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8. ACCIDENT ANALYSES

8.0 Introduction

In previous sections, features important to safety have been identified and discussed. The purpose of this section is to identify and analyze a range of credible accident occurrences (from minor accidents to the design basis accidents) and their causes and consequences formatted in accordance with Regulatory Guide 3.62 (Ref. 1).

ANSI/ANS-57.9-1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," (Ref. 7) defines four categories of Design Events that establish design requirements to satisfy operational and safety criteria. Design Event I is associated with normal operation. Design Events II and III apply to events that are expected to occur with moderate frequency, or once per calendar year or during the lifetime of the installation. Design Event IV is concerned with severe natural phenomena and low probability events.

The first Design Event is addressed in Sections 4 and 5 and need not be discussed further. Design Events of the second type (moderate frequency or once per calendar year) are addressed in Section 8.1 and the third (once per lifetime) and fourth design events are addressed in Section 8.2.

Events that require analysis have been identified with the aid of overall fault trees (Figures 8.0-1, 8.0-2 and 8.0-3). The three separate trees, one for each of the main stages of operation, refer to passive storage, transfer cask reception operations and fuel transfer operations. The number associated with each event refers to the subsection of Section 8 in which the event is analyzed.

1. Allocation of Events to Sections 8.1 and 8.2

   Each event can be represented on a consequence frequency diagram (see Figure 8.0-4), which can be divided into four regions:

   High frequency, low consequence (Design Event II).

   High frequency, high consequence.

   Low frequency, high consequence (Design Events III + IV).

   Low frequency, low consequence.

   The MVDS design ensures that there are no high frequency, high consequence events. Events which have a probability estimated as 1.0E-8 per year or less are referred to in Section 8 but are not given a full analysis. Such low probabilities of occurrence are considered to be below a level where a complete analysis of the event and the consequences is necessary.

To meet the constraints of Regulatory Guide 3.62 (Ref. 1) Design Events with high frequency, low consequence are addressed in Section 8.1 and Design Events with low frequency, high consequence are addressed in Section 8.2.

2. Hazard Categories and Interlock Philosophy

Potential hazards are placed into three categories on the basis of severity of the consequences. Direct radiation and indirect radiation hazards (i.e., inhalation risks), are considered in the possible consequences. Table 8.0-1 lists the Hazard Categories that have been used. Radiological consequences were conservatively assessed at a controlled area boundary distance of 100 meters rather than the actual 113 meter distance.

Interlocks are provided to prevent potentially hazardous operations. The degree of protection provided is related to the level of the hazard. Table 8.0-2 lists the means used to achieve the necessary level of protection.

Table 8.0-1. Hazard Categories.

Hazard Category	A	B	C
	Doses to the general public in excess of 5 rem (whole body) (10 CFR 72.106)	Doses to the general public in the range of 25 mrem (whole body) to 5 rem (whole body). (10 CFR 72.104/106).	Doses to the general public in the range < 25 mrem (whole body) (10 CFR 72.104).
	Serious radiation hazard which could result in a whole body dose to an operator of greater than the annual limit (5 rem). (10 CFR 20.1201).	Radiation hazard which could result in a whole body dose to an operator less than the annual limit.	Inadvertent radiation doses in excess of those expected in normal operation but less than the annual limit.

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Table 8.0-2. Method Of Achieving Protection.

HAZARD CATEGORY	INTEGRITY	METHOD OF ACHIEVING PROTECTION	
		REMOTE MANUAL CONTROL	MANUALOPERATION
A	Probability of less than 10^{-6}	a. Three separate electrical interlocks and circuits or b. Mechanical interlocks	a. Administrative security demanded by permissive key or b. Mechanical interlocks
B	Probability of less than 10^{-4}	a. Two separate electrical interlocks or b. Mechanical interlock	As above
C	Probability of Less than 10^{-2}	a. Single electrical interlock or b. Mechanical interlock	a. Administrative interlock demanded by written non-routine instruction or b. Mechanical interlock

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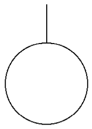
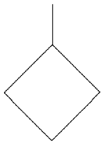
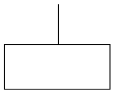
FAULT TREE SYMBOLISM FOR FIGURES 8.0-1 THROUGH 8.0-3



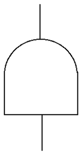
The CIRCLE describes a basic fault event that requires no further development. Frequency and mode of failure of items as identified are derived from empirical data.



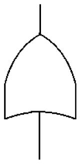
The DIAMOND describes a fault event that is considered basic in a given fault tree. The possible causes of the event are not developed because the event is of insufficient consequence.



The RECTANGLE identifies an event that results from the combination of basic events through the logic input gates.



The AND gate describes the logical operations whereby the co-existence of all input events is required to produce the output event.



The OR gate defines the situation whereby the output event will exist if one or more of the input events exist.

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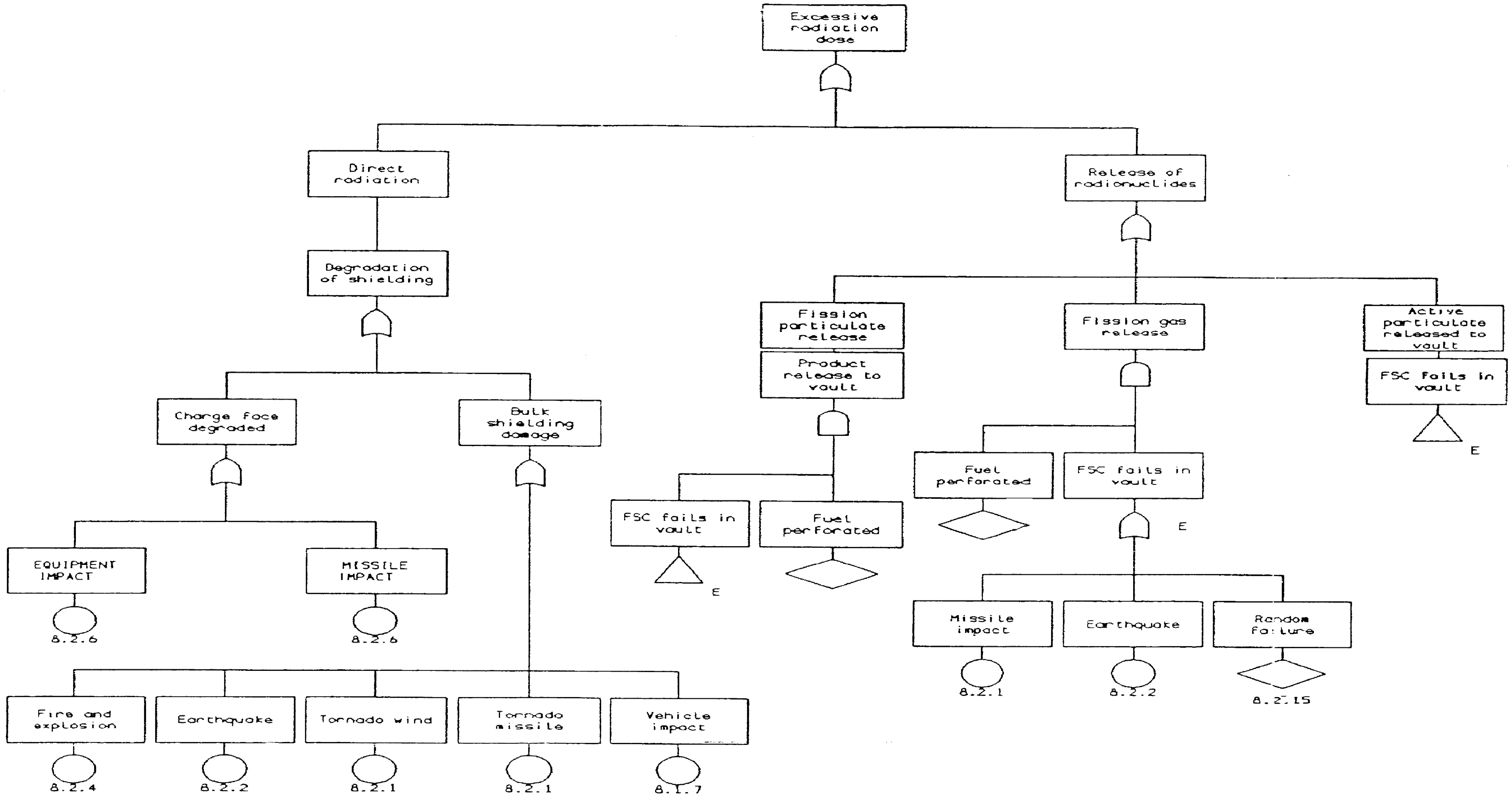

