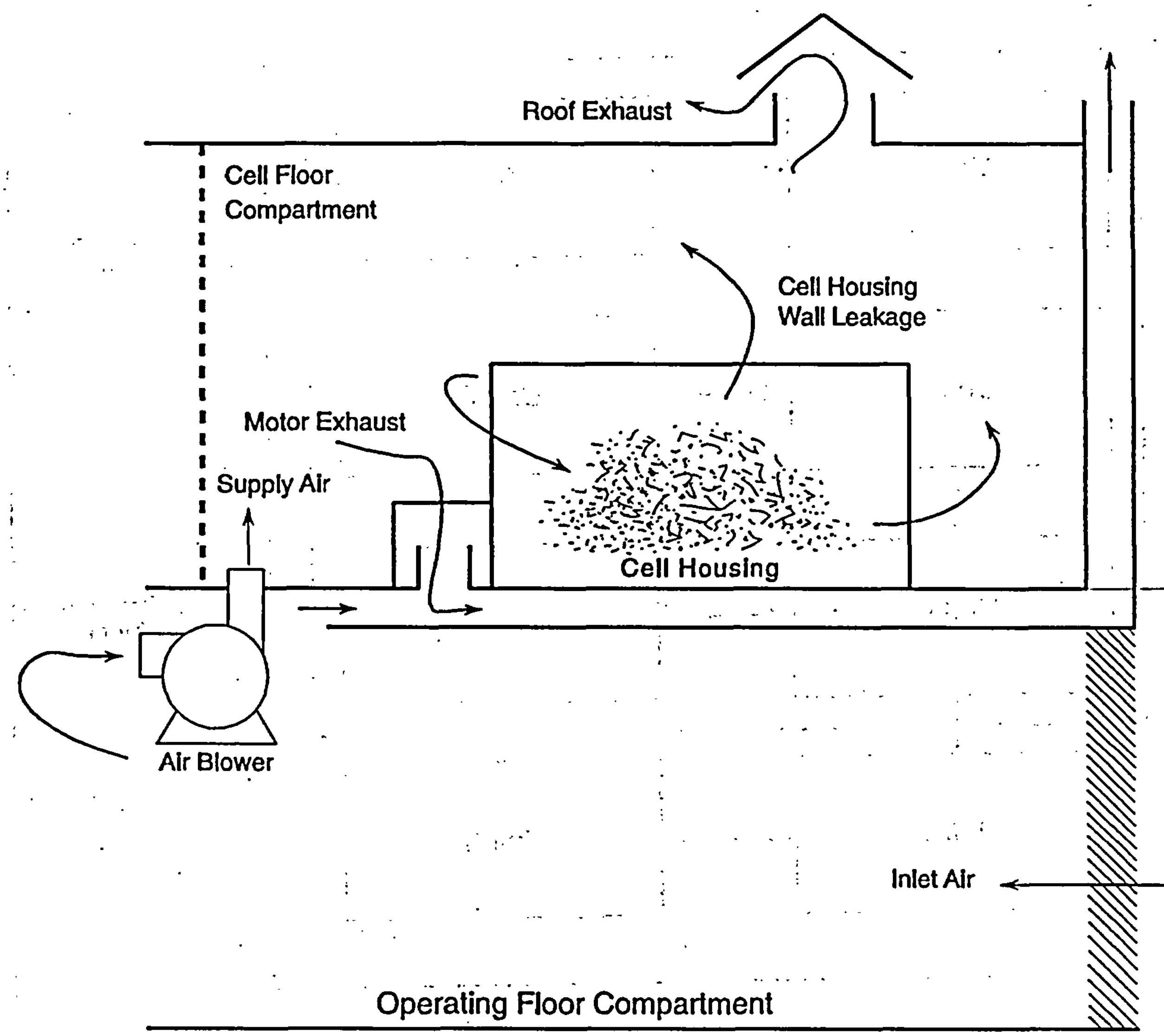


Figure 4.3-2. Summer ventilation pattern of one unit of the process building.

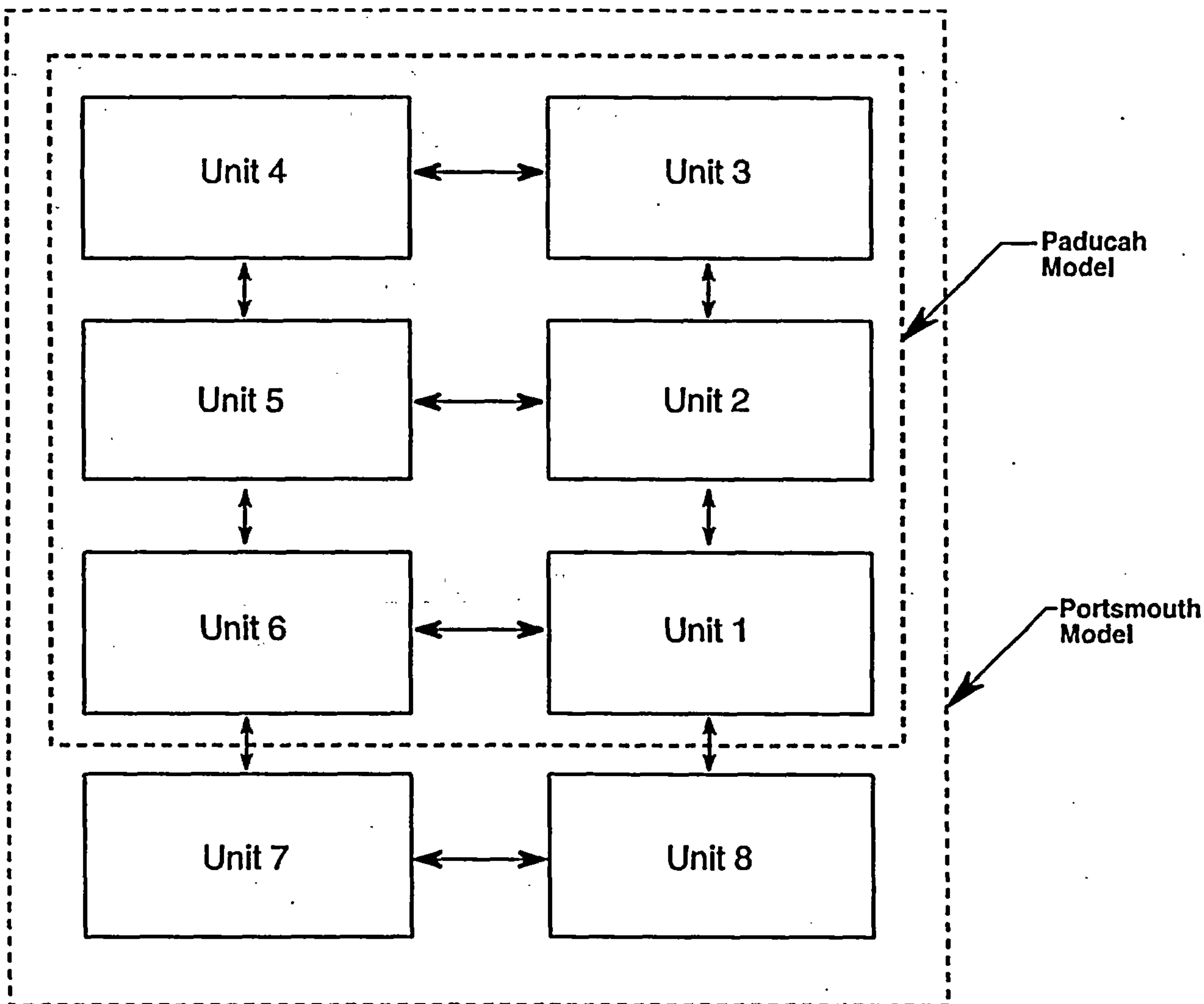


Figure 4.3-3. Control volume and unit layout of a "000" building.

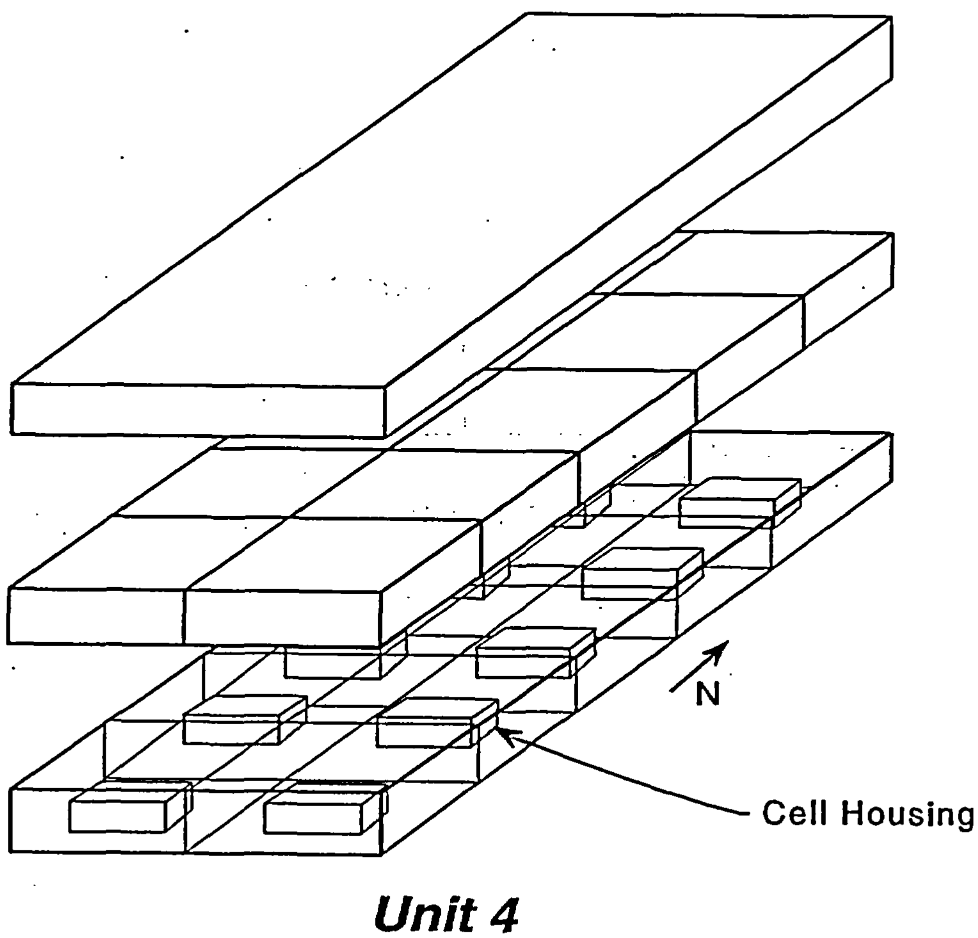


Figure 4.3-4. MELCOR control volumes of one unit in the process building.

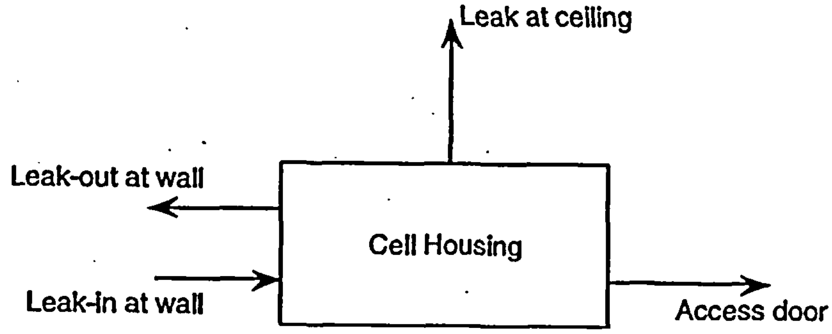


Figure 4.3-5. Assumed MELCOR flow paths of cell housing leakage.

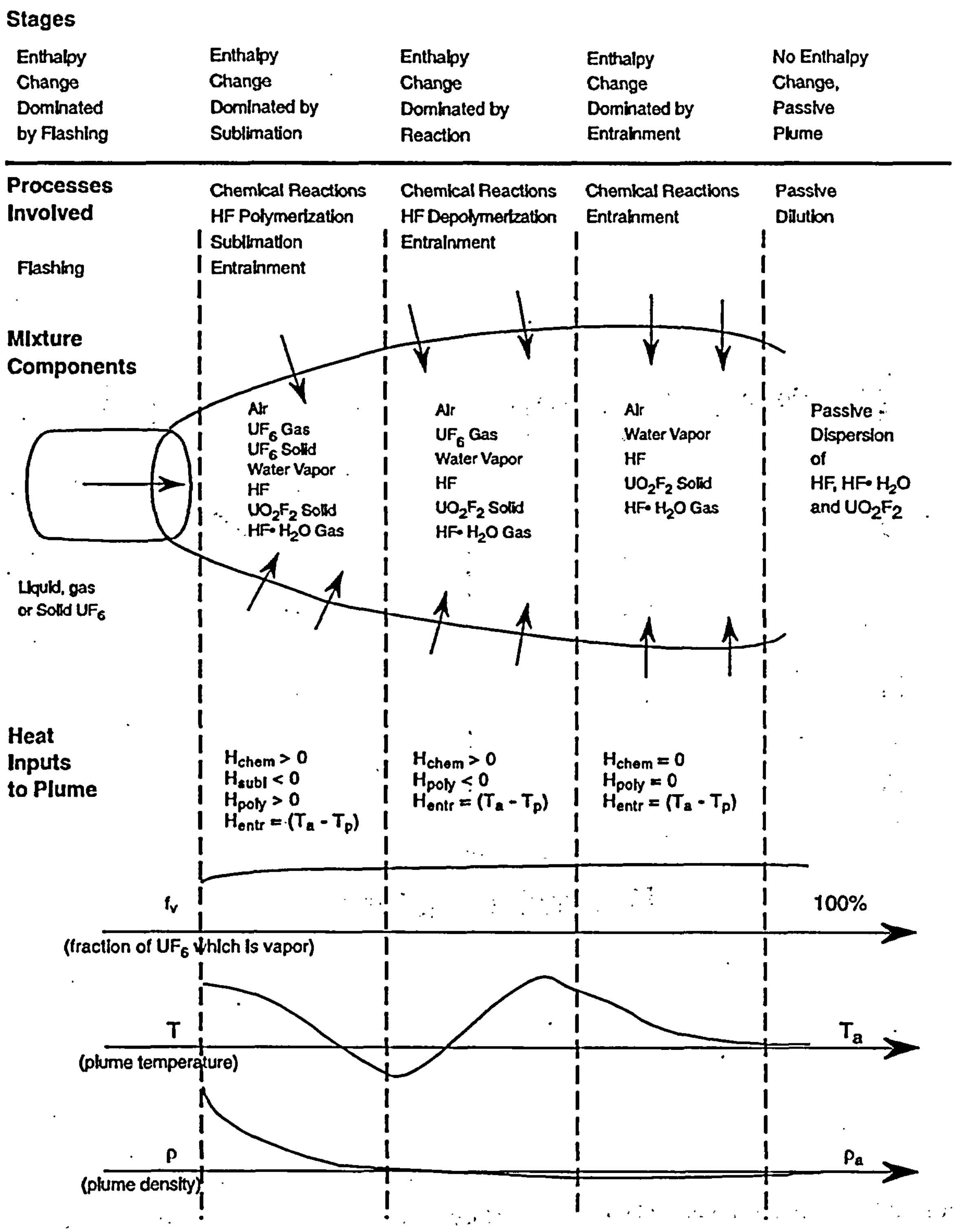


Figure 4.3-6. Schematic diagram of processes involved in UF_6 releases.

