Dry
Transfer
System

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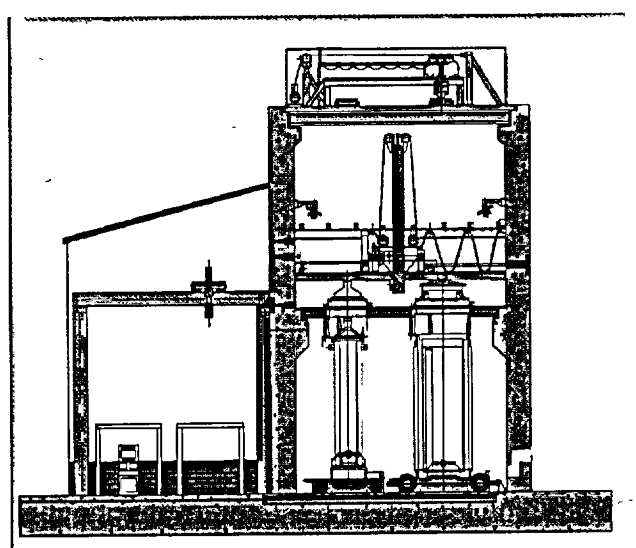
Topical Safety Analysis Report

Volume III



U.S. Department of Energy
Office of Civilian Radioactive Waste Management

CHAPTER 8

ACCIDENT ANALYSES

In previous chapters of this SAR, the features of the DTS system which are important to safety have been identified and discussed. The purpose of this chapter is to present the engineering analyses for normal and off-normal operation conditions, and to establish and qualify the system for a range of credible and hypothetical accidents.

In accordance with NRC Regulatory Guide 3.48 (Reference 8.1), the design events identified by ANSI/ANS 57.9 (Reference 8.2), form the basis for the analyses performed for the DTS system. Four categories of design events are defined. The calculations of design event Types I and II which cover the normal and off-normal conditions are addressed in Section 8.1. The calculations of design event Types III and IV covers a range of postulated accident conditions are addressed in Section 8.2. These events provide a means of establishing that the DTS design satisfies the applicable operational and safety acceptance criteria as specified in Chapter 3.

Since this is a Topical Report, the majority of analyses presented throughout this chapter are based on bounding conservative assumptions and methodologies, with the objective of establishing upper bound values for the design basis events. The operating equipment has been analyzed for the worst case loadings, which result from the seismic analysis and dead and live loads on the equipment. Effects on the operating equipment from other design basis events are discussed, but not analyzed. These evaluations will be provided in the site specific applications.

8.1 Off-Normal Events

This section evaluates Category I and II events as defined in ANSI/ANS 57.9-1992. Category I events are those events that are expected to occur regularly or frequently in the course of normal operations. Category I events shall not result in radioactive releases to the personnel, the public or the environment which exceed regulatory allowable limits. The evaluation of normal operating conditions is presented in Section 8.1.1.

Category II events are those which are expected to occur with moderate frequency on the order of once per calendar year. Category II events shall not result in radioactive releases to the personnel, the public or the environment which exceed regulatory allowable limits. In case of a category II event, the cause shall be determined and resolved. Operations can be immediately resumed after repairs are made. The following category II events are evaluated.

- Failure of any single active component to perform its intended function upon demand.
- Loss of external power supply for up to 24 hours.
- A single operator error followed by proper corrective action.
- Spurious operation of active components.
- Heavy snow storm.
- Failure of monitoring and control system.

- Failure of HVAC Subsystem.

- Lightning.

The DTS is designed such that a single failure of a component will not result in unacceptable high radiation levels outside the DTS, in any damage to a fuel assembly, in any damage to the lid or the shield plug or in the prevention of recovery of the fuel within the DTS.

Section 8.1.2 addresses each off normal design event independently. For each design event, the postulated cause of the event, detection of the event, analysis of effects and consequences and corrective actions are addressed.

8.1.1 Evaluation of Normal Conditions

8.1.1.1 Thermal Evaluation

The DTS is designed to reject the heat from the spent fuel being transferred and the equipment being operated while maintaining temperatures within specified limits.

Regardless of the condition outside the DTS, the HVAC Subsystem is designed to ensure relatively constant indoor conditions. In extreme cold conditions or extreme hot ambient conditions, the HVAC Subsystem also ensures that the temperature gradient across the concrete walls of the DTS does not exceed 70°F. This requirement ensures that the thermal stresses in the walls of the DTS do not exceed concrete design standards. If the temperature differential approaches 70°F, the inside temperature set point is adjusted.

The design basis for the heat dissipation during normal conditions is the following:

- A nominal full load of spent fuel assemblies in the receiving cask with a maximum heat load of 15.5 kW;

- Intact fuel; and

- Turnaround time of 10 days for the receiving cask and 1 day for the source cask.

The 15.5 kW decay heat load corresponds to twenty-one 10-year cooled fuel assemblies in the DTS. Originally, 5-year cooled fuel was to be accommodated by the DTS.

This cooling period corresponds to the requirement that the MPC system store 5-year cooled fuel. Initial HVAC design evaluations resulted in larger HVAC equipment which required a bigger DTS footprint to house the equipment. Recognizing that the receiving cask design basis is an MPC in a transportation overpack that will be designed for 10-year cooled fuel, it was reasonable to adopt a heat load equivalent to 10-year cooled fuel for the DTS.

This approach considerably reduced fuel temperatures during the transfer process and thus minimized the rate of fuel cladding degradation when fuel is in an air environment. This

approach allows mixing of less than 10-year cooled fuel with longer cooled fuel while maintaining a total heat load of 15.5 kW.

The DTS is provided with a dedicated HVAC system which is described in Section 3.5.1 and designed to maintain air temperatures in the DTS at or below 70°F (21°C) and remove the following heat loads:

TCA:

15.5 kW of decay heat load
1.5 kW of equipment heat load (continuous)

Roof Enclosure Area:

3.0 kW of equipment heat load for short durations

Lower Access Area:

15.5 kW of decay heat load
0.5 kW of equipment heat load (continuous)

Preparation Area:

15.5 kW of decay heat load
20 kW of equipment heat load (continuous)

Note that the total decay heat load is 15.5 kW which could potentially be dissipated in the TCA, the Lower Access Area or the Preparation Area. The high equipment heat load in the Preparation Area is mainly from the heat dissipated by the welding operation and welding equipment.

The above heat loads are in addition to the continuous heat loads generated by the HVAC equipment and heat addition from environmental conditions (ambient temperature, solar heat). The thermal inertia of the DTS structure (concrete and steel) and the equipment (including the casks) is very large (more than 325 tons of steel and 2,000 tons of concrete). Heat loads from equipment used for short durations in the DTS will have an insignificant impact on the average 70°F (21°C) air temperature in the DTS.

Heat Removal During Fuel Transfer Operations

During fuel transfer operations, the source and receiving casks will be mated to the TCA through the Cask Mating Subsystem. All equipment to be operated is in the TCA or under the protective cover above the TCA. The sources for heat generation are described below.

The sources for heat generation in the TCA, the Lower Access Area and the Roof Enclosure Area during fuel transfer and lid/shield plug handling are illustrated in Figures 8.1-1 through 8.1-

3.

In the TCA:

- Spent fuel from the source and receiving casks dissipating heat upwards into the TCA. This is a fraction of the total decay heat load of 15.5 kW and estimated to be about 35%.

- Continuous heat load generated by the cameras and its associated lighting equipment (1.5 kW).

- Fuel transfer and lid/shield plug handling equipment which is used for short durations and does not exceed 3 kW.

The TCA HVAC equipment has the capacity to dissipate the heat load from decay heat, from mechanical equipment (including the HVAC Subsystem) and from environmental conditions. The air temperatures will easily be maintained at 70°F (21°C).

In the Roof Enclosure Area:

- Lid/shield plug handling equipment which is used for short durations and does not exceed 3 kW.

In the Lower Access Area:

- Spent fuel from the source and receiving casks dissipating heat radially into the Lower Access Area. This is a fraction of the total decay heat load of 15.5 kW and estimated to be about 65%.

- Continuous heat load generated by the cameras and its associated lighting equipment (0.5 kW).

The Lower Access Area HVAC equipment has the capacity to dissipate at least 16 kW. Air temperatures in this area will easily be maintained at 70°F (21°C).

In the Preparation Area:

Sources for heat generation dissipate negligible heat (no activity in this area during fuel transfer).

Fuel Temperature During Fuel Transfer

The thermal design of the source and receiving casks strongly influences the temperatures of the fuel in these casks. The following evaluation shows that the design basis source cask (four PWR assemblies) and receiving cask (21 assembly MPC with transportation overpack) will maintain fuel temperatures below the design limits.

Source Cask:

Typically, the source cask will be used to transfer fuel from the fuel pool to the DTS and would be designed to meet the requirements of 10CFR Part 72. With a design basis turnaround time of one day, the cask would be designed to transfer fuel in air while maintaining fuel cladding temperatures at or below the 240°C limit established for a two week period. This temperature limit would not be exceeded under the most severe ambient condition which typically is 115°F (46°C) ambient with insolation. When the cask is placed inside the DTS, the surrounding temperature is reduced to 70°F (21°C) and the solar heat is eliminated. Hence the fuel cladding temperature will remain below 240°C. When the cask lid is removed in the TCA, heat is also dissipated upwards through the lid opening further reducing fuel cladding temperatures. The removal of assemblies from the cask will rapidly decrease the heat load resulting in a further reduction in fuel cladding temperatures.

Receiving Cask:

To assess the potential fuel cladding temperatures of a receiving cask with its lid on or off in the DTS, a thermal study was performed using the TN-24P storage cask. This cask design is a forged thick shell with a welded bottom. The cask has a 24 assembly basket designed to accommodate W17x17 or W15x15 5-year cooled fuel. The maximum heat load permissible in the cask is 24 kW. The backfill medium is helium. The TN-24P TSAR thermal analysis predicts a maximum fuel clad temperature of 350°C under an ambient temperature of 47°C and a solar heat load of 7 kW for 10 hours a day (Reference 8-3).

Under a cooperative program sponsored by DOE, Virginia Power and EPRI, Idaho National Engineering Laboratory (INEL) performed thermal testing of this cask in the horizontal and vertical positions with three different internal storage environments (nitrogen, helium, and vacuum). The result of the tests have been discussed in detail in EPRI Report NP-5128 (Reference 8-4). The maximum fuel cladding temperatures (vertical orientation with helium and nitrogen back fill) measured were:

- With helium backfill 214°C
- With nitrogen backfill 232°C

The tests were conducted under the following conditions:

- Ambient temperature 20°C
- Decay heat load 20.6 kW

The EPRI report also presents the results of a three dimensional analysis using the COBRA-SFS computer code developed by Pacific Northwest Laboratory (PNL). For the same conditions, the following fuel clad temperatures were predicted:

- With helium backfill 220°C
- With nitrogen backfill 247°C

Recognizing that the thermal properties of nitrogen and air are nearly identical, the steady state fuel clad temperatures for this cask with the lid in place in the DTS would be less than 250°C with a heat load of 20.6 kW. With a 15.5 kW load, the maximum fuel cladding temperature would be less than 200°C.

In an effort to assess the thermal consequences resulting from storing a receiving cask in the DTS with the lid/shield plug removed, Transnuclear requested PNL to perform a scoping calculation using the existing computer model of TN-24P. A simple modification was made where the gas flowing down the downcomers at the lid region is set at 20°C. The results showed that there was a significant drop in fuel cladding temperature when an additional heat removal path is created when the lid is opened. It was estimated that about 35% of the decay heat would be rejected upwards. The maximum fuel cladding temperature would drop even further to an estimated 160°C. This estimated fuel cladding temperature limit would be below the 2 year handling limit of 175°C.

The DTS design basis calls for the receiving cask to be an MPC in a transportable overpack. Since a licensed design of this configuration is not available at the time of this study, an assessment of MPC thermal design was made using the concept presented in the MPC Conceptual Design Report (Reference 8-5). The MPC transport overpack is to be designed to maintain fuel cladding temperatures below 340°C and meet all the requirements of 10 CFR 71. The cask designer could use nitrogen or helium as the inert backfill gas depending on the design for the fuel basket (promoting gaseous conduction or convection).

The PNL report PNL-8451, "Spent Nuclear Fuel Storage - Performance Tests and Demonstrations" (Reference 8-6), concludes that in the vertical orientation, the fuel cladding temperatures would be within 10% if nitrogen or helium is used as the backfill gas. Since the thermal properties for air and nitrogen are similar, it would be logical to conclude that the steady state fuel cladding temperatures for the receiving cask with the lid/shield plug on will be approximately at or below the temperature limit of 340°C if stored indefinitely in the DTS. The two dimensional thermal analysis presented in the MPC Conceptual Design Report was reviewed and qualitatively evaluated as follows to represent the actual conditions that the MPC would be in the DTS:

- Heat load changed from 14.2 kW to 15.5 kW
- Ambient temperature changed from 38°C to 21°C
- 10 CFR 71 solar heat removed

- Helium environment replaced with air in cask/canister
  - Orientation changed from horizontal to vertical
  - Increased convection due to vertical orientation
  - Increased surface area for heat dissipation from cask ends with no insulating impact limiters and cask on transfer trolley
  - Increased heat dissipation from shield plug which is directly exposed to the DTS environment (no MPC lids or overpack lids)
  - Convection from annulus between the MPC and the transportation overpack

The following qualitative estimates for fuel cladding temperatures in the MPC with the shield plug on and off are made based on the TN-24P performance studies above:

With shield plug on	
conservative estimate	270°C
optimistic estimate	230°C
With shield plug off	
conservative estimate	190°C
optimistic estimate	160°C

The loading of the 21 assembly receiving cask requires 6 loading cycles with a 4 assembly source cask. During each cycle the shield plug will be removed when fuel is transferred from the source cask to the receiving cask. Note that the empty fuel compartments serve as downcomers for natural convection, enhance the convection promoting lower temperatures. At the end of the fifth loading cycle, 95% of the total heat load could potentially be in the MPC. If at this point the receiving cask is allowed to reach thermal steady state, the maximum fuel cladding temperature will most probably be below the 240°C limit. Since adiabatic heatup of a 250,000 lb cask is about 1°C/hr, it would be more than 80 hours before this can occur. With a 1 day design basis turnaround for the source cask, the receiving cask would be reopened in the next 48 hours to load the last assembly and maintain fuel cladding temperatures below 240°C. The MPC will be inerted within 2 to 3 days following the transfer of the last assembly.

Based on the above assessment, it is concluded that fuel cladding temperatures for the design basis receiving cask are expected to remain below 240°C while in an air environment of the DTS. Confirmatory analysis or tests, if necessary, will be performed on the actual receiving cask design to demonstrate the performance of the receiving cask. The turnaround time for the receiving cask plays an important role in determining the allowable temperature for the fuel. If a cask with the TN-24P equivalent thermal performance is used as a receiving cask, the turnaround time can be relaxed considerably.

Site-specific analyses will be provided by the applicant, to confirm the thermal performance of the fuel for the selected casks and the turnaround times.

8.1.1.2 Building Structural Analysis

The structural calculations for normal operating conditions are briefly summarized here. They are included in more detail in Appendix 8A.1. Table 8.1-1 shows the normal operating loads for which the DTS structural components are designed. The table lists the individual components which are affected by each loading. The magnitude and characteristics of each load are described in this section.

Table 8.1-1

DTS Normal Operating Loads

Load Type	Affected Component				
	Reinforced Concrete Structure	Protective Cover	Roof Plate	Mezzanine Plate	Sliding Door
Dead Loads	X	X	X	X	X
Operational Handling Loads	X		X	X	
Live Loads	X	X	X	X	
Normal Thermal Loads	X	X	X	X	X
Internal Pressure	X	X	X	X	X
Design Basis Wind Pressure	X	X			

Dead Loads

Table 8.1-2 shows the weights of various components of the DTS. The dead weight of each component is determined based on nominal component dimensions.

Operational Handling Loads

The operational handling loads are included in the weight of the equipment presented in Table 8.1-2.

Live Loads

As discussed in Section 3.0, a live load of 250 lbs/ft^2 (11,970 Pa) is conservatively selected to envelope all postulated live loads acting on the DTS, including the effects of snow and ice.

Normal Thermal Loads

The DTS is subject to thermal expansion loads associated with normal operating conditions. The range of normal operating temperature used for the design of the DTS is 60°F to 100°F (16°C to 38°C) in the Preparation Area and 40°F to 130°F (4°C to 54°C) in other areas. In the event of extremely low external temperatures, the HVAC System will be set to establish a temperature of 50° F to ensure that the temperature gradient through the structural walls is less than 70° F.

Internal Pressure

The internal pressures (created by the HVAC system) during operation are as follows:

- TCA: 1 in (25.4 mm) H_20 less than ambient.
- Lower Access Area: 0.5 in (12.7 mm) H_20 less than ambient.
- Preparation Area: 0.25 in (6.4 mm) H_20 less than ambient.

Design Basis Wind Pressure

Design wind pressures for the structure have been determined for various elevations above grade, and are summarized in Table 3.2-3.

A. Reinforced Concrete (Structure) Structural Analysis

The structure is designed to withstand a number of different loads and combinations of loads. The relevant normal operating loads are as follows (refer to Table 8.1-1):

- Dead loads
- Operational handling loads
- Live loads
- Normal thermal loads
- Internal pressure
- Design basis wind pressure

The DTS reinforced concrete wall thickness is primarily dictated by shielding requirements. For calculation of stresses, the design is dominated by the design basis tornado (DBT) and safe shutdown earthquake (SSE) loads. The stresses in the concrete wall due to normal operating conditions are negligible, with the exception of the thermal stresses. For example, the design basis wind pressure of 59 lb/ft^2 (2,825 Pa) is much less than the design basis tornado wind, which is 447 lb/ft^2 (21,400 Pa). In general, loads which are clearly not limiting are not evaluated; brief checks are included on less obviously unimportant loads.

The thermal analysis of the concrete building is also evaluated. Thermal loads within the structure due to the presence of the fuel assemblies and operating equipment induce two effects in the concrete walls.

- Bending due to temperature gradients across the walls
- Expansion due to rise in bulk temperature above base (setting) temperature

The results of the thermal analysis show that the maximum allowable temperature gradient across the wall is 70°F (39°C). The wall expansion due to bulk rise in temperature is small and the stress is found to be negligible.

The HVAC subsystem ensures that the temperature gradient is not exceeded during all design events.

B. Protective Cover Structural Analysis

For normal operating conditions, a design load of 250 lbs/ft^2 (11,970 Pa) is conservatively used to calculate the stress as in the protective cover roof plate.

Table 8.1-2

DTS Component Weights

Component Description		Calculated Weight
Reinforced Concrete Structure		2,249,836 lbs (1,020,508 kg)
R. C. Basemat		2,673,250 lbs (1,212,566 kg)
Protective Cover & Beams		123,024lbs (55,803 kg)
Roof Plate Level	Roof Plate	163,421 lbs (74,127 kg)
	Support Beam	59,492 lbs (26,985 kg)
	Equipment (including handling loads)	27,260 lbs (12,365 kg)
Fuel Handling Crane		22,000 lbs (10,000 kg)
Mezzanine Plate Level	Mezzanine Plate	24,600 lbs (11,158 kg)
	Support Beam	12,180 lbs (5,525 kg)
	Equipment (including handling loads)	49,500 lbs (22,400 kg)
Sliding Door		85,000 lbs (38,560 kg)

The protective cover is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

C. Roof Plate Structural Analysis

Normal operating loads on the roof plate and supporting beams are analyzed using classical engineering methods. Detailed calculations are provide in section 8A.1.5.4 of Appendix 8A.1. Results of the analysis are given in Tables 8.2-4a and 8.2-4b.

Both the roof plate and beams are bolted to the reinforced concrete. Oversized holes are provided at the plate and beam connection points to allow free thermal expansion.

D. Mezzanine Plate Structural Analysis

Normal operating condition loads on the mezzanine plate consist of the plate weight, the support beam dead weight, the Receiving and Source Cask Mating Subsystem dead weight, the Receiving and Source TC port cover weights, the receiving cask shield plug weight and the source cask lid weight. Normal operating loads on the roof plate and supporting beams are analyzed using classical engineering methods. Detailed calculations are provide in section 8A.1.5.5 of Appendix 8A.1. Results of the analysis are given in Tables 8.2-4a and 8.2-4b.

For thermal expansion, the required minimum clearance between the end of the plate and the inside surface of the concrete wall is approximately 0.125"(3 mm). Adequate clearance is provided between the plate and the concrete wall to permit free thermal expansion under the maximum differential temperatures expected during normal operation. The mezzanine plates are bolted to the support beams and the beams are bolted to the reinforced concrete. Oversized holes have been provided in the support beams and will permit free thermal expansion of the support beams and thus minimize thermal stress.

E. Sliding Door Structural Analysis

The design of the sliding door is based on shielding requirements. For the dead load analysis, the most limiting conditions are considered. By considering the sliding door to be supported at the rails, the weight of the sliding door is conservatively increased by a factor of 1.5. The maximum tensile stress at the door cross section is 106 psi (731,000 Pa) which is negligible. Other loads are much smaller; for example, the internal pressure is 2.59 lb/ft^2 (124 Pa), and is much less than the suction on the door due to the tornado wind, which is 419 lb/ft^2 (20,100 Pa). In general, loads which are clearly non-limiting are not considered explicitly; brief checks are included on less obviously unimportant loads. The stress calculations due to the DBT and SSE loads are described in Section 8.2.

The sliding door is a free standing structure which permits free thermal expansion. Therefore, there are no significant thermal stresses.

8.1.1.3 Operating Equipment Structural Analysis

The operating equipment is designed to withstand all normal operating loads. In general, the equipment is sheltered from environmental loads by the DTS structure. One exception is the cask transfer subsystem, which during loading is located outside of the Preparation Area. All the equipment has been selected to function properly for the full range of operating temperatures and pressures. The Cask Transfer Subsystem is evaluated in Appendix 8A.2. The Cask Mating Subsystem is evaluated in Appendix 8A.3. The Source Cask Lid and Receiving Cask Shield Plug Handling Subsystem is evaluated in Appendix 8A.4. Appendix 8A.4 also includes the evaluation of the TC port covers and the upper shield port covers. The Fuel Handling Subsystem is evaluated in Appendix 8A.5.

Transportation package receipt, inspection, unloading, maintenance and loading are considered normal operations. The lifting equipment is sized in accordance with applicable industry standards to ensure that adequate safety factors are incorporated into the design. The lifting equipment within the DTS is designed in accordance with NOG-1, Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder) with Single Failure-Proof Features (Type I Cranes).

Maintenance on equipment is performed on contact after removal of fuel and casks from the DTS and equipment decontamination. Remote systems are designed with backup measures to ensure that the DTS can be brought to a condition which would allow access for maintenance in the event of equipment failure. The system is designed to minimize the spread of contamination.