Figure 8.0-1. **Master Logic Diagram for Passive Storage.**

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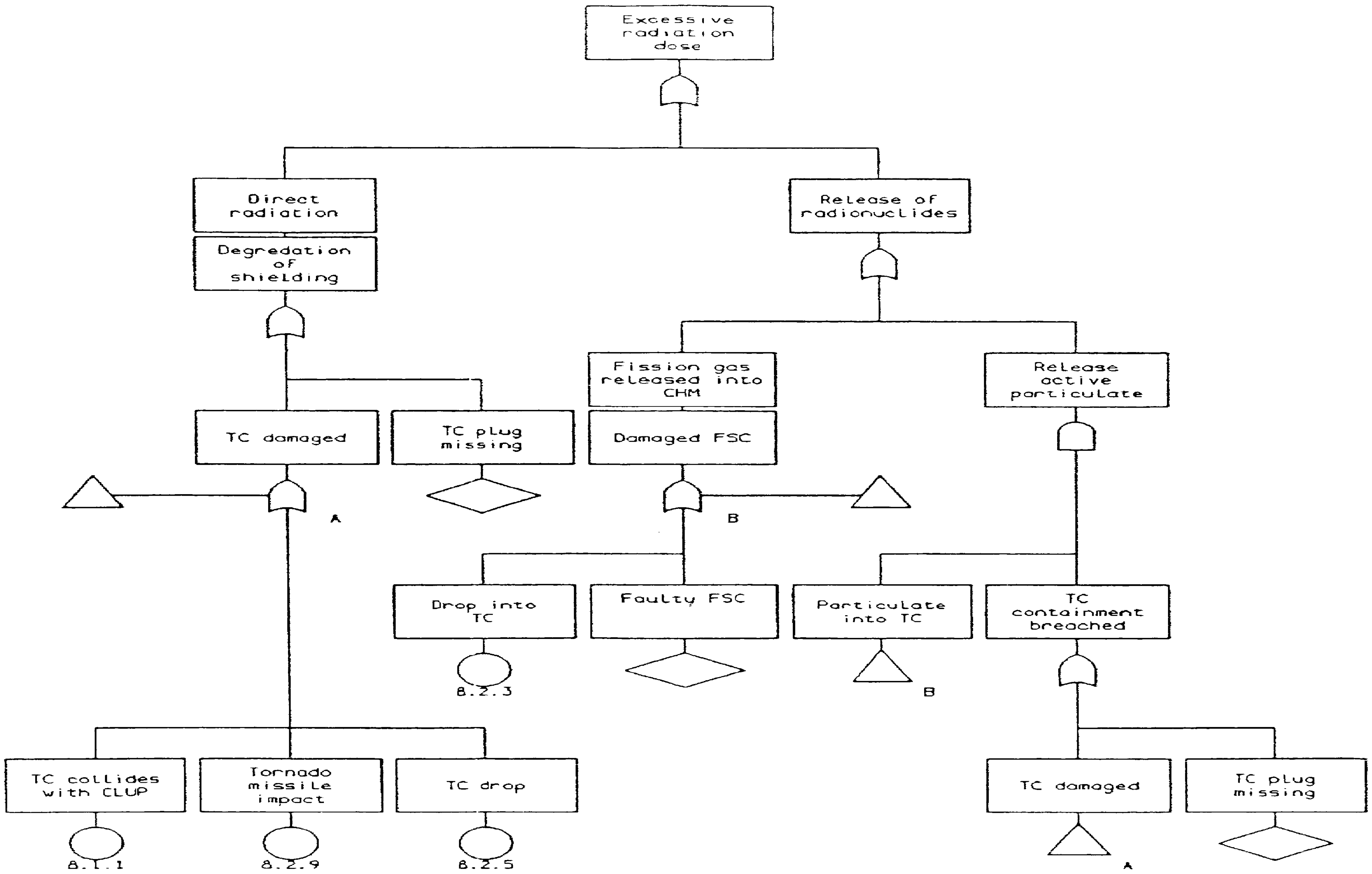

Figure 8.0-2. Master Logic Diagram for Transfer Cask Operations

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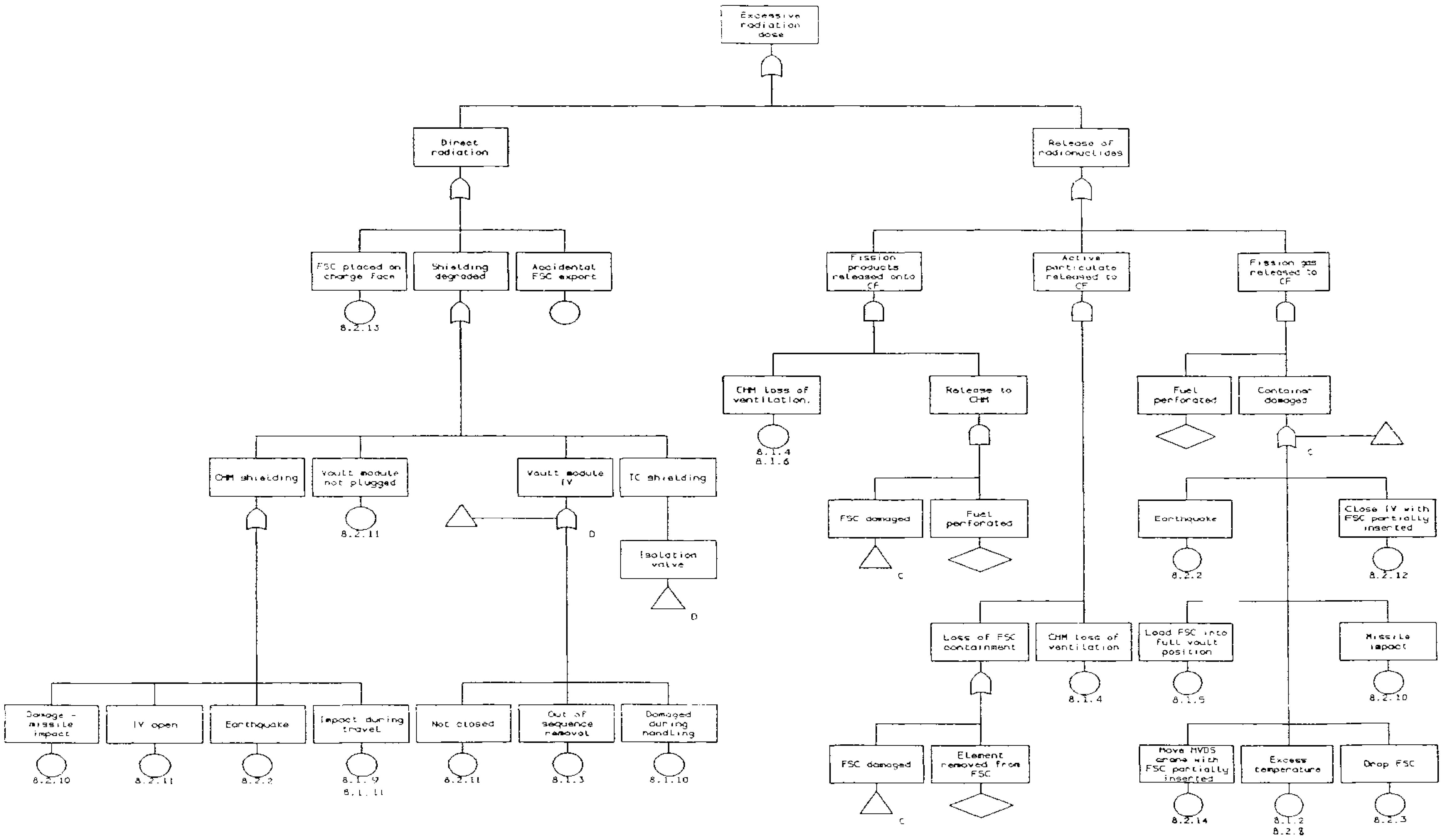

Figure 8.0-3. Master Logic Diagram for Fuel Transfer Operations.