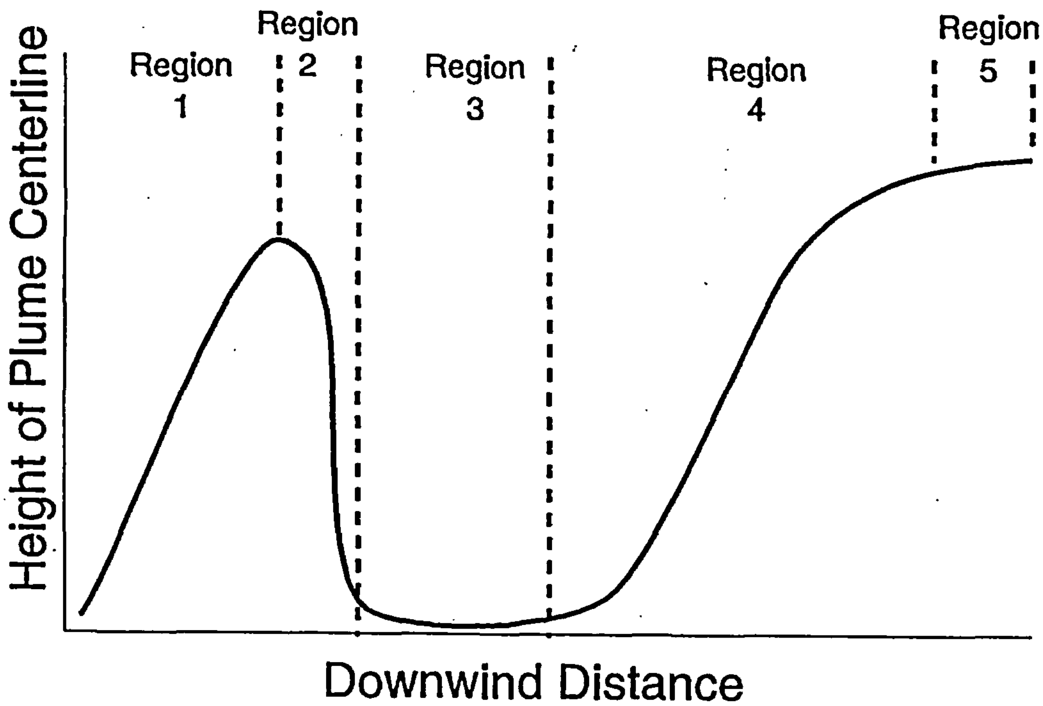


Figure 4.3-7. Example of a possible plume trajectory from a moderate-velocity, vertical release of UF_6 vapor.

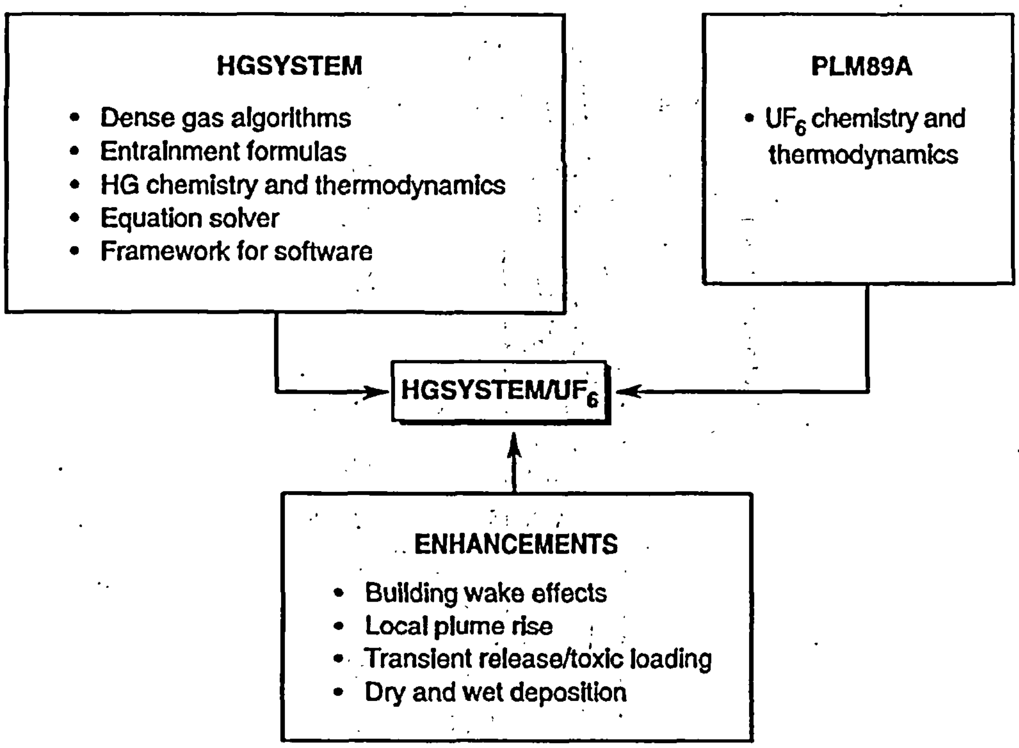


Figure 4.3-8. Schematic showing the development and enhancements of HGSYSTEM/UF_6.

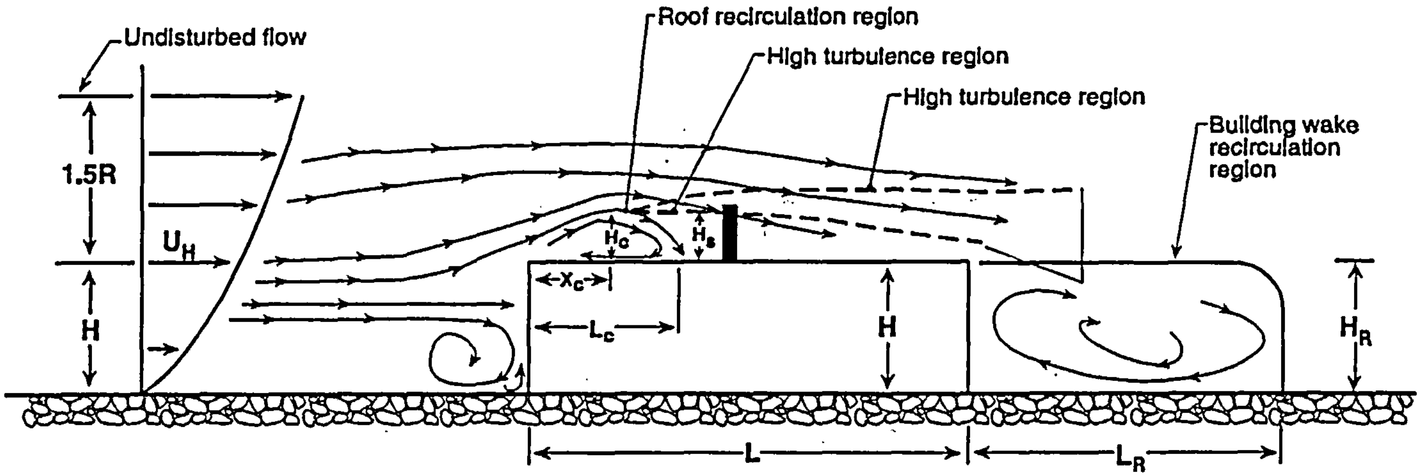


Figure 4.3-9. Flow over a building for wind normal to the upwind face.

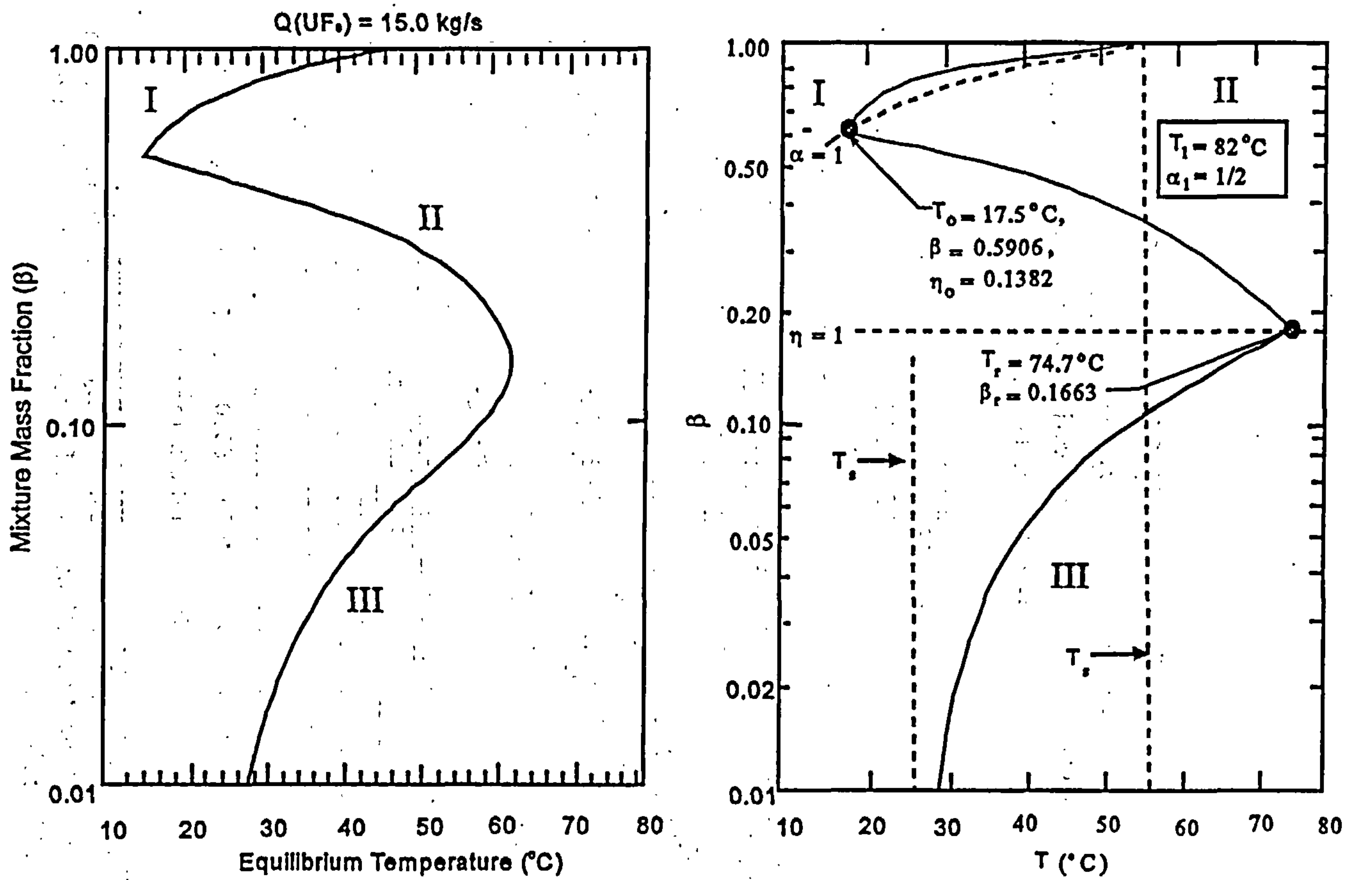


Fig. 4.3-10. Mixture mass fraction, β, for HGSYSTEM/UF predictions (left side) and for Rodean's (1989) equilibrium solution (right side). Three regions are seen: (I) cooling due to evaporation of solid UF6; (II) warming due to reaction of UF6 vapor with water vapor; and (III) dilution of products (HF and UO2F2) by entrainment.