Equipment backup or remote access exists for all equipment involved in transferring fuel. The fuel handling crane is designed with single failure proof features.

Removal and installation of lids and shield plugs are normal operations. The source cask lid and receiving cask shield plug are installed and removed remotely by a single failure proof crane.

Removal and installation of the MPC lids and overpack lid are performed in the Preparation Area. This lifting equipment is not designated as Important to Safety, since in the event of a crane failure, the lids would fall onto or into the cask. The design of the casks prevents the lids from impacting the fuel assemblies. The cask cannot tipover due to a drop of a lid, and the fuel is shielded at all times. If a lid is dropped, the cask could be moved back into the Lower Access Area until a new lid could be brought into the DTS. Further, if there was damage to the cask sealing area, the cask could be brought back into the Lower Access Area, and the fuel could be transferred back into the source cask, and returned to its origin until a new receiving cask could be obtained.

8.1.1.4 Confinement

One of the primary design functions of the DTS structure is to provide a physical barrier for the purpose of preventing the release of radioactive particulate matter (to the environment) above the radiological protection limits described in Section 4.2. The achievement of ALARA in this regard is provided by the HVAC Subsystem to further control and confine potential contamination that may be released during transfer operations.

The source of the radioactive particulate under normal and most off-normal conditions is the crud on the external surfaces of the fuel rods and hardware. The primary confinement barrier for the escape of particulate from the fuel is the fuel cladding whether it is integral or contains pinholes or hairline cracks. Degradation of the cladding due to stress rupture and fuel oxidation (a time-at temperature phenomenon) will be minimized by maintaining low fuel cladding temperatures during the short duration of the fuel transfer process. The dedicated active cooling of the HVAC Subsystem will dissipate the decay heat from the fuel. Based on the study performed by Einziger (Effects of an Oxidizing Atmosphere in a Spent Fuel Packaging Facility, 1991), the following fuel cladding temperature limits have been adopted for the DTS:

- 464°F (240°C) for a two week period (before the receiving cask is inerted)
- 441°F (227°C) for a one month period
- 347°F (175°C) for a two year period

The design basis turnaround time for the source cask is 1 day and the receiving cask is 10 days. Considering that the receiving cask will be only partially filled during most of the actual transfer period, will be open during the transfer operations, has a large thermal mass, and is continuously maintained in a 70°F (21°C) ambient condition, it would be unlikely that fuel cladding temperatures would exceed the two week temperature limit of 464°F (240°C) during the 10 day design basis turnaround period. Site-specific confirmatory thermal analyses will be performed by the applicant for the actual receiving cask and spent fuel to be used, and for the anticipated maximum turnaround period.

During fuel transfer, the confinement boundary for crud on the fuel assemblies is the physical enclosure formed by the DTS concrete walls including its sealed penetrations; the sliding door between the Preparation Area and the Lower Access Area; the weather protective cover, and the HEPA filters of the HVAC Subsystem. An additional level of confinement is provided by the HVAC Subsystem maintaining the TCA at negative atmospheric pressure so that air infiltration is into this area, and air flow from this potentially contaminated area is exhausted through a HEPA filtration system to the environment.

8.1.2 Evaluation of Off-Normal Conditions

8.1.2.1 Failure of a Single Active Component

A failure of any single active component to perform its intended function upon demand is considered a Category II event. All systems which are relied upon for prevention or mitigation of events have been provided with redundancy or sufficient design factors such that multiple failures must occur before there is an unanalyzed condition, else the event is not credible.

Tables are provided for each subsystem, as listed below, which show the various functions performed by the operating subsystems, the failure mode, most probable failure cause, the possible effects of the failure, how the failure is detected and compensating provisions incorporated into the DTS to recover from the failure.

1. Cask Transfer System
2. Cask Mating Subsystem
3. TC Port Covers and Related Instrumentation
4. Upper Shield Port Cover, and Related Instrumentation
5. Upper Crane, and Related Instrumentation

6. Fuel Handling Subsystem
7. HVAC Subsystem
8. Control Subsystem
9. TC Port/Shield and Lid/Plug Handling Subsystem
10. Cameras, and Related Lighting.
11. Port Cover Locking

A. Failures of the Cask Transfer Subsystem

The design of the Cask Transfer Subsystem addresses the need to protect the loaded fuel assemblies as well as the cask lids and closure systems. The cask tip-over and trolley collisions that could result in cask or cask lid damage or fuel assembly damage, in either the PA or the LAA, are prevented. In particular, the cask trunnion cradle tie-down system, the trolley to rail restraint system ("anti-taking off plate"), and the special rail installation, are all designed to protect the source and the receiving casks in case of a seismic event or the tornado missile impact. In addition, the control system and associated brakes, locking pins and related interlocks are designed to prevent inadvertent contact of the cask trolleys with one another or with the DTS structure or the LAA sliding door. The trolleys and casks are designed to withstand inadvertent contact between the trolleys or between the trolleys and the DTS structural components.

The rate of movement of the trolleys is intentionally very slow (0.7 ft/min within six feet of the transfer location, as given in Chapter 5). This allows the operator who controls the movements using a local (LAA) control panel to intervene should the operator observe a potential problem during the positioning of the trolleys. Training of the operators and monitoring of the positioning from the Control Room are intended to assure safe positioning and warning of off-normal conditions.

Based on these design and operational features, it is not necessary to consider a cask tip-over or collision that might prevent removal of fuel assemblies from the casks. However, the following failures of the Cask Transfer Subsystem have been postulated, and presented in Table 8.1-9:

- Trolley will not move
- Trolley is incorrectly positioned
- Trolley moves without activation
- Trolley will not lock
- Trolley will not unlock
- Cask not secured on trolley
- Cask will not fit on trolley
- Cask will not come off trolley
- Limit switch fails to stop trolley motion

If the trolley will not move, it may be the result of a motor failure, a failure of the brakes to disengage, a lock which is still engaged or the jamming of the trolley. First, the operator would check the status of the locks. The rails would also be checked to ensure that there are no

obstructions. If all is in order, the brakes would be checked. The service and emergency brake can both be manually disengaged. If the trolley still does not move, it is recommended that the trolley be moved into the Preparation Area for maintenance. The trolley can be pulled out of the Lower Access Area by attaching a prime mover. The cask should be closed and sealed prior to maintenance. Maintenance on the trolleys are performed on contact. The motor, brakes, guiding rollers and anti-taking off devices can be removed and replaced or repaired if necessary.

If the trolley is incorrectly positioned in the Lower Access Area or in the Preparation Area, it is probably due to a failed sensor, incorrectly positioned sensor, or a failure of the Control Subsystem. The incorrect positioning would be detected by the inability to lock the trolleys in place. The positioning of the trolley can be performed by manual jogging of the trolley until maintenance can be performed. The limit switches can be repositioned or replaced as necessary. Repairs would be performed on contact.

If the trolley were to move without operator activation, it would most probably be due to an operating mistake, a malfunction of the Control Subsystem, or an earthquake. This event could result in damage to the trolleys or damage to the casks. The worst likely result of an untimely activation is a collision of the two trolleys or a collision with the wall of the Lower Access Area or the sliding door. Failure would be detected visually. During engagement and Preparation Area operations, the trolley is always locked in place. Therefore, the operating mistake or the malfunction of the Control Subsystem should not result in movement of the trolley. The locking pin is also designed to withstand the seismic load. Brakes are also engaged when the trolley is not being moved.

If the trolley is in the loading/unloading area outside the DTS, the casks are either closed or empty. The casks are designed to withstand potential collisions in the area.

Bumper guards minimize damage to the trolley in the event of a collision. Limit switches mounted on each trolley in the front and back stop motion in the event of a collision. Limit switches at the end of the runway rails stop motion if the trolley over-travels.

If the trolleys will not lock, the trolley is either out of position or there is a problem with the jack. Positioning can be verified visually on contact. The locking jacks can be repaired on contact..

Cask fitup and securing are manual operations. The guides are adjustable and can be repositioned as necessary. As these operations are performed prior to opening the cask, there is no radiological consequence due to this event other than the increased worker radiation doses due to the extended period near the cask.

If the trolleys will not unlock, the locking jacks can be repaired on contact.

If a limit switch fails to stop the movement of the trolley, it is the operator's responsibility

to stop moving the trolley. Over-travel limit switches and bumpers minimize damage to the trolley or cask. All operations are controlled locally.

There are no radiological effects of events regarding the operation of the Cask Transfer Subsystem. There would be additional radiation exposure to workers performing the repair, but the fuel is shielded by the casks. Operator actions to determine the specific failure and subsequent correction, as well as maintenance, repair, replacement of parts, adjustments, etc. would require that the operators perform these actions by being nearer the trolley holding the loaded source (receiving cask) than would be required under normal circumstances. The result is that the operator(s) would be working in a radiation level higher than the one they would be required to enter under normal circumstances. In some cases, such as in the case of a failed sensor or proximity switch or other component that is not attached to the trolley, the trolley may be moved to reduce the radiation field that the operator(s) must enter. However, if the failed component is part of the trolley, it has to be determined whether to perform the corrective actions with the loaded cask in place or to remove the cask from the trolley (if that is feasible under the circumstances).

All such activities as described above, will be planned and carried out with consideration of ALARA. Radiation exposure will be monitored at all times in accordance with written procedures which will be developed with full participation of the DTS staff representing Operations, Maintenance, Radiation Protection, and Shift Supervision.

B. Failures of the Cask Mating Subsystem

The following failures of the Cask Mating Subsystem have been postulated, and presented in Table 8.1-10:

- The annular platform will not lower
- The annular platform only partially lowers
- The annular platform lowers without activation
- The annular platform is positioned incorrectly
- The seals are damaged
- The annular platform cannot be lifted
- The annular platform only partially lifts
- The annular platform lifts without activation
- The bellows tear or are punctured.
- The electric jack vertical positioning is erroneously reported to the PLC.
- The load sensor on an electrical jack reads higher than actual.
- The load sensor on an electrical jack reads lower than actual.

The annular platform will not lower if the load sensors or the electrical jacks are not working properly. This can be detected using the CCTV Subsystem or the jack vertical positioning sensor. Maintenance would be performed on contact after surveying the Lower Access Area and ensuring that both casks are closed.

The annular platform will only partially lower if there is an electrical jack failure, a failure of the load sensors, or a problem with the Control Subsystem. This problem would be detected by at least one of the following: the CCTV camera, a timing device in the PLC which would indicate that the operation is taking too long to perform, or the load sensors. Maintenance would be performed on contact after surveying the Lower Access Area and ensuring that both casks are closed.

If the annular platform lowered without activation, maintenance on the sensors or the Control Subsystem would be required. Damage to the Mating Subsystem could occur if a cask was moved into the Lower Access Area when the platform was in the wrong position. This error would be detected visually.

If the annular platform is positioned incorrectly, or if it lifts without activation, the error may be detected using the CCTV cameras, the load sensors on the electrical jacks, or by the vertical position indicators of the electrical jacks. Potential effects of this error are that particulate could enter the Lower Access Area during fuel transfer. This potential is unlikely since the HVAC Subsystem maintains a pressure differential which ensures that air flows into the TCA from the Lower Access Area. If contamination is spread to the Lower Access Area, the LAA would be decontaminated by conventional means.

The seals are inspected prior to each fuel transfer campaign, and are unlikely to be damaged. However, if the seals are damaged, particulate is confined by the HVAC Subsystem.

If the annular platform cannot be lifted or only partially lifts, it is probably the result of failure of the jacks. This failure will prevent movement of the cask. This error could be detected visually, by the jack load sensors or the jack position sensors. The casks would be closed and repair would be performed on contact.

If the bellows tear or are punctured, this condition would be detected visually. The HVAC Subsystem would provide particulate confinement.

If the position of the electrical jack is erroneously reported in the Control Center, it is easily checked by the operator using the CCTV camera.

If the electric jack load sensor reads higher than actual, the jacks will stop before reaching the proper mating position, rendering mating impossible. This error would be detected by the PLC timing device, which would generate a low level alarm if mating is not successful in a specified period of time.

If the electrical jack load sensor reads lower than actual, the jacks could become overloaded. Mating would not occur since the jack would never reach its mating pressure. This would also be detected by the timing device.

If there is an indication that the Cask Mating Subsystem has been damaged or is malfunctioning, the casks would be closed after completing the fuel transfer. If possible, the casks would be moved into the Preparation Area prior to maintenance and repair operations on the Cask Mating Subsystem.

There are no radiological effects of events regarding the Cask Mating Subsystem, since the HVAC Subsystem can maintain sufficient negative pressure within the Transfer Confinement Area to avoid particulate release to the Lower Access Area even assuming excess leakage of the Cask Mating Subsystem. There would be no particulate release to the environment, since the sliding door and concrete structure provide a barrier to the Preparation Area and the outside. There would be additional radiation exposure to workers performing the repair, but the fuel is shielded by the casks any time that the Cask Mating Subsystem would require repairs.

C. Failures of the TC Port Covers and Related Instrumentation

The potential failures of the TC port covers and related instrumentation are presented in Table 8.1-3. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

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Recovery can be made from the potential failures listed in Table 8.1-3. The radiological effects of events regarding the TC port covers are insignificant. They provide only minimal shielding, and during operation, all personnel are out of the Lower Access Area.

If the TC port covers can not be open, closed, locked or unlocked by normal means, they can be activated manually from outside of the DTS through penetrations in the concrete wall as described in Chapter 5, Section 5.2.6.2. Maintenance and repair operator dose assessments will be performed on a site-specific basis.

D. Failures of the Upper Shield Port Covers and Related Instrumentation

The potential failures of the upper shield port covers and related instrumentation are presented in Table 8.1-4. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-4. There are no radiological effects of events regarding the upper shield port covers. If the upper shield port covers are not working properly, the shield plug would be returned to the receiving cask, the source cask lid would be installed, and the TC port covers closed. Then, personnel can enter the Roof Enclosure Area and perform maintenance on the Upper Shield Port Covers. Maintenance and repair operator dose assessments will be performed on a site specific basis.

Table 8.1-3
TC Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
TC port cover Opening	No Opening	Failure of Electrical Jack; Derailing	Subsequent operations cannot be performed.	Visual Position Sensors Inability to engage lock	Motors are placed outside the TCA and the port covers can be actuated manually
	Partial Opening	Failure of Electrical Jack		Visual Position Sensors; Inability to engage lock	
	Untimely Opening	Spurious signal; error in processor	Potential contamination of Lower Access Area	Visual Position Sensors	Interlock prevents opening during fuel assembly lowering or lifting;
TC Port Cover Closing	No closing	Failure of electrical jack; derailing	Subsequent operations cannot be performed.	Visual Position Sensor Inability to proceed to next operation	Motors are placed outside the TCA and the port covers can be actuated manually.
	Partial closing	Failure of electrical jack	Subsequent operations cannot be performed	Visual Position sensor Inability to proceed to next operation	
	Untimely closing	Spurious signal; error in processor ; operator error	Fuel assembly could be lowered onto the TC port cover. Collision with fuel assembly	Visual Position Sensors	Interlock prevents port cover closing if fuel grapple is not in "upper position"

Table 8.1-3 (Continued)

TC Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
TC Port Cover Locking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not engage	Mechanical or electrical failure of lock	TC Port Covers can collide with fuel assembly during a seismic event	Subsequent operations cannot be performed. Alarm	Shield Plug and Source Cask lid will be returned to casks, casks will be removed, and maintenance will be performed on lock after casks have been removed from the DTS.
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	Since lock is in the open position, fuel transfer can be completed. Access to the lock drive mechanism can be made through a penetration in the DTS wall to manually release the lock.
TC Port Cover Limit Switch failure	No position detection	Sensor Failure	Port Cover not stopped in proper position	Alarm CCTV	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed or off centered position		Lid/shield plug could be left in an unsafe position on the port cover and this position may not be predictable. Closing operations may be compromised.	CCTV	Marks on the mezzanine floor show the proper positions of the covers. Centering guides on the port covers prevent improper positioning of the lid/shield plug on the TC port cover.
	Erroneous detected open position		Locking operating can be processed in an improper position	Alarm	Time out on locking operation generates an alarm.

Table 8.1-4

Upper Shield Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
upper shield port cover opening	No Opening	Failure of Electrical Jack; Derailing	Subsequent operations cannot be performed.	Position Sensors	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. Fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Partial Opening	Failure of Electrical Jack			
	Untimely Opening	Spurious signal, error in processor	Potential loss of shielding on the roof	Position Sensors Radiation Monitoring Alarm	Interlock prevents opening during fuel assembly lowering or lifting; Upper Shield port covers are locked during fuel transfer.
upper shield port cover closing	No closing	Failure of electrical jack; derailing	Subsequent operations cannot be performed.	Position Sensor Inability to proceed to next operation	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. Fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Partial closing	Failure of electrical jack	Subsequent operations cannot be performed.	Position sensor Inability to proceed to next operation	
	Untimely closing	Spurious signal; processor error; operator error	Collision with upper crane grapple or cables	Alarm Position Sensors	Interlock prevents port cover from closing if upper crane hoist is not in upper position.

Table 8.1-4 (Continued)

Upper Shield Port Cover Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
Upper shield port cover Locking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not engage	Failure of lock	potential loss of shielding due to a seismic event	Subsequent operations cannot be performed Alarm	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	
upper shield port cover limit switch failure	No position detection	Sensor Failure	Port Cover not stopped in proper position	Alarm overtravel indicator	Overtravel electrical switches on each side of the runway rails stop motion.
	Erroneous detected closed or off centered position		Locking could be processed in an improper position. Improper shielding of port covers during fuel transfer	Alarm Radiation Monitoring Alarm	Range of time to process the operation controlled by the PLC generates an alarm. Upper shield port cover locks are interlocked with fuel transfer hoist.
	Erroneous detected open position		Locking operating can be processed in an improper position.	Alarm	Time out on locking operation generates an alarm.

E. Failures of the Upper Crane and Related Instrumentation

The potential failures of the upper crane and related instrumentation are presented in Table 8.1-5. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-5. There are no radiological effects of events regarding the upper crane since the crane is housed in a shielded area. If the crane will not function, and the casks are not open, personnel can enter the Roof Enclosure Area and repair the crane. If the crane is not functioning properly, and the casks are open, personnel can enter the Roof Enclosure Area for short periods of time to perform repairs. Maintenance and repair operator dose assessments will be performed on a site specific basis.

F. Failures of the Fuel Handling Equipment

The potential failures of the fuel handling equipment and related instrumentation are presented in Table 8.1-6. The failure, the probable cause, possible failure effect, means of detecting the failure and compensating provisions are listed.

Recovery can be made from the potential failures listed in Table 8.1-6. The radiological effects of events regarding the fuel handling equipment are minimal since backup equipment, remote access or manual activation is provided which precludes the need to enter the DTS for repair until the fuel is loaded safely in either the source or receiving cask and the casks are closed. Maintenance and repair operator dose assessments will be performed on a site specific basis.

Manual operation of the trolley and rotating platform is performed as follows as described in Chapter 5, Section 5.2.6.4.

Table 8.1-5

Upper Crane Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Release of service brakes	No release	Brake failure	subsequent operation cannot be performed. Motor damage	Interlock alarm Crane trolley cannot move Sensor	Electrical interlock prevents motor actuation if brake is not released. Crane trolley is only moved when upper shield port covers are closed. Therefore, manual repairs can be made since the Roof Enclosure Area is shielded.
	Untimely release	Operating Error	Damage to Lid or Shield Plug	Sensor	Interlock prevents Z movement if X brakes are released.
Trolley movement	No movement	Motor failure; jammed trolley; derailing	Subsequent operation not possible	Sensors Timing device alarm	Range of time to process operation is controlled by PLC and will indicate that a failure has occurred. Manual repairs can be made in the Roof Enclosure Area.
	Incorrect positioning	Sensor failure	Grapple lowering cannot be performed.	Timing device alarm	
	Untimely movement	Operator error	Damage to lid or shield plug	alarm	Interlocks prevent trolley movement unless the grapple is in the full up position. Brakes immobilize trolley.
	Excessive movement	Sensor failure	Damage to trolley	overtravel limit switches	Limit switches stop motion. Motor overload detection stops motion
Trolley braking	No braking	Brake failure. Operator mistake	Possible movement of trolley due to seismic event.	Sensors indicate if trolley is out of position	Interlock prevents hoist movement if trolley brakes are released
	Untimely braking		Subsequent operations can not proceed.	Trolley will not move	Brakes can be deactivated manually in the Roof Enclosure Area.

Table 8.1-5 (Continued)

Upper Crane Postulated Failures, Effects and Compensating Provisions

Function	Failure Mode	Probable Cause	Possible Effect	Failure Detection	Compensating Provisions
Grapple lowering	No lowering	Motor failure	Plug/lid grapple can not be engaged. Lids cannot be put back on cask.	Visual Position indicator of hoist	Movement can be activated manually.
	Partial lowering	Failure of cable position indexing	Plug/lid grapple cannot be engaged. Lids cannot be put back on cask.	Visual Position indicator	
	Untimely lowering	Operator error; hoist failure	Collision of grapple or lid/shield plug with a port cover.	Visual	Interlocks Failure proof hoist Operating steps shown on control monitor
	Erroneous z position	Program error; operator error	Collision of grapple or lid/shield plug with a port cover	Visual	Testing prior to operation; Operating steps shown on control monitor.
Grapple lifting	No lifting	Motor failure	Subsequent operations can not proceed	Visual Position Sensors	Movement can be activated manually
	Partial lifting	Motor or position indicator failure			
	Excessive lifting	Position indicator failure	Damage to equipment Collision with trolley	Overtravel alarm	Overtravel stop
	Untimely lifting	Operator mistake	Drop of plug/lid during lifting resulting in damage which could prevent plug from being used.	Visual Interlocks	Overtravel stop
Shield plug/lid removal	No opening of grapple	Grapple failure jamming of fingers	Subsequent operations cannot proceed	Grapple engagement sensors	Grapple can be manually disengaged through a penetration in the TCA wall or from the Roof Enclosure Area after the TC port covers are closed.
	Partial opening of grapple	Grapple failure Jamming of fingers	Drop of plug/lid during lifting	Grapple engagement sensors interlocks	
	Untimely opening of grapple	Operator error.	Drop of plug/lid during lifting	Grapple engagement sensors; interlocks	Interlocks prevent opening of grapple under load or in incorrect position.