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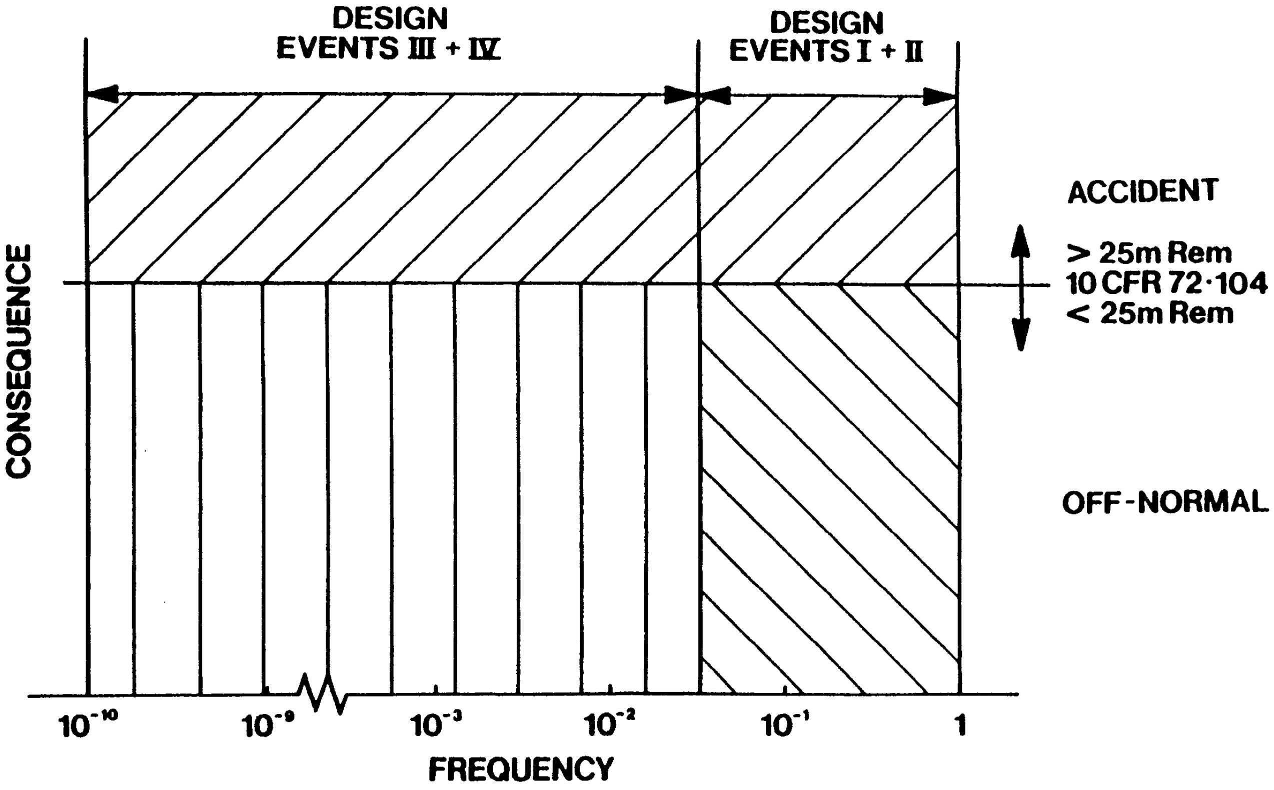

Figure 8.0-4. Consequence/Frequency Diagram.

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8.1 Off-Normal Operations

In this section, design events of the second type (Design Event II) as defined by ANSI/ANS-57.9-1984 (Ref. 7) are addressed. These consist of events (Off-normal) that might occur with moderate frequency or on the order of once during any calendar year of operation and are postulated as follows:

1. Transfer cask collides with access hatch or CLUP (Section 8.1.1)
2. Full or partial blockage of air inlet to vault module (Section 8.1.2).
3. Lifting of equipment out of sequence (Section 8.1.3).
4. Short term loss of AC electrical power (Section 8.1.4).
5. Loading a full FSC into a full vault position (Section 8.1.5).
6. CHM HEPA filtration system fails or is not connected (Section 8.1.6).
7. Vehicular impact (Section 8.1.7).
8. Contaminated CHM returned to CLUP (Section 8.1.8).
9. Drop CHM from MVDS crane (Section 8.1.9).
10. Equipment impacts on isolation valves positioned at vault module or CLUP (Section 8.1.10).
11. Traverse MVDS crane into end stops (with CHM) (Section 8.1.11).

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The postulated 'off-normal' events identified above are all events resulting in offsite doses of less than or equal to 25 mrem per 10 CFR 72.104 (Ref. 8).

In the following events involving fuel movements during ISFSI unloading operations, it is assumed that the MVDS unloading will take one year to complete. Thus, the unloading operation probabilities stated only apply to the year fuel unloading is performed.

8.1.1. Transfer Cask Collides with Access Hatch or Cask Load/Unload Port

8.1.1.1. Postulated Cause of Event

The process of loading a transfer cask into the CLUP requires the transfer cask to be lifted from its horizontal position on the transport trailer to the vertical using the MVDS crane, through the adjacent access hatch. The transfer cask is then traversed along the access hatch and lowered into the transfer cask support collar.

The postulated cause of this event is the transfer cask being out of alignment with the access hatch, or being traversed too far into the transfer CLUP prior to lowering into the support collar.

All transfer cask and trailer alignments are achieved by operator judgment, viewed from positions above and below the CLUP. The probability of an operator error is estimated at 1.0E-3 per operation (Ref. 2). Assuming 2 crane operations per transfer cask and 252 transfer cask operations per year, this results in an event probability of 0.5/year.

8.1.1.2. Detection of Event

The transfer cask load/unload operations are visually observed by the MVDS crane operator and the operators positioned in the TCRB. It is considered that a collision course of the transfer cask with the access hatch or CLUP during loading operations is immediately apparent. The MVDS crane is controlled via a pendant, allowing the operator to view loading of the transfer cask through the access hatch by standing near the safety railings.

8.1.1.3. Analysis of Effects and Consequences

There are no radiological consequences resulting from this event.

The worst case consequence of an impact may result in a transfer cask being dropped from its maximum raise height of approximately 7 ft. into the TCRB, followed by a topple. The dropping of a transfer cask is covered in Section 8.2.5 where it is shown that the integrity of the transfer cask or vault module is not breached. However, for drops in excess of 4 inches the FSC integrity cannot be guaranteed, and possible activity release internal to the transfer cask may result.

8.1.1.4. Corrective Actions

Stop the MVDS crane and return the transfer cask to a non-contact position and inspect and evaluate the equipment. If the problem is caused by a misalignment of the trailer or MVDS crane, the load must be lowered and secured, and the trailer or crane repositioned prior to further operations.

The FSC contained within the transfer cask cannot be guaranteed for drops greater than 4 inches (Appendix A8-6).

8.1.2. Full or Partial Blockage of Air Inlet to Vault Module

8.1.2.1. Postulated Cause of Event

A number of possible causes of inlet blockage can be postulated including blockage by windblown debris such as leaves, weeds, waste paper, plastic sheeting or by snow drifts and floods.

Blockage due to windblown debris such as leaves, weeds and waste paper is unlikely due to the installation of a trash fence directly in front of the inlet ducts. Most windblown debris would be stopped by the trash fence, and would not impede air flow into the inlet ducts. Blockage from these causes is unlikely to produce a reduction in available inlet area of more than 10% due to the trash fence and large area of the inlets (protected by mesh).