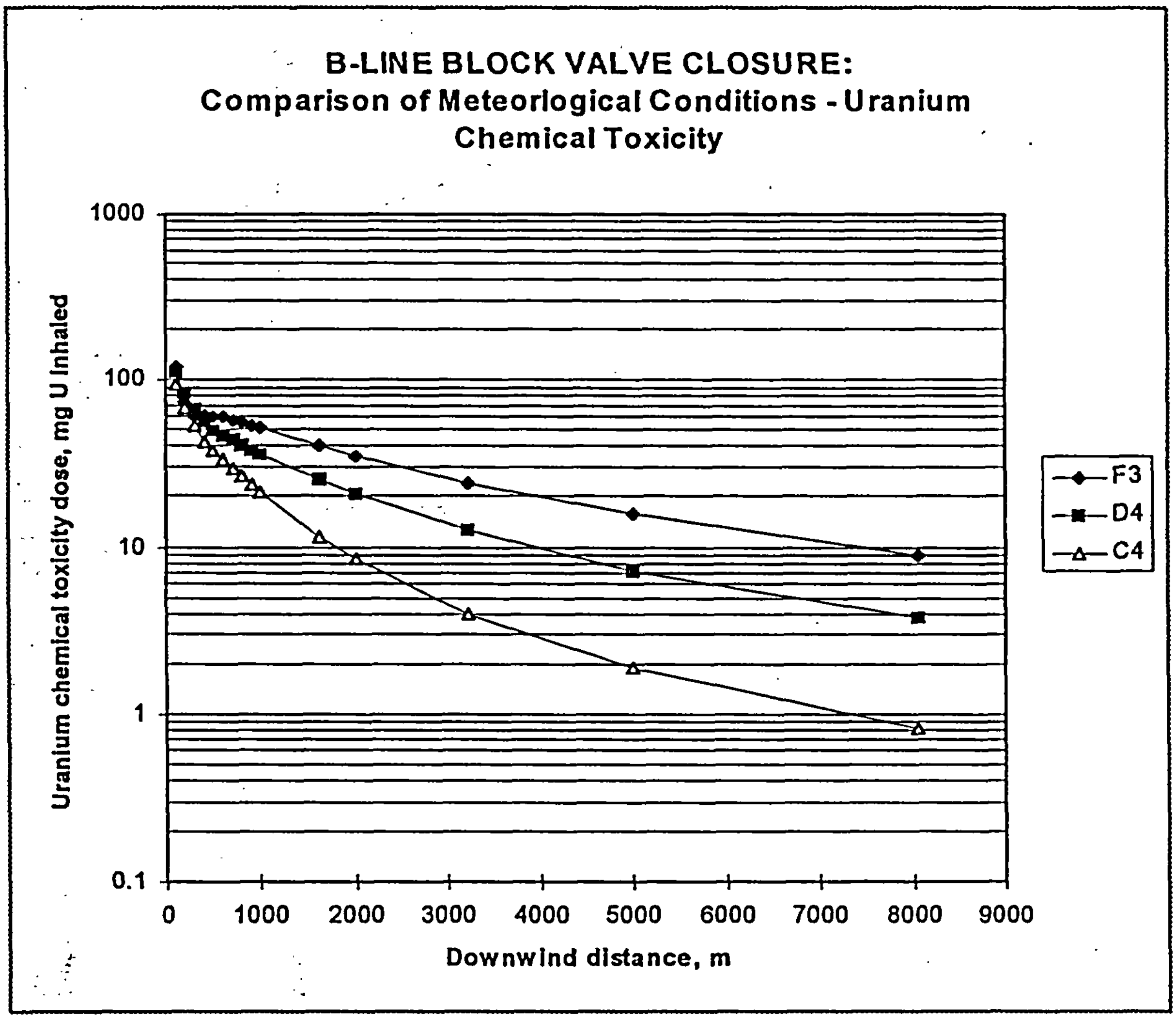


Figure 4.3-11. Estimated uranium chemical toxicity vs. downwind distance for three meteorological conditions after a UF_6 release associated with a B-line rupture in Building X-333.

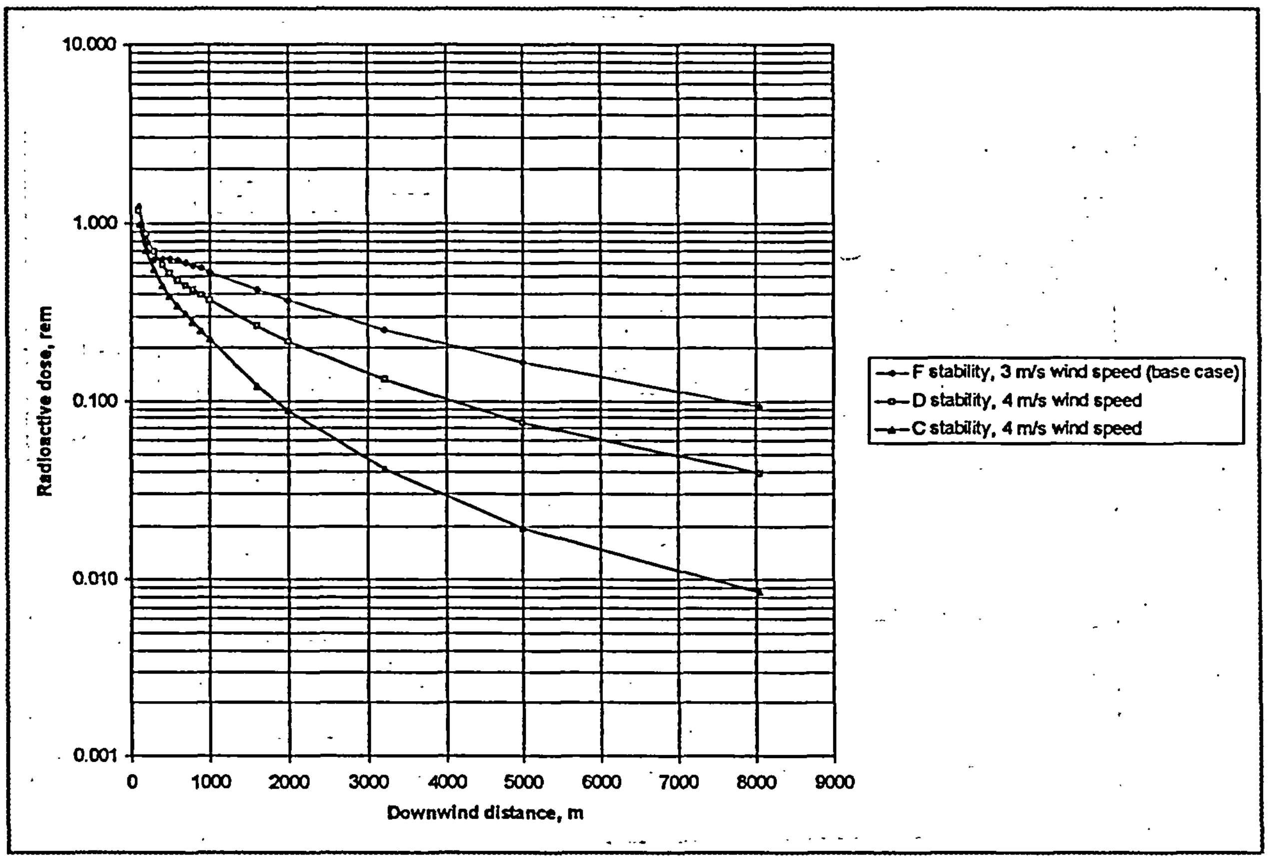


Figure 4.3-12. Estimated radiocative dose vs. downwind distance for three meteorological conditions after a UF_6 release associated with a B-line rupture in Building X-333.

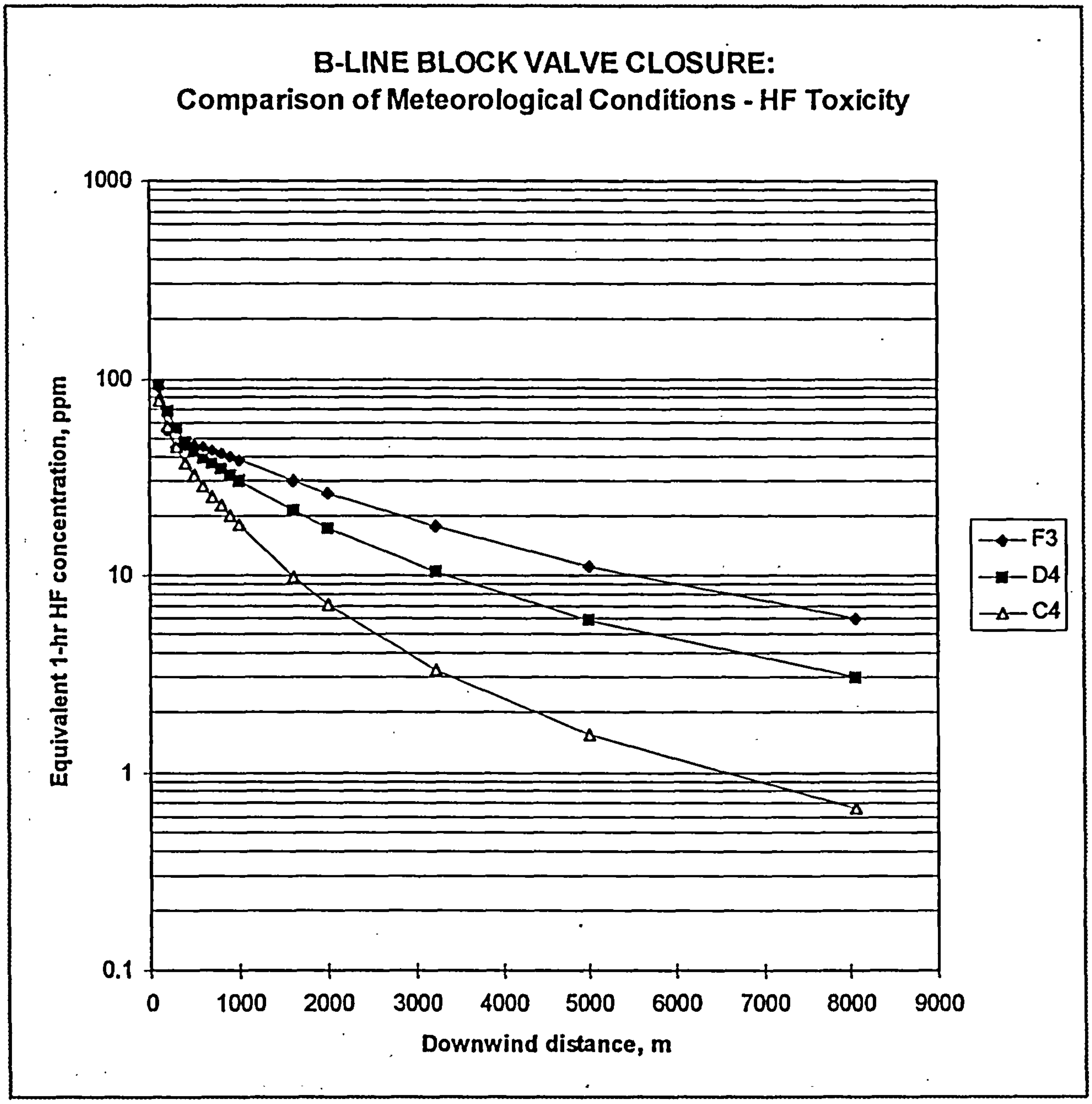


Figure 4.3-13. Estimated hydrogen fluoride (HF) toxicity vs. downwind distance for three meteorological conditions after UF_6 release associated with a B-line rupture in Building X-333.

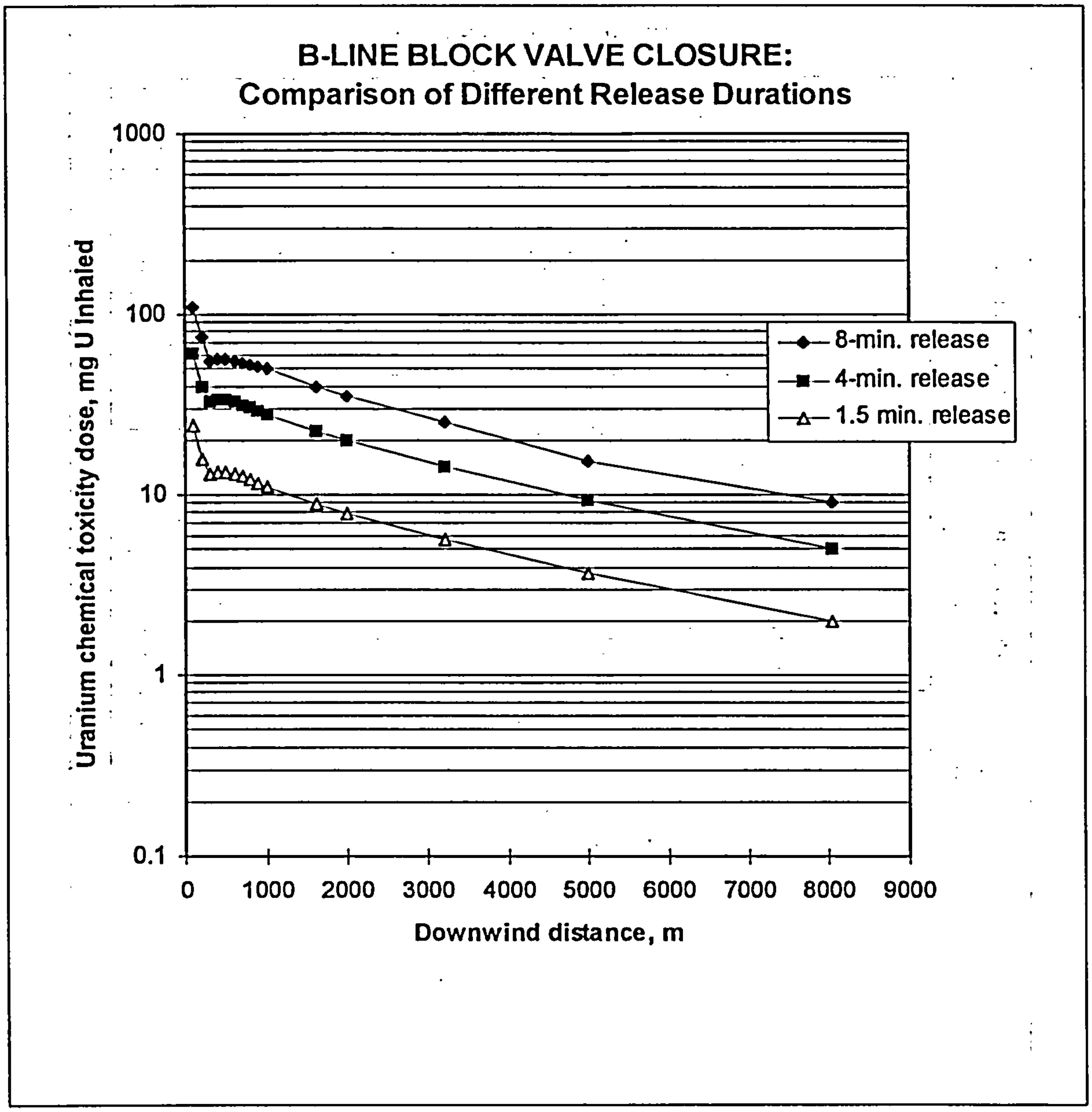


Figure 4.3-14. Comparison of uranium chemical toxicity vs. downwind distance for three different UF_6 release durations associated with a B-line rupture in Building X-333.