Table 8.1-6

Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions

	Function	Failure Modes	Most probable Failure Cause	Possible Failure Effect	Failure Detection	Compensating Provisions	Recommendations or Remarks
1	Indexing (Defining reference input (X, Y, θ)	No indexing	Operating mistake	Transfer Tube positioning made impossible	Visual	Unlocking of the parking brakes possible only after validation of indexing.	
		Wrong indexing	Wrong data input		Visual	Position of the crane is checked via video cameras	
2	Release of Service brakes	Untimely release	Operating mistake	Untimely movement of crane inducing potential damage to FA* and to the crane.	Visual and control panel	Emergency brake. Interlock prevents "Z movement" of crane if X, Y, θ brakes are released.	
		No release	Brake failure	Subsequent operations made impossible Potential damage to motors.	Visual	Electrical interlock prevents motor actuation if brakes are not released.	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

3	Transfer Tube Positioning	Wrong positioning	Indexing failure (see 1) Failure of monitoring system	FA grappling or lowering made impossible	Visual Loss of load on grapple signal and position signal of the cable inconsistent.	Visual validation of the position of the crane by operator before next sequence.	
4	Crud catcher opening	No opening	Operating mistake Failure of actuator Jammed device	FA or grapple lowering made impossible	Visual Load on crane cable and position signal of the cable inconsistent	Visual validation of the position of the device by operator before next sequence Actuator can be operated manually	Manual operation of the actuator is possible from a given position using a specific tool from outside the TCS**
			Signal failure from fuel assembly handling crane sensors, rotating platform sensors, or crud catcher position indicator.	Subsequent operations cannot be performed	Visual	Verify Conditions via CCTV, bypass interlock	
		Partial opening	Failure of actuator	FA or grapple lowering made impossible	Visual Limit contact is not activated	"Z movement" sequence possible only after validation of position of device.	
		Untimely opening	Operating mistake Lock failure	Crud or radioactive particle dispersion on TCS floor	Visual	Interlock prevents opening if crane is not in position	Consequences are minor. Reparation is performed after evacuation of FA, and closing of the TC port covers.

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

5	Grapple lowering	No lowering	Failure of motor	FA gripping impossible	Visual Position indicator of cable	Redundancy of motors, with separate and independent power sources.	Movement is achieved with spare motor. Motor driven in manual mode to allow completion of sequence.
			Signal failure from crud catcher position indicator, FA handling crane carriage, or rotating platform sensors	FA gripping impossible	Alarm, Visual	Verify conditions via CCTV, bypass appropriate interlock	
		Partial lowering	Failure of cable positioning Failure of motor	FA gripping made impossible	Visual Position indicator of cable	Redundancy of motors, with separate and independent power sources.	
		Untimely lowering	Operating mistake Failure of cable brakes Breaking of the cable	Damage to FA	Visual Position indicator of Cable Loss of load on cable	Interlock prevents grapple lowering as crane is not locked and crud catcher not open Overspeed switch activates emergency brake Redundant load path	Breaking of cable is considered beyond design

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

6	Fuel Assembly gripping	No gripping	Failure of actuators Jamming of fingers	FA grappling is made impossible	Limit contact is not activated Visual	Cask plugs and trap doors are closed and grapple is changed by operator in the cell	
			Signal failure from FA handling hoist, grapple finger position indicator, or FA presence indicator sensors	FA grappling is made impossible	Alarm	Confirm conditions via redundant sensors and CCTV, bypass corresponding interlock.	
		Partial gripping	Jamming of fingers Wrong positioning of grapple	Drop of FA during lifting	Limit contact is not activated Visual	Interlock prevents lifting if fingers are not totally engaged. Validation of "grappling" (limit contact) before "lifting"	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

7	Fuel Assembly lifting (Z)	No lifting	Failure of motor	FA unloading is impossible	Visual position indicator of cable		Spare motor is used to lift grapple, plugs and doors are closed and reparation of the motor is performed.
			Signal failure from grapple finger position or fuel assembly presence detector	FA unloading is impossible	Visual, Alarm	Disengage fuel, bypass interlock	Spare motor is used to lift grapple, plugs and doors are closed and reparation of the motor is performed.
		Partial lifting	Failure of motor Failure of cable position indexing	FA stuck partially inserted in cask and transfer tube	Visual Position indicator of cable.	Redundancy of motors, with separate and independent power sources.	Movement can be achieved in manual mode.
		Excessive lifting	Failure of cable position indexing.	Damage to FA	Motor overload.	Limit switch stops motion Overload signal stops motor.	
		Untimely lifting	Operating mistake	Drop of FA	Visual	Interlock prevents lifting as grapple is not closed (limit contact activated)	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

8	Crud catcher closing	No closing	Operating mistake Failure of actuator Jammed device.	Crud or radioactive Material dispersion during transfer	Visual Position signal of the device.	Visual validation of the position of the device by operator before next sequence Interlock prevents crane unlocking if device is not closed.	Manual operation of the actuator is possible from a given position using a specific tool from outside the TCS.
			Signal failure from fuel assembly handling hoist sensors or crud catcher position indicator	Subsequent operations cannot be performed	Visual, Alarm	Verify Conditions via CCTV, bypass interlock	
		Partial closing	Failure of actuator Jammed device FA lifting not complete.	Crud or radioactive material dispersion during transfer.	Limit contact is not activated Visual		
		Untimely closing	Operating mistake	Motor overload	Visual	Interlock prevents device closing of lifting is not achieved and validated	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

9	Trolley movement (Y)	No movement	Failure of motor	FA stuck in the transfer tube	Visual	Motor can be manually activated Specific tools can force bridge movement Anti-derailing and anti-taking off devices	Manual operation allow for completion of transfer in progress, and access to the TCS is possible after evacuation of sources.
			Signal failure from Port sensors, FA handling hoist or Crud Catcher position indicator	FA stuck in basket	Alarm, Visual	Verify conditions via CCTV, bypass appropriate interlock	
		Wrong positioning	Indexing failure (see1) Failure of monitoring system	Basket cell opening can not be found Lowering of FA between basket cells	Visual Unexpecte d load reduction reported	Fine positioning in manual mode Validation of positioning by operator after visual control Load reduction stops motion	
		Untimely movement	Operating mistake Earthquake	Damage to FA	Visual	Interlock prevents "trolley moving" if "FA lifting" and "crud catcher closing" are not completed Brakes for immobilization of trolley	
		Excessive movement	Failure of positioning system	Damage to trolley	Visual Limit switch activation Motor overload	Motor overload detection stops motion Limit switch stops motion	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

10	Bridge movement (X)	No movement	Failure of motor	FA stuck in the transfer Tube	Visual	Motor can be manually activated Specific tools can force bridge movement Anti-derailing and anti-taking off devices	Manual operation allow for completion of transfer in progress, and access to the TCS is possible after evacuation of sources
			Signal failure from Port sensors, FA handling hoist or Crud Catcher position indicator	FA stuck in basket	Alarm, Visual	Verify conditions via CCTV, bypass appropriate interlock	
		Wrong positioning	Indexing failure (see1) Failure of monitoring system	Basket cell opening can not be found Lowering of FA between basket cells	Visual Unexpected load reduction reported	Fine positioning in manual mode Validation of positioning by operator after visual control Load reduction stops motion	
		Untimely movement	Operating mistake Earthquake	Damage to FA	Visual	Interlock prevents "bridge moving" if "FA lifting" and "crud catcher closing" are not completed Brakes for immobilization of bridge	
		Excessive movement	Failure of positioning system	Damage to trolley	Visual Limit switch activation Motor overload	Motor overload detection stops motion Limit switch stops motion	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

11	Transfer Tube movement (θ)	No movement	Failure of motor Jammed equipment	FA stuck in the transfer tube	Visual	Motor can be manually activated Anti-derailing and anti-taking off devices	Manual operation allow for completion of transfer in progress, and access to the TCS is possible after evacuation of sources
			Signal failure from crud catcher or FA handling hoist position indicators	FA stuck in the transfer tube	Alarm, Visual	Verify conditions via CCTV, bypass interlock	
		Excessive movement	Signal failure from rotating platform orientation encoders	FA stuck in the transfer tube	Alarm, Visual	CCTV, over travel limit switch provides redundancy	
		Wrong positioning	Indexing failure (see 1) Failure of monitoring system	Basket cell opening can not be found Lowering of FA between basket cells	Visual Unexpected loss of load reported	Fine positioning in manual mode Validation of positioning by operator after visual control Loss of load stops motion	
			Signal failure from rotating platform orientation encoders	Basket cell opening cannot be found. Lowering of FA between basket cells.	Visual, Unexpected load reduction reported	Fine positioning done in manual mode. Validation of positioning by operator after visual control. Load reduction stops motion.	
		Untimely movement	Operating mistake Earthquake	Damage to FA	Visual	Interlock prevents "tube moving" if "FA lifting" and "curd-catcher closing" are not completed Brakes for immobilization of tube	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

12	Fuel Assembly Lowering (Z)	No lowering	Failure of motor Crud catcher not open	FA stuck in the transfer tube	Visual Position indicator of cable	Redundancy of motors, with separate and independent power sources	Spare motor is used to lift grapple, plugs and doors are closed and reparation is performed
			Signal failure from crud catcher position indicator, crane carriage sensors, or rotating platform sensors	FA stuck in the transfer tube	Alarm, Visual, subsequent actions cannot be performed	Verify conditions via CCTV, bypass interlock	
		Partial lowering	Failure of motor Wrong positioning of Transfer Tube Failure of cable position indexing	FA stuck partially Inserted in cask and transfer tube	Visual Position indicator of cable	Redundancy of motors, with separate and independent power sources Validation of positioning by operator after visual control Loss of load stops motion	Movement can be achieved in manual mode
		Excessive lowering	Failure of cable position indexing Cable overspeed	None	Limit switch Unexpected loss of load Overspeed detection	Limit switch stops motion Overload signal stops motor Overspeed signal activates emergency brakes	
		Untimely lowering	Operating mistake	Damage to FA	Visual Positioning indicator of cable	Interlock prevents lowering as the positioning of transfer tube is not validated, if crane is not locked and if crud-catcher is not open	

Table 8.1-6 Fuel Handling Subsystem Postulated Failures, Effects and Compensating Provisions (Cont.)

13	Grapple opening	No opening	Failure of actuators Jamming of fingers	FA can not be disengaged	Visual Limit contact "open" not activated	Two independent drive mechanisms	
			Failure of FA handling hoist load cell or positioning sensor signal failure	FA can not be disengaged	Alarm	Verify conditions via CCTV and redundant sensors, bypass interlock.	
		Partial opening	Jamming of fingers	FA can not be disengaged	Visual Limit contact "open" not activated	Two independent motorizations	
		Untimely opening	Operating mistake Failure of fingers	Drop of FA	Visual Loss of load on cable	Interlock prevents opening, if cable is in load and if "FA lowering" has not been validated Mechanical design of grapple prevents it from opening in load	

* Fuel Assembly

** Transfer Confinement Subsystem

G. Failure of the HVAC Subsystem Components

The potential failures of the HVAC Subsystem component failures are presented in Table 8.1-7. The failure, detection, probable cause, consequences, and recovery are listed. The radiological effects of events regarding the HVAC component failures are minimized by the redundancy of critical equipment.

The air conditioning system for each of the three areas of the DTS only conditions the air by maintaining the set temperature and humidity in the areas. As stated in Section 1.2.4.1, the HVAC Subsystem maintains air temperature at design levels for the design heat load to allow proper functioning of the operating equipment, monitors, cameras and lighting, as well as to ensure that the fuel clad temperature does not exceed specified levels. Maintenance of the set temperature and humidity is accomplished by the heating and cooling components of the air handling units (AHU-1, AHU-2, and AHU-3) in the area.

Table 8.1-7 postulates the failure of the air conditioning (heating or cooling) subsystem in the LAA. This failure does not significantly effect the pressure differentials, and any small effects that may be there will be compensated by the motorized dampers. In this event, the AHUs of the TCA and/or the PA will compensate for the absence of heating or cooling by the AHU of the LAA by providing additional heating or cooling as called for by the sensors in those areas. Thus, there is no significant change in the pressure differential between the areas.

The ventilation system that provides the airflow pattern is an independent system. As stated in Section 1.2.4.1, the HVAC Subsystem maintains negative pressure in the PA, the LAA, and the TCA, relative to the ambient, and provides high efficiency filtration for the particulate that may be released from the assemblies.

As explained in Section 4.3.1, with respect to the maintenance of negative pressure relative to ambient, the HVAC Subsystem is designed to provide an additional level of confinement of the radioactive material, during the transfer of spent fuel assemblies, by directing the airflow from areas of low levels of potential contamination to areas of higher levels of potential contamination. The airflow is also designed to control the temperatures of the spent fuel, fuel transfer equipment, as well as the DTS structure and the associated components.

The HVAC performs its confinement function by maintaining negative pressures in various areas relative to atmospheric pressure. By establishing pressure differentials, airflow is directed from the ambient into the Preparation Area through the Lower Access Area to the TCA. This ensures that leakage is into the DTS, and in the unlikely event of a release of radioactive particulate anywhere in the system, contaminants would be retained within the DTS or in the HVAC ducting/filtration system.

Figure 4.3.1 is a schematic of the HVAC. As shown, there are two exhaust fans (EF-1 and EF-2). One of them is designated the 'lead exhaust fan'. Motorized dampers in the ducts between the areas of the DTS modulate, as required, to maintain the static differentials between the areas.

As stated in Section 4.3.1, the system reacts to changes by speeding up or slowing down the fan and opening or closing the dampers as necessary to maintain the pressure differential set-points. The lead fan and the backup fan are located at the exhaust side of the three areas and only one fan is required to maintain the appropriate pressure differentials.

The failure of the ventilation exhaust fan is listed as a separate item in Table 8.1-7.

H. Failure of the Control Subsystem Components

Failures of sensors are included in the sections regarding the specific equipment which is being controlled or monitored. Sensor failures result in absence of detection or erroneous information. The PLC will then have information that is either undetermined or erroneous. Inconsistent information is not considered in the sensor failures analysis as this is detected by the PLC which generates an alarm, stops the equipment and requires operator identification to resume the operations. Failure of the Control Subsystem Components are described in more detail in Appendix 5A.

Some potential failures of the Control Subsystem are not specific to the equipment, either because the responses to the failures are the same for all equipment or because the failure can influence the general control and monitoring of the process. These general types of failures are discussed below.

A "watch dog" detects the failure of the PLC's CPU (Central Processing Unit), based on an internal operations timer, and automatically stops the equipment in operation by resetting its outputs. A coupler failure, a network disconnection of the PLC, a network failure between the PLC and the monitoring PC or between the main control panel and the PLC are detected and the equipment is automatically stopped. A failure of the link between the PLC and the electronic cabinets results in a de-energizing of the controlled equipment that activates the emergency brakes. A loss of control (wire disconnection/breaking) between the electronic cabinets and the equipment has the same effect.

A loss of power directly stops the operating equipment. All equipment returns to a safe condition in the event of a power failure, for example, all grapples engage. The PLCs and the PC are supplied by an independent (battery) backup which maintains historical information (process, positions...) and updates the equipment status (stopped) upon loss of power.

Interlock failures are described in Table 8.1-8. Interlocks can be bypassed by authorized personnel provided that they provide proper identification.

There are no radiological consequences of a failure of the control subsystem.

The various sensors such as limit switches, position indicators, temperature indicators and radiation monitors are not designed to withstand a natural occurrence such as an earthquake. Sensors not protected by the DTS concrete structure could fail during a tornado or storm, but are accessible for repair or replacement.

In the event of an accident, the first step is to shut off power to all subsystems other than the HVAC system. This will minimize any additional damage to the systems that may occur because of shorting or fire affecting the wiring. After the accident or storm has taken its course, any damages to the system will be assessed. Control system interlocks can be overridden following retrieval procedures (to be developed for each site-specific application) if the sensors are damaged, so as to allow the fuel to be safely transferred to the nearest cask. If fuel is outside of a cask, it will be placed in the nearest cask. This will eliminate the need to lift fuel and will require only horizontal transfer or lowering of the fuel. The fuel can be transferred by manually operating the subsystems from outside of the DTS structure if necessary. Once all fuel is placed in a cask, the covers or shield plugs can be installed by similar means to allow safe entry to the appropriate areas to repair or replace sensors. A complete pre-operative test will be performed after the event to ensure that all equipment and sensors are operating properly before proceeding with transferring the fuel.

In the event of a seismic event, it is necessary to rely on visual observation of the DTS equipment. The TV cameras and lights within the Transfer Confinement Area will be seismically qualified. Redundant cameras and lights are provided which are powered by separate cable systems. The TV cameras and lights within the Transfer Confinement Area are designated as Important to Safety.

Table 8.1-7

HVAC Subsystem Failure Mode Analysis

Failure Mode	Detection	Probable Cause	Consequences	Recovery
Blow out of a HEPA filter in primary HEPA filter bank.	Reduction of pressure across HEPA filter. This will trigger an alarm on the Control Subsystem panel.	Manufacturing defect in HEPA filter. The filter bank consists of a pre-filter and two HEPA filters as shown in Figure 4-3-5.	None. Second HEPA filter in bank will maintain confinement function of the DTS	Return DTS to safe mode condition where all fuel is in the casks and lid/shield plug is in place. Manually shut down the exhaust fan only (not the heating/cooling system). Activate the motorized dampers for the HEPA filter banks, and switch from primary to secondary HEPA filter bank. Startup exhaust fan and adjust speed to obtain the static pressure setpoint in the TCA. Verify pressures across the individual HEPA filters in the secondary bank are within acceptable values. Resume normal operations in the DTS. Replace defective HEPA filter bank when the loading cycle is complete and the casks are removed from the Lower Access Area.
Clogged HEPA filter in primary HEPA filter bank.	Increase in pressure across a HEPA filter. This will trigger an alarm on the Control Subsystem panel.	Pre-filter/HEPA filter clogged due to excess dust or particulate.	None. Confinement function of HEPA filter bank continues to remain functional	Same as above.
Failure of primary exhaust fan.	Loss of negative pressure differentials in DTS. This will trigger an alarm on the Control Subsystem panel.	Failure of an exhaust fan component.	None. Confinement function of HEPA filter bank continues to remain functional	Return DTS to safe mode condition where all fuel is in the casks and lid/shield plug is in place. Manually shut down the exhaust fan only (not the heating/cooling system). Activate motorized dampers and switch from primary to secondary exhaust fan. Startup exhaust fan and adjust speed to obtain the static pressure setpoint in the TCA. Resume normal operations in the DTS. Replace defective exhaust fan when the loading cycle is complete and the casks are removed from the Lower Access Area.
Loss of cooling system in TCA.	Exhaust air temperature sensor will increase and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the cooling system	None. Temperatures in the TCA will increase but will remain within the normal operating temperature range because of the continued operation of the cooling system in the Lower Access Area and the upper crane enclosure.	Continue normal operations until the loading cycle is complete, and the casks are removed from the Lower Access Area. Repair defective cooling system.

Table 8.1.7 (Continued)

HVAC Subsystem Failure Mode Analysis

Failure Mode	Detection	Probable Cause	Consequences	Recovery
Loss of cooling system in Lower Access Area.	Exhaust air temperature sensor will increase and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the cooling system.	None. Decay heat released in the Lower Access Area will be transferred to the TCA along with the air flow. The cooling system in the TCA will dissipate this heat.	Continue normal operations until the loading cycle is complete, and the casks are removed from the Lower Access Area. Repair defective cooling system.
Loss of heating system in TCA	Exhaust air temperature sensor will decrease and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the heating system.	None. Pre-heated air from the Lower Access Area will continue to keep temperatures in the TCA within the normal operating temperature range.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair defective heating system
Loss of heating system in Lower Access Area.	Exhaust air temperature sensor will decrease and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the heating system	None. The heating system in the TCA will continue to provide heat to maintain normal operating temperatures.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair defective heating system
Loss of control of static pressure in TCA.	Pressure differential in TCA not within set limits. This will trigger an alarm on the Control Subsystem panel.	Failure of PLC controlling the exhaust fan speed.	None. PLC will automatically shutdown fan. Exhaust fan can be manually started up to run at the preset speed.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair problem.

Table 8.1.7 (Continued)

HVAC Subsystem Failure Mode Analysis

Failure Mode	Detection	Probable Cause	Consequences	Recovery
Loss of cooling system in Lower Access Area.	Exhaust air temperature sensor will increase and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the cooling system.	None. Decay heat released in the Lower Access Area will be transferred to the TCA along with the air flow. The cooling system in the TCA will dissipate this heat.	Continue normal operations until the loading cycle is complete, and the casks are removed from the Lower Access Area. Repair defective cooling system.
Loss of heating system in TCA	Exhaust air temperature sensor will decrease and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the heating system.	None. Pre-heated air from the Lower Access Area will continue to keep temperatures in the TCA within the normal operating temperature range.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair defective heating system
Loss of heating system in Lower Access Area.	Exhaust air temperature sensor will decrease and will trigger an alarm on the Control Subsystem panel.	Failure of a component of the heating system	None. The heating system in the TCA will continue to provide heat to maintain normal operating temperatures.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair defective heating system
Loss of control of static pressure in TCA.	Pressure differential in TCA not within set limits. This will trigger an alarm on the Control Subsystem panel.	Failure of PLC controlling the exhaust fan speed.	None. PLC will automatically shutdown fan. Exhaust fan can be manually started up to run at the preset speed.	Continue normal operations until the loading cycle is complete and the casks are removed from the Lower Access Area. Repair problem.
Loss of electric power	All components of the HVAC Subsystem will shut down.	Loss of primary electric power.	None. Confinement function of HEPA filter bank continues to remain functional.	Switch to secondary power supply. Startup the exhaust fan, HEPA filter pressure monitoring system, and the exhaust air temperature monitoring system. Return DTS to safe mode condition where all fuel is in the casks, and lid/shield plug is in place.

Table 8.1-8

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Crud Catcher (Closed Indicator)	Erroneous crud catcher closed position information	FA crud spreading during motion. FA damaged or stuck due to motion or platform rotation if not fully retracted into transfer tube.	CCTV	Transfer tube positioning (x,y,θ) interlocked with the grapple upper z position.
	Erroneous crud catcher open position information	Lowering of the FA onto the crud catcher. Damage to the FA. Stuck FA in the transfer tube because of crud catcher stuck in closed position.	CCTV Unexpected loss of load	Loss of load stops motion. Crud catcher position validated visually before lowering FA.
Fuel Assembly Handling Crane Carriage	Erroneous movement detected	Interlocks prevent subsequent operations; Potential for collision if TC port covers are activated	CCTV	Bypass interlock.
	Movement not detected	Able to lower fuel assembly when carriage is in motion; Able to open crud catcher when crane carriage is in motion		Interlock with crud catcher closed position.
Fuel Assembly Handling Grapple	Erroneous FA gripping information	Unsafe lifting of FA. High radiation levels at upper level due to possible unlocking and opening of the upper shield ports	Alarm due to inconsistency between grapple fingers position and FA presence	Open and closed grapple fingers position sensors. Redundancy on proper gripping information with fuel assembly presence sensor. Upper shield ports interlocked with load cell and radiation monitoring.
Fuel Assembly Handling Hoist (Absolute Position Indicator)	Erroneous z position information of the FA hoist system	Damage to FA due to disconnection above the proper position.	CCTV Alarm due to inconsistency between load and position	Redundancy on FA disconnection based on underload situation. Mechanical design of grapple prevents its opening when loaded.