Frost has been observed to form on the inlet screens ("bird mesh") in the winter months on occasion, when temperature and humidity conditions are conducive. Due to the spacing of the wire mesh (approximately one-half inch squares, considered necessary to prevent entry by birds and rodents), heavy frosting has at times resulted in a substantial fraction of the inlet mesh being completely filled with frost. This frost is very delicate and pores exist through which some air can flow. Severe frosting conditions could result in nearly complete frost coverage of the inlet screens. Personnel who regularly inspect the MVDS identify the frost formation and remove it from the inlet screens, so that it does not significantly impact inlet airflow and removal of heat from the FSCs. Frost removal takes only several minutes, and does not result in any measurable doses to personnel.

The outlet screens at the top of the chimney appear to be less susceptible to frost formation than the inlet screens. Substantial frost coverage of the outlet screens has not been observed, possibly due to warmer air exiting the chimney, the elevation difference of the inlet and outlet ducts, and/or the fact that the outlet duct is open on all four sides. Should it occur, and remain for times approaching 24 hours, DOE has means to gain access to these screens for frost removal.

It is considered possible that icing of the inlet screens could occur, which would pose a greater threat than frost in impeding airflow into the inlet ducts. Icing would require conditions of freezing rain, which are rare in Colorado. Should icing occur, it would be identified by personnel who regularly inspect the MVDS, and removed in a timely manner.

Windblown debris other than leaves, weeds or waste paper may cause blockages of greater than 10%, but with a much lower probability. A large plastic sheet or vehicle tarpaulin could be blown onto one inlet totally obscuring the inlet to one module, or the inlet could be blocked as a result of tornado missile impact by a massive soft missile (automobile). See Section 8.2.1. Inlets may be blocked partially or totally as a result of extreme weather conditions such as tornadoes if there is a suitable source of debris in the vicinity.

In addition to windblown debris, a snow drift of 4.8 ft maximum (see Section 4, Appendix A4-1, Design Calculation 1.2.2) piled up against the inlets may cause a 42% blockage assuming all inlets to be blocked to this level, and is taken as the worst case snow drift considered credible.

There was an actual inlet duct blockage occurrence due to snow and ice, which took place in March 1992. The mode of blockage was not, however, drifting snow. On March 9, 1992, a severe snowstorm resulted in snow accumulation of approximately 1.5 ft. in the FSV area. There was not significant drifting at the inlet structure and blockage was not significant. However, on subsequent days, snow on top of the inlet structure melted, and water trickled down on the wire mesh over the inlet duct. The water froze, forming a relatively clear sheet of ice over the inlet duct wire mesh. On March 11, 1992, security personnel making routine inspections identified the icing on the inlet duct wire mesh, and the ice was promptly removed. It was estimated that 96.1% of the inlet duct area experienced blockage on March 11, 1992. The following two actions were taken as a result of this event:

1. A steel gutter was installed on the roof of the inlet structure. This gutter collects water which runs down the roof, and drains it to one side of the ISFSI structure, preventing water from draining over the inlet ducts.

2. GEC performed analyses to determine the effects of blockages beyond the 95% inlet duct blockage previously analyzed.

Since its installation, the gutter has demonstrated its capability to effectively drain water from the roof of the inlet structure, and prevent water from contacting the inlet duct wire mesh. Therefore, with the gutter in place, the 42% blockage by drifting snow identified above is still considered to represent the maximum credible snow blockage. While blockages of greater than 95% are not considered credible, the results of the GEC analyses for greater blockage and long term duration are summarized in Appendix A8-11.

A 55% inlet blockage caused by a 6-foot flood (see Section 3.2.2) also is considered assuming all inlets to be blocked to this level. No credible accident is identified which can result in a prolonged total blockage of all six vault inlets at any one time. As discussed in Reference 12, maximum allowable temperatures for accident conditions of the fuel, FSCs, and concrete would not be reached until after 14 days, 9.7 days, and 14 days respectively with 100% blockage of the inlet or outlet ducts, conservatively assuming peak rate fuel with only 600 days decay (150 watts per element). However, since fuel was loaded in June 1992, an additional decay of greater than 6,000 days has occurred. Hence, a surveillance interval of 7 days is acceptable.

The analysis for this event is bounded by a worst case, 95% blockage of all six vault inlets for an indefinite period. Such a prolonged major blockage is considered incredible and no event is identified as the cause of such a severe blockage.

8.1.2.2. Detection of Event

Inlet blockage would be detected by routine inspections conducted on a 7 day interval.

8.1.2.3. Analysis of Effects and Consequences

It is shown in the analysis of Appendix A8-11 that a reduction in cooling flow from a 95% blockage of all six inlets at any one time for an indefinite period, does not cause significant temperature rise in the fuel stored. For an inlet temperature of 120 degrees Fahrenheit, a 95% inlet blockage results in a peak fuel temperature (at centerline) of 253 degrees Fahrenheit. This is significantly less than the maximum allowed storage temperature of 750 degrees Fahrenheit (see Section 3.3.2.2.3) and the maximum design temperature of the FSC of 300 degrees Fahrenheit.

The dose to an operator undertaking to clear the inlet ducts is estimated at a peak rate of 20 mrem/hour, on the mesh grill 5 feet above the floor (Appendix A8-10). It is conservatively assumed that 1 person hour per duct is required to clear airborne debris blockages and 4 person hours per duct is required to clear snow blockages, therefore an operator will receive a peak dose of 480 mrem from clearing all six inlet ducts.

The radiological dose will be an upper bound value since not all the time spent clearing obstructions will be spent in areas where the high dose rates occur. This conservative dose did not exceed the dose requirements of 10 CFR 20.101 in effect at the time of initial FSV ISFSI licensing, nor does it exceed the current requirements of 10 CFR 20.1201 (Ref. 9).

8.1.2.4. Corrective Actions

Once an obstruction has been detected, it can be cleared by means of snow plows, hand tools or manual removal of debris as appropriate.

8.1.3. Lifting of Equipment Out of Sequence

The MVDS crane is used to lift items of equipment within the MVDS facility. There are four postulated events, involving out of sequence lifts, as listed below:

1. CHM lifted while attached to the isolation valve.
2. CHM lifted with CHM valve or isolation valve open.
3. SPHDs (including the USPHD) lifted with the isolation valve open.
4. Isolation valve lifted off the charge face structure, SSWs, or CLUP after the shield plug is removed.

Items 2, 3 and 4 are addressed in Section 8.2.11.

8.1.3.1. Postulated Cause of Event

The CHM is bolted to the isolation valve prior to any handling operations. The MVDS crane remains attached to the CHM lifting frame during these operations.

The postulated cause of this event involves the crane being raised by an operator prior to removing the securing bolts from the base of the CHM. The removal of the CHM from an isolation valve is by administrative control.

The probability of an operator error is estimated at 1.0E-3/operation (Ref. 2). Assuming four CHM/isolation valve interactions per transfer cask operation and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 4.0E-3/year.

Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 1.0/year.

8.1.3.2. Detection of Event

If lifting of the CHM is attempted prior to unbolting from the isolation valve, the MVDS crane overload alarm will actuate at 104,500 lbs and the crane will automatically cut out at 110,000 lbs.

8.1.3.3. Analysis of Effects and Consequences

The isolation valve will not be raised out of its position on the charge face or CLUP due to the tensile strength of the twelve, 1-1/2 inch bolts whose combined tensile strength exceeds the maximum crane lifting capacity (see Section 4, Appendix A4-2).

There are no radiological consequences resulting from this event.

8.1.3.4. Corrective Actions

Lower crane hoist and inspect and evaluate the equipment. Remove bolts, inspect and evaluate for deformation prior to further operations. Perform corrective actions as dictated by the evaluation.

8.1.4. Short Term Loss of AC Electrical Power

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The event considered is loss of AC electrical power to the MVDS for a limited duration (less than or equal to 1 hour).

8.1.4.1. Postulated Cause of Event

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Failure in the offsite power utility network.

8.1.4.2. Detection of Event

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Loss of function in powered equipment.

8.1.4.3. Analysis of Effects and Consequences

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Handling operations will be suspended and the potential exists for a FSC or fuel element to be suspended in its position at the time power is lost.If a FSC or fuel element is suspended fully in the CHM or transfer cask or partially inserted into a vault module, the fuel temperature rise will be insignificant. See Appendix A3-1.