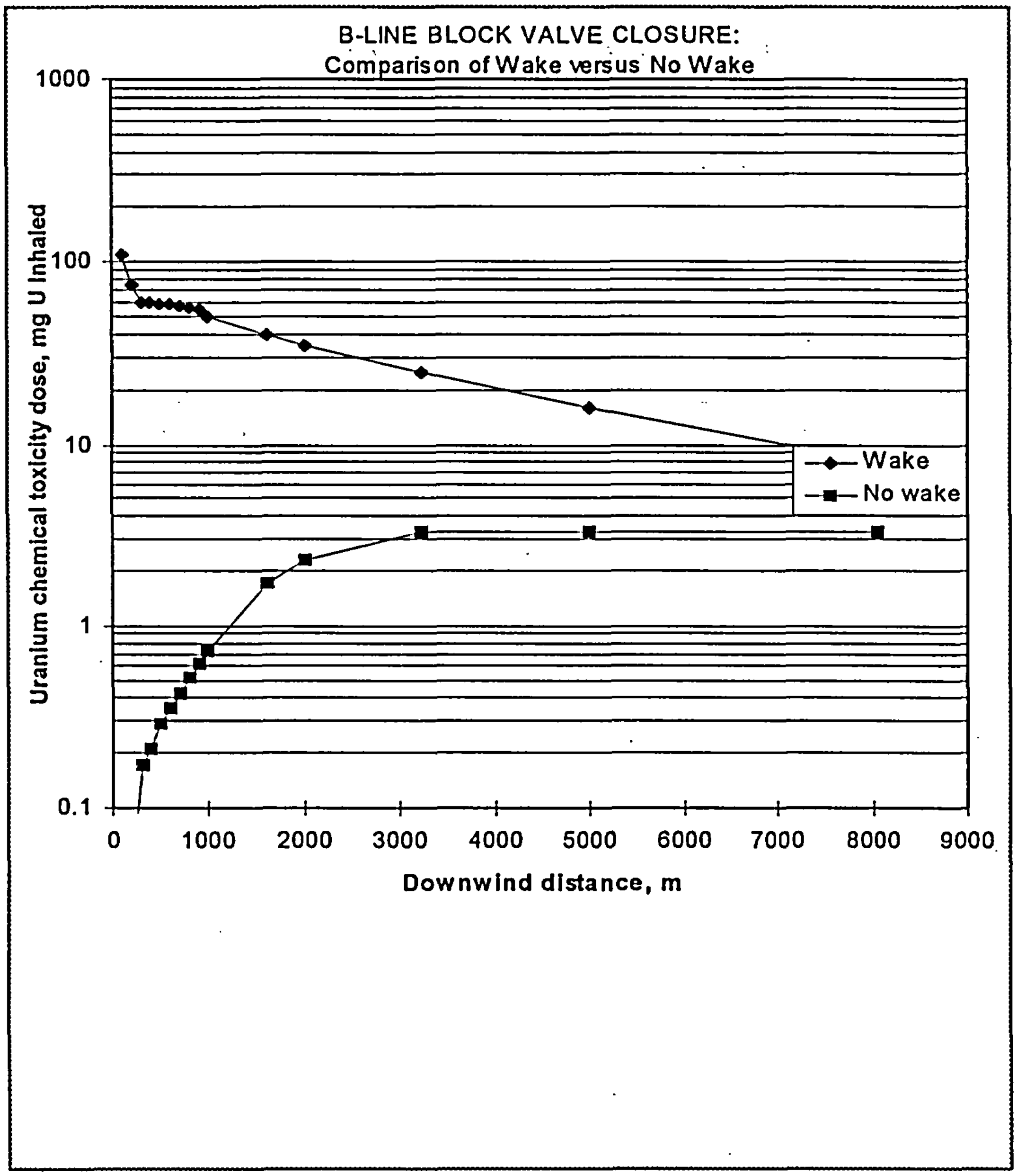
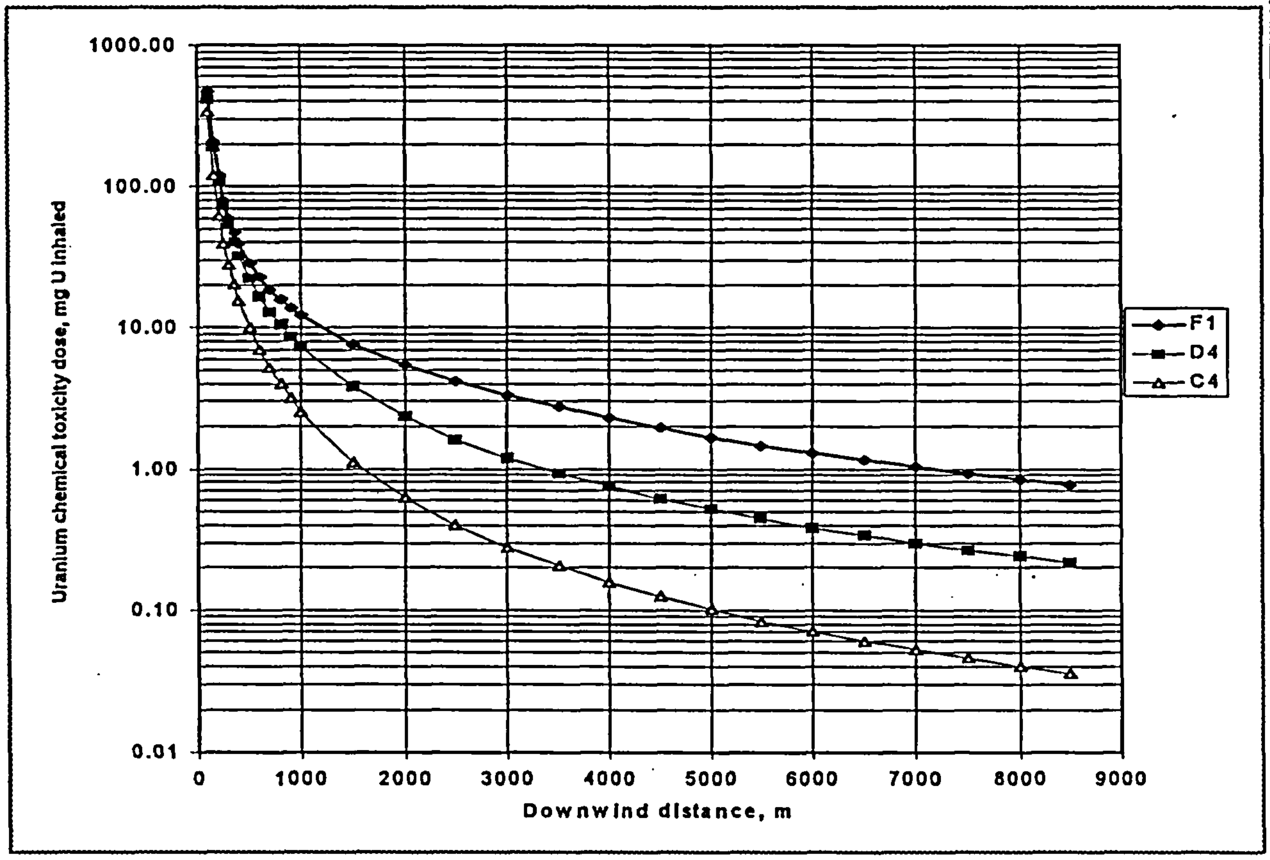


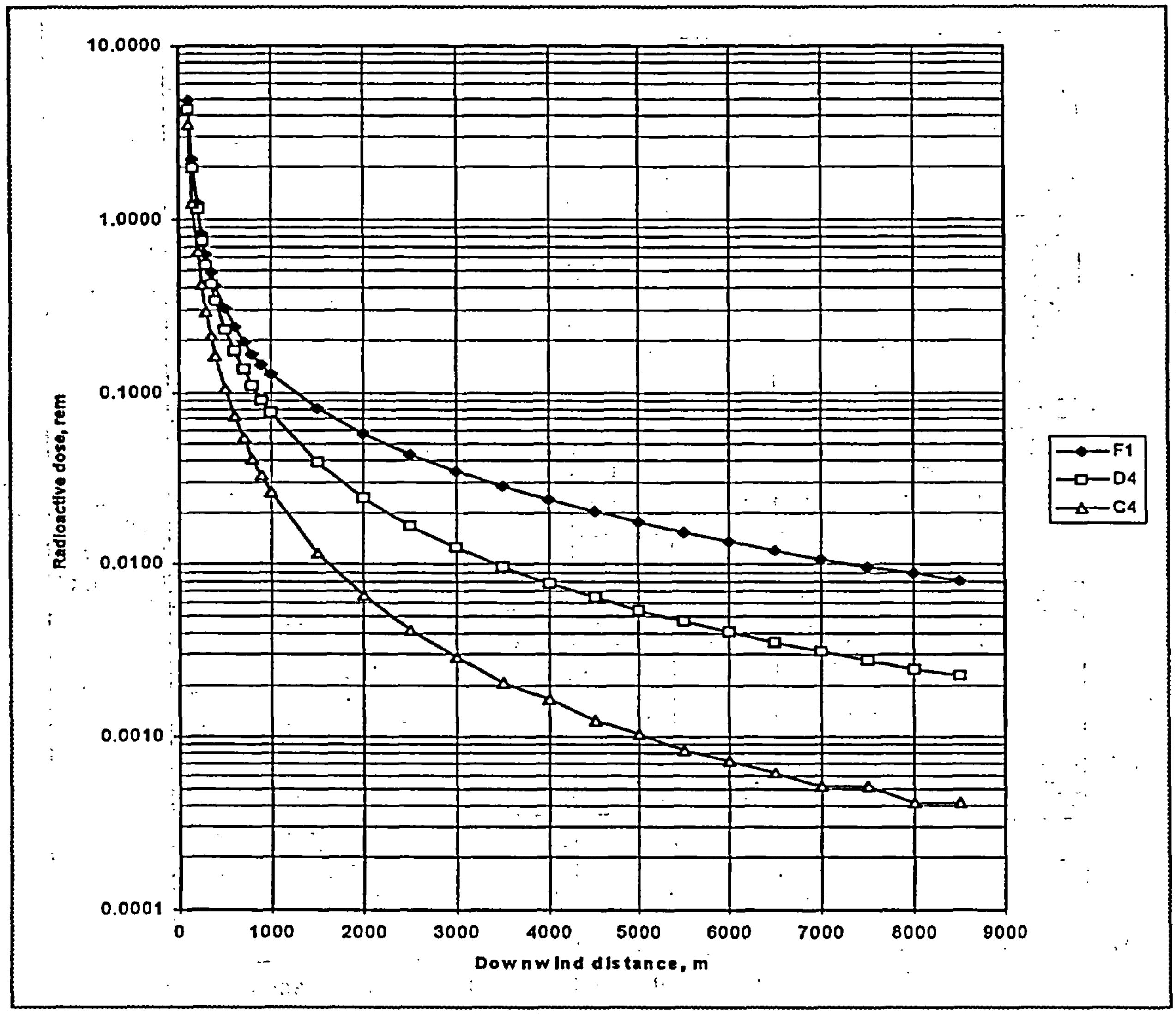
Figure 4.3-15. Comparison of uranium chemical toxicity vs. downwind distance for building wake and no building wake after a UF_6 release associated with a B-line rupture in Building X-333.