Table 8.1-8 (Continued)
Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Fuel Assembly Handling Hoist (Load Cell)	Erroneous underload information	Damage to FA due to disconnection above the proper position High radiation levels at the upper level due to upper shield port opening FA stuck in the transfer tube because of damage to transfer tube due to collision with TC port cover.	CCTV Alarm due to inconsistency between position and load	FA disconnection interlocked with position encoder. Mechanical design of grapple prevents its opening when loaded. Upper shield port interlocked with gripping status and radiation monitoring device. TC port cover closing interlocked with gripping status.
Fuel Assembly Handling Hoist (Upper Position Indicator)	Erroneous upper position information	Damage to FA due to crane motion or platform rotation with FA not fully retracted into the transfer tube. Damage to FA and crud catcher due to crud catcher closure on FA.	CCTV	Crane carriage and rotating platform motion interlocked with crud catcher position. Visual verification prior to closing crud catcher.
Fuel Assembly Handling (Absolute Position Indicator)	Erroneous x,y position information	Damage to the lid/shield plug Dropping of the lid/shield plug, gripping of the grapple	CCTV	Visual verification prior to lift the lid/shield plug. Minimum speed imposed by PLC under the safety level
Lid/Shield Plug Hoist (Absolute Position Indicator)	Erroneous z position information of the lid/shield plug hoist system	Damage to the lid/shield plug due to disconnection of the lid/shield plug above the proper position	CCTV Alarm due to inconsistency between load and position	Lid/shield plug disconnection interlocked with load cell (underload situation)
		Lid/shield dropping or damage due to closure of TC port cover on the handling cables.	CCTV	The grapple position is visible and has to be validated before closing a TC port cover.

Table 8.1-8 (Continued)

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Lid/Shield Plug Hoist (Grapple Position)	Erroneous gripping status	Unsafe lifting and dropping of the lid/shield plug	Alarm due to inconsistency between gripping information	Open and closed grapple fingers position sensors Redundancy on proper overlid gripping Open and closed overlid fingers position Overlid fingers gripping detection
Lid/Shield Plug Hoist (Load Cell)	Erroneous underload information	Damage to lid/shield plug due to dropping of the lid/shield plug above the proper position	CCTV Inconsistency between load and position	Redundancy on lid/shield plug disconnection based on z position.
Lid/Shield Plug Hoist (Upper Position)	Erroneous upper position information	Dropping of the lid/shield plug due to closure of an upper shield port on the handling cables.	CCTV	Upper shield ports closure interlocked with gripping status.
		Unsafe handling of the lid/shield plug due to upper crane motion.		Upper crane motion interlocked with upper shield ports closed position.
Radiation Monitor - Upper Level	Erroneous dose rate	High dose rate at the upper level due to upper shield port unlocking and opening during FA transfer or with cask and TC port cover open.	CCTV Radiation monitoring alarms Inconsistency between radiation monitoring devices	Radiation monitoring equipment alarms on failure. Upper shield port unlocking and opening interlocked with TC port covers positions, FA grapple and load cell status.
Radiation Monitor -Sliding Door	Erroneous dose rate	High dose rate at the sliding door level.	Inconsistency with Preparation Area radiation monitoring	Radiation monitoring equipment alarms on failure. Sliding door opening requires severe administrative procedure

Table 8.1-8 (Continued)

Failure of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Sliding Door Locking Device	Erroneous sliding door locked position	High dose rates in case of a seismic event due to sliding door opening	Direct viewing	Operating procedure. Operation performed on contact.
Receiving Cask TC Port Cover - Closed Indicator Receiving Cask TC Port Cover - Off-Center Indicator Source Cask TC Port Cover - Closed Indicator	Erroneous TC port cover closed (or off-center) position	High dose rates at the upper level due to upper source cask opening with TC port cover not closed or off-centered	CCTV	Upper shield port opening interlocked with radiation monitoring.
Receiving Cask TC Port Cover - Open Indicator Source Cask TC Port Cover - Open Indicator	Erroneous TC port cover open position	Prevents subsequent operations; Potential collision with fuel assembly grapple	CCTV	Bypass Fuel assembly Z-motion has underload sensor which stops motion.
Receiving Cask TC Port Cover Locking Device Source Cask TC Port Cover Locking Device	Erroneous TC port cover lock position	Unsafe FA transfer with TC port cover unlocked which could damage the FA in case of a seismic event Collision between source cask lid or receiving cask shield plug and FA crane carriage.	Alarm	Unlocked position information provided by jack. Locking operation validated with time information.
Receiving Cask Transfer Trolley Locking Device Source Cask Transfer Trolley Locking Device	Erroneous cask transfer trolley lock position	Transfer trolley can be projectile in case of a seismic event. Damage to FA in case of transfer.	Visual	Operating procedure. Operation performed on contact.

Table 8.1-8 (Continued)

Failures of the Control Subsystem Interlocks

Interlock	Failure	Possible Failure effect	Failure Detection	Compensating Provisions Remarks
Upper Crane - Source Cask Upper Crane -Receiving Cask	Erroneous upper crane position	Cask opening or closing impossible Damage to the lid/shield plug grapple onto the upper plate.	Alarm Unexpected loss of load or inconsistency between load and position.	Time information is used to validate the upper crane positioning information.
Receiving Cask Upper Shield Port - Closed Indicator Source Cask Upper Shield Port - Closed Indicator	Erroneous upper shield port position	Dropping of the lid/shied plug or unsafe lifting due to upper crane motion. High dose rates at the upper level during opening/closing of the opposite cask.		Upper crane motion interlocked with upper z grapple position. Upper shield port opening interlocked with radiation monitoring
Receiving Cask Upper Shield Port Locking Device Source Cask Upper Shield Port Locking Device	Erroneous upper shield port lock position	High dose rates at the upper level during FA transfer in case of a seismic event.		Unlocked position information provided by jack. Locking operation validated with time information.

Table 8.1-9 Cask Transfer Subsystem

	Function	Failure Modes	Most probable Failure Cause	Possible Failure Effect	Failure Detection	Compensating Provisions	Recommendations or Remarks
1	Trolley movement (X)	No movement	Failure of motor Jammed trolley Derailing	Subsequent operation made impossible	Visual	As cask is closed, repair is performed directly on the trolley Guiding rollers + anti-taking-off device	To limit dose exposure, it is recommended that the trolley be pulled in to the preparation area and the cask be removed.
		Wrong positioning	Failure of monitoring system	Cask preparation or cask mating can not be achieved	Visual		Locking can not be performed if trolley positioning is not correct
		Untimely movement	Operating mistake Earthquake	Cask damage	Visual	Brakes and locking pins prevent untimely movement. Unlocking must be manually checked by operator, before the motion.	Locking pin is designed to earthquake loads
		Excessive movement	Failure of positioning system	Damage to trolley	Limit switch activation Motor overload	Motor overload detection stops the motion Limit switch stops the motion (over travel)	

Table 8.1-9 Cask Transfer Subsystem (Cont.)

2	Trolley locking	No locking	Operating mistake Lock failure	Trolley may move during unloading	Limit contact not activated	Interlock prevents cask opening if trolley is not locked	Locking must be manually checked by operator before next sequence
			Locking device signal failure		Visual	Direct Viewing, bypass interlock.	
		Incorrect lock disengaged signal	Locking device signal failure	Subsequent operations cannot be performed	Visual, Alarm	Direct Viewing, bypass interlock.	
		Untimely locking	Operating mistake	Delayed operation No effect on fuel assemblies	Visual		
3	Trolley unlocking	No unlocking	Pin jack failure	Subsequent operation made impossible	Visual Limit contact activated Motor overload	As cask is closed, repair is performed directly on the trolley	
			Locking device signal failure	Subsequent operations cannot be performed	Visual	Direct viewing, bypass interlock.	
		Incorrect lock engaged signal	Locking device signal failure	Subsequent operations cannot be performed	Visual	Direct Viewing, bypass interlock	
		Untimely unlocking	Operating mistake Earthquake	Untimely trolley movement	Limit contact not activated	Interlock prevents unlocking if cask is not closed	Locking pin is designed to earthquake loads
4	Cask locking on trolley	No locking	Operating mistake	Cask may tip-over in case of earthquake	Visual	Cask locking on trolley is manually checked by operator, before the motion.	
5	Cask unlocking on trolley	Untimely unlocking	Locking system failure	Cask may tip-over in case of earthquake	Visual	Locking system is a passive system	Locking system is designed to earthquake loads

Table 8.1-10 TC Cask Mating Subsystem

	Function	Failure Modes	Most probable Failure Cause	Possible Failure Effect	Failure Detection	Compensating Provisions	Recommendations or Remarks
1	Platform lowering	No lowering	Failure of jacks	Mating made impossible	Visual		As the cask is closed, repair is accomplished by operators in the Lower Access Area after having closed the other cask.
			Transfer trolley locking device signal failure		Visual, Operating Procedure	Bypass Interlock	
		Partial lowering	Failure of jacks Failure of positioning system	Ineffective mating	Visual Jack load indicators		
		Untimely lowering	Operating mistake	Damage to cask or platform if cask transfer	Visual	Operation procedure prevents lowering during cask movements and after positioning and locking have been validated	No radiological consequences
2	Positioning of the platform	Wrong positioning	Failure of positioning system	Ineffective mating Possible contamination dispersion	Visual Pressure monitoring Jack position monitoring	Monitoring of the pressure differential Operation procedure prevents cask trolley unlocking	Contamination monitoring in the Lower Access Area

Table 8.1-10 TC Cask Mating Subsystem (Cont.)

3	Seals inflating	No inflating	Failure of compressed air supply, hole in the seal	Ineffective mating	Monitoring of seal air pressure	The platform is fitted with two inflatable seals. One is enough to ensure tightness.	The pressure differential between the TCA and LAA will prevent spread of contamination unless there are large openings
		Partial inflating	Failure of compressed air supply Hole in the seal	Ineffective mating	Monitoring of seal air pressure		
		Untimely inflating	Operating mistake	Fine positioning and mating made more difficult	Visual Pressure monitoring	Operation procedure; inflating only after positioning and locking have been validated	No radiological consequences
4	Seals deflating	No deflating	Failure of seal valve	Disconnecting of platform more difficult	Control of seal air pressure		
		Partial deflating	Failure of seal valve	Ineffective mating	Control of seal air pressure	HVAC system assists with minimizing spread of contamination	Depression in the TCS ensures a complementary dynamic confinement.
		Untimely deflating	Failure of seal valve Failure of seal Operating mistake	Ineffective mating	Control of seal air pressure	Interlock prevents deflating as cask is not closed.	

Table 8.1-10 TC Cask Mating Subsystem (Cont.)

5	Platform lifting	No lifting	Failure of jacks	Cask motion made impossible	Visual Jack load indicators Limit switch not activated	Repair is performed in the Lower Access Area	
		Partial lifting	Failure of jacks or positioning system		Visual	Repair is performed in the Lower Access Area	
		No / partial lifting	Signal Failure of TC shield port limit switches		Visual, Alarm	Check conditions via CCTV, bypass interlock	
		Untimely lifting	Operating mistake	Confinement failure	Visual Monitoring of TCS* air pressure	Interlock prevents lifting as cask is not closed	Depression in the TCS ensures a complementary dynamic confinement.
6	Confinement	Failure of bellows	Embrittlement due to irradiation Tearing by mechanical equipment	Possible contamination dispersion Confinement failure	Visual Control of TCS air pressure	Preventive maintenance program Depression in the TCS ensures a complementary dynamic confinement.	Bellows replacement after having closed and removed the two casks

* Transfer Confinement System

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem

	Function	Failure Modes	Most probable Failure Cause	Possible Failure Effect	Failure Detection	Compensating Provisions	Recommendations or Remarks
1	Release of service brakes	No release	Brake failure	Subsequent operation made impossible Damage to motors	Visual	Electrical interlock prevents motor actuation if brakes are not released	
		Untimely release	Operating mistake	Damage to lid or plug	Visual and control panel	Interlock prevents Z movement if X brake released	
2	Trolley movement (X)	No movement	Failure of motor Jammed trolley Derailing	Subsequent operation made impossible	Visual	Normal procedure is contact maintenance after access to the protective cover Anti-derailing and anti-taking off devices	Manual operations
		Wrong positioning	Failure of positioning system	Grapple lowering impossible	Visual Unexpected loss of load reported	Redundancy provided by two limit switches for proper upper crane positioning over source and receiving casks.	
		Untimely movement	Operating mistake Earthquake	Damage to lid or plug	Visual	Interlock prevents trolley moving if grapple is not in "upper" position Brakes for immobilization of trolley	
		Excessive movement	Failure of positioning system	Damage to trolley	Visual Limit switch activation Motor overload	Motor overload detection stops motion Limit switch stops motion	

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

3	Trolley braking	No braking	Operating mistake Braking system failure	Untimely movement (see 2)	Visual Braking contact not activated	Interlock prevents hoist movement if trolley brakes are released	
		Untimely braking	Operating mistake Braking system failure	Subsequent operation impossible	Visual Braking contact activated	Manual unlocking	
4	Shield port cover opening	No opening	Failure of motor	Subsequent operation impossible	Visual	Shielded port cover can be actuated manually	Anti-derailing device is designed to seismic event
			Signal Failure from upper or TC shield port limit switches or fuel assembly grapple sensors	Subsequent operation impossible	Alarm, Visual	Check Conditions via CCTV, bypass interlock	
			Signal failure from upper shield port locking device	Subsequent operation impossible	Visual	PLC checks consistency between pin locked and pin unlocked sensors. Bypass interlock.	
		Excessive Movement	Signal failure from upper shield port limit switch	Damage to equipment	Alarm, Visual	Redundancy provided by limit switches for both proper positioning and over travel	
		Partial opening	Failure of motor		Visual	Shielded port cover can be actuated manually	
		Untimely opening	Operating mistake Earthquake	Irradiation of operator during repair operations	Visual Mobile alarm system, dose rate monitoring	Port cover actuators are disconnected as operators are over the TCS Interlock prevents opening if TC port cover is not closed	Dose rate control during operator presence over TCS

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

5	TC port cover opening	No opening	Failure of Motor	Subsequent operation made impossible	Visual	Motors are placed outside the TCS Port cover can be actuated manually	Anti-derailing device is designed to seismic event
			Signal failure from sliding door lock position indicator	Subsequent operation made impossible	Visual, Alarm	Verify Condition via CCTV, bypass interlock	
			Signal Failure from upper shield port	Subsequent operation made impossible			
		Excessive Movement	Signal failure from TC port cover limit switch	Damage to Equipment	Visual		Redundancy provided by limit switches for both proper positioning and over travel.
		Partial opening	Failure of Motor	Subsequent operation made impossible	Visual "open" limit contact not activated	Port cover can be actuated manually	
		Untimely opening	Operating mistake Earthquake	Irradiation of operators during repair operations if open cask is in position Lid/plug drop	Visual Radiation monitoring system	Port cover actuators are disconnected as operators are over the TCS Interlock prevents opening during grapple lowering or lifting (Z)	Dose rate control during operator presence in the TCS

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

6	Grapple lowering	No lowering	Failure of motor	Plug/lid gripping impossible	Visual Position indicator of cable	Motors are placed outside the TCS	Movement can be achieved manually
			Signal Failure from upper crane limit switch	Subsequent operations cannot be performed	Alarm	Redundancy provided by two limit switches for proper upper crane positioning over source and receiving casks.	
			Signal Failure from upper shield / TC port limit switches	Damage to plug/lid	Visual, Alarm	PLC checks consistency between pin locked and pin unlocked sensors.	
			Signal failure from fuel handling crane carriage sensors	Subsequent operations cannot be performed	Alarm, Visual	Verify conditions via CCTV, bypass interlock.	
		Partial lowering	Failure of cable positioning indexing Failure of motor	Plug/lid gripping made impossible	Visual Position indicator of cable	Motors are placed outside the TCS	Movement can be achieved manually
			Signal failure from plug handling load cell or plug hoist system absolute positioning indicator	Damage of plug/lid	Alarm, visual	Redundancy provided between load cell and positioning indicator	
		Untimely lowering	Operating mistake Failure of cable brakes Breaking of the cables	Damage to plug/lid	Visual Position indicator of cable Loss of load of cable	Interlock prevents grapple lowering as crane and TC port cover or shielded port cover brakes are released. Redundant cables	Operation can be achieved with one cable

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

7	Shield plug/lid gripping	No gripping	Failure of actuators Jamming of fingers	Plug/lid gripping made impossible	Limit contact is not activated Visual	Grapple and grappling device can be separately disengaged	TC port covers can be closed to allow operator access to the TCS
			Signal failure from plug grapple gripping device presence signal or plug hoist load cell	Plug/lid gripping made impossible	History, Admin. Controls	Manual repairs can be made in the Roof Enclosure Area.	
		Partial gripping	Jamming of fingers Wrong positioning of grapple	Drop of plug/lid during lifting	Limit contact is not activated Visual	Interlock prevents lifting if fingers are not totally engaged. Validation of "gripping" (limit contact) before "lifting"	
			Signal failure from finger position sensors	Drop of plug/lid during lifting	Alarm	Verification via grapple finger position sensor and gripping device finger position sensor provides redundancy	

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

8	Grapple lifting (Z)	No lifting	Failure of motor	Subsequent operation made impossible	Visual Position indicator of cable	Motors are placed outside the TCS	
			Signal failure from lid / shield plug grapple sensors	Subsequent operation made impossible	Visual, Alarm	Disengage fingers. Manual repairs can be made in Roof Enclosure Area.	
			Signal failure from upper crane limit switches	Subsequent operation made impossible		P position verified by operator before grapple lifting process initiated	
		Partial lifting	Failure of motor Failure of cable position indexing	Damage to plug/lid	Visual Position indicator of cable	Motors are placed outside the TCS	Movement can be achieved in manual mode
		Excessive lifting	Failure of cable position indexing		Visual Motor overload	Limit switch (over travel) Overload signal stops motor	
		Untimely lifting	Operating mistake	Drop of plug/lid during lifting	Visual	Interlock prevents lifting as grapple is not closed (limit switch activated)	

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

9	TC port cover closing	No closing	Failure of motor Derailing	Subsequent operation made impossible	Visual	Actuators are placed outside the TCS Port cover can be actuated manually	Anti-derailing device is designed to seismic event
			TC Port Cover lock position or motorization status indicators signal failure	Subsequent operation made impossible	Visual	Verify conditions via CCTV, bypass interlock	
			Signal failure from fuel handling carriage motorization status indicator, fuel assembly handling sensors, or lid/shield plug hoist system sensors	Subsequent operation made impossible	Alarm, Visual	Verify conditions via CCTV, bypass interlock	
		Excessive movement	Signal failure from TC port cover limit switch	Damage to equipment	Alarm, Visual		Redundancy provided by limit switches for both proper positioning and over travel.
		Partial closing	Failure of actuators	Subsequent operation made impossible	Visual	Actuators are placed outside the TCS Port cover can be actuated manually	
		Incorrect TC port cover closed signal	Signal failure from TC port cover limit switch	Irradiation of operators during repair operations.	Visual, Radiation monitoring system	Position of Port Cover verified via CCTV.	
		Untimely closing	Operating mistake Earthquake	Damage to FA* during FA unloading	Visual	Interlock prevents port cover actuation during FA handling or lid/plug handling	

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

10	Grapple lowering	(See 6)					
11	Shield plug/lid removal	No opening of grapple	Failure of actuators Jamming of fingers	Plug/lid can not be disengaged	Visual Limit contact "open" not activated	Grapple and gripping device can be separately disengaged	
			Signal failure from plug hoist system sensors or finger position sensors	Plug/lid can not be disengaged	Alarm, Visual	Verify conditions via redundant sensors and CCTV, bypass interlock	
		Partial opening of grapple	Jamming of fingers	Plug/lid can not be disengaged	Visual Limit contact "open" not activated	Grapple and gripping device can be separately disengaged	
		Untimely opening of grapple	Operating mistake Failure of fingers	Drop of plug/lid	Visual Loss of load on cable	Interlock prevents opening if cable is in load Mechanical design of grapple prevents it from opening in load	
12	Grapple lowering	(See 8)					

Table 8.1-11 Transfer Confinement Port/Shield and Lid/Plug Handling Subsystem (Cont.)

13	Shielded port cover closing	No closing	Failure of motor	Subsequent operation made impossible	Visual	Shielded port cover can be actuated manually	Anti-derailing device is designed to seismic event
			Lid/Shield plug handling hoist system sensors signal failure	Subsequent operation made impossible	Visual	Verify conditions via CCTV, bypass interlock	
		Partial closing	Failure of motor		Visual "closed" limit contact not activated	Shielded port cover can be actuated manually	
		Excessive movement	Upper shield port limit switch failure	Damage to equipment	Alarm		
		Untimely closing	Operating mistake Earthquake	Damage to plug/lid or cables	Visual	Interlock prevents port cover closing as grapple is not in "upper" position	

DER** = Dose Equivalent Rate FA* = Fuel Assembly

Table 8.1-12 Cameras and Related Lighting

	Function	Failure Modes	Most probable Failure Cause	Possible Failure Effect	Failure Detection	Compensating Provisions	Recommendations or Remarks
1	Cameras and related lighting	Loss of viewing by cameras	Malfunction of equipment, or components Power failure	Loss of video capability	Visual, in control trailer	Redundant cameras, redundant cabling. A 2 kW secondary power source available (specified in Section 4.3.2)	If both visual systems were to fail during postulated accident, supplementary cameras and lighting would need to be entered into the TCS. Visual confirmation is required for safe operation

Table 8.1-13 Port Cover Locking

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
TC Port Cover Locking / Unlocking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not engage	Mechanical or electrical failure of lock	TC Port Covers can collide with fuel assembly during a seismic event	Subsequent operations cannot be performed. Alarm	Shield Plug and Source Cask lid will be returned to casks, casks will be removed, and maintenance will be performed on lock after casks have been removed from the DTS.
		Signal failure from TC port cover limit switch or motorization status indicator	Subsequent operations cannot be performed	Alarm	Verify conditions via CCTV, bypass interlock.
	Erroneous unlocked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	Since lock is in the open position, fuel transfer can be completed. Access to the lock drive mechanism can be made through a penetration in the DTS wall to manually release the lock.
		Signal failure from fuel handling crane carriage motorization status indicator or fuel assembly handling sensors			Verify conditions via CCTV, bypass interlock.

Table 8.1-13 Port Cover Locking (Cont.)