The thermal consequences of this event are enveloped by the 'Long Term Loss of Electrical Power' event (Section 8.2.7).

The potential for extremely minor amounts of radioactive material to be present in the body of the CHM exists during the handling of uncontained elements or damaged FSCs, originating from the exterior of the fuel elements. No mechanism is identified under these circumstances for the preferential release of particulate originating from a fuel element. Gaseous products, which account for approximately 15% of the inventory release during FSC lid removal, (see Appendix A8-9) are previously released in a controlled manner during FSC venting and lid removal at the SSW.

If the CHM HEPA filtration system fails (not operating) a decontamination factor of 1 (1,000 when operating) is conservatively assumed. There is no pressure differential between the CHM and the charge hall (when the filtration system is not operating) which would account for any significant release potential. Radioactive material would remain contained, however minor amounts may escape if present in the CHM body.

During SSW operations, adequate protective equipment is used, thus assuring the operators are protected from minor amounts of radioactive material which may escape from the CHM if the postulated power failure occurred. The dose criteria of 10 CFR Part 20 (Ref. 9) are not exceeded.

The radiological consequences at the controlled area boundary are less serious than a release from the MVDS stack following a significant FSC leak into the vault, or a puff release onto the charge face following FSC removal. See Appendix A8-9 where it is shown that the requirements of 10 CFR 72.106 (Ref. 8) are met.

8.1.4.4. Corrective Actions

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Handwinds on the MVDS crane travel and hoist and CHM raise/lower mechanism can be used to complete handling operations. There is however, no requirement to do this as the temperature increase is small and no fuel deterioration will occur.

8.1.5. Loading a Full Fuel Storage Container into a Full Vault Position

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8.1.5.1. Postulated Cause of Event

It is assumed that a full FSC removed from the MVDS for unloading is returned to a full fault position in the MVDS. During the FSC unloading process, the isolation valve may be relocated to prepare another FSC for removal, or transfer a FSC to a SSW. Correct location of the isolation valve on the charge face is by administrative control.

The postulated cause of the event is the failure to remove a full FSC prior to replacement of a full FSC, or the incorrect location of the isolation valve in preparation for replacement of a FSC for storage. The probability of an operator error is approximately 1.0E-3/operation (Ref. 2). Assuming one FSC is loaded per year for FSC maintenance or repair, this results in an event probability of 1.0E-3/year. Assuming 252 FSCs are moved per year for unloading operations, this results in an event probability of 0.25/year.

As the FSC is lowered into the vault module, it is supported by the FSC already present. The raise/lower mechanism underload protection system stops further movement of the leadscrew and prevents the grapple from being disengaged outside the release band.

8.1.5.2. Detection of Event

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The CHM stops lowering when the FSC is supported on the stored FSC as this is above the defined release band of the grapple (see Section 8.2.3).

The supported height shows that the FSC is not fully lowered and the operator response is to raise the FSC back into the CHM.

8.1.5.3. Analysis of Effects and Consequences

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There are no radiological consequences resulting from this event.

8.1.5.4. Corrective Actions

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Raise the FSC back into the CHM and move the CHM to a holding park area to allow the isolation valve to be correctly located before proceeding with normal storage operations. Inspect for equipment damage and evaluate. Perform corrective actions as dictated by the evaluation. Evaluate the fuel accountability program for discrepancies (see Section 5.3).

8.1.6. Container Handling Machine HEPA Filtration System Fails or is not Connected

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8.1.6.1. Postulated Cause of Event

The CHM HEPA filtration system is normally used during off-normal operations at the SSWs to prevent the release of airborne contamination during fuel handling operations. This is the only time when the electrical power supply umbilical is connected. Operations at the SSWs can take place at any time during plant life.

There are a number of possible causes for the failure of the HEPA filtration system to operate properly:

1. Loss of power supply to the CHM.
2. Mechanical failure of the system components.
3. Operator fails to use the system.

There are no protection systems preventing operation of the CHM while the HEPA filtration system is not operational.

The failure rate for item 2 above is estimated to be 2.0E-4/hour (Ref. 4) and for item 3 the probability of operator error is approximately 1.0E-3/operation (Ref. 2). The duty cycle of the system is estimated to be once per year for 1 hour resulting in an event probability of 1.2E-3/year.

8.1.6.2. Detection of Event

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Loss of CHM HEPA filtration due to items 1 and 2 above is immediately apparent to the operator by the CHM flow indicator (differential pressure across the filter). If the HEPA filtration system is not operating, the loss is apparent when the system is demanded. Operator response time is immediate (less than 1 hour) when loss of ventilation occurs or on discovery of a fault.

Failure to use the CHM HEPA filtration system would be detected by procedural controls.

8.1.6.3. Analysis of Effects and Consequences

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If the CHM is undertaking handling operations at a SSW, the HEPA filtration system is used (procedural controls).

The potential for extremely minor amounts of radioactive material to be present in the body of the CHM exists during the handling of uncontained elements or damaged FSCs, originating from the exterior of the fuel elements. No mechanism is identified under these circumstances for the release of particulate originating from a fuel element. Gaseous products, which account for approximately 15% of the inventory release during FSC lid removal (see Appendix A8-9), are previously released in a controlled manner during FSC venting and lid removal at the SSW.

If the CHM HEPA filtration system fails (not operating) a decontamination factor of 1 (1,000 when operating) is conservatively assumed. There is no pressure differential between the CHM and the charge hall (when the filtration system is not operating) which would account for any significant release potential. Radioactive material would remain contained, however minor amounts may escape if present in the CHM body.

During SSW operations, adequate protective equipment is used, thus assuring the operators are protected from the potential inhalation of minor amounts of radioactive material which may escape from the CHM if the postulated ventilation system failure occurred. The dose criteria of 10 CFR Part 20 (Ref. 9) are not exceeded.

The radiological consequences at the controlled area boundary (100 meters) are less than a release from the MVDS stack following a FSC leak (Maximum Credible Accident, see Section 8.2.15) into the vault, or a 'puff' release onto the charge face following FSC lid removal. See Appendix A8-9 where it is shown that the requirements of 10 CFR 72.106 (Ref. 8) are met.

8.1.6.4. Corrective Actions

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Return the fuel element or container to the SSW and seal, restore power or repair the HEPA filtration system.

8.1.7. Vehicular Impact

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8.1.7.1. Postulated Cause of Event

Vehicles may impact on the outside of the MVDS structure. The most likely postulated event would be an impact of the transfer cask transport trailer in the reception bay. The probability of an operator error is estimated at 1.0E-3 per operation (Ref. 2) assuming two transport trailer movements per transfer cask operation in the reception bay and 252 transfer cask operations per year, this results in an event probability of 0.5/year.

The MVDS is within the boundary of a controlled site to the which vehicle access is restricted. In particular, there is no highway passing close to the building.

8.1.7.2. Detection of Event

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Vehicle impact on the structure would be readily detected by the operators.

8.1.7.3. Analysis of Effects and Consequences

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Site speed limits will be administratively limited to 10 mph, such that the heaviest vehicles on the site traveling at this speed have less momentum than the worst tornado generated missile for which the building is designed to withstand. (See Section 8.2.1)

The consequences of a vehicle impact on the lower structure will be significantly less severe than those of the heavy tornado generated missiles, which may damage the outside of the building, but have no radiological consequences. Should the transfer cask and trailer impact the MVDS structure, the transfer cask full of fuel will not be breached by the impact.

8.1.7.4. Corrective Actions

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Remove vehicle to non-contact position and inspect equipment and structures and evaluate prior to continued operation. Perform corrective actions as dictated by the evaluation.

8.1.8. Contaminated Container Handling Machine Returned to Cask Load/Unload Port

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8.1.8.1. Postulated Cause of Event

The CHM can be used for normal operations of transferring full FSCs from the transfer cask to selected vault modules and for off-normal events at the SSWs.

Contamination of the CHM arising from normal operations comes from handling a contaminated FSC during unloading or due to an event leading to release of contamination during the handling of a FSC.