Figure 4.3-16. *Figure Deleted*



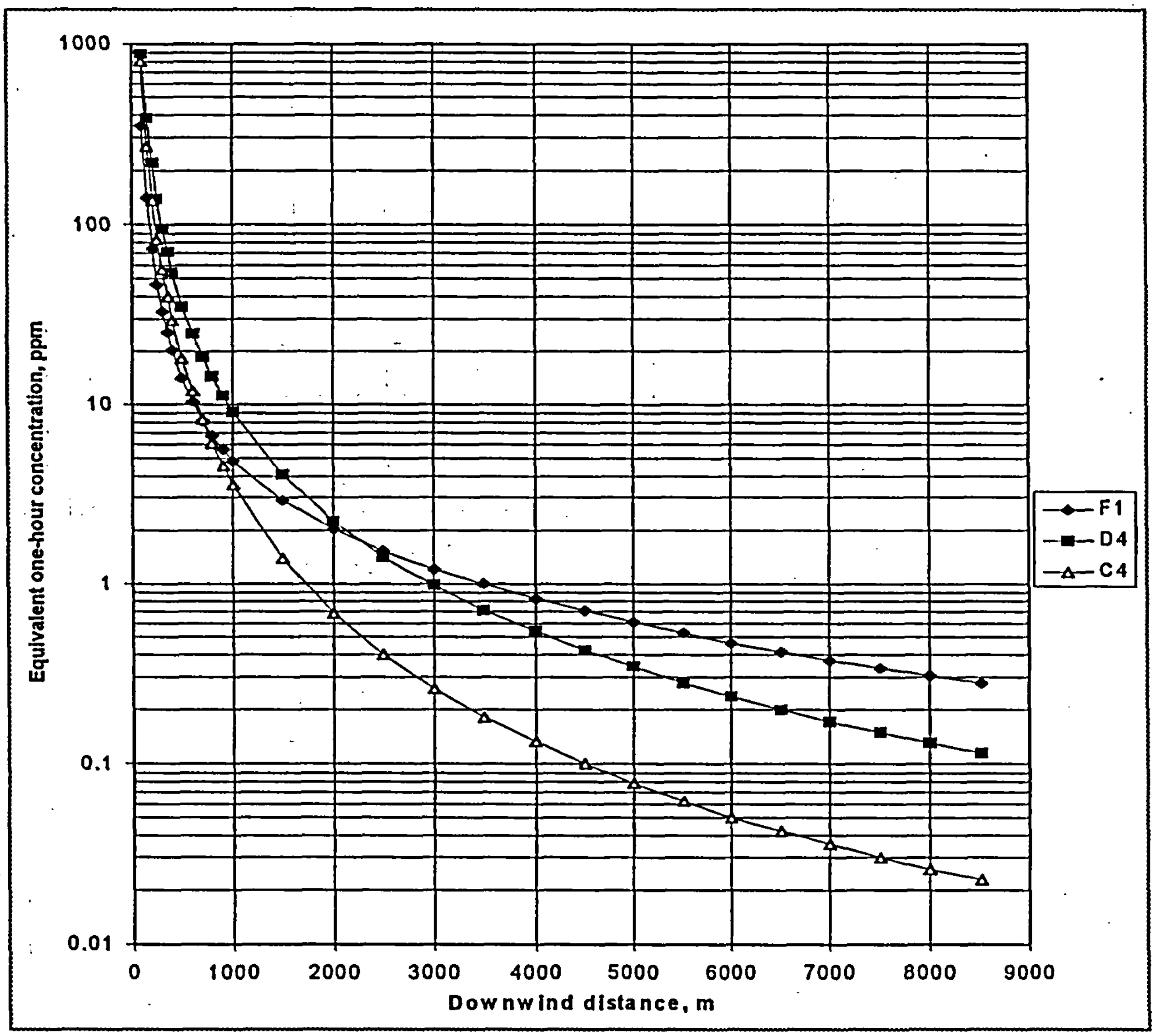
F1 = F stability, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-17. Estimated uranium chemical toxicity vs. downwind distance for three meteorological conditions after a 45-second release during transfer of UF_6 from the parent to daughter cylinders.



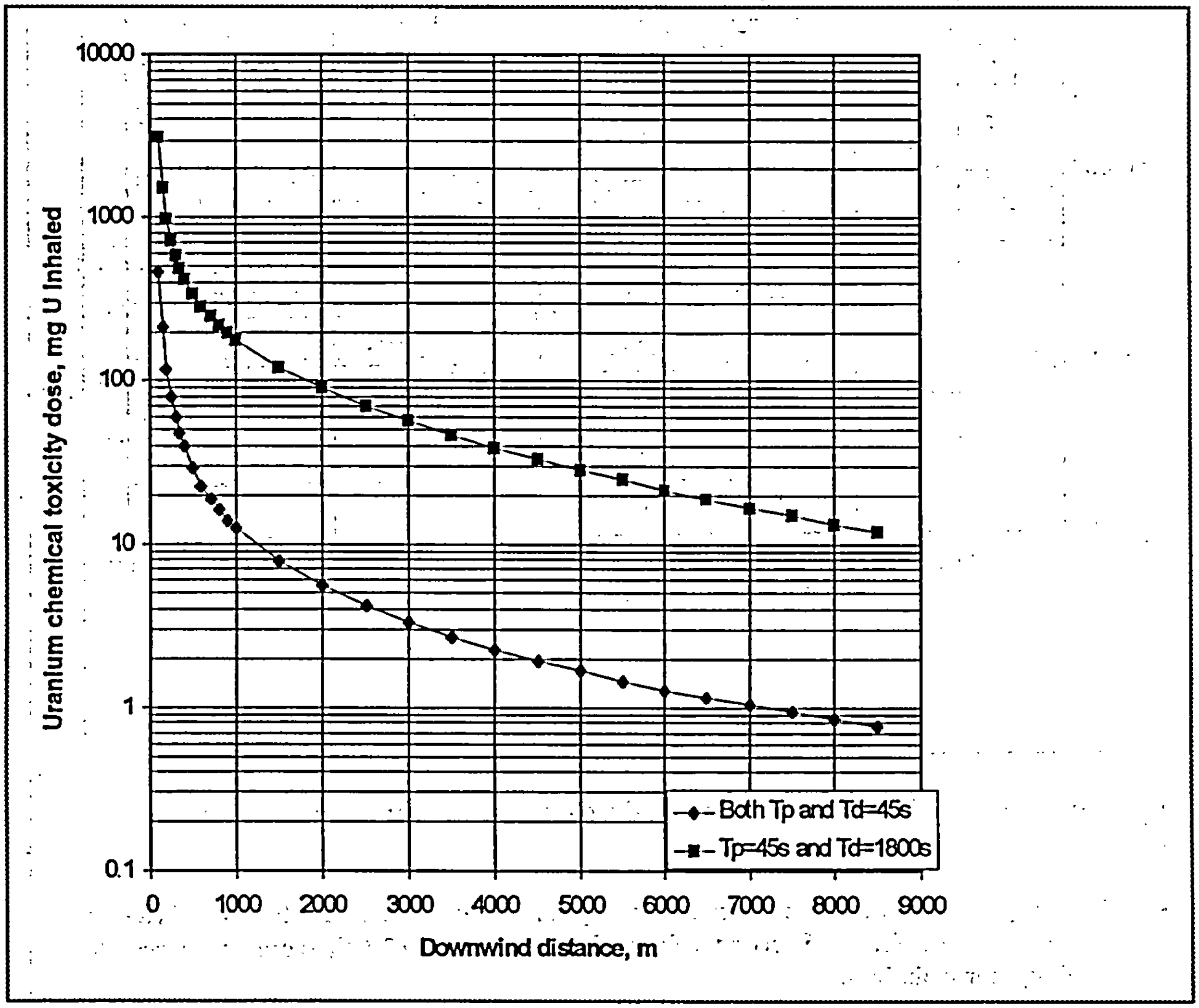
F1 = F stabillity, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-18 Estimated radioactive dose vs. downwind distance for three meteorological conditions after a 45-second release during transfer of UF_6 from the parent to daughter cylinders.



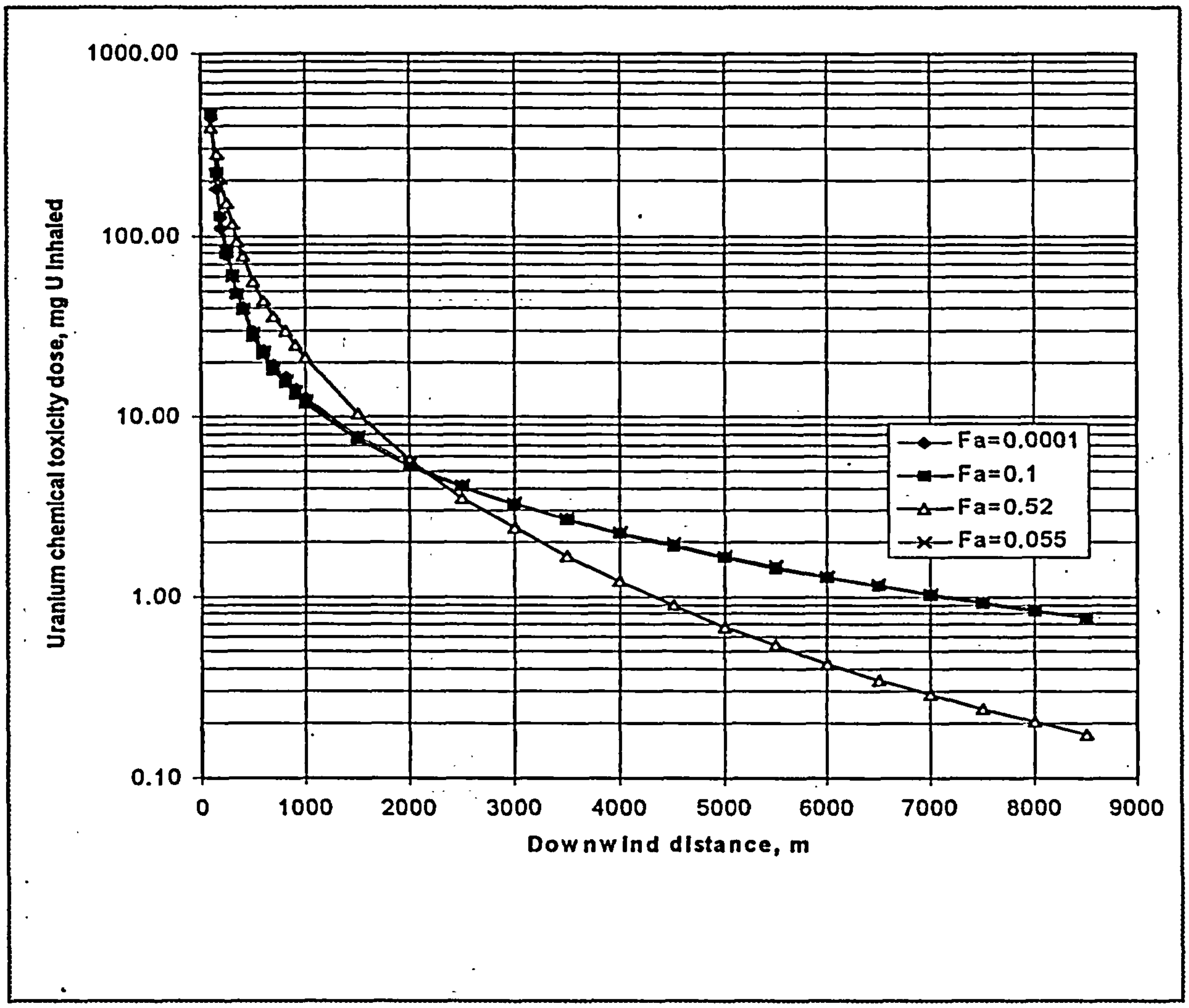
F1 = F stability, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-19. Estimated hydrogen fluoride (HF) toxicity vs. downwind distance for three meteorological conditions after a 45-second release during transfer of UF_6 from the parent to daughter cylinders.



T_p = time for parent cylinder
T_d = time for daughter cylinder

Figure 4.3-20 Comparison of uranium chemical toxicity vs. downwind distance for two different release durations during transfer of UF_6 from the parent to daughter cylinders.



F_a = the ratio of the plume's cross-sectional area exiting the building over the cross-sectional area of the building

Figure 4.3-21. Comparison of uranium chemical toxicity vs. downwind distance for four different release areas for a 45-second release during transfer of UF_6 from the parent to daughter cylinders.