Function	Failure Mode	Probable Cause	Possible effect	Failure Detection	Compensating Provisions
Upper shield port cover Locking / Unlocking	Erroneous locked position information transmitted to PLC	Spurious signal; sensor failure	Erroneous validation of a safety condition	Alarm	PLC checks consistency with pin unlocked position. Range of time to process the operation (minima and maxima) controlled by the PLC.
	Erroneous unlocked position information transmitted to PLC	Spurious signal; sensor failure	Subsequent operation made impossible		
	Lock will not engage	Failure of lock	potential loss of shielding due to a seismic event	Subsequent operations cannot be performed. Alarm	Jacks are located in the Roof Enclosure Area which can be accessed under controlled conditions for maintenance or repair. fuel assemblies would be moved into the casks, and the casks would be closed prior to entry.
		Signal failure of upper shield port limit switch	Subsequent operation made impossible	Visual, Alarm	Verify conditions via CCTV, bypass interlock
	Lock will not disengage	Mechanical or electrical failure of lock	TC Port Cover cannot be closed.	Alarm Subsequent operations cannot be performed.	
		Signal Failure of fuel assembly grapple sensors	Subsequent operation made impossible	Alarm	Verify Conditions via CCTV, bypass interlock.
		Signal Failure of Upper Crane Limit Switch	Subsequent operation made impossible	Alarm	Manual Repairs can be made in the Roof Enclosure Area

I. Failure of the Radiation Monitoring Equipment

The Radiation Monitoring Subsystem is designed to have two monitors in the Preparation Area, one monitor in the Lower Access Area, one monitor in the Transfer Confinement Area, one monitor in the Roof Enclosure Area, and one monitor in the HVAC Subsystem. Each monitor is equipped with a battery backup for loss of power and with audible and visible alarms indicating detector failure.

Redundancy does exist in the Radiation Monitoring Subsystem should one detector fail. Two monitors are located in the Preparation Area. If one of the three radiation monitors within the DTS structure (the Lower Access Area, the Transfer Confinement Area, and the Roof Enclosure Area) should fail then the remaining two are adequate for reading dose rates within the DTS until fuel handling is completed.

The Radiation Monitoring Subsystem, which includes the area radiation monitors and the airborne monitors, is designated as Not Important to Safety. There are no radiological consequences of a failure of the Radiation Monitoring Equipment.

J. Failure of Equipment in the Preparation Area

Repair and maintenance of equipment in the Preparation Area will be by "hands-on" means, once the casks have been removed from the area. There are no radiological effects due to failure of equipment in the Preparation Area.

K. Failure of Gearing in Drive Mechanisms

Except for the rotating platform pinion and ring gear couple, the failure of gear teeth (or other failure in component drive mechanisms which could result in locking up of a drive gear couple or train) that can prevent movement in any direction is accounted for in all systems by design provisions. The design of the linkage allows retrieval operation by forceful manual means or continued operation by redundant actuators. In the case of the rotating platform, should their gearboxes lock, the bridge or trolley can be forcefully dragged along their track, with locked wheels, while the rotating platform incorporates a slip coupling which allows its forceful manual rotation. Similarly, locking failure of the crud catcher actuator can be overridden to force it open by virtue of a mechanical release connection, described in revised Section 5.2.5. In the latter case, lock-up of any one of the fuel or upper crane grapple linear actuators will not prevent operation of the alternate actuator, since the actuators always transmit their load effectively through the normally locked non-operating actuator. Furthermore, the locked, or failed, TC port cover actuators can be remotely disengaged as described in Section 5.2.6.2.

Lock-up failure of the rotating platform due to pinion or ring gear failure is not considered to be a credible event because of the substantial over-sizing of the components relative to the normally very low rotational operating loads.

As long as a proper maintenance schedule (which includes lubrication of various bearings, motors and gear drives), is performed the gears on the various driving mechanisms will last the life of the DTS. All gears will be conservatively oversized for the intended application.

The only possible failure mode for the gears would be faulty manufacturing, which, in the case of the rotating platform pinion and ring gears, will be precluded by rigorous inspection requirements further verified by pre-operational testing.

As an added design feature, any gear drive mechanisms not totally enclosed will be provided with a cover to prevent entry of foreign objects that could cause rotating elements to jam.

8.1.2.2 Loss of External Power Supply for up to 24 hours

In the event of a power supply failure for a limited period of time, operations would normally cease until power is restored. Since fuel is shielded and confined at all times, there are no radiological effects of a short term loss of power.

The Radiation Monitoring Subsystem components have battery backup and the Control Subsystem has a battery backup which is used to save critical information such as sensor status, positioning information, etc.

Loss of power will result in the shut down of all components of the HVAC Subsystem. The confinement function of the HEPA filter bank continues to remain functional. The exhaust fans, the HEPA filter pressure monitoring system, and the exhaust air temperature monitoring system will be manually switched to the secondary power source.

There are no radiological effects due to a loss of power for a short period of time.

8.1.2.3 Heavy Snow Storm

Heavy snow storms result in loadings on the roof, weather protective cover and butler building. These have been designed for loads considerably greater than those expected from a heavy snow storm.

The stacks will be designed to ensure that snow and water do not drain into the DTS.

There are no radiological effects due to a heavy snow storm.

8.1.2.4 Lightning

Lightning is expected to occur regularly in the course of normal operation. Lightning arresters will be installed on the roof and/or the stack of the DTS to ensure that if the DTS is struck, minimal damage will result. No damage to the DTS structure will result. Lightning may result in a loss of power for a short period of time which is addressed in Section 8.1.2.2.

8.1.3 Radiological Impact from Off-Normal Operations

The radiological impact from Off-Normal Operations is expected to be minimal, since the DTS has been designed so that backup equipment is available for all operations which are performed remotely. All sensors which provide information on safety operations are also provided with backup sensors to verify that the operations are being performed in a safe manner.

The worker doses as a consequence of five specific potential failure scenarios that require personnel to be near the cask for an extended period of time to perform manual operations have been identified. The actions required for the specific failures and the subsequent corrective actions are described below for evaluation of worker doses. The five specific failures discussed are:

(i) Improper operation of shield plug and fuel assembly grapple,
(ii) Malfunction of cask mating system force cells,
(iii) Loss of cameras and associated lighting on the base of the transfer tube,
(iv) Failure of trolley position sensors, and
(v) Failure of trolley over travel switches.

(i) Improper operation of the shield plug and fuel assembly grapple.

The grapple used to lift the shield plug or lid is part of the Upper Crane located in the Roof Enclosure Area. During all of the off-normal conditions that affect the Upper Crane, the doses to workers performing corrective actions would essentially be at background levels. Some of the malfunctions that could affect the Upper Crane are provided below:

- The Lid / Shield Plug Grapple does not engage and lift the lid / shield plug. The Grapple would be retracted back to its housing in the Roof Enclosure Area. Operators would verify that both the TC Port Cover and Upper Port Covers are closed. Personnel could then enter the Roof Enclosure Area to repair the grapple. The openings of both the source and receiving casks would be shielded by the presence of the lid / shield plug, the TC port cover, and the Upper Port Cover. No direct shine from an open cask would be present in the Roof Enclosure Area, however, there is a potential for some scatter radiation. Prior to personnel entry to the Roof Enclosure Area for repair operations, Health Physics at the site would measure the dose rates and additional temporary shielding will be used if necessary.

- The Lid / Shield Plug Grapple engages and lifts the lid / shield plug but stops mid-lift while the TC Port Cover is open. Operators will verify that the other TC Port Cover is closed. Personnel would enter the Roof Enclosure Area and the grapple would be lowered manually to place the lid /shield plug back into the source / receiving cask. The grapple would then release the lid/shield plug and would be retracted to a point above the TC Port Cover. The TC Port Cover would be closed and then the grapple would be manually retracted above the Upper Port Cover. The Upper Port Cover would then be closed. Repairs on the Upper Crane would continue.

The workers have not been subjected to direct exposure to the fuel through an open port from any portion of this process. Similar to the previous description, some scatter radiation from the casks could be present in the Roof Enclosure Area.

- The Lid / Shield Plug Grapple engages and lifts the lid / shield plug but stop mid-lift while the TC Port Cover is closed. Personnel would enter the Roof Enclosure Area and would prepare to manually lower the lid/shield plug back into the source/receiving cask. Once workers are ready, the TC Port Cover would be opened. The lid/shield plug would be lowered into the source/receiving cask and released. Once the grapple clears the TC Port Cover and the Upper Port Cover, these covers would be closed to provide additional shielding to the workers. Workers will not be exposed to any direct exposure to the fuel through an open port from any portion of this process. However, some scatter radiation from the casks could be present in the Roof Enclosure Area.

- The Lid / Shield Plug Grapple does not disengage from the lid / shield plug. Operational steps are taken to either (1) lower the lid /shield plug back into the source / receiving cask or (2) lower the lid/shield plug back onto the TC port cover. Once in this position, an extension rod tool will be inserted through the appropriate penetration in the DTS wall to access the manual-actuation hex-drive of the grapple. The grapple will be manually disengaged from the lid/shield plug. Temporary shielding will be placed around the rod in the penetration and the CCTV system will be used to guide the tool to the grapple. There is no direct radiation to the worker from these operations, since the fuel in the cask is shielded by the lid/shield plug and/or the TC Port Cover, and the worker will not be performing direct viewing through the penetration. Doses are expected to be at background levels to workers at the side penetration since there are several layers of shielding (lid/shield plug, mezzanine plate, and concrete walls of the DTS). Once the grapple is disengaged, it will then be retracted to the Roof Enclosure Area and the Upper Port Cover will be closed. Once in this position, personnel will enter the roof enclosure area and repair/replace the grapple.

Worker will not be subjected to direct exposure from the fuel assemblies through any of the repair operation to the Upper Crane (including the Lid/Shield Plug Grapple). Operational measures will be taken to ensure that shielding always exists between the open cask and the worker. However additional measures will be taken to ensure that doses are as low as reasonably achievable during repair operations. For example, the equipment in the Roof Enclosure Area will be wiped or vacuumed to remove any loose contamination or lead blankets could be placed on the floor prior to performing any repair operation in this area.

The grapple used to lift the fuel assembly is part of the Fuel Handling Equipment. Discussion of the Fuel Assembly Handling System is provided in Section 5.2.6.4.

(ii) Malfunction of cask mating system force (load) cells

Malfunction of the cask mating system would be detected when the casks are either entering or exiting the lower access area. The malfunctions which could affect the cask mating system while a filled source / receiving cask is present are described below.

- The cask mating system will not lower for fit up with an entering receiving/source cask. The receiving and source casks would be removed from the Lower Access Area to the Preparation Area. Once in the Preparation Area, temporary shielding would be erected to reduce worker exposures.
  Health physics would enter the Lower Access Area and decontaminate the work area as necessary. Workers would then enter the Lower Access Area and repair the cask mating subsystem. Doses are expected to be around background levels.

- The cask mating system will not raise for a source/receiving cask leaving the facility. The only component which could have malfunctioned is one of the electrical screw jacks. Again should this component malfunction, health physics would enter the Lower Access Area first, perform any necessary decontamination and place temporary shielding as necessary to protect workers. From the control center, personnel will know which of the three electrical screw jacks is malfunctioning. Worker would use a ladder or scaffolding, remove the malfunctioning electrical screw jacks and replace it. Workers would then leave the Lower Access Area. The removed electrical screw jack could be repaired or disposed. Once personnel exit the Lower Access Area, the control room would continue with operations. The only dose would be direct radiation from a filled source/receiving cask. These operations are expected to take a total of 1 hour. The worker is expected to be near the top of a filled receiving cask removing and replacing the electric screw jack for about 30 minutes. The total dose to the worker during this off-normal operation is 70 mrem assuming temporary shielding is not used.

(iii) Loss of cameras and associated lighting on the base of the transfer tube.

The cameras and lighting system in the TCA are redundant. If one of the lights or cameras should fail, operations would be completed. The source and receiving cask would be closed and removed from the Lower Access Area. Health physics personnel would enter the Lower Access Area first with long handled cleaning tools (e.g. vacuum and wipes) and remove any loose contamination. Once decontamination is complete, personnel would be permitted to enter the TCA. The workers would remove and replace the affected equipment. Removed equipment could be repaired at a remote location. Doses to these workers would be minimal.

(iv) Failure of trolley position sensors & (v) failure of trolley over travel switches.

Failure of the trolley position sensors and failure of the trolley over travel switches would not require personnel to be near the cask for an extended period of time performing manual operations. Two possible malfunctions could occur with the source / receiving cask trolleys.

- Failure of the trolley position sensors and failure of the trolley over travel switches in the Preparation Area. Two possible corrective actions could take place:

  1. The source and receiving casks would be removed from the trolley and placed in the Preparation Area away from the trolley and its rails. Additional temporary shielding could be placed around the cask while workers are fixing the sensors/over travel switches thereby minimizing worker doses.

2. The source and receiving casks could be moved and locked into place in the Lower Access Area.

   The sliding doors to the Lower Access Area could be closed while workers are performing repairs in the Preparation Area thereby minimizing worker doses.

- Failure of the trolley position sensors and failure of the trolley over travel switches in the Lower Access Area. The source and receiving casks would be moved out of the Lower Access Area to the Preparation Area. Once in the Preparation Area the casks could be either locked in place or removed from the trolleys. Again, additional temporary shielding could be placed around the cask while workers are performing repairs in the Lower Access Area.

In either case, steps will be taken to minimize worker exposures. The time required for personnel to be near a loaded cask will be minimized.

Estimated doses due to such off-normal operations will be provided on a site-specific basis.

Figure 8.1-1

Transfer Confinement Area Equipment Heat Loads

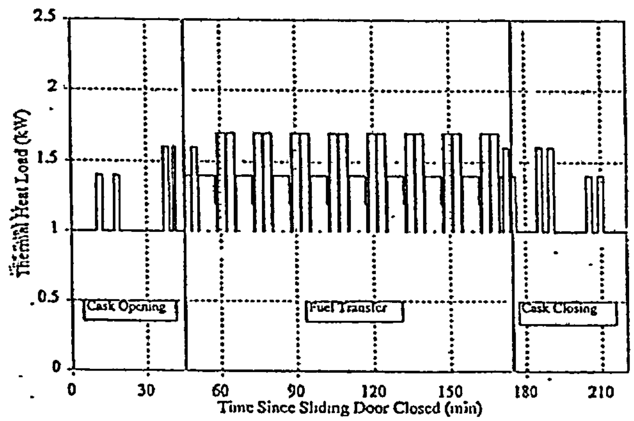


Figure 8.1-2

**Roof Enclosure Area
Equipment Heat Loads**

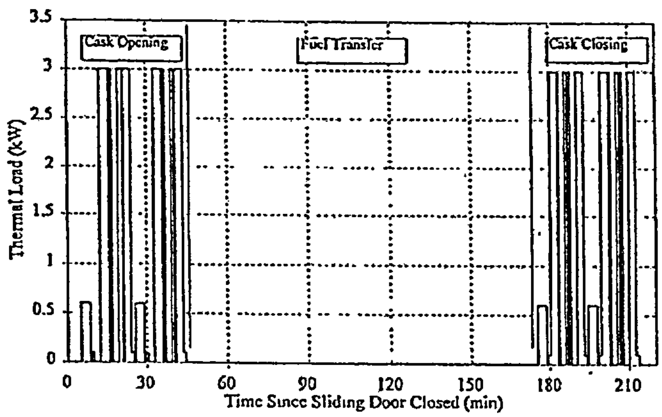
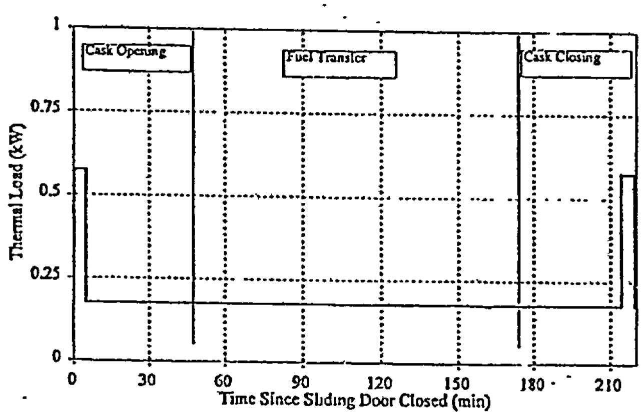


Figure 8.1-3

**Lower Access Area
Equipment Heat Loads**



8.2 Accidents

Category III events are infrequent events that are postulated to occur once in the life of the DTS. Category III events shall not result in radioactive releases to the personnel, the public or the environment which exceed limits for radiological effects in accidental conditions. A category III event may result in a long interruption in operations. The following category III events are evaluated.

- A loss of external power supply for an extended interval.
- Stuck fuel assembly or inability to insert a fuel assembly into a cask.
- Failure of the fuel grapple to disengage.

Category IV events are those events that are unlikely to occur, but are postulated because their consequences may result in the maximum potential impact on the immediate environs. These events are anticipated to occur less than once during the lifetime of the DTS. Category IV events shall not result in radioactive releases to the personnel, the public or the environment which exceed limits for radiological effects in accidental conditions. The following category IV events are evaluated.

- Seismic Event.
- Tornado missiles, hurricanes and high winds.
- Fire.
- Major mechanical malfunction involving the spent fuel handling system during operation resulting in dropping of a fuel assembly.
- Complete loss of HEPA filters and loss of pressure differential
- Loss of a shield plug or source cask lid (either by damage or inability to be placed on the cask)
- Electrical surges and explosions.

8.2.1 Loss of External Power for an Extended Interval

In the event of loss of the primary electrical power for an extended interval, the DTS would be shut down in the safest configuration. The secondary power source would be manually switched on-line to provide power to the following equipment:

HVAC subsystem exhaust fans and motorized dampers;
DTS operating equipment (excluding the receiving cask trolley, which requires 15 kW of power. The HVAC subsystem could be shut down for a short period of time to operate the receiving cask trolley);
Control Subsystem equipment; and
CCTV and Lighting Subsystem equipment.

The CPU (Central Processing Unit) of the Control Subsystem would automatically switch to a battery back up to prevent any loss of information until secondary power is provided. The radiation monitors and the emergency lighting will automatically switch to battery backup as well.

If fuel was being transferred, the fuel assembly would be lowered into the nearest cask by the secondary hoist system which is operated on the secondary power supply. The grapple would be disengaged using the secondary grapple electrical drive system. The source cask lid and the receiving cask shield plugs would be replaced on the casks. The casks would then remain in the Lower Access Area until power could be restored. The HVAC exhaust fans and motorized dampers are run to ensure that the fuel pin cladding temperature remains below acceptable limits.

If the power outage extends beyond several weeks, the sliding door would be connected to the emergency power supply and opened. The cask would be brought into the Preparation Area and inerted. Portable equipment (e.g. a generator) can be brought to the DTS to perform cask inerting operations. If primary power is restored in a shorter period of time, these operations are not necessary.

There are no radiological implications of this event since the fuel can be brought to a safe, well shielded condition.

8.2.2 Stuck fuel assembly or inability to insert a fuel assembly into a cask

A stuck fuel assembly or the inability to insert a fuel assembly into a cask would increase the site boundary dose due to increased time of operations with the fuel assembly in the TCA.

There are several measures which have been taken in the design of the system to make this potential accident extremely unlikely, such as load sensors on the hoisting device which automatically stop motion if the load is greater than or less than the expected load, sufficient clearance and lead-ins for the transfer tube, interlocks which prevent movement of the fuel handling equipment in the X, Y or θ directions if the fuel assembly is not in the full up position and acceptance of only structurally intact fuel.

If, despite the preventative measures taken, the fuel assembly still becomes stuck, special recovery procedures would be followed to free the assembly. These would include carefully monitoring the lifting or lowering load, jogging the fuel hoist in both directions to free the assembly, using special equipment through the penetrations in the TCA wall to free foreign material, etc. The CCTV cameras on the fuel handling subsystem and on the walls of the TCA allow full viewing of recovery operations.

Since the fuel assembly may be in the TCA for an extended period of time, the dose at the site boundary could increase.

If a fuel assembly is stuck part way out, the bridge, trolley and rotating platform are unable to move since the fuel grapple is not in the full upright position.

The fuel assembly would be lowered back into the cask. This scenario could either result from a foreign object being jammed between the fuel assembly and the fuel cell, or if there are protrusions on the inside of the cask which could result in the fuel assembly getting caught. The fuel assembly load cell would automatically stop movement if abnormal loads are encountered while lifting the fuel assembly. Using bypasses, the fuel would be slowly lowered back into the cask. If the fuel will move neither up or down, through administrative control and the use of bypasses, the load cell limit could be increased to allow additional force to lift the assembly. It may be necessary to jog the fuel assembly from side to side. This is recommended as a last resort only.

There is no time limit in which to free the assembly, since the fuel is shielded and provided that the HVAC System is working, fuel cladding temperatures will remain well below the temperature at which fuel cladding failure would occur.

If a fuel assembly has become so bowed or distorted that it cannot be inserted into either the source or receiving cask, but is free from both casks, a special "recovery" cask would need to be provided to contain the damaged fuel. This could be a source cask with an oversized basket. The fuel assembly would be moved laterally, as far away from the sliding door as possible. A fully shielded tent would be built in the Preparation Area, enclosing the sliding door and providing enough room to completely enclose the source cask and its trolley. The Preparation Area and all surrounding areas would be evacuated.

The lid would be placed on the source cask. The source cask may have fuel assemblies in it. The source cask would be disengaged from the cask mating subsystem and the trolley would be unlocked. These operations would be done remotely, without entering the Lower Access Area. Using bypasses, the sliding door would be opened. Radiation levels outside and inside of the shielding tent would be carefully monitored. The source cask and the trolley would be moved into the shielding tent, and the sliding door would be closed. These operations would also be performed remotely.

Using the standard operating procedures, the source cask would be bolted, tested, inspected and removed from the DTS. After the source cask is unloaded from the trolley, the recovery cask would be placed onto the source cask trolley and secured. The recovery cask and trolley would be moved into the shielding tent. While carefully monitoring radiation levels in and around the shielding tent, the sliding door would be opened. The recovery cask would be moved into the Lower Access Area and positioned below the source cask mating subsystem. These operations would be performed remotely. The lid of the recovery cask would be removed, and the damaged fuel assembly would then be loaded into the recovery cask.

If a fuel assembly is stuck in the upright position, the maximum expected dose rates around the DTS structure would be the same as calculated in Section 7.3.2 and illustrated in Figures 7.3-2 and 7.3-3.

Assuming the assembly remains stuck for two weeks (336 hours), the off site maximum dose rates at various distances from the DTS are provided in Table 8.2-1.