Operations at the SSWs are off-normal and there is the potential for contamination during the handling of uncontained fuel elements or damaged FSCs.

8.1.8.2. Detection of Event

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In the event of a hoisting or transportation fault this is immediately apparent to the operator and possible contamination is anticipated. Operators' response is to immediately contact Health Physics personnel to establish if contamination has occurred.

Checks for contamination of the CHM are under administrative control.

8.1.8.3. Analysis of Effects and Consequences

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Potential airborne release of radioactive gas and particulate into the body of the CHM may occur during SSW operations involving the handling of damaged FSCs and/or uncontained fuel elements (see Section 8.1.7).

Decontamination of the CHM grapple is performed at the TCRB under procedural controls following SSW operations. Adequate protective equipment is used, thus assuring the operators are protected from any radioactive material and the dose criteria of 10 CFR Part 20 (Ref. 9) are not exceeded. Decontamination will involve removal and replacement of the HEPA filtration units where necessary and also the exchange of the individual fuel element grapple following SSW operations. Contaminated equipment such as the element grapple are removed using bagging techniques.

8.1.8.4. Corrective Actions

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Decontaminate the CHM.

8.1.9. Drop Container Handling Machine from MVDS Crane

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8.1.9.1. Postulated Cause of Event

The CHM is transported using the MVDS crane attached to the CHM lifting frame.

The postulated cause of the event is an uncontrolled lowering (dropping) of the CHM onto the charge face, CLUP, isolation valve or onto any structural part of the 19 feet 11 inch level due to a failure of the MVDS crane hoisting system. The probability of an uncontrolled lowering of the CHM is estimated to be 1.7E-5/operation (Ref. 5). Assuming five CHM movements per transfer cask operation and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 8.5E-5/year. Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 2.0E-2/year.

8.1.9.2. Detection of Event

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The uncontrolled lowering of the CHM would be readily detected by the operator following impact.

8.1.9.3. Analysis of Effects and Consequences

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There are no radiological consequences resulting from this event because:

1. The CHM is designed to withstand a maximum drop of 4 inches onto its four shock absorbing legs and not topple (see Section 4.0, Appendix A4-2). The CHM traverse height is set by a survey of the whole of the crane coverage of the 19 ft 11 inch level to give a minimum ground clearance of 1 inch on the four shock absorbing leg outrigger pads. The tolerance specified for the 19 ft 11 inch level is such that the maximum deviation in height is limited to within 2 inches (peak to trough). A 1 inch setting allowance has been assumed resulting in a maximum

drop of the CHM of 4 inches (i.e., 1 inch clearance + 2 inches civil tolerance + 1 inch setting allowance).

Dropping of the CHM from 4 inches onto the park pedestal position does not result in damage to the vault integrity (see Appendix A8-8).

2. The CHM raise/lower mechanism is a single failure proof high integrity system (Ref. 3). The FSC/element is retained by the CHM grapple inside the CHM following this drop.

3. The isolation valve is designed and built to high integrity standards. The analysis in Appendix A8-8 shows that the shielding integrity of the isolation valve is not affected by a drop of the CHM onto the isolation valve positioned over the CLUP or a vault module. The analysis in Appendix A8-8 also shows that a drop of the CHM onto an isolation valve positioned over the CLUP during transfer cask unloading operations will not cause failure of the CLUP structure or transfer cask support collar, thus preventing a secondary and more serious event involving a full unlidded transfer cask dropping through onto the TCRB floor.

Equipment impacts on the charge face structure following a CHM drop are discussed in Section 8.2.6 where it is shown that there are no radiological consequences.

Following a limited drop, the CHM shielding is assured and FSC containment is not breached (see Appendices A8-6, A8-8 and A4-2 of Section 4.0). However, if an uncontained fuel element is being carried during off-normal operations some minor amounts of particulate originating from the exterior of the element may be dislodged into the CHM body by the disruption of the machine during the postulated drop. No mechanism is identified under these circumstances for the release of particulate originating from a fuel element. The fuel element is retained by the grapple following a CHM drop.

The CHM HEPA filtration system is used during off-normal operations at the SSWs and a decontamination factor of 1,000 (filtration system on) across the CHM and charge face is assumed. Any particulate present in the CHM body will be extracted prior to venting to the charge face by the HEPA filtration. During SSW operations, adequate protective equipment is used, thus assuring the operators are protected from the inhalation of any radioactive material and the dose criteria of 10 CFR Part 20 (Ref. 9) are not exceeded.

8.1.9.4. Corrective Actions

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Inspect and evaluate equipment for damage prior to completing operation. Also check for contamination and decontaminate as required. Perform corrective actions as dictated by the evaluation.

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8.1.10. Equipment Impacts on Isolation Valves Positioned at a Vault Module or Cask Load/Unload Port

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8.1.10.1. Postulated Cause of Event

Isolation valves positioned at a vault module or the CLUP acts as the primary shielding during FSC operations.

The use of dedicated slings results in equipment traverse heights by the MVDS crane being lower than the height of an isolation valve above the charge face. The MVDS crane travel is at a low speed of 5 ft/min. Routing of the equipment being traversed is controlled by the crane operator.

The postulated cause of this event is failure of the operator to route traversing equipment around the isolation valve. The probability of an operator error is estimated as 1.0E-3/operation (Ref. 2). Assuming five crane movements per transfer cask operation and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 5.0E-3/year. Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 1.26/year.

Movement of equipment at speeds in excess of 5 ft/min are prevented by the crane protection system consisting of two electrical interlocks from the crane load cells. Speeds greater than 5 ft/min are prevented when a load greater than 5,000 lbs is being carried. Failure of the protection system is estimated at 1.2E-5/operation (Ref. 10).

8.1.10.2. Detection of Event

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The MVDS crane operator is in visual contact with the crane and the load being carried. Potential impacts between traversing equipment and the isolation valve would be immediately visible.

8.1.10.3. Analysis of Effects and Consequences

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The isolation valve is designed and built to high integrity standards and it is bolted down in position prior to handling operations. The very high shear capacity of the isolation valve equipment prevents movement of the isolation valve from the fixed position over a vault module or the CLUP. Appendix A8-2 shows the shear capacity of the isolation valve to be adequate to withstand a seismic event and is taken as a bounding case for equipment impacts. The slow traverse speed of the MVDS crane when carrying equipment prevents impacts of any significance. Impacts with the isolation valve will not result in significant damage to the isolation valve, and no radioactivity will be released.

8.1.10.4. Corrective Actions

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Traverse equipment back to a non-contact position. Inspect and evaluate the isolation valve and equipment for damage prior to further operations. Perform corrective actions as dictated by the evaluation.

8.1.11. Traverse MVDS Crane into End Stops (with Container Handling Machine)

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8.1.11.1. Postulated Cause of Event

The MVDS crane has long and cross travel capability with fixed end stops in both directions. When transporting the CHM in cross travel, the crane trolley can travel 33 inches further to the end stops after the CHM legs have impacted the MVDS wall structure. In long travel, the CHM is prevented from impact by long end stops which stop the MVDS crane with the CHM legs 36 inches clear of the wall structure. The cross end stops are positioned because of the travel required for transfer cask handling at the CLUP.

Operation and movement of the CHM is controlled by the operator. During operations, the trolley will approach the cross travel end stops frequently and experiencing an impact is considered a credible event.

When the crane is loaded the traverse speed is fixed to 5 ft/min and movements above this speed are prevented by the crane protection system. Traversing of the crane when loaded at speeds in excess of 5 ft/min is considered in Section 8.1.12.

The postulated cause of this event is the failure of the MVDS crane operator to stop cross travel before an impact occurs. The probability of an operator error is estimated as 1.0E-3/operation (Ref. 2). Assuming five CHM movements per transfer cask operation and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 5.0E-3/year. Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 1.26/year.

8.1.11.2. Detection of Event

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The traverse speed of the MVDS crane is slow (5 ft/min) and coupled with the proximity of the operator to the CHM any potential impact would be evident.

8.1.11.3. Analysis of Effects and Consequences

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Should the CHM traverse until impact occurs with the concrete structure the legs will take the impact. The impact will be minor at such low speeds.