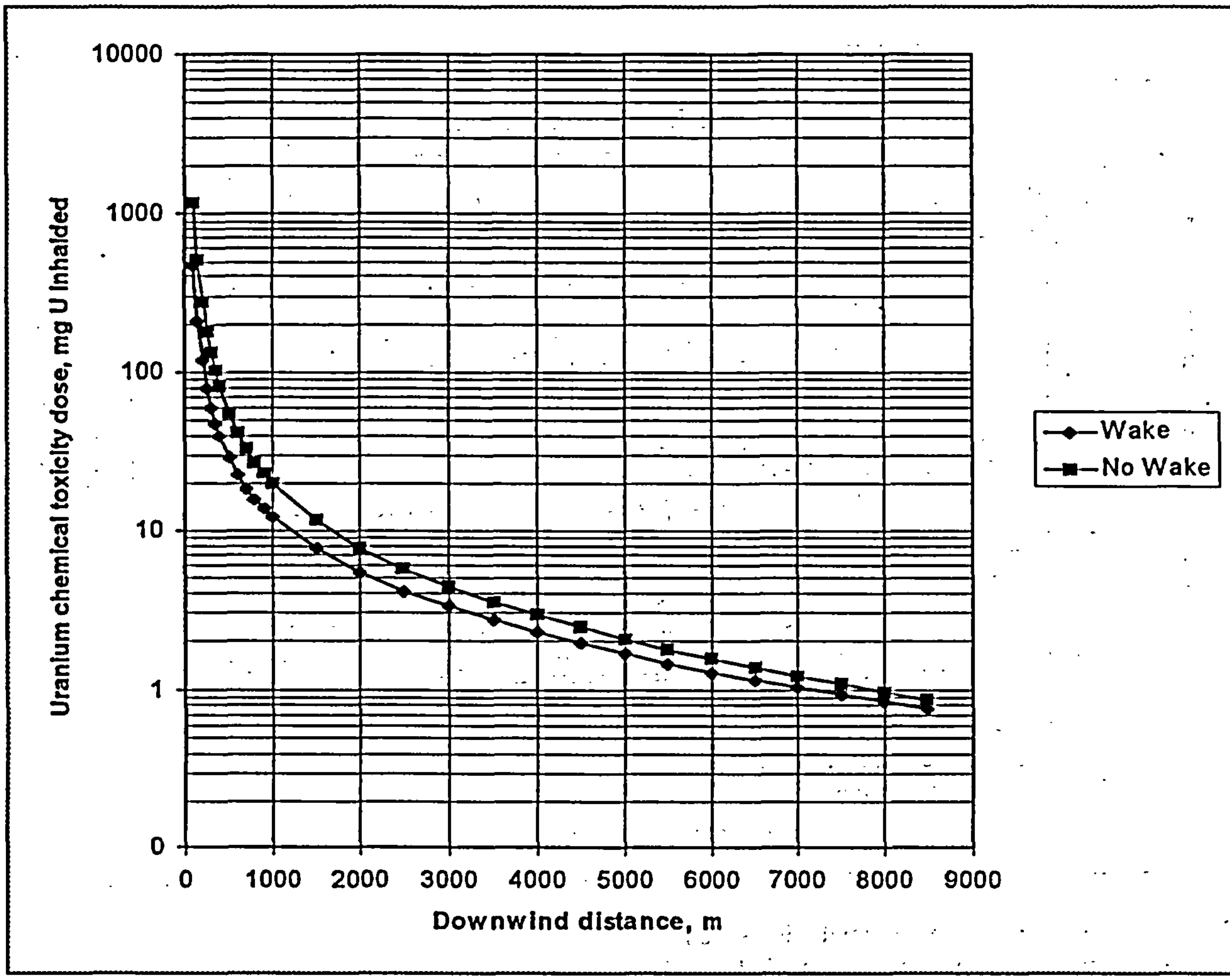
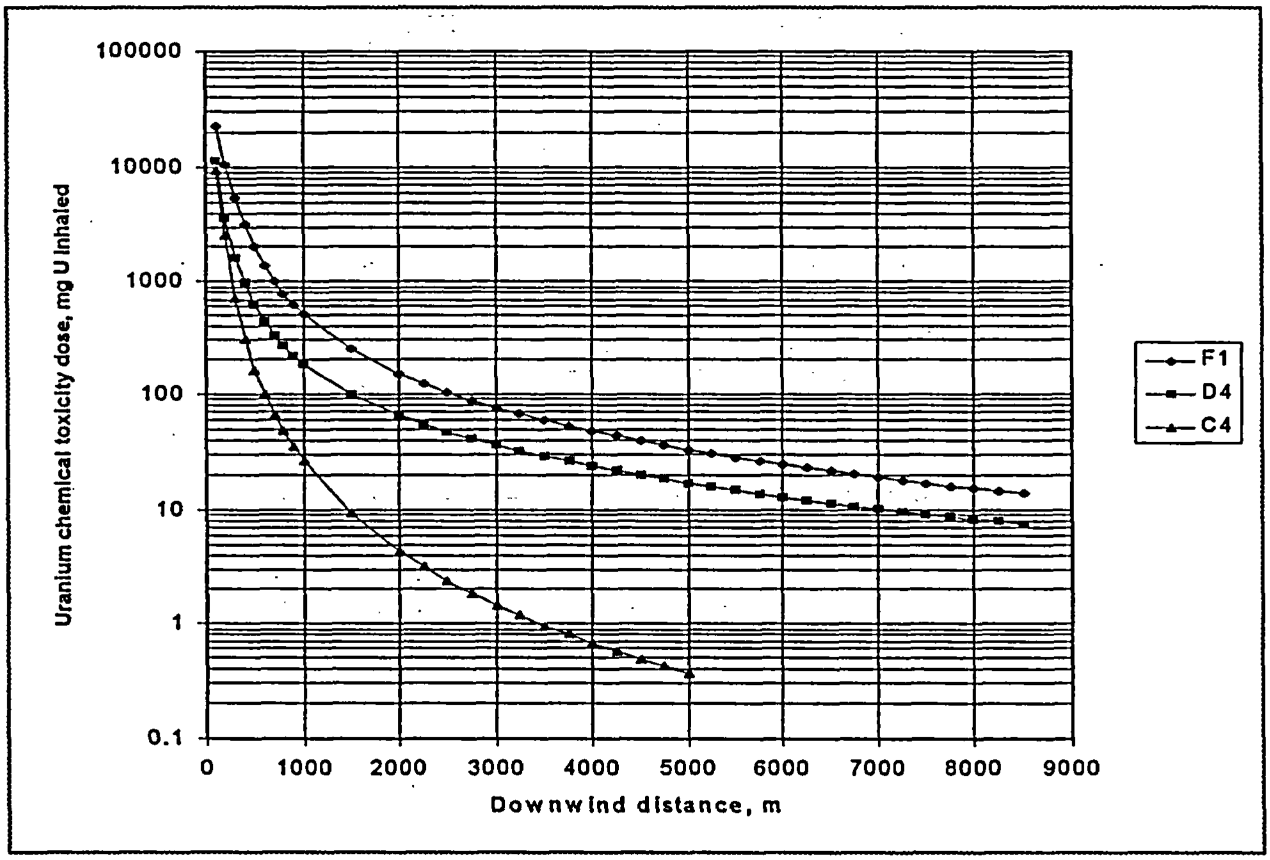
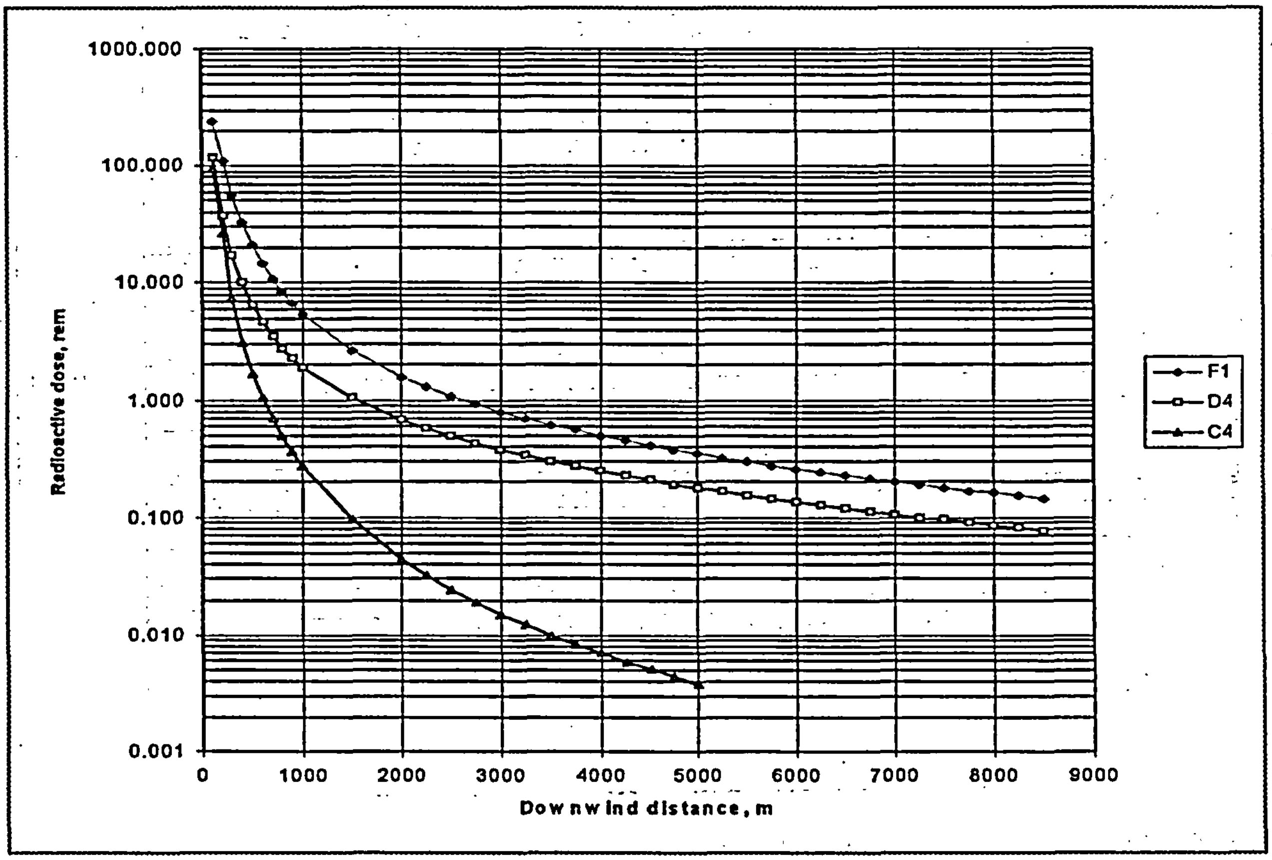


Figure 4.3-22. Comparison of uranium chemical toxicity vs. downwind distance for building wake and no building wake cases after a 45-second release during transfer of UF_6 from the parent to daughter cylinders.



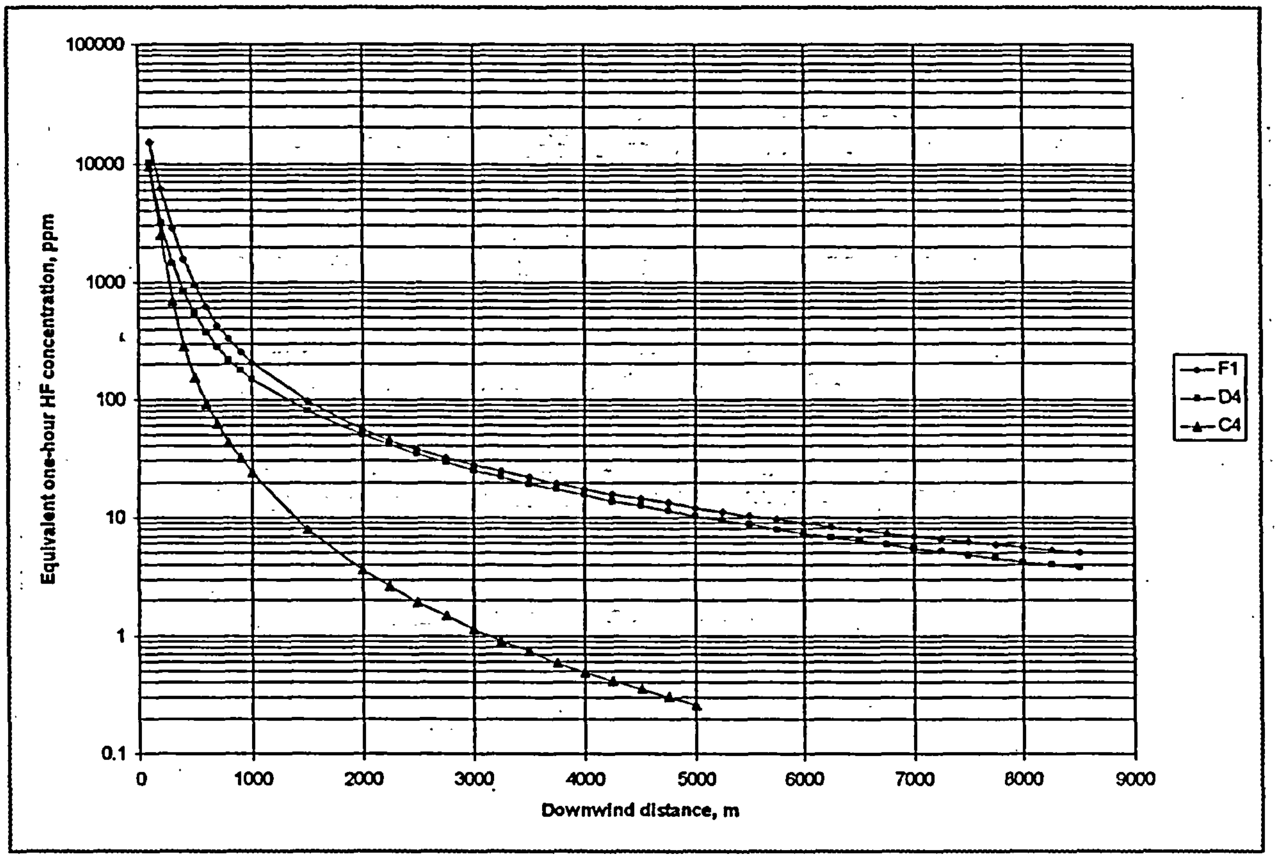
F1 = F stability, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-23. Estimated uranium chemical toxicity vs downwind distance for three meteorological conditions after a UF_6 from a liquid-filled cylinder (i.e., dropped cylinder).



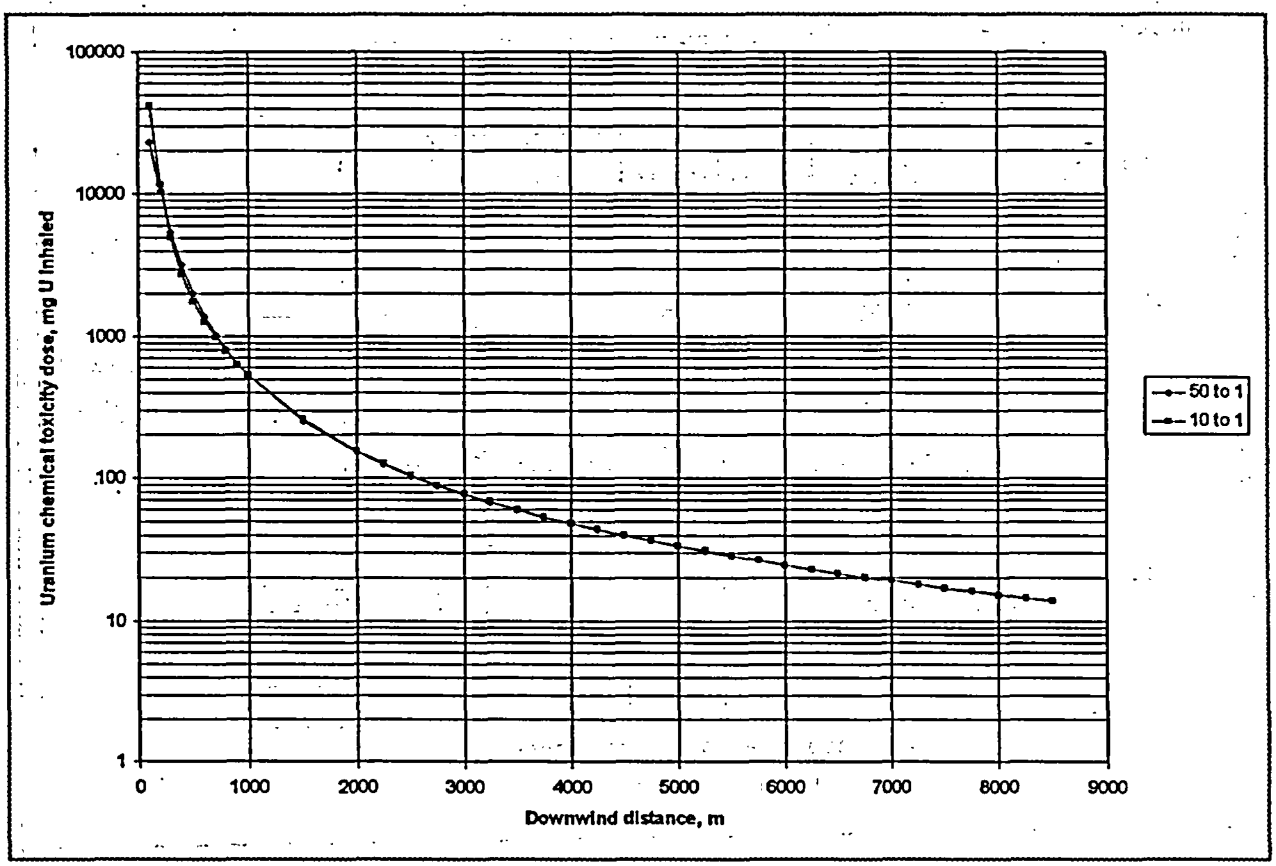
F1 = F stability, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-24 Estimated radioactive dose vs. downwind distance for three meteorological conditions after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).