Table 8.2-1

Radiological Consequences from a Stuck Fuel Assembly

Distance from DTS	Direct Dose Rate[1]	Skyshine[2]	Total Dose Rate	Total Dose
100 m (328 ft)	0.12 mrem/hr (0.0012 mSv/hr)	1.6E-02 mrem/hr (1.6E-04 mSv/hr)	1.4E-01 mrem/hr (1.4E-03 mSv/hr)	47 mrem (0.47 mSv)
200 m (646 ft)	2.8E-02 mrem/hr (2.8E-04 mSv/hr)	3.6E-03 mrem/hr (3.6E-05 mSv/hr)	3.2E-02 mrem/hr (3.2E-04 mSv/hr)	11 mrem (0.11 mSv)
500 m (1640 ft)	4.7E-03 mrem/hr (4.7E-05 mSv/hr)	2.8E-04 mrem/hr (2.8E-06 mSv/hr)	5.0E-03 mrem/hr (5.0E-05 mSv/hr)	1.7 mrem (0.017 mSv)

1 Assuming the face of the DTS building with the highest dose rates (the side with the sliding door) is facing the boundary.

2 Assuming the assembly is stuck while the Receiving Cask filled with 21 assemblies.

The results of this analysis shows that the total dose at the site boundary (at least 100 meters from the DTS) is 47 mrem (0.47 mSv) which is less than the design basis accident dose allowable of 5 Rem (50 mSv). This analysis is based on freeing the stuck fuel assembly within 2 weeks.

8.2.3 Failure of the fuel grapple to disengage

Two independent grapple activation mechanisms with independent power lines are provided to prevent the fuel grapple from becoming stuck in the engaged position. In addition, extensive testing prior to and after installation of the grapple is required to ensure that the likelihood of this event is extremely low. If the grapple were to fail, fiberscopes or other special viewing devices would be lowered into the DTS through penetrations in the roof plate. Special procedures and special tools would be required to deactivate the grapple.

There is no significant increase in the site boundary doses since the fuel assembly would be in the shielded cask.

The dose rates to workers would be evaluated prior to recovery operations.

After recovery, no fuel transfer would occur until a complete check out and repair of the fuel grapple was performed.

8.2.4 Seismic Event

The concrete structure of the DTS is designed to safely withstand the seismic event, but depending on the severity of the event, the DTS may not return to normal operations. The DTS concrete structure is designed to withstand the seismic event without collapsing. In addition, the structure has been analyzed to ensure that the seismic loadings on specific operating equipment will not cause the equipment to become projectiles. The fuel handling crane and the upper crane are designed so that they will not drop their load due to the seismic event. The following subsections address the seismic event as related to the specific structure, the HVAC Subsystem, the Major Operating Subsystems and the Control Subsystem.

8.2.4.1 Seismic Effects on Structure

DTS Concrete Structure

Seismic loads have been evaluated for the reinforced concrete structure including the base mat, the weather protective cover, the roof plate, the mezzanine plate and the sliding door. The structure is designed to withstand seismic loads due to the SSE without collapse. The seismic analysis of the structure is fully described in Appendix 8A.1. The analysis is summarized below.

The seismic analysis of the DTS assumes that the structure is founded on competent rock. In this circumstance, the phenomenon of Soil Structure Interaction (SSI) in which there is dynamic interaction between the structure and supporting soil medium need not be considered. Furthermore the structure can be analyzed as fully fixed at the base of the shear walls at the top of the basement.

The DTS structure is a relatively stiff shear wall structure of reinforced concrete supporting equipment on two flexible internal structural steel floors. In common with normal practice, equipment and internal structural steel floors are assumed not to contribute to the stiffness of the supporting reinforced concrete structure.

The structure has been modeled for seismic analysis purposes using the computer code ANSYS. Rigid equipment is generally represented as lumped translational masses. Internal floors (including the roof plate and mezzanine plate) which support major equipment are flexible in the vertical direction and have been represented as structural beam elements supporting vertical mass elements representing equipment, self weight, and floor imposed loading.

All reinforced concrete walls have been represented by four-node shell elements with elastic material properties based on gross uncracked concrete sections. Walls have been modelled at center line locations throughout the model.

A fixed base modal analysis technique was used to predict the structure response (in terms of acceleration) to the design earthquake input motion. A damping level of 7% was used which reflects the overall damping in a reinforced concrete structure stressed to levels approaching yield at the SSE.

A separate modal analysis has been carried out for each earthquake direction. The results from the 3 runs were combined using the square root sum of the squares method (SRSS). Results for individual earthquake direction analysis have been combined using the Complete Quadratic Combination technique (CQC).

Results from the modal analysis are as follows:

- Mode shapes, frequencies and mass participation factors for all structure modes of vibration up to approximately 50 Hertz.

- Zero period accelerations (rigid body accelerations) at selected locations throughout the structure. These represent the maximum acceleration response at the locations in 2 horizontal and the vertical translational directions on the structure.

Zero period accelerations are subsequently adjusted manually by adding base input accelerations by SRSS to correct for:

- Dynamic mass missing from the modes considered and

- Base input motion constant acceleration profile.

These corrected zero period accelerations are used for structure design purposes and as a starting point for estimating secondary response spectra for equipment design.

The detailed calculations and results of the structural design are described in Appendix 8A.1, and the stresses are within allowables.

An analysis is also performed to establish the worst case factor of safety against overturning of the DTS building. The overturning moment is 62,755 kNm (555,434 in-kip) and the stabilizing moment is 144,205 kNm (1,276,333 in-kips). The result of this analysis indicates that the DTS building will not overturn during a seismic event. The margin of safety against overturning is 2.3. Summaries of the results are provided in Tables 8.2-2, 8.2-3, and 8.2-4.

Stresses in the concrete are less than the tensile limit, ignoring the additional tensile strength contributed by the rebar. Minor concrete cracking may result at particularly highly stressed locations, but the reinforcement would still be only lightly loaded and will prevent collapse. Stresses in the steelwork are considerably less than the allowable stresses.

The SSE causes no damage to the building structure which might lead to release of radioactivity.

Table 8.2-2 Summary of Stresses In Concrete Structures Due to Various Loads

Critical Component	Maximum Stresses					Maximum Stresses due to Tornado Loads (Wt)						
	Dead Load (D)	Live Load (L)	Wind Load (W)	Thermal Load (Ta)	SSE Seismic Load (Ess)	Tornado Wind (Ww)	Tornado Differential Pressure (Wp)	Tornado Missile* (Wm)	Ww+0.5Wp	Ww+Wm	Ww+0.5Wp +Wm
Wall at Base (ele. 0.0")											
Max. Axial Stress compressive (+) (psi.)	73.35	8.59	13.39	-	236.10	77.10	79.62	123.0	116.90	200.10	239.90
Max. Axial Stress Tensile (-) (psi.)	-	-	-13.39	-	-236 10	-77.10	-79.62	-123.00	-116 90	-200.10	-239.90
Max. in-plane shear stress (psi)	-	-	8 39	-	86.0	48.34	51.44	47 7	74.1	96.0	121.8
Critical Wall Panel											
Max. out-of-plane beam shear stress (psi)	-	-	1.94	-	4.06	11.17	15.60	156 0	18.95	166.2	173 95
Max. punching shear stress (psi)	-	-	-	-	-	-	-	139 0	-	139 0	139.0
Max. out-of-plane moment at ends. (Kip-in/ft)	-	-	49 2	1909 8	283.40	283.1	353.4	1297.0	459.8	1580.1	1756.8
Max. out-of-plane moment at midspan. (Kip-in/ft)	-	-	24.6	1909 8	141.70	141 6	176.7	2619.3	230 0	2760.9	2849.3
Total horizontal load in wall panel (Kips)	-	-	28.7	-	165.5	165.3	206.3	704	268.5	869.3	972.5
Foundation Mat											
Max. foundation bearing pressure along long edge (psf)	2170	416	+/-142.3	-	+/-2135	+/-820	+/-850	+/-1233	+/-1245	+/-2053	+/-2478
Max. foundation bearing pressure along short edge (psf)	847	261	+/-71.8	-	+/-1070	+/-413	+/-429	+/-842	+/-628	+/-1255	+/-1470
Max. shear stress along longitudinal face (psi)	17.18	2 01	1.7	-	25 8	9.9	10.3	14 9	15.1	24.8	30.0
Max. shear stress along transverse face (psi)	12 8	1.5	1.8	-	26.1	10.1	10.5	20.5	15.4	30.6	35.9
Max. cantilever moment along longitudinal face (Kip-in/ft)	1440	169	145	-	2165	831	863	1250	1263	2081	2512
Max. cantilever moment along transverse face (Kip-in/ft)	1633	194	294	-	4368	1687	1751	3438	2563	5125	5999
Max. moment for internal slab (Kip-in/ft)	450	53	45	-	677	260	270	391	395	651	786
Min. factor of safety against sliding	-	-	28.52	-	1.19	4.72	4.70	5.07	3.14	2.44	1.94
Min. factor of safety against overturning	-	-	32.14	-	2.32	5.32	5.43	3.75	3.57	2 20	1.83

Table 8.2-3 Summary of Stresses In Concrete Structures Due to Applicable Combinations

Critical Component	1.4D+1.7L	1.4D+1.7L +1.7W	D+L+Ess	D+L+Wt	D+L+Ta	D+L+Ta+Ess	1.05D+1.3L +1.05Ta	1.05D+1.3L +1.3W+1.05Ta	allowable values
Wall at Base (ele. 0.0")									
Max. Axial Stress compressive (+) (psi.)	117.3	140.1	318.0	321.84	81.9	318.0	88.37	105.8	1785.0
Factor of safety	15.22	12.74	5.61	5 55	21.78	5.61	20.20	16 87	
Max. Tensile Stress In Re-bars (Ksi.)	-	-	17.44	18.83	-	17.44	-	-	60.0
Factor of safety			3 44	3.19		3.44			
Max. in-plane shear stress (psi)	-	14.3	86.0	121.76	-	86.0	-	10.9	93.1
Factor of safety		6.51	1.08	0 80*		1.08		8.54	
Critical wall panel									
Max. out-of-plane beam shear stress (psi)	-	3.3	4.06	173.95	-	4.1	-	2.52	93.1
Factor of safety		28 21	22.93	.54*		22.93		36.94	
Max. punching shear stress (psi)	-	-	-	139.0	-	-	-	-	186.2
Factor of safety				1.34					
Max. out-of-plane moment at ends (Kip-in/ft)	-	83.64	283.4	1756 8	1909.8	2193.2	2005.3	2069.0	3202
Factor of safety		38.28	11.30	1.82	1.68	1.46	1.60	1.55	
Max. out-of-plane moment at midspan (Kip-in/ft)	-	-	141.7	2849 3	1909.8	2051.5	2005.3	2029.9	3202
Factor of safety			22.60	1.12	1 68	1.56	1.60	1.58	
Total horizontal load in wall panel (Kips)	-	48.79	165.5	972.5	-	165.5	-	37.3	3354
Factor of safety		68.74	20.27	3.45		20.27		89.92	

(Allowable values are based on ultimate strength design for reinforced concrete structure ACI 318-95 Code)
Factor of safety = Allowable value / Calculated value
*Factor of safety < 1.0 indicates that there will be local shear cracks in the vicinity of tornado missile impact location. However, there will not be any missile punching or collapse of the wall as indicated by factor of safety > 1.0 for punching shear stress, out-of-plane moment, and total horizontal load.

Table 8.2-3 (continued)

Summary of Stresses in Concrete Structures Due to Applicable Combinations									
Critical Component Foundation Mat	**1.4D+1.7L**	**1.4D+1.7L +1.7W**	**D+L+Ess**	**D+L+Wt**	**D+L+Ta**	**D+L+Ta+Ess**	**1.05D+1.3L +1.05Ta**	**1.05D+1.3L +1.3W+1.05Ta**	**allowable values**
Max. foundation bearing pressure along long edge (psf)	3745	3987	4721	5064	2586	4721	2819	3004	-
Max. foundation bearing pressure along short edge (psf)	1630	1388	2178	1950	1108	2178	1229	1322	-
Max. shear stress along longitudinal face (psi)	27.5	30 4	45.0	49.2	19.2	45.0	20.7	22.9	93.1
Factor of safety	3.4	3.1	2.1	1.9	4.8	2.1	4 5	4.1	
Max. shear stress along transverse face (psi)	20.5	23.5	40.4	44.9	14.3	40.4	15.4	17.7	93.1
Factor of safety	4.5	4.0	2.3	2.1	6.5	2.3	6.0	5.3	
Max. cantilever moment along longitudinatal face (Kip-in/ft)	2303	2548	3774	4121	1609	3774	1732	1919	5686
Factor of safety	2.5	2.2	1.5	1.4	3.5	1.5	3.3	3.0	
Max. cantilever moment along transverse face (Kip-in/ft)	2616	3116	6195	6952	1827	6195	1967	2349	10984
Factor of safety	4.2	3.5	1.8	1.6	6 0	1.8	5.6	4.7	
Max. moment for internal slab (Kip-in/ft)	683	756	1118	1289	477	1118	513	569	5686
Factor of safety	8.3	7.5	5.1	4.4	11.9	5.1	11.1	10.0	
Min. factor of safety against sliding	-	16.78	1.19	1.94	-	1.19	-	21.9	1.11
Min. factor of safety against overturning	-	18.91	2.32	1.83	-	2.32	-	24.7	1.5

Factor of safety = Allowable value / Calculated value

Source: Appendix 8A.1

Roof Plate

The maximum calculated seismic accelerations for the roof plate are 0.77g horizontally and 0.4g vertically. An analysis using these seismic loads shows that the roof plate will not lift off of the support beam. The resulting stresses in the support beam due to the vertical seismic loads are also determined and included in the appropriate load combinations. The results show the maximum combined stress of 12,390 psi (85.4 MPa) which is much less than the allowable stress of 40,300 psi (278 MPa). For the load evaluation of the roof plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.77g is assumed to be resisted by the one hundred and ten (110) - 5/8"(16 mm) bolts. The maximum shear stress in the bolt is 6,010 psi (41.4 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa). This analysis is presented in Appendix 8A.1.

Protective Cover.

The protective cover is analyzed in Appendix 8A.1. The seismic loadings do not result in stresses which would result in a loss of confinement.

Mezzanine Plate

The maximum calculated seismic accelerations for the mezzanine plate are 0.5g horizontally and 0.7g vertically. With the mezzanine plate bolted to the support beam, the beam stresses due to the resulting 0.7g vertical acceleration are calculated by factoring the normal operating condition load analysis results reported in Section 8.1.1.5. The maximum combined beam stress obtained from this analysis is 38,250 psi (263.7 MPa) which is less than the allowable stress of 44,160 psi (304.4 MPa). For the load evaluation of the mezzanine plate due to seismic accelerations in the lateral direction, the resulting equivalent acceleration of 0.5g is assumed to be resisted by the sixty three (63) - 5/8" (16 mm) bolts, the shear stress in the bolt is 2,630 psi (18 MPa) which is less than the allowable shear stress of 52,500 psi (362 MPa). This analysis is presented in Appendix 8A.1.

Table 8.2-4a Summary of Stresses in Steel Structures Due to Various Loads							
			Maximum Stresses (ksi)				
Critical Component	Location	Type of Stress	Dead Load (D)	Live Load (L)	Wind Load (W)	Thermal Load (Ta)	SSE Seismic Load (Ess)
Protective Cover						N.A.	
Roof Panel (1.5"PL.)	Midspan of Panel	Bending	0.65	2.61	0.14 / -0.77	-	0.26
Roof Support Beams (W12x120)	Midspan of Beam	Bending	3.53	10.19	0.54	-	1.41
Wall Panel (1.5"PL.)	Midspan of Panel	Bending	-	-	0 83	-	0.63
	Edge of Panel	Shear	-	-	0.03	-	0.12
Support Columns (W12x120)	Midspan of Column	Axial/Bending	0.38	0.53	1.40	-	1.26
1"Diam. Anchor Bolts for 1.5"PL.	-	Shear	-	-	0.25	-	1.12
		Axial (+Tensile)	-0.85	-0 15	0.14	-	1.23
Roof Plate							
7" PL.	Midspan of Panel	Bending	0.21	0.15	0.01	-	0 08
Support Beams (W14x550)	Midspan of Beam	Bending	2.15	1.16	0.06	-	0.86
5/8" Diam. Anchor Bolts	-	Shear	-	-	-	-	12.55
Mezzanine Floor							
1 5" PL.	Midspan of Panel	Bending	3.48	4.99	0.26	-	2.43
Support Beams (W12x120)	Midspan of Beam	Bending	7 06	9 19	0 49	-	4.94
5/8" Diam. Anchor Bolts	Midspan of Panel	Shear	-	-	-	-	24.79

Table 8.2-4a (continued)

Critical Component	Location	Type of Stress	Maximum Stresses due to Tornado Loads (Wt) Tornado Wind (Ww)	Tornado Differential Pressure (Wp)	Tornado Missile*(Wm)	Ww + 0.5Wp	Ww + Wm	Ww+ 0.5Wp + Wm
Protective Cover								
Roof Panel (1.5"PL)	Midspan of Panel	Bending	0.8 / -4 43	-4.52	-	.8 / -6 69	0.8 / -4.43	.8 / -6.69
Roof Support Beams (W12x120)	Midspan of Beam	Bending	3.11 / -17.26	-24.34	-	3.11 / -29.43	3.11/-17.26	3.11 / -29.43
Wall Panel (1.5"PL.)	Midspan of Panel	Bending	4.78	5.67	-	7.62	4.78	7.62
	Edge of Panel	Shear	0.15	0.15	-	0.23	0.15	0.23
Support Columns (W12x120)	Midspan of Column	Axial/Bending	8.07	9.57	-	12.86	8 07	12.86
1"Diam. Anchor Bolts for 1.5"PL.	-	Shear	1.41	1.40	-	2.11	1.41	2.11
		Axial (+Tensile)	0.78	0.77	-	1.17	0.78	1.17
Roof Plate								
7" PL.	Midspan of Panel	Bending	0.05	-	-	0.05	0.05	0.05
Support Beams (W14x550)	Midspan of Beam	Bending	0.40	-	-	0.40	0.40	0.40
5/8" Diam. Anchor Bolts	-	Shear	-	-	-	-	-	-
Mezzanine Floor								
1.5" PL.	Midspan of Panel	Bending	1.52	-	-	1.52	1.52	1.52
Support Beams (W12x120)	Midspan of Beam	Bending	2.78	-	-	2.78	2.78	2.78
5/8" Diam. Anchor Bolts	Midspan of Panel	Shear	-	-	-	-	-	-

*Maximum depth of penetration for tornado generated missiles in horizontal and vertical directions are 0.64" and 0.40 " respectively. These depths of penetration are less than the available thickness of 1.5" of the cover plate. External Kinetic energy will be absorbed in the elastic/plastic deformation of the missile and target structure. Maximum stresses in the vicinity of the impact will exceed the yield stress value. However due to the unibody type of construction, there will not be any collapse of the protective cover plate structure.

Table 8.2-4b Summary of Stresses in Steel Structures Due to Various Load Combinations

Critical Component	Location	Type of Stress	Maximum Stresses (ksi)						
			D+L	D+L+W	Allowable Stress 'S'*	D + L + Wt	D + L + Ess /D+T+Ta+Ess	D+L+Ta	Allowable Stress MIN('1.6S', Fy**)
Protective Cover									
Roof Panel (1.5"PL.) Factor of safety	Midspan of Panel	Bending	3.26 8 28	3.40 7.94	27.00 -	4.06 8.87	3.52 10.23	3.26 11.04	36.00
Roof Support Beams (W12x120) Factor of safety	Midspan of Panel	Bending	13.72 1.75	14.26 1 68	24.00 -	16.83 / -25.90 #VALUE!	15.13 2.38	13.72 2 62	36.00
Wall Panel (1.5"PL.) Factor of safety	Midspan of Panel	Bending	- -	0.83 32.53	27.00 -	7.62 4.72	0.63 57.14	- -	36.00
Wall Panel (1.5"PL.) Factor of safety	Edge of Panel	Shear	- -	0.03 480.00	14.40 -	0.23 100.17	0.12 192.00	- -	23.04
Support Columns (W12x120) Factor of safety	Midspan of Panel	Axial/Bending	0.91 26.37	2.31 10.39	24.00 -	13.77 2 61	2.17 16.59	0.91 39.56	36.00
1"Diam. Anchor Bolts for 1.5"PL. Factor of safety	-	Shear	- -	0.25 85 00	21.25 -	2.11 16.11	1.12 30.36	- -	34.00
1"Diam. Anchor Bolts for 1.5"PL. Factor of safety		Axial (+Tensile)	-1.00 -41.66	-0.86 -48 44	41.66 -	0.17 392.09	0.23 289.81	-1.00 -66.66	66 66
Roof Plate									
7" PL. Factor of safety	Midspan of Panel	Bending	0.36 75.00	0.37 72.97	27.00 -	0.41 87.80	0.44 81.82	0.36 100.00	36.00
Support Beams (W14x550) Factor of safety	Midspan of Beam	Bending	3.31 7.25	3.37 7.12	24.00 -	3.71 9.70	4.17 8.63	3.31 10.88	36 00
5/8" Diam. Anchor Bolts Factor of safety	-	Shear	- -	- -	15.00 -	- -	12 55 1.91	- -	24.00
Mezzanine Floor									
1.5" PL. Factor of safety	Midspan of Panel	Bending	8.47 3.19	8.73 3.09	27.00 -	9.99 3.60	10.90 3.30	8.47 4.25	36.00
Support Beams (W12x120) Factor of safety	Midspan of Beam	Bending	16.25 1.48	16.74 1.43	24.00 -	19.03 1.89	21.19 1.70	16.25 2.22	36.00
5/8" Diam. Anchor Bolts Factor of safety	Midspan of Panel	Shear	- -	- -	21.25 -	- -	24.79 1.37	- -	34.00

* 1.0S is allowable stress based on AISC Manual of Steel Construction, ninth edition.
** Fy is yield stress of material.
Factor of safety = Allowable value / Calculated value

Source: Appendix 8A.

Sliding Door

The maximum calculated seismic accelerations for the sliding door are 0.7 g vertically, 0.37 g longitudinally, and 0.5 g laterally. With the sliding door hanging on the support rails, the door stresses due to the resulting 0.7 g vertical acceleration are calculated by factoring the dead load analysis results reported in Section 8.1.1.6. The maximum combined door shell stress obtained from this analysis is 180 psi (1.24 MPa). For the stress evaluation of the sliding door due to seismic acceleration in the lateral direction, the resulting equivalent static acceleration of 0.5 g is assumed to be resisted by four (4) - 2"(508 mm) dia. pin. The local bearing stresses of the sliding door at the support pin locations are calculated to be 483 psi (3.33 MPa). For the stress evaluation of the sliding door due to seismic acceleration in the longitudinal direction, axial retainers are included in the design of the sliding door support system to prevent pulling off the door in the axial direction during a postulated seismic event. For a longitudinal load, the stresses induced in the sliding door due to the restraining action of these support rails are evaluated and found to be negligible.