There are no radiological consequences resulting from this event.

8.1.11.4. Corrective Actions

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Traverse CHM to a non-contact position. Inspect and evaluate CHM legs (point of impact) prior to commencing further operations. Perform corrective actions as dictated by the evaluation.

8.1.12. Radiological Impact of Off-normal Events

A summary of the off-normal events described in Section 8.1 and their radiological impact is given in Table 8.1-1.

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Table 8.1-1. Radiological Impact Of Off-normal Events.

	EVENT	ESTIMATED DOSES	DETECTION	CAUSE	CORRECTIVE ACTIONS	EFFECTS AND CONSEQUENCES
8.1.1	Transfer Cask Collision with Access Hatch or CLUP	No radiological consequences	Self annunciating event	Operator error	Return to non-contact position, reposition load, and inspect equipment	No conceivable effects.
8.1.2	Full or Partial Blockage of Air Inlet to Vault Module	Operator dose of 20 mrem/hr max during clearing operation	Routine visual inspection	Snow drift, wind blown debris	Clear inlets as required	No conceivable effects
8.1.3	Lifting Equipment out of Sequence	No radiological consequences	Self annunciating event	Operator error	Stop raise, remove bolts and continue	No conceivable effects
8.1.4	Short Term Loss of Electrical Power	No radiological consequences	Self annunciating event	Power utility network failure	Restore power, use handwinds	No conceivable effects
8.1.5	Loading a Full FSC into a Full Vault Position	No radiological consequences	Hoist protection system and grapple release bands	Operator error	Remove and reload FSC into empty vault	No conceivable effects
8.1.6	CHM HEPA Filtration System Fails or is not Connected	No operator dose uptake	Visual/audible	Power/mechanical failure	Repair/restore power	Minor contamination of CHM interior
8.1.7	Vehicular Impact	No radiological consequences	Self annunciating event	Operator error	Remove vehicle and inspect MVDS structure	No conceivable effects
8.1.8	Contaminated CHM Returned to CLUP	No operator dose uptake	Health physics monitoring	Off-normal operations at SSW	Decontaminate CHM	Contamination of CHM if not cleaned can result in marginal increase in radiation dose to operators
8.1.9	Drop CHM from MVDS Crane	No radiological consequences	Self annunciating event	MVDS crane failure	Inspect CHM crane repair. Reconnect and continue	No conceivable effects
8.1.10	Equipment Impacts on IV's Positioned at a Vault Module or CLUP	No radiological consequences	Self annunciating event	Operator error	Remove to non contact position and inspect equipment	No conceivable effects
8.1.11	Traverse MVDS Crane into End Stops (with CHM)	No radiological consequences	Self annunciating event	Operator error	Traverse back and inspect equipment	No conceivable effects

8.2 Accidents

This section addresses the design events of the third and fourth types as defined by ANSI/ANS-57.9-1984 (Ref. 7), and other credible accidents of low probability that could impact the safe operation of the FSV ISFSI facility. The postulated events are as follows:

1. Tornado and tornado generated missiles (Section 8.2.1).
2. Earthquake (Section 8.2.2).
3. Dropping a FSC (Section 8.2.3).
4. Fire and explosions (Section 8.2.4).
5. Dropping a transfer cask (Section 8.2.5).
6. Impacts on charge face structure (Section 8.2.6).
7. Long term loss of AC electrical power (Section 8.2.7).
8. Full or partial blockage of outlet ducts to vault module (Section 8.2.8).
9. Tornado generated missile impact on the transfer cask in the TCRB or CLUP (Section 8.2.9).
10. Tornado generated missile impact on CHM (Section 8.2.10).
11. Lifting equipment out of sequence (Section 8.2.11).
12. Close isolation valve onto partially inserted FSC or fuel element (Section 8.2.12).
13. Deposit FSC/fuel element on the charge face (Section 8.2.13).
14. Traverse CHM with load partially inserted (Section 8.2.14).
15. Maximum credible accident (see Section 8.2.15).

The postulated accidents listed above are all events identified resulting in offsite doses less than 5 rem per 10 CFR 72.106 (Ref. 8).

In those events listed above which postulates the handling of individual fuel elements following a failed FSC on a frequency of once per year, this frequency is considered extremely conservative and highly unlikely to occur. This is based on the design requirements for the FSC and the inability to identify any credible failure mechanisms.

8.2.1. Tornado and Tornado Generated Missiles

8.2.1.1. Cause of Accident

The most severe tornadic parameters assumed for the MVDS DBT are discussed in Section 3.2.1.1.

8.2.1.2. Accident Analysis

This is a Design Event IV category (see Section 8.0). The tornado poses two types of threat to the MVDS. Wind loads, caused by static pressure drop and dynamic wind pressure, and missiles lifted by the wind and accelerated into the MVDS structure.

8.2.1.2.1. Tornado Wind Loads

The structure of the MVDS is designed to withstand the loads imposed by a DBT without gross failure. See Section 4, Appendix A4-1. Hence, the safe operation of the MVDS is assured in the event of a tornado. The structural steelwork is designed to carry the full DBT loading although the cladding enclosing the Charge Hall may be displaced at wind speeds in excess of 110 mph.

These secondary generated missiles will not cause any significant increase in damage and are considered to be bounded by the DBT generated missiles.

The lack of warning of a tornado event during the operation of the MVDS has been considered in the design. The following activities are vulnerable to tornado winds:

1. Transporting a FSC in the CHM using the MVDS Building Crane.
2. Raising or lowering the FSC at the Vault, at the CLUP, or at the SSWs.

<u>Transporting a FSC within the CHM</u>

Protection against a tornado is provided by:

1. Tornado Clamps on the MVDS Building Crane

   The tornado clamps on the MVDS Building Crane will be automatically applied when the trolley or gantry drives are isolated or when a signal is received from the seismic tremor switch.

2. MVDS Crane Hoist Failure

   Dropping of the CHM due to the failure of the MVDS crane hoist while transporting the CHM is avoided by the use of seismic restraints. These restraints attach the CHM to the crane structure, thus preventing a drop and possible toppling of the CHM while it contains a loaded FSC.

Raising and Lowering the FSC at the Vault/CLUP/SSW

During transfer of the FSC either into or out of the Vault/CLUP/SSW, the CHM is bolted down to an Isolation Valve which in turn is bolted to the Charge Face Structure. The analysis presented in Reference 11 shows that the tornado force acting on the CHM is less than the most conservative seismic forces addressed in calculation A4-2.2.3 number 4. This calculation shows that the maximum overturning moment on the machine base is 16.13E+6 pounds per inch.

8.2.1.2.2. Tornado Generated Missiles

The effects of tornado generated missiles vary depending on the position at which they impact on the building. Although in many cases equipment or structures will be damaged, the surviving equipment and structures will continue to protect the fuel and limit the radiological consequences to acceptable levels per 10 CFR 72.106 (Ref. 8). It is considered incredible that the MVDS facility will be significantly damaged by more than one design basis missile because of its (MVDS) relatively small size.

Impact and subsequent damage by any of the tornado generated missiles on the following reinforced concrete structures will not result in any significant increase in the dose rates to the operators or at the controlled area boundary:

Walls surrounding the storage vaults

Air outlet stack

Walls surrounding the TCRB

Walls surrounding the charge hall

Charge hall floor (not including the charge face)

The structures listed above are adequately designed so that none of the missiles will penetrate them, or cause chips of concrete, which would otherwise act as secondary missiles, from the inner surface. Local damage to the outer parts of the structures will not prevent them from bearing the loads for which they are designed (see Section 4, Appendix A4-1).

Above the 30 ft level, only missiles A, B, C and E (see Table A8-1.2 of Appendix A8-1) might enter the charge hall through the roof or wall cladding with almost undiminished speed and impact equipment and structures inside.

Missiles A, B, C or E could hit any part of the main frame of the steel superstructure. The steelwork is not designed to withstand missile impact, so it must be assumed that any one load bearing member may be lost as a result. Under the continuing loads applied by the tornado wind pressures, the steelwork may then be severely damaged locally. However, it will not generate any secondary missiles which pose more of a threat than would the original missile, had it penetrated the cladding and entered the charge hall. (See Section 4, Appendix A4-1).