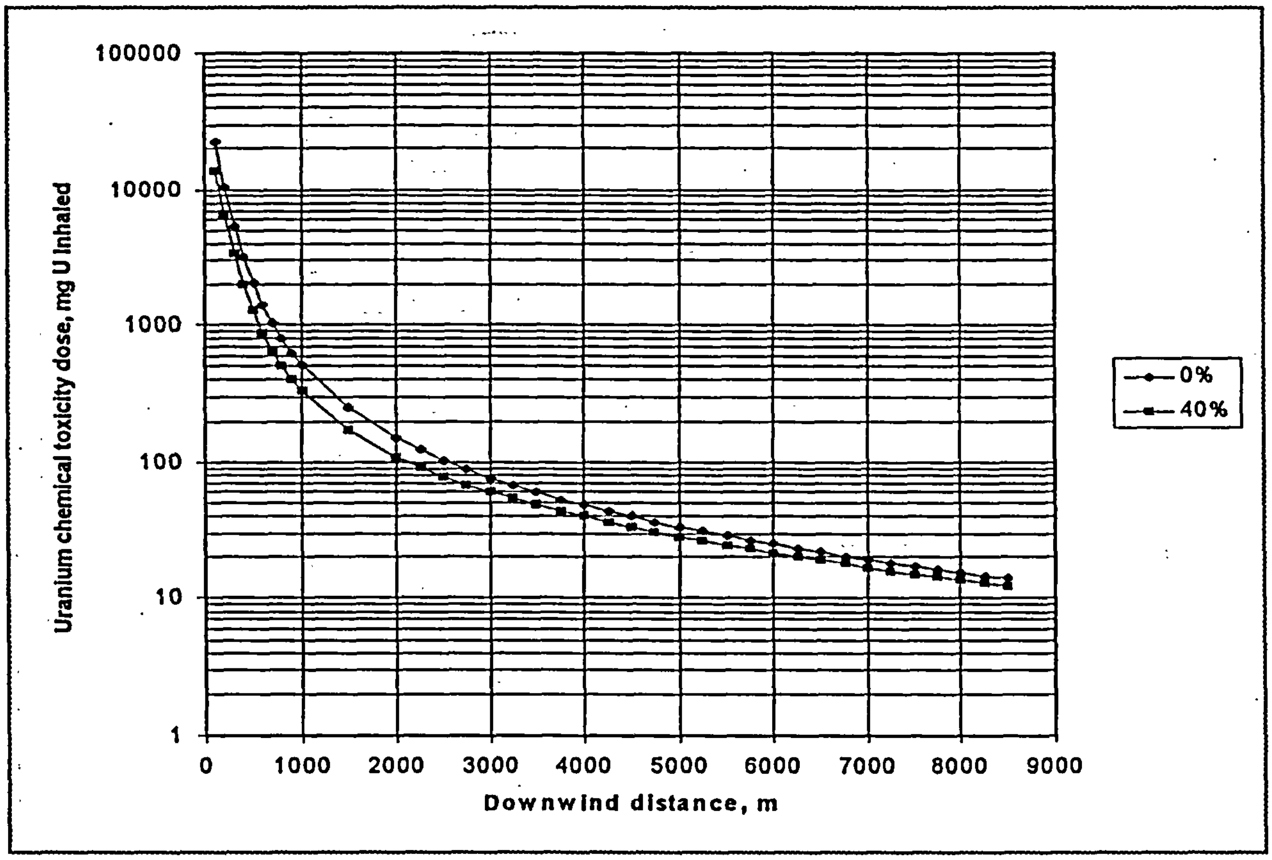
F1 = F stability, 1 meter per second wind speed
D4 = D stability, 4 meters per second wind speed
C4 = C stability, 4 meters per second wind speed

Figure 4.3-25. Estimated hydrogen fluoride (HF) toxicity vs. downwind distance for three meteorological conditions after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).



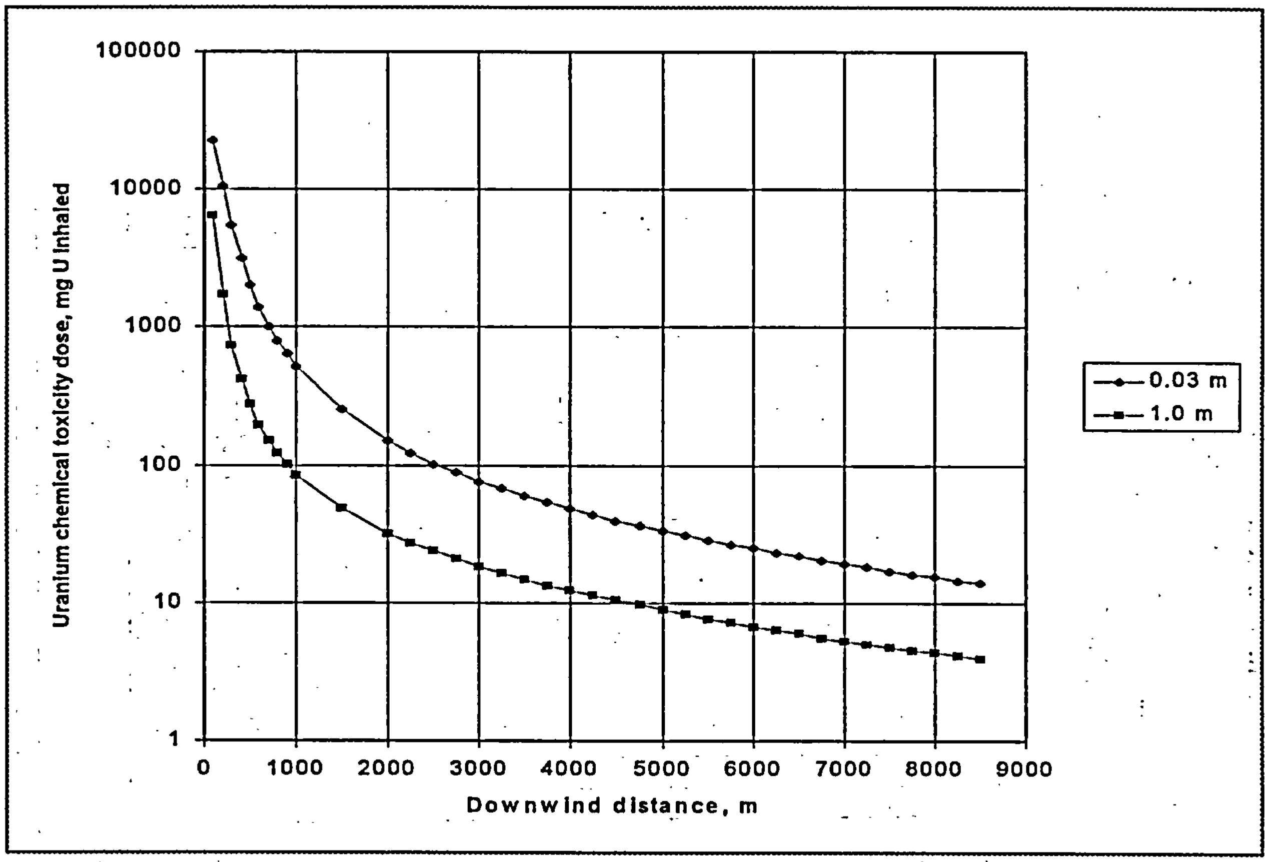
-♦- = assumed 50 to 1 initial mixing ratio
-■- = assumed 10 to 1 initial mixing ratio

Figure 4.3-26. Comparison of uranium chemical toxicity vs downwind distance for two different initial mixing cases after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).



-◆- = assumed 0 percent initial deposition
-■- = assumed 40 percent initial deposition

Figure 4.3-27. Comparison of uranium chemical toxicity vs. downwind distance for two different initial deposition cases after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).



-◆- = assumed surface roughness height of 0.03 meters
-■- = assumed surface roughness height of 1.0 meters

Figure 4.3-28. Comparison of uranium chemical toxicity vs. downwind distance for two different surface roughness heights after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).

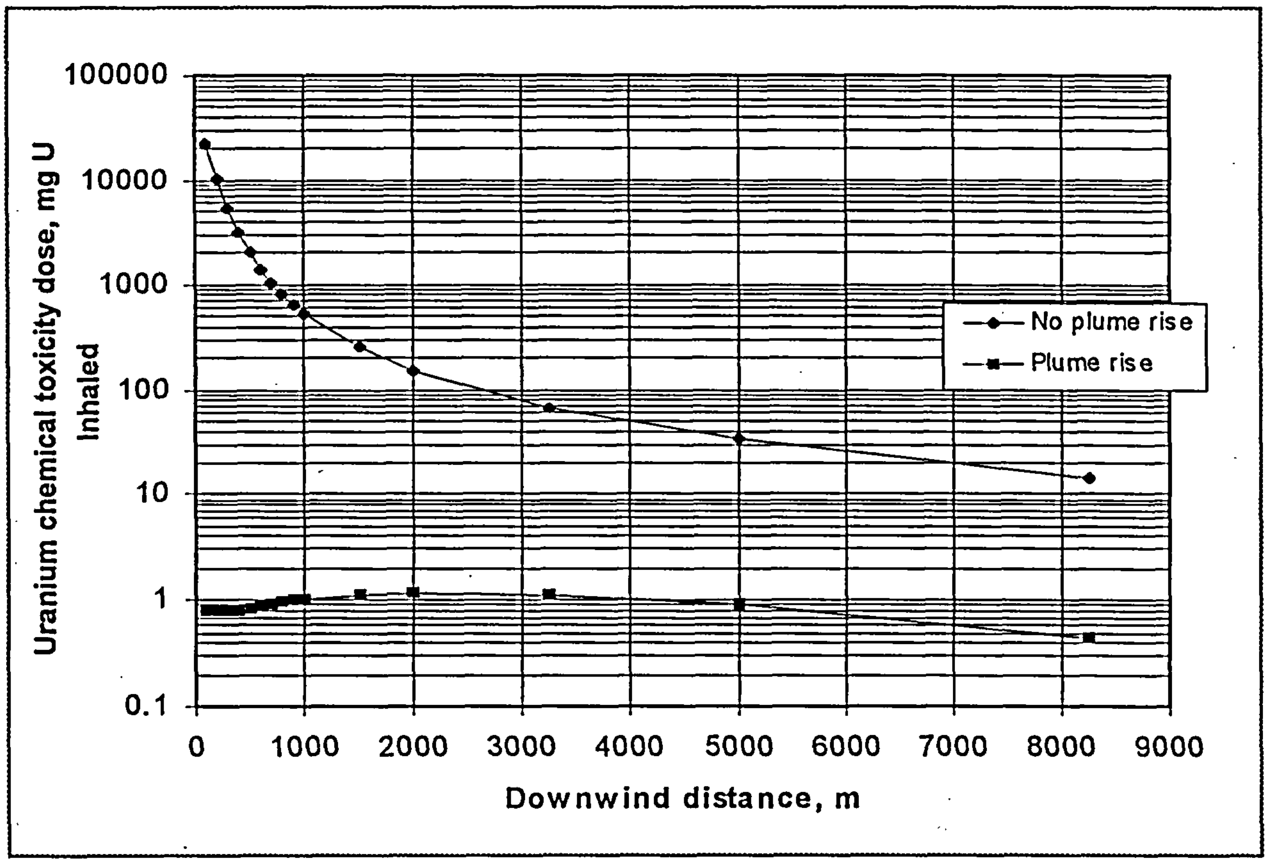
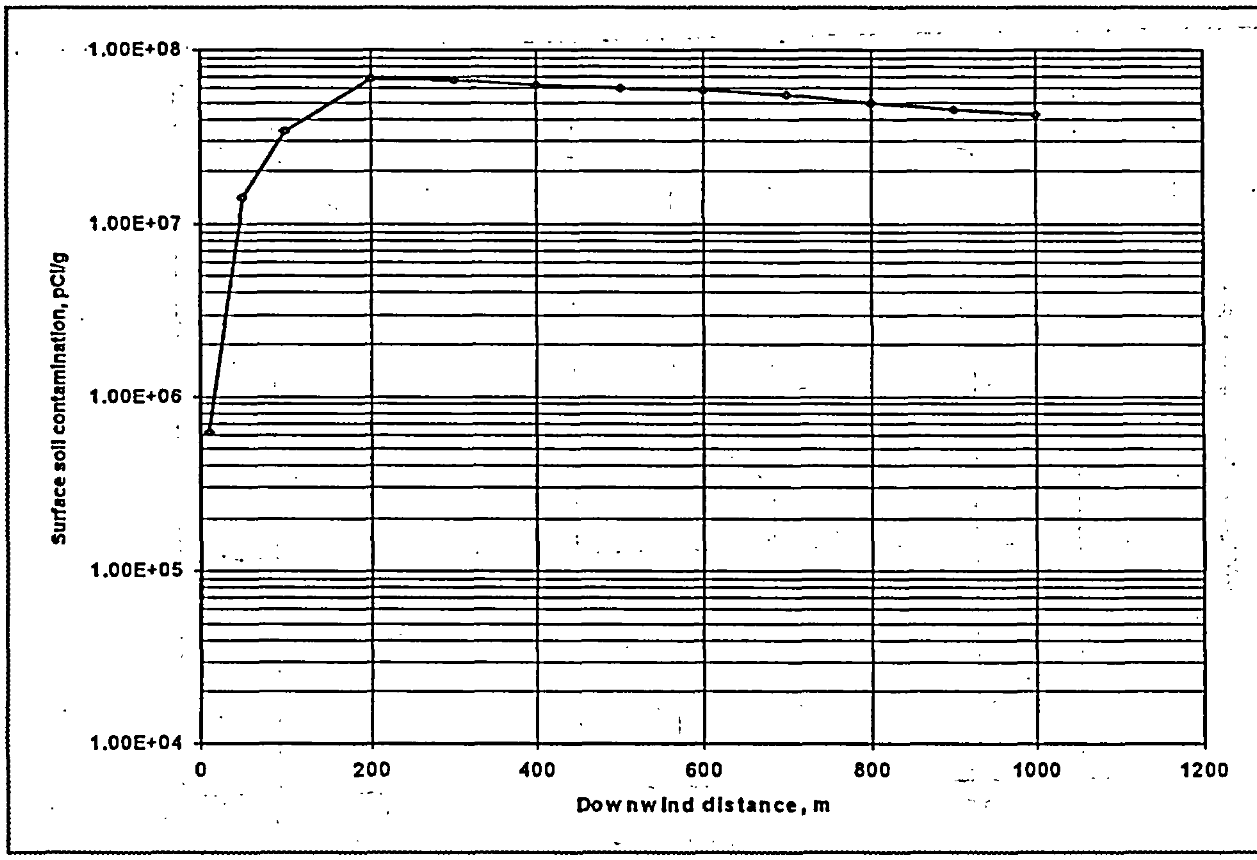