Preparation Area

The Preparation Area structure is not designed to withstand the seismic event. However, since it does not provide shielding or confinement, there are no radiological consequences of losing the Preparation Area structure. Heavy load drops initiated by seismic events or crane failures (e.g. lid drops) will be evaluated to show no fuel failure or significant particulate releases occur on a site specific basis (specific cask designs will be evaluated for the postulated drops).

There are no immediate radiological consequences of losing the Preparation Area structure. The trolleys are designed to prevent tipover of the casks and the trolleys due to the design basis SSE. The Preparation Area can be rebuilt by conventional means if the DTS is to return to normal operation. The concrete base mat is designed to withstand the seismic event.

8.2.4.2 Seismic Effects on HVAC Subsystem

Loss of any of the ventilation components (not the cooling system components) of the HVAC Subsystem results in a loss of the additional level of confinement provided by the system. The physical boundary consisting of the DTS concrete structure, the sliding door, weather protective cover and the HEPA filtration units will continue to provide confinement of radioactive particulate. The duct work associated with the HEPA filtration units will be seismically restrained. It is extremely unlikely that the duct work, filtration system or both exhaust fans will be rendered inoperable during a seismic event.

Failure of both ventilation and cooling system would cause the active cooling process to be disrupted and results in the DTS attempting to re-establish its thermal equilibrium based on passive cooling only.

Because of the large thermal mass and inertia of the DTS system: i.e. equipment (76,800 lbs, 34,700 kg); sliding door (85,000 lbs, 38,600 kg); mezzanine floor and its support beams (33,500 lbs, 15,100 kg); roof plate and its support beams (223,600 lbs, 101,400 kg); source cask (60,000 lbs, 27,200 kg); and receiving cask (250,000 lbs, 113,100 kg); the temperature response is very slow. The adiabatic temperature rise in the DTS with the design heat load of 15.5 kW is about 0.68°F (0.38°C) per hr. The actual temperature rise will be considerably less due to heat dissipation through the sliding door, the steel roof plate and the concrete structure.

A qualitative assessment of the steady state temperatures within the DTS was performed using the following assumptions:

- Fuel decay heat load of 15.5 kW
- Ambient temperatures of 115 °F
- Insolation is applied to the protective cover and concrete walls
- Heat is dissipated from the outer surfaces of the protective cover and concrete walls via natural convection and radiation to the ambient
- Radiation heat transfer between the roof plate and protective cover, the mezzanine plate and the roof plate, and the mezzanine plate and the concrete walls in the TCA.
- Within the LAA, the cask dissipates heat via natural convection and radiation to the mezzanine plate, sliding door, and concrete walls.

The qualitative assessment of temperatures within the Dry Transfer System is performed by an iterative heat balance evaluation, and by making simplifying assumptions for a receiving cask. Initial estimates of the amount of heat from the fuel assemblies that reaches the Roof and Transfer Confinement Areas were made. From the amount of heat entering the roof area, temperatures within it were determined. A mezzanine plate temperature was then determined that results in heat dissipated into the roof plate and TCA concrete walls equal to the heat travelling upwards into the TCA from the fuel. The validity of the amount of heat reaching the Roof Area is then checked using an iterative process.

From the mezzanine plate temperature, an average receiving cask temperature was determined that results in heat transfer to the mezzanine plate equal to the initial estimate. The amount of heat reaching the sliding door and concrete walls in the Lower Access Area was then found. The total heat transfer out of the DTS was then checked against the decay heat load of the fuel.

Heat transfer from the outer surfaces of the DTS was modeled as natural convection and radiation to the bounding ambient temperatures of -20°F and 115°F. Insolation was applied to the concrete walls and protective cover. Only radiation heat transfer was considered between the roof plate and protective cover, the mezzanine plate and surfaces within the TCA, and between the receiving cask and the sliding door and concrete walls. Natural convection and radiation heat transfer between the receving cask and mezzanine plate are considered.

The following qualitative estimates for temperatures within the DTS are made from the above assessment:

Equipment Temperature within the Roof Protective Area	
conservative estimate	134 °F
optimistic estimate	131 °F
Equipment Temperature within the Transfer Confinement Area	
conservative estimate	179 °F
optimistic estimate	156 °F
Equipment Temperature within the Lower Access Area	
conservative estimate	182 °F
optimistic estimate	172 °F
Fuel Cladding Temperature in Cask	
conservative estimate	647 °F
optimistic estimate	575 °F
Fuel Cladding Temperature of Assembly in Fuel Tube	
conservative estimate	209 °F
optimistic estimate	186 °F
Mating Subsystem Bellows Temperature	
conservative estimate	348 °F
optimistic estimate	312 °F
Concrete Thermal Gradient	
realistic estimate	42 °F

It is extremely unlikely that the DTS will reach its steady state temperatures before fuel can be recovered after an accident condition or the exhaust fan can be repaired. The exhaust fans are easily accessible for replacement. These are located outside the DTS structure. The exhaust fans and duct work are standard commercial items. With the ventilation system operable, the air flow, alone, through the DTS will maintain temperatures within the DTS and of the spent fuel well below the steady state values listed above.

8.2.4.3 Seismic Effects on the Major Operating Equipment

The seismic event is considered to occur during any time, including when operations are occurring. The equipment is evaluated for a seismic event in the loaded or unloaded condition and in the positions that would result in worst damage.

The major operating equipment is designed so that it does not become a projectile due to seismic loads. Also, the upper shield ports are locked in the closed position, to ensure that shielding is not removed during the seismic event. The cranes are also designed so that there is no loss of load. The equipment may or may not be operable by normal means. The operating equipment, with the exception of the Z motion of the fuel handling equipment and the fuel handling grapple can be activated manually or repaired from outside of the TCA or from inside the Roof Enclosure Area.

If the operating equipment cannot be operated by normal means or by the backup means after the seismic event, special equipment can be lowered into the TCA from the Roof Enclosure Area for viewing and special recovery operations. Attachments to the TCA and the penetrations will be installed in the DTS. Recovery equipment will be designed as required.

Cask Transfer Subsystem

The cask trolleys are designed so that they do not allow the cask to tip over due to seismic loading. The trolleys are also designed with special devices which prevent derailing due to the seismic event. When not being moved, the trolleys are normally locked in the Preparation Area and the Lower Access Area which prevents movement of the trolleys due to seismic loading.

The cask trolleys are evaluated for seismic loading in Appendix 8A.2. The locking pins, transmission cradles and anti-derailing devices are evaluated for seismic loading.

The stresses on the components which provide a safety related function are summarized in Tables 8.2-5 and 8.2-6.

Cask Mating Subsystem

The components of the Cask Mating Subsystem which perform a lifting function are evaluated in Appendix 8A.3 for normal loading and seismic loading. The components which form part of the load path are designed with a safety factor of 6 to yield strength and 10 to ultimate strength for normal loads. The stresses are summarized in Table 8.2-7.

Shield Plug and Source Cask Lid Handling Subsystem

The components of the Shield Plug and Source Cask Lid Handling Subsystem, including the TC Port Covers and the Upper Shield Port Covers are analyzed in Appendix 8A.4 for normal loading and seismic loading. The resulting stresses are summarized in Table 8.2-8. The upper crane meets the criteria of a Class I crane in accordance with NOG-1 (Reference 8-9).

Table 8.2-5

Summary Source Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 MPa	96 MPa	6 bolts M30 (1.2 in dia.)	3
Plate of anti-taking off device	Seismic	186 MPa	11 MPa	30 mm thick (1.2 in)	17
Bolts of anti-taking off Device	Seismic	287 MPa	19 MPa	4 bolts M16 (0.6 in)	15
Diameter of the locking pin	Seismic	103 MPa	33 MPa	D = 80 mm (3.2 in)	3.1
Wheel diameter	Static	39,449 lbf	24,811 lbf	D = 450 mm (17.7 in)	1.5
Rail width minimum	Static	39,449 lbf	24,811 lbf	b = 40 mm (1.6 in)	1.5

Table 8.2-6

Summary Receiving Cask Transfer Trolley Stresses

Part	Loading	Allowable stress or value	Calculated Stress or Value	Size	Safety Factor
Bolts of Cradle	Seismic	287 Mpa	172 MPa	6 bolts M30 (1.2 in dia.)	1.6
Plate of anti-taking off device	Seismic	186 MPa	138 MPa	40 mm thick (1.6 in)	1.3
Bolts of anti-taking off Device	Seismic	287 MPa	153 MPa	4 bolts M24 (1 in)	1.8
Diameter of the locking pin	Seismic	103 MPa	47 MPa	D = 120 mm (4.8 in)	2.2
Wheel diameter	Static	151,141 lbf	79,946 lbf	D = 700 mm (27.6 in)	1.9
Rail width minimum	Static	151,141 lbf	79,946 lbf	b = 100 mm (3.9 in)	1.9

Table 8.2-7

Summary - Stresses in the Cask Mating Device Lifting Components

Part	Load	Allowable Value (ksi)	Calculated Value(ksi)	Calculated Size
Axis for finger of the overlid diameter	Static	36 (yield) 58 (tensile)	12.6 (shear) 21.0 (shear)	25 mm (1.0 in)
Overlid finger thickness	Static	36 (yield) 58 (tensile)	25.3(bending) 42.2(bending)	50 mm (2 in.)
Plug Pintle thickness	Static	36 (yield) 58 (tensile)	22.3(bending) 37.2(bending)	50 mm (2 in.)
Overlid Pintle Thickness	Static	36 (yield) 58 (tensile)	22.2(bending) 37.0(bending)	40 mm (1.6 in.)

Table 8.2-8

Summary of Results
Shield Plug and Source Cask Lid Handling Subsystem

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Cable Diameter	Static	88,042 N	70,000 N	12 mm (0.48 in.)	1.25
Trolley Wheel Diameter	Static	11,109 lbf	5,540 lbf	139 mm (5.5 in.)	2
Rail Width	Static	11,109 lbf	5,540 lbf	37 mm (1.45 in)	2
Anti-Taking Off Device Bolt	Seismic	287 MPa	19 MPa	16 mm dia. (0.63 in)	15
Anti-Taking Off Device Plate Thickness	Seismic	186 MPa	27 MPa	20 mm (0.8 in)	6.8
Anti-Seismic Bumper Bolt Diameter	Seismic	287 MPa	215 MPa	16 mm dia. (0.63 in)	1.3
Finger of grapple axis diameter	Static	200 MPa	15.6 MPa	30 mm (1.2 in)	12.8

Table 8.2-8 (Continued)

Summary of Results
Shield Plug and Source Cask Lid Handling Subsystem

Component	Load	Allowable Value	Calculated Value	Size	Safety Factor
Grapple finger thickness	Static	399 MPa	36.7 MPa	60 mm (2.4 in)	10.9
Compensator axis diameter	Cable Breaking	93 MPa	42 MPa	40 mm (1.6 in.)	2.2
Trolley locking pin diameter	Seismic	103 MPa	47 MPa	30 mm (1.2 in)	2.2
Upper Shield Port locking pin diameter	Seismic	103 MPa	49 MPa	24 mm (1 in)	2.1
Receiving Cask TC port cover locking pin diameter	Seismic	103 MPa	48 MPa	40 mm (1.6 in.)	2.1
Source Cask TC port cover locking pin diameter	Seismic	103 MPa	47 MPa	50 mm (2 in)	2.2

Fuel Handling Subsystem

The fuel handling subsystem is evaluated in Appendix 8A.5 for lifting and seismic loads. The results of the analysis are summarized in Table 8.2-9. The fuel handling subsystem meets the criteria of a class I crane in accordance with NOG-1.

Table 8.2-9

Fuel Handling Crane Results

Part	**Load**	**Allowable Value**	**Calculated Value**	**Calculated Size**	**Safety Factor**
Cable Diameter	Static	21,420 N	15,000 N	12 mm (0.48 in.)	1.4
Bridge wheel diameter	Static	12,321 lbf	6,070 lbf	153 mm (6.1 in.)	2
Bridge Rail Width	Static	12,321 lbf	6,070 lbf	37 mm (1.45 in)	2
Trolley Wheel Diameter	Static	7,878 lbf	3,906 lbf	99 mm (3.9 in)	2
Trolley rail width	Static	7,878 lbf	3,906 lbf	37 mm (1.45 in.)	2
Bolt of Bridge anti-taking off device	Seismic	287 MPa	177 MPa	16 mm (0.63 in)	1.6
Plate of Bridge anti-taking off Device	Seismic	186 MPa	114 MPa	t = 30 mm (1.2 in.)	1.6

Table 8.2-9 (Continued)

Fuel Handling Crane Results

Part	Load	Allowable Value	Calculated Value	Calculated Size	Safety Factor
Bolt of Trolley anti-taking off Device	Seismic	287 MPa	233 MPa	16 mm (0.63 in.)	1.2
Plate of Trolley anti-Taking Off Device	Seismic	186 MPa	150 MPa	t= 30 mm (1.2 in)	1.2
Bolts of Rotating Platform anti-taking Off Device	Seismic	287 MPa	1321 MPa	16 mm (0.63 in.)	2.1
Plate of Rotating Device Anti-Taking Off Device	Seismic	186 MPa	64 MPa	t = 25 mm (1 in)	2.9
W 6 x 20 Beam of the Platform Anti-taking Off Device	Seismic	186 MPa	68 MPa	W 6 x 20	2.7
Bolts of Bridge anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia. (0.63 in)	1.2

Table 8.2-9 (Continued)

Fuel Handling Crane Results

Part	**Load**	**Allowable Value**	**Calculated Value**	**Calculated Size**	**Safety Factor**
Bolts of Trolley anti-seismic bumper	Seismic	287 MPa	226 MPa	16 mm dia (0.63 in.)	1.2
PWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	6.7 ksi (shear) 11.2 ksi (shear)	18 mm dia. (0.7 in.)	>6 to yield >10 to ultimate
BWR Grapple Finger Axis	Static	36 ksi yield 58 ksi tensile	5.7 ksi (shear) 9.4 ksi (shear)	18 mm dia. (0.7 in)	>6 to yield >10 to ultimate
Grapple Finger (PWR and BWR)	Static	36 ksi yield 58 ksi tensile	30.5 ksi (bending) 50.9 ksi (bending)	t = 20 mm (0.8 in)	>6 to yield >10 to ultimate

8.2.4.4 Seismic Effects on the Control Subsystem

In case of a seismic event, the Control Center can be damaged. The operator can lose the human/machine interface to monitor and control the DTS process. The PLC's, housed in control cabinets in the Preparation Area, can be damaged by shock or vibration or equipment which has become projectiles in this area. The Control Subsystem can be completely lost in a seismic event. The only requirement for recovery is that the electrical wires of the fuel assembly handling hoist and grapple remain accessible from the Preparation Area, since it is the only equipment without manual backup or accessible motorization.

8.2.4.5 Seismic Effects on CCTV Subsystem

The Control Center, the cameras, lights and rotating devices may get damaged in a seismic event. The attachment of the cameras and lights prevent them from becoming projectiles.

For recovery, fiberscopes can be introduced in the DTS using the different penetrations for the manual backup equipment or using the upper shield port openings.

8.2.4.6 Conclusions

If a seismic event were to occur, the DTS would remain intact, providing shielding and confinement. The DTS might no longer be operable. If required, special equipment could be used to return the fuel to the casks for removal. The HVAC Subsystem can fail due to the seismic event, but can be easily replaced or repaired so that temperatures within the DTS can be maintained. The accident site boundary dose rates would not be significantly larger than those evaluated for normal operations.

8.2.5 Tornado Missiles, Hurricanes and High Winds

The DTS structure is designed to withstand loadings due to tornado missiles, hurricanes or high winds. In the event of a tornado warning or watch, the DTS will be shut down.

Any unsealed or partially sealed casks in the Preparation Area will be moved into the Lower Access Area. The sliding door will be closed. Any fuel in the transfer process will be lowered into the closest (either source or receiving) cask. The TC port covers and upper shield port covers will be closed. The fuel handling grapple will be moved to its highest position. The control center trailer, if deemed appropriate by the utility, may be disconnected and moved to a sheltered area.

The Radiation Monitoring Subsystem and the HVAC Subsystem will continue to operate. Personnel will be evacuated from the site. The site will be locked to prevent unauthorized entry. Operations will not be restarted until the tornado watch has passed.

8.2.5.1 Tornado and tornado missiles effects on structure

The tornado poses two types of threats to the structures: wind loads (caused by the static pressure drop and the dynamic wind pressure), and missiles lifted by the wind and accelerated into the structures. These two types of threats are considered separately. Detailed calculations are presented in Appendix 8A.1.

Tornado Wind Load

The overturning moment due to the tornado wind pressure is 70,340 kNm (622,567 in-kips) and the building stabilizing moment is 138,225 kNm (1,223,409 in-kips). Since the overturning moment is smaller than the stabilizing moment, the DTS building will not overturn. The resulting factor of safety against overturning effects for DBT wind loads is 1.97. Tornado wind loads will not cause structural damage to the DTS.

Tornado Missiles

The side walls of the reinforced concrete are 36 inches thick (914 mm). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Section 3.0. Nevertheless, in order to demonstrate the adequacy of the DTS design for tornado missiles, detail analysis of the concrete wall has been performed and presented in Section 3.2.1.4. The items evaluated include the resistance to penetration, spalling, scabbing and perforation for a postulated missile impact.

Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the structure cause only superficial damage. The structure thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the structure will not compromise their confinement capability. Local repair to the structure will be performed if required after a missile impact.

Protective Cover

The protective cover is analyzed to verify its adequacy for local barrier impingement of a DBT missile. Detail analysis of the protective cover has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, there is a adequate protection against local design basis tornado missile impact damage. Local bending and distortion to protective cover is acceptable, since the DTS will not be operated during a tornado watch or warning. The effect of the tornado wind load is analyzed in Section 8A.1.6.2.

Sliding Door

The sliding door is evaluated for both tornado wind loads and tornado missiles.

Tornado Wind Load

The sliding door design is evaluated for the effects of tornado wind loads in accordance with the design criteria indicated in Section 3.0. The maximum stresses induced in the sliding door by DBT wind pressure loads are very conservatively calculated using the correlation presented in Roark, page 228, Case 48 (Reference 8.8). The wind pressure load, 419 lbs/ft^2, (0.02 MPa) is applied as a uniform load over the entire surface. Substituting the sliding door physical dimensions and an equivalent uniform distributed load of 419 lbs/ft^2 (0.02 MPa) into the correlation, the maximum calculated shell stress is 564 psi (3.9 MPa). Since the resulting sliding door stress is a small fraction of the code allowable, DBT wind loads are not considered further.

Tornado Missiles

The thickness of the sliding door is 7" (bottom) and 9" (top) (178 mm and 229 mm, respectively). The walls are designed to provide adequate radiation shielding and easily meet the minimum acceptable barrier thickness requirements for local damage against tornado generated missiles, specified in Section 3.0. Detailed analysis of the sliding door has been performed and presented in Section 3.2.1.4. Based on the analysis shown on Section 3.2.1.4, tornado missile impacts on the sliding door cause only superficial damage. The sliding door thickness is far greater than the minimum required thickness. Local damage to the outer surfaces of the sliding door will not compromise their confinement capability.

The maximum stress induced in the sliding door by the automobile impact load is calculated using the correlation presented in Roark, page 226, Case 38 (Reference 8.7). The impact pressure, 196 psi (1.35 MPa) is applied as a uniform load over the impact area, 4029.4 in^2 (2.6 m^2). Substituting the sliding door physical dimensions and the pressure load into the correction, the maximum calculated stress is 8,704 psi (60 MPa) which is less than the allowable stress of 21,600 psi (148.9 MPa).

Preparation Area

The Preparation Area structure is not designed to withstand tornados. The Preparation Area structure may collapse or be completely removed by the tornado. There are no radiological consequences of losing the Preparation Area.

8.2.5.2 Effect of Tornado on HVAC Subsystem

It is possible that a missile from the tornado event could damage a HVAC component that is located outside the DTS. This includes the exhaust fans and their ductwork, and the three condensing coil units for the air conditioning systems in the DTS.

Damage to the ducting of the exhaust fans is possible and could render the ventilation system inoperable. In this scenario, the cooling system will continue to operate maintaining temperatures in the DTS, assuming that the cooling units have not also been rendered inoperable by the tornado.

The filters are housed within the DTS structure and protected from the tornado missiles.

Loss of the cooling system has an insignificant impact when the ventilation system is operable. The air flow through the DTS will continue to dissipated the spent fuel decay heat.

The damage of the HVAC Subsystem due to the tornado has no radiological consequences since, during tornado conditions, the receiving and source casks will be closed (shield plug and source cask lid installed) and the DTS will not operate if the HVAC Subsystem is destroyed by a tornado. The casks would be removed from the Lower Access Area and inerted after the tornado has passed.

The effect of losing both the cooling system and the ventilation system is discussed in Section 8.2.4.2.

8.2.5.3 Effect of Tornado on Major Operating Subsystem

In the event of a tornado warning or watch, the DTS will be shut down. The fuel assembly in transfer (if any) will be lowered into the nearest cask (source or receiving), the receiving cask shield plug and the source cask lid will be lowered onto the casks. It will take less than 2 hours to get the casks in this "safest" condition, provided that either the primary or backup electrical system is functional.

If the casks are being worked on in the Preparation Area, they will be moved into the Lower Access Area. The sliding door will be closed. In this way, the casks will not tipover due to impact of a tornado missile onto a cask.

All the DTS operating equipment is protected from damage due to tornado missiles, hurricanes and high winds by the DTS structure, with the exception of the motors and jacks used to manipulate the TC Port Covers. These jacks can be removed and replaced in the event of tornado impact. Since the fuel is brought back into the source or receiving casks prior to a tornado, these jacks can be damaged with no effect on fuel recovery, shielding or confinement. The jacks would be repaired prior to resumption of normal operations.

The major operating equipment are all protected by the DTS structure during a tornado event. If the structure is hit by a tornado missile, some of the impact force may by transmitted to the equipment. It is anticipated that these forces will be well below the forces resulting from the seismic event. Transmitted forces to the equipment due to tornado missile impact on the building structure will be evaluated on a site specific basis.

If the TC port cover motors or jacks are hit by a tornado missile, they can be removed and replaced without entering the DTS.

8.2.5.4 Effect of Tornado on Control Subsystem

The DTS and its subsystems can withstand a tornado strike anywhere in the fuel transfer process. The sliding door will be closed in the event of a tornado warning or watch. If a tornado watch or warning is issued while a cask is being transferred into the lower access area, the transfer will be completed prior to closing the sliding door. If a tornado watch or warning is issued while fuel is being transferred, the fuel will be placed into the nearest cask. The covers will be left off to allow air circulation to reduce fuel cladding temperature increases. There is no need to control or monitor the operations during these events, and there is no recovery requirement on the Control Subsystem. The Control Trailer may be moved to a protected area if deemed appropriate by the site, and again, if time allows. The PLCs are housed in a tornado proof enclosure and will shutdown the equipment if the Control Trailer is intentionally disconnected or if it is lost in the tornado. After the tornado has passed, the protected or new control trailer can be reconnected to the PLC. All equipment must be evaluated and tested prior to commencing normal operations.