Figure 4.3-29. Comparison of uranium chemical toxicity vs. downwind distance for no plume lift-off vs plume lift-off after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).



surface soil contamination = Ac_s

Figure 4.3-30 **Estimated downwind uranium contamination in the soil after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).**

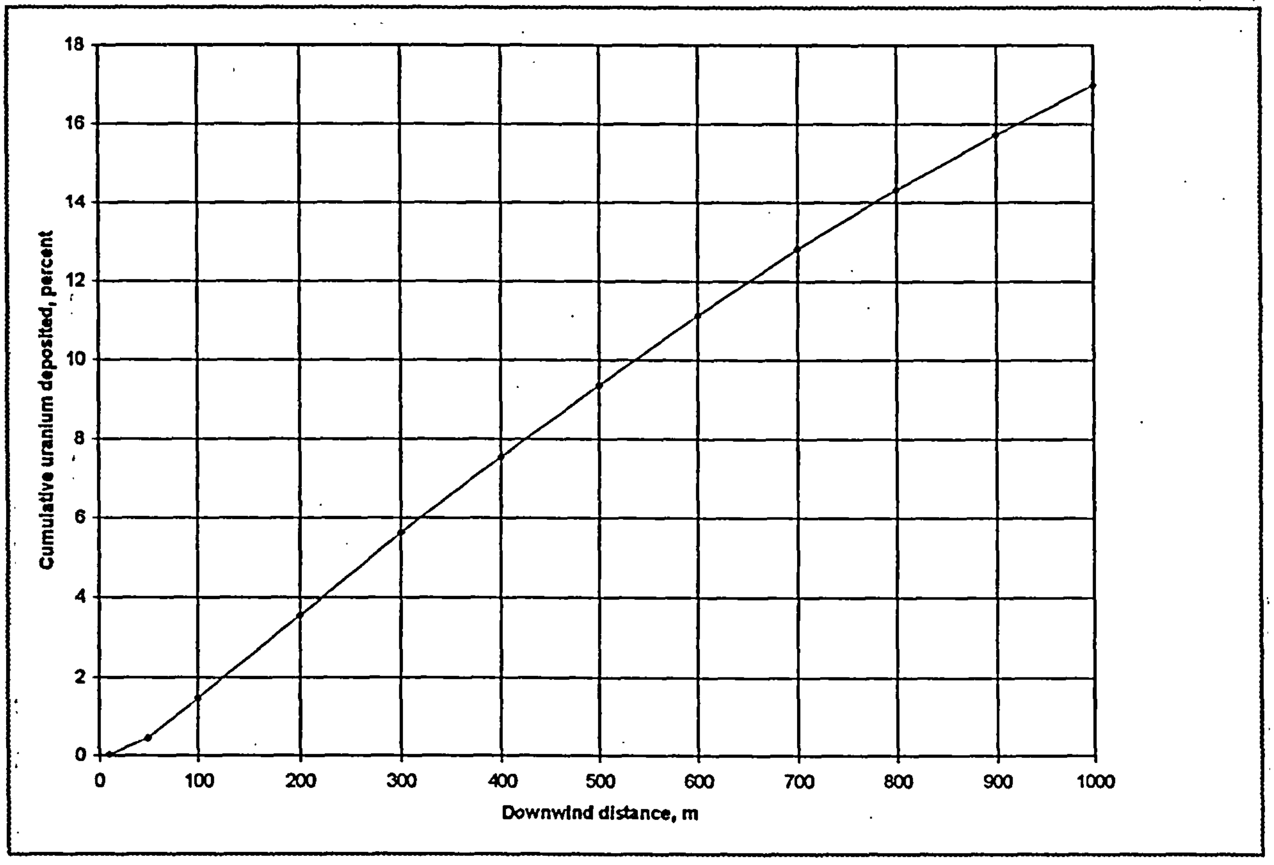


Figure 4.3-31. Estimated cumulative fraction of uranium removed from the plume after a UF_6 release from a liquid-filled cylinder (i.e., dropped cylinder).

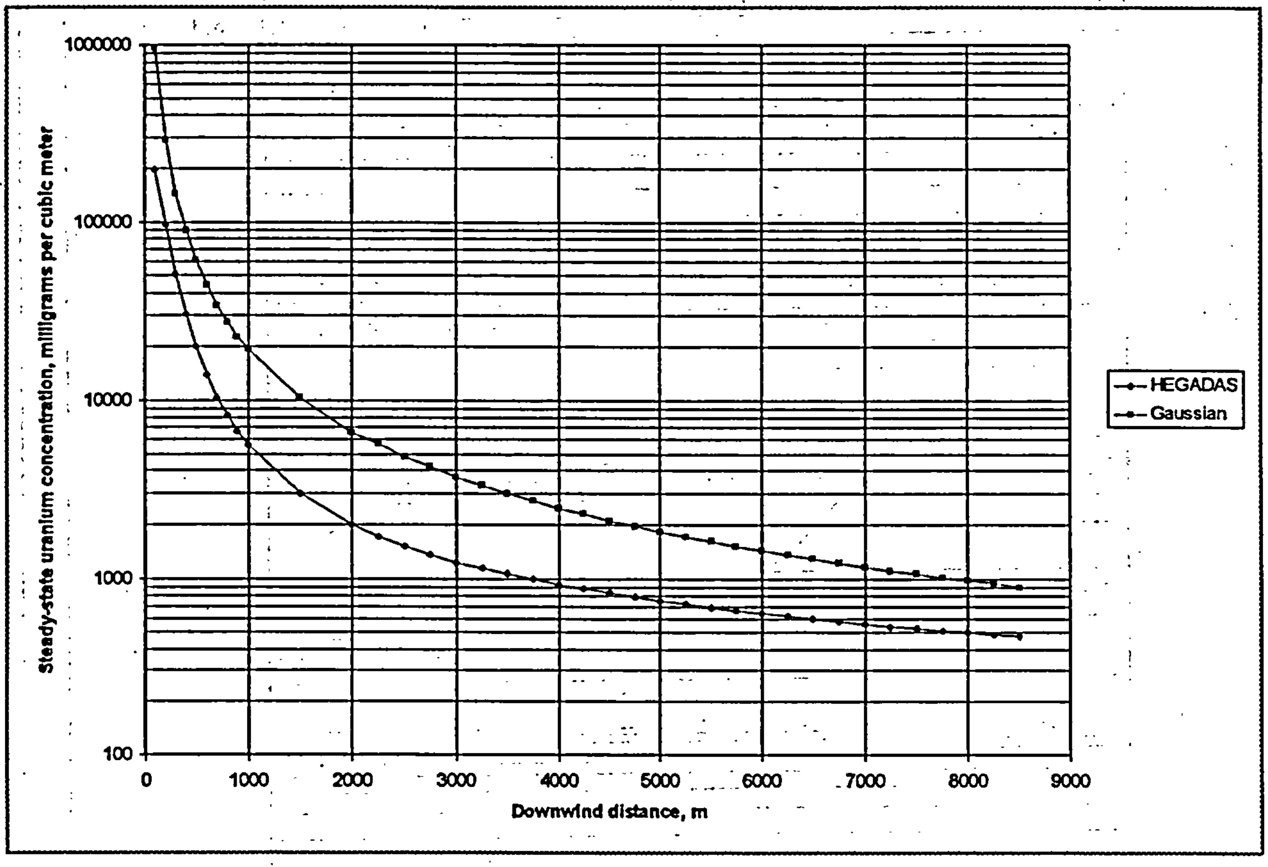


Figure 4.3-32. Comparison of results (steady-state uranium concentrations vs. downwind distance) between HEGADAS/UF$_6$ and the Gaussian plume equation after a UF$_6$ release from a liquid-filled cylinder (i.e., dropped cylinder).

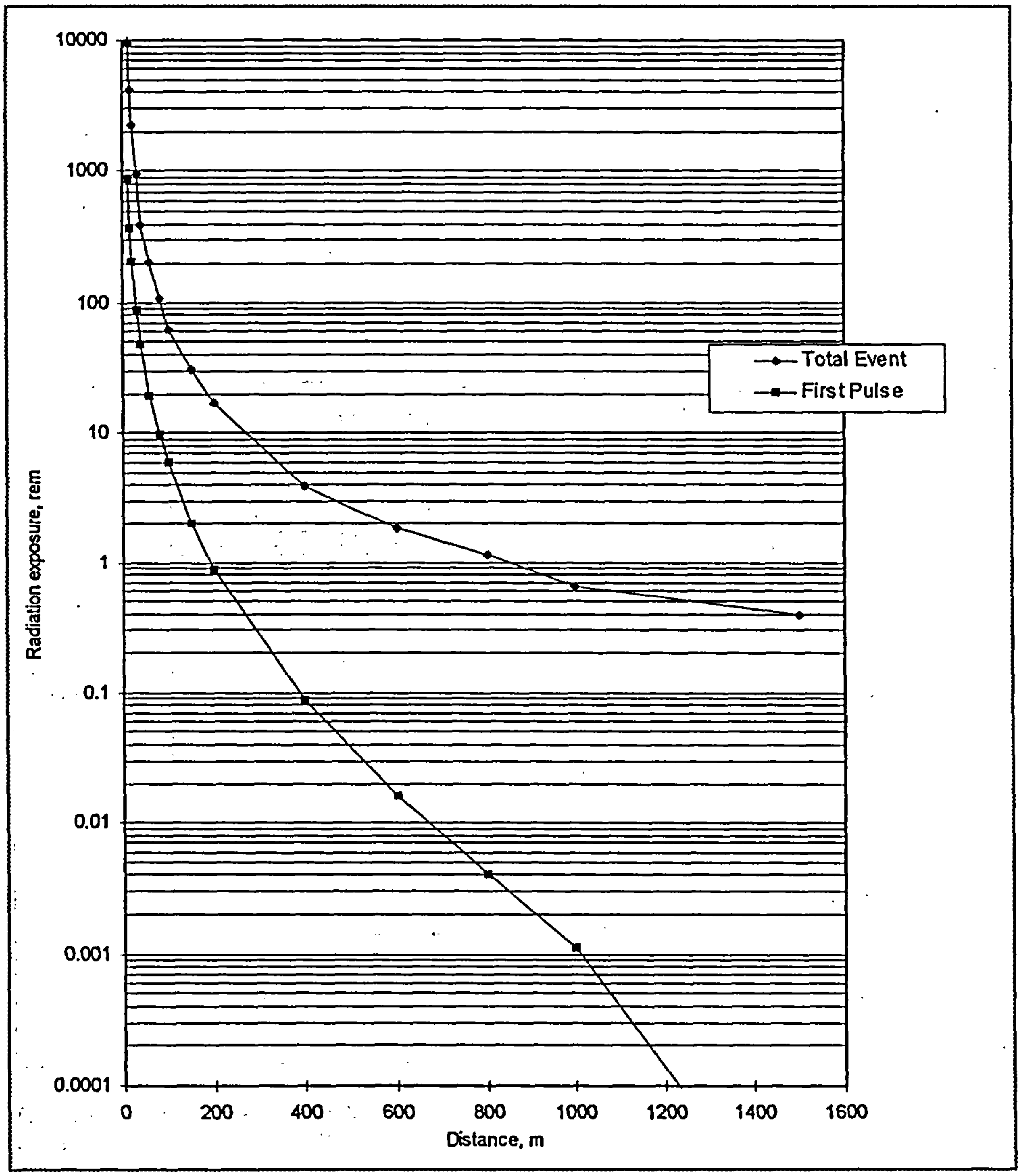


Figure 4.3-33. **Total event (10^{19} fissions over 8 h) and first pulse (10^{18} fissions in 0.5 s) radiation exposures for Reg. Guide 3.34 accidental criticality event (no-shielding - air attenuation only).**