8.2.5.5 Closed Circuit Television Subsystem

In the event of a tornado, the CCTV Subsystem is used before the event to place the system in its safety condition. The Preparation Area houses the interface between the cameras, lights, pan and tilt devices and the Control Center. This interface equipment can be lost. Operations which are required to replace the CCTV equipment can be performed on contact.

8.2.5.6 Conclusions

Tornado winds, tornado missiles or hurricanes will not result in a significant radiological release. To aid in recovery operations, the DTS will be shut down in the event of a tornado watch or warning.

8.2.6 Fire

The DTS is designed so that fires within the DTS structure are avoided through choice of materials and proper cooling techniques. To prevent spread of a postulated fire in the DTS such as a small electrical fire, a Fire Suppression Subsystem will be installed in the DTS.

The DTS will be located such that fire or explosion near the DTS is also very unlikely.

8.2.6.1 Fire Effects on Structure

Fire-fighting equipment will be supplied for the building and personal access-way on a site specific basis. Local fire extinguishers will be provided as dictated by site specific conditions.

The DTS is constructed from steel and concrete and there is no scope for major fire.

Minor local fires or hydro-carbon fires, will be dealt with by local extinguishers or CO_2 injectors built into electrical control cabinets. There are no foreseeable situations where a minor fire can compromise the containment boundary or the integrity of the structure.

8.2.6.2 Fire Effects on HVAC Subsystem

In the event of a fire, some of the filters could be burned. This accident is bounded by the analysis of the case where the filters have been destroyed presented in Section 8.2.8.

8.2.6.3 Fire Effects on the Major Operating Equipment

All major operating equipment is either accessible or is backed up by manual means, with the exception of the fuel assembly hoist and grapple. There are two independent drive mechanisms for this equipment. The cables are separated to ensure that if there is a fire, the two separate drives will not both be affected and that the fire will not travel along the cable. The CO_2 Fire Suppression Subsystem will be installed above the motors to put out electrical fires.

8.2.6.4 Fire Effects on the Control Subsystem

In the event of a fire in the Control Center, the monitoring system can be lost. A failure of the Control Panel can result in the submittal of an erroneous order to the PLC's which are located in the Preparation Area, but the PLC's software is designed to refuse unsafe orders. Therefore some equipment could be controlled by the PLC without any specific operator order. This would not result in an unsafe operation. The PLCs interlocks are based on sensor information which come directly from the equipment but not from the Control Center. In case of a network failure due to the fire, the PLC's detect the failure and place the equipment in its safety conditions.

In the event of a fire in the Preparation Area, the PLC's are housed in control cabinets which include a temperature monitoring sensor directly linked to the PLCs. In case of abnormal high temperature, the PLC places the equipment in its safe condition disconnecting the link between the Control Subsystem and the mechanical or HVAC equipment at the level of the motorization.

The HVAC Subsystem operations can be resumed immediately in manual mode, not using the dedicated PLC.

The mechanical equipment operations can be resumed after PLC replacement if necessary.

8.2.6.5 Closed Circuit Television Subsystem

In case of fire in the Control Center or in the Preparation Area, the complete remote viewing can be lost. The equipment to be replaced is accessible.

8.2.6.6 Conclusions

A small electrical fire is the only credible fire event in the DTS. This fire results in no significant effect on the DTS structure or equipment. Backup equipment or manual means can be used to completely recover from a fire. The DTS would need to be inspected and repaired prior to return to normal operations. The effect of a fire on the off-site doses is less severe than the hypothetical accident of losing all the HEPA filters which is addressed in Section 8.2.8. The effect of a fire on operator doses will depend on the type of fire, location of the fire, and longevity of the fire. Operator doses due to repairs required to the DTS to bring it back to full operation will be evaluated on a site specific basis.

8.2.7 Fuel Assembly Drop

The fuel assembly grapple and hoisting system are designed so that a fuel assembly drop is not credible. The basis for this is the single failure proof design of the hoisting system and the gripping components. This design is accomplished in combination with the application of a very conservative double safety factor (the greater of 6 on yield strength, or 10 on ultimate strength) generally imposed on non-single failure proof critical load lifting systems. Furthermore, the grapple design incorporates passive mechanical interlocks (which physically prevent the fingers from disengaging from the lifted fuel assembly) and electrical interlocks (which prevent operation of the grapple finger retraction actuators when under load). Sensors are also incorporated into the grapple, which will not allow the hoist to lift until the grapple fingers are properly engaged with the fuel assembly.

Additionally, to prevent fuel assembly failure during the transfer operation, fuel assemblies to be transferred shall be known to be intact, robust, and structurally sound with no damage history. The condition of the fuel shall be verified by visual examination prior to being placed in the source cask. Once the fuel is in the source cask, the source cask shall be moved directly to the DTS. If an event which could cause damage to the fuel occurs while in the source cask (such as a cask drop accident), the fuel will not be transferred in the DTS.

8.2.8 Complete loss of HEPA filters and loss of pressure differential

The following postulated accident scenario is not considered to be credible. It is hypothesized solely to demonstrate the inherent safety of the DTS by subjecting it to a set of simultaneous multiple failures, any of which is far beyond the capability of natural phenomena or man-made hazards to produce. A simultaneous failure of protective layers of confinement is postulated to occur by unspecified means during a fuel drop accident.

This is equivalent to loss of HVAC system, loss of HEPA filtration capability, failing all of the cladding in five fuel assemblies (gap activity release), and finally failing the fuel pellets themselves such that volatiles, gases and fines are released from the fuel matrix. Table 7.2-1b provides the radionuclide content of a single design basis fuel assembly. The methodology of NUREG-1536 (Ref 8-16) as revised by ISG-5 (Ref 8-17) is used to determine the releasable source term from the DTS.

Detailed analysis of this design event is provided in Appendix 8A.6.

The release is assumed to occur over a period time greater than 20 minutes. The relative concentrations (χ/Q) at 100 meters and 500 meters are determined by the method of Regulatory Guide 1.145 (Reference 8.15). Section 1.1.1, assuming stable (Pasquill F) atmospheric conditions and a slow wind speed of 1 m/s. These conditions provide a high estimate of relative concentration. At 100 meters, $\chi/Q = 8.65E\text{-}03\ s/m^3$ and at 500 meters, $4.74E\text{-}04\ s/m^3$. This condition exists over a 30 day period.

Dose components are calculated following the method of Regulatory Guide 1.109 (Reference 8.16) and utilizing dose conversion factors from EPA Federal Guidance Reports Numbers 11 and 12 (References 8.14 and 8.15).

Following Regulatory Guide 1.109, the internal committed dose (inhalation) is calculated by:

$$Dose_{isotope} = R * \chi * DCF_{inhalation\text{-}isotope}$$

Similarly, the external deep dose (air immersion) is calculated using the following equation:

$$Dose_{air\ imm} = \chi * DCF_{air\ immersion} = Q * \chi/Q * DCF_{air\ immersion}$$

These calculations are detailed in Appendix 8A.6. The TEDE for a 30 day release is shown below in Table 8.2-10a. The committed dose equivalent to each organ plus the deep dose for a 30 day release is shown below in Table 8.2-10b. These table demonstrate that the criteria of 72.106 have been met.

Table 8.2-10a
Total Effective Dose Equivalent

	Dose (mrem/30 day)	
	100 meters	500 meters
Deep Dose (external)	1.70E+00	9.34E-02
Committed Dose Equivalent (internal)	9.14E+00	5.01E-01
TEDE	1.08E+01	5.94E-01

Table 8.2-10b
Committed Dose Equivalent to Each Organ Plus Deep Dose

	Dose at 100 meters (mrem/30 day)	Dose at 500 meters (mrem/30 day)
Deep Dose (total)	**1.70E+00**	**9.32E-02**
Gonad	4.15E+00	2.27E-01
Breast	3.73E+00	2.04E-01
Lung	9.20E+00	5.04E-01
Red Marrow	8.62E+00	4.72E-01
B. Surface	**3.84E+01**	**2.10E+00**
Thyroid	3.14E+01	1.72E+00
Remainder	4.84E+00	2.65E-01
Total - Deep Dose plus + Committed Dose Equivalent to Worst Organ (bone surface)	**4.01E+01**	**2.20E+00**
Skin	**1.89E+02**	**1.04E+01**

8.2.9 Loss of a Shield Plug or Source Cask Lid

The shield plug and source cask lid handling subsystem is designed as single failure proof. The upper crane and the load path items of the cask mating subsystem are designed with a safety factor of 6 to yield and 10 to ultimate strength. In addition, interlocks are provided which prevent opening of the grapple if the grapple is under load or if the grapple is positioned incorrectly for release of the load. Therefore, a loss of a shield plug or a source cask lid during operations is not considered credible. However, for completeness, recovery methods for this hypothetical accident are addressed below.

If a source cask lid is damaged and cannot be replaced on the cask, the fuel must be completely transferred to the receiving cask. The shield plug will be installed on the receiving cask, and the source cask will be removed from the Lower Access Area without the lid on. The receiving cask would then be removed from the Lower Access Area. The source cask lid would be retrieved from the TCA after appropriate decontamination measures, by entering the TCA through the Lower Access Area.

If a receiving cask shield plug is damaged or cannot be replaced on the cask, it is a much more significant event. All of the fuel must be transferred to source casks to be removed from the DTS. Procedures to be followed would be similar to the event of a stuck fuel assembly described in Section 8.2.2.

There is no time limit in which to recover the fuel, since the fuel is shielded and provided that the HVAC System is working, fuel-cladding temperatures will remain well below the temperature at which fuel cladding failure would occur.

A fully shielded tent would be built in the Preparation Area, enclosing the sliding door and providing enough room to completely enclose the source cask and its trolley. The Preparation Area and all surrounding areas would be evacuated.

The source cask would be loaded with fuel emptied from the receiving cask. The lid would be placed on the source cask. The source cask would be disengaged from the cask mating subsystem and the trolley would be unlocked. These operations would be done remotely, without entering the Lower Access Area. Using bypasses, the sliding door would be opened. Radiation levels outside and inside of the shielding tent would be carefully monitored. The source cask and the trolley would be moved into the shielding tent, and the sliding door would be closed. These operations would also be performed remotely.

Using the standard operating procedures, the source cask would be bolted, tested, inspected and removed from the DTS. After the source cask is unloaded from the trolley, another source cask would be placed onto the source cask trolley and secured. The source cask and trolley would be moved into the shielding tent. While carefully monitoring radiation levels in and around the shielding tent, the sliding door would be opened. The recovery cask would be moved into the Lower Access Area and positioned below the source cask mating subsystem.

The sliding door would be closed. These operations would be performed remotely. Source casks would be loaded and removed from the DTS using this approach until the receiving cask has been completely emptied.

After all of the fuel has been removed from the DTS, and the TCA and Lower Access Area have been decontaminated, the shield plug would be repaired or removed as necessary allowing personnel access into the TCA.

8.2.10 Electrical Surges and Explosions

Electrical surges may cause the PLC to receive erroneous or sporadic information from sensors. Because of the "watch dog" detection system of the PLC, described in Section 8.1.2.1.8 (Failure of the Control Subsystem Components), this erroneous information will generate an alarm and stop movement of equipment. It will also require verification by the operator. This will leave the equipment and the fuel assemblies in a fail-safe condition.

Since there are essentially no explosive gases or combustible material within the DTS, (other than the electrical cabling which will be specified to be fire retardant), when the requirements of IEEE 383 are met, any sparking caused by electrical surges will result only in localized smoldering of cable insulation or electrical equipment. This condition has been evaluated in Section 8.2.6.4.

If the cabling is damaged by an electrical surge, major operating equipment can be operated manually or by redundant means, for placing the fuel in a cask and leaving the equipment in a safe condition. The DTS structure and equipment will then need to be inspected, as well as repaired and tested, prior to returning to normal operations.

8.3. Combination of Failure Modes

8.3.1 Normal Conditions Combined With Off-Normal Events

1. Control system failure resulting in spurious equipment operation while normal operation is in progress: Typical conditions could be bridge or trolley motion while fuel is being lifted; or cask trolley motion while the plug or lid is being installed. The conditions could result in fuel damage or equipment damage, which could lead to exceeding radiation dose limits to operator personnel or members of the public. Recovery from these conditions is based on operator interference since he will be monitoring system operation using the CCTV monitoring subsystem. Upon observation of any unspecified motions, the operator will shut down the system utilizing the control panel emergency stop function. In addition, the various interlocks described in Section 5 provide a backup to operator personnel when the consequences of an improper operation are significant.

2. Failure of any system component while fuel is in a closed, non-inerted cask: This combination of events could result in fuel overheating and damage if the time required for recovery operations exceeds the design basis for a closed cask condition. If equipment failure occurs while both the lid and shield plug are installed then, depending on the situation and anticipated repair time, either the lid and/or shield plug will be removed to allow fuel cooling or the cask will be inerted by the addition of argon or other inert gas, which is stored in the LAA, as soon as possible to minimize fuel damage.

8.3.2 Normal Conditions Combined With Accident Events

1. Cask mated to cask mating subsystem during a seismic event: There is a possibility that a seismic event may occur while a cask is attached to the cask mating subsystem. Both the cask transfer subsystem and the cask mating subsystem have been independently analyzed and are acceptable under seismic conditions. The combination of the cask mated to the cask mating subsystem will be evaluated on a site specific basis. The additional mass of the annular platform on top of the cask will not be significant enough to change the design of components such as the trolley, locking pins and anti taking off devices because of their conservative design safety factors. Since the cask and mating subsystem are flexibly tied together with rubber confinement bellows and pivoting actuators, no significant damage should result from the small relative motion imparted on the two systems by the seismic event.

2. Fuel assembly positioned halfway out of a cask during a seismic event: Load combination could possibly result in damage to a fuel assembly due to possible relative motion between the cask and the transfer tube due to flexing and/or rotations or due to sliding of the crane or trolley on its tracks. If the fuel is not significantly damaged, it will be lowered back into the originating cask or transferred and inserted into the other cask.

If the fuel damage is severe, the fuel will be raised into the transfer tube, if possible, and extraordinary means (to be determined at the time of the event) will be utilized to recover it, which may include an emergency recovery cask. Adequate time will be available to evaluate, develop and execute a recovery plan since there is no criticality concern and fuel overheating will not be a factor since both casks will be opened to allow cooling of the fuel. Furthermore, the DTS structure will provide shielding to allow resolution of the situation before affecting off-site dose assessments.

3. Unsealed cask in Preparation Area during a tornado Watch or Warning: If a tornado watch or warning is in effect, a cask lid will not be unsealed. It is considered unlikely that a tornado will develop without warning during the relatively short time required to unseal a cask lid and move it into the LAA. If however an unsealed cask is in the Preparation Area and a tornado warning or watch is issued, the cask on the transfer trolley will be immediately moved into the LAA.

4. Sliding door open during a tornado Watch or Warning: Although highly unlikely, a tornado may occur while a cask is being transferred into or out of the Lower Access Area or immediately after the sliding door is open to prepare for cask removal from the LAA. In this event, the cask will be returned to the LAA and closed.

5. Open Cask in the Lower Access Area During a Tornado: If a tornado strikes while the casks in the Lower Access Area are open, there will be no damage to the equipment in the DTS structure since the building is tornado resistant. However, it is possible that completion of fuel transfer operations will be delayed due to loss of power or equipment damage outside the DTS. To prevent excessive temperature rise in the DTS building, the exhaust fans and duct work have been protected from tornado damage in a separate tornado resistant structure. The fans can be restored to operation in a short period of time, using site power or backup power. The separate (from the DTS tornado) resistant structure which houses the exhaust fans will also house the PLC. A sketch for the design of the structure is shown on Figure 8.3-1, detail structural analysis of the enclosure is provided in Appendix 8A.1-7.

6. Transferring cask trolley during seismic event: As discussed in Section 8.1.2.1.1 the worst effect caused by an earthquake while moving a cask trolley is a collision with either the DTS wall or another cask trolley. A collision is unlikely since the brakes are applied to the trolley if it is not in motion. During cask movement, operations personnel walk alongside the trolley, and can stop the trolley motion at any time. If in fact, there is a collision, properly sized bumpers on the trolley and rail will prevent significant damage from occurring to the DTS structure, the trolleys or the casks."

Figure 8.3-1

Conceptual Design of a Tornado Resistant Structure for Housing the Exhaust Fans and the PLC

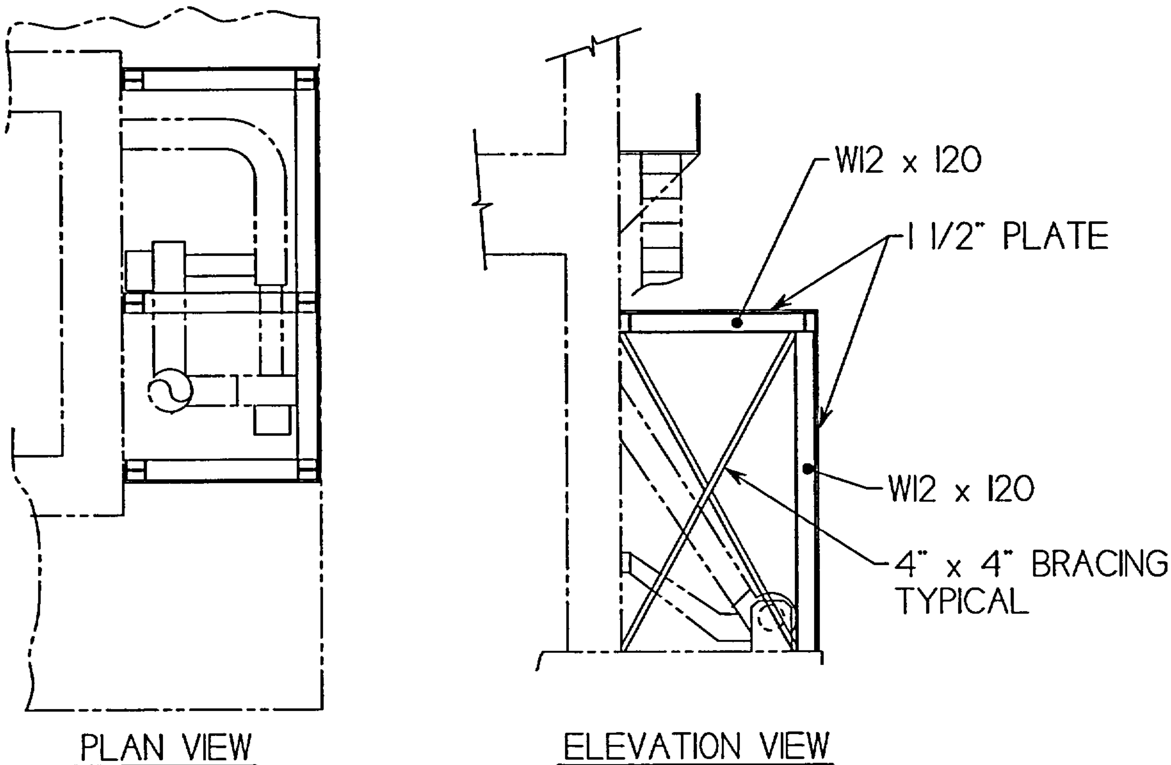
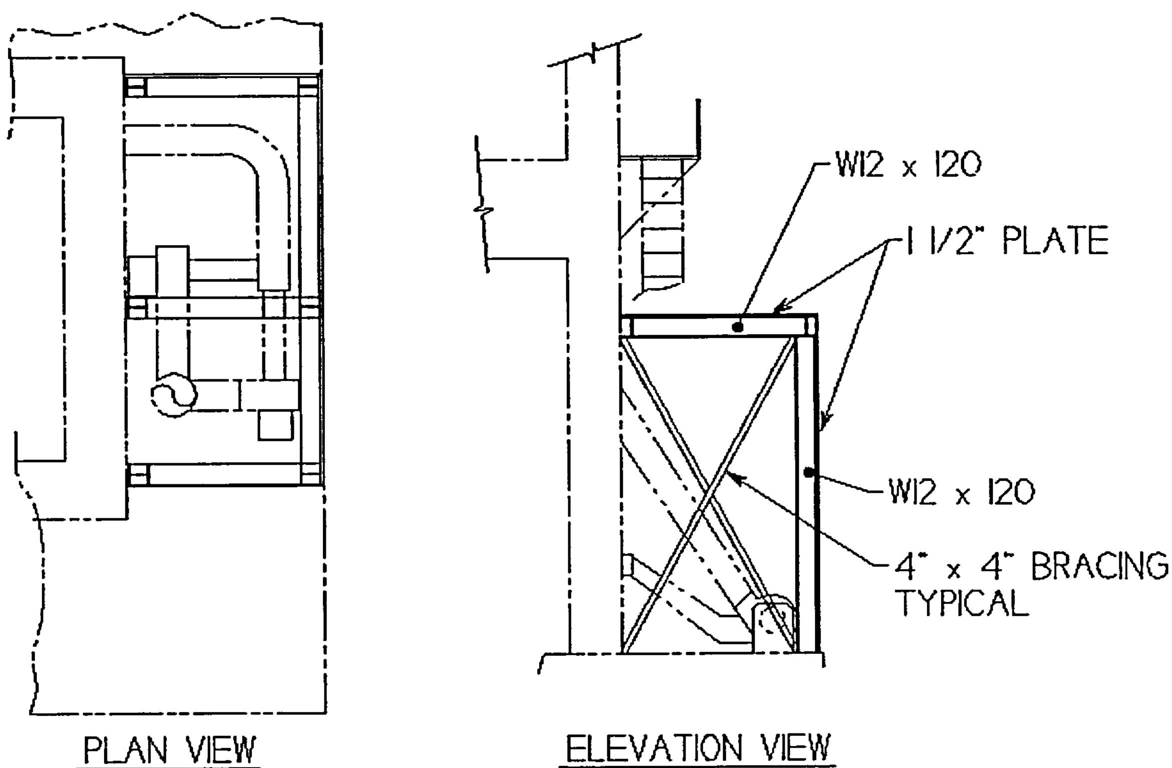


Figure 8.2-1

Conceptual Design of a Tornado Resistant Structure for Housing the Exhaust Fans and the PLC



8.4 Site Characteristics Affecting Safety Analysis

A site has not been selected for the Dry Transfer System at this time. The bounding site characteristics are discussed in Chapter 3, Principal Design Criteria.

8.5 References

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