The following are considered relative to missile impacts:

Air inlets and outlets (this Section).

Charge face structure (Section 8.2.6).

Transfer cask (Section 8.2.9).

CHM (Section 8.2.10).

Impacts on other equipment and structures are possible but are not considered to compromise the safe operation of the MVDS. These other impacts also do not result in radiological consequences in excess of 10 CFR 72.106 (Ref. 8) requirements.

The degree of protection of FSCs against tornado generated missiles varies throughout the operating cycle. A FSC is safest when fully contained in a plugged vault module or in a closed transfer cask. This is discussed in more detail in Section 8.2.10.

Missiles can enter the TCRB, which is below the 30-foot level, via the roller shutter entry door. Impact on the transfer cask in the TCRB is considered in Section 8.2.9 as indicated above.

Missile impacts will be detected visually during the inspection of the facility following severe environmental disturbances such as tornadoes.

Air Inlets and Outlets

It is considered incredible that a tornado generated missile could damage stored FSCs by entering the vault by way of the air inlets. A full analysis is included in Appendix A8-1.

To enter the vault by way of the air inlet, a missile would first have to penetrate the mesh and bounce almost vertically off the floor slab. It must then bounce off the roof of the inlet plenum at least once, and probably twice or more. The analysis in Appendix A8-1 shows that only missiles A and C can penetrate and enter the vault via the collimator gaps. At the point of reaching the collimators, both have lost much of their kinetic energy and cannot damage the collimators. If they do enter the vault module, they have insufficient energy to damage a FSC.

A missile which enters only part way through the air inlet ducting may constitute a blockage only. Inlet blockage is further considered in Section 8.1.2.

The outlet canopy comprises structural steelwork and cladding enclosed with mesh. The steel structure is designed to withstand the wind loading associated with a DBT but the cladding can be displaced at wind speeds in excess of 110 mph.

Redundancy is built into the design of the structure such that any primary main member can be damaged by a DBT generated missile and no significant secondary missile is produced.

As a result of the suction forces created by the DBT it is considered unlikely that the cladding would fall down the stack and result in a significant blockage. Outlet stack blockage is considered in more detail in Section 8.2.8.

Missile entry into a vault module via the outlet stack is considered to be extremely unlikely to occur due to the stack height (80 ft 6 in) and the small area of the opening, compared to the area of the tornado in which the missiles are distributed. The probability of a missile entering the stack is conservatively estimated to be 1.0E-8/year. An analysis is given in Appendix A8-1.

For a missile to then negotiate the 45 degree bend at the base of the stack, penetrate the collimators and impact a stored FSC, in an orientation capable of causing significant damage (i.e., rupture), reduces the probability to significantly less than 1.0E-8/year and is considered to be below a level where further analysis of the consequences is necessary.

<u>Radioactive Material Other Than Spent Fuel Stored at the ISFSI</u>

As discussed in Section 7.6.4, radioactive sources are stored in the source storage cabinet against the south wall of the charge face, low-level radioactive waste may be temporarily stored at the ISFSI while awaiting disposal, and the depleted uranium plugs (DUPs) are normally stored on the charge face. The radioactive source storage cabinet is restrained such that it would remain in place in the event of a severe tornado which could blow off panels above the concrete walls in the charge hall. The probability of a tornado-driven missile striking this storage cabinet is diminishingly small (Ref. 14). The high density DUPs would be expected to remain in place in this event. Low-level radioactive waste is expected to consist primarily of dry radioactive waste generated during maintenance, surveillance, defueling or decommissioning operations related to spent fuel storage. This waste, which would not be expected to exceed 100 cubic feet, would be stored in 55 gallon steel drums. It is considered possible that a tornado striking the ISFSI could result in breached drums and the release of some radioactivity.

8.2.1.3. Accident Dose Calculations

A tornado does not have the potential to cause a release of radioactivity from within the FSCs. As stated above, some radioactivity could possibly be released due to breach of drums containing low-level radioactive waste. Ref. 14 assumed that low-level radioactive waste is blown out of the ISFSI and deposited in a circular area of ground having a 20 meter radius, with an individual located in the center of this plane source for two hours. It was conservatively assumed that 1.0 curie of activity is contained in the waste, all of which is cobalt-60. The whole body dose (taken as 18 inches above the ground) to the individual was calculated to be 48 mrem.

The inhalation dose to an individual was calculated (Ref. 14) conservatively assuming that 1.0% of the 1.0 curie activity contained in the drums becomes airborne in respirable size particles. For this calculation, it was assumed that the radionuclides and their concentration ratios were the same as that actually measured on the internal surfaces of the fuel handling machine at the FSV plant (Ref. 15), which is representative of contamination which could result from fuel element handling operations. A dispersion factor of 4.59 E-4 sec/m^3 (Reference 16, Section 3.4.2) was assumed, which is the annual average dispersion factor for FSV in consideration of the increased dispersion that would occur in the event of tornado conditions. The dose to an individual assumed to be positioned at the emergency planning zone boundary (100 meters from the ISFSI) for the duration of the release was calculated to be less than 1 mrem to the whole body and to the lungs (maximum exposed organ).

8.2.2. Earthquake

8.2.2.1. Cause of Accident

The cause of this accident is a DBE as described in Section 3.2.3.

8.2.2.2. Accident Analysis

This is a Design Event IV category (see Section 8.0).

Civil Structure

The MVDS structure is designed to withstand seismic loads due to a DBE. A full seismic analysis, including response spectrum analysis has been performed. See Section 4, Appendix A4-1.

Container Handling Machine

The CHM is designed to safely contain a FSC or fuel element during a seismic event. A seismic analysis of the CHM has been performed and is included in Appendix A8-2.

Fuel Storage Container and Standby Storage Well Structural Elements

An analysis of the FSC and SSW structural elements has been carried out using a conservative accelerating factor taken from the building seismic analysis. The results are given in Appendix A8-2, where it is shown that the integrity of the FSC and SSW are maintained.

MVDS Crane

The MVDS crane is mechanically restrained in its stopping position by the automatic application of the restraint system.

The MVDS crane and hoist unit are designed to remain on their rails during a seismic event. Load retention by the MVDS crane is not guaranteed but if the CHM is dropped it will be retained in an upright position by the seismic restraint guides. See Section 4.4.2.1. Dropping of equipment will not affect the safe operation of the MVDS facility. See Sections 8.1.11, 8.2.5 and 8.2.6.

Radioactive Source Storage Cabinet

The radioactive source storage cabinet, which contains sources necessary to perform required calibration and functional tests of radiation monitoring instruments and for analysis of ISFSI samples, is located at the south end of the charge face. As discussed in Section 7.6.4, it is restrained in a manner such that it will not topple in the event of a design basis earthquake. The possibility was considered (Ref. 14) of something falling on and breaching the cabinet during an earthquake, though this is unlikely. Were the cabinet to breach, sources could fall out of the cabinet and onto the charge face. Sources would be contained on the charge face, or in the transfer cask reception bay if they fell through the cask load/unload port (CLUP), located at the south end of the ISFSI structure. The hatch cover and the adapter plate normally cover the CLUP, except when a transfer cask is loaded in the CLUP, such as would be the case during defueling operations. If the CLUP were open at the time of an earthquake and sources fell through the CLUP into the transfer cask reception bay, they would remain in the bay and would not pose a threat to the health and safety of the public. Radiation Protection personnel would be contacted to safely gather the sources. Exposures to occupational radiation workers in the ISFSI, including those handling sources for the cleanup operation, would not be expected to exceed 100 mrem.

8.2.2.3. Accident Dose Calculations

There are no radiological consequences from this accident.

8.2.3. Dropping a Fuel Storage Container

8.2.3.1. Cause of Accident

The accident considered in this Section is the dropping of a FSC from its maximum probable height of 4 inches in the CHM into a transfer cask, vault module, or SSW. Several causes are postulated all of which have low probabilities.

The CHM raise/lower mechanism comprises an acme thread leadscrew, drive unit, trunnion mounted nut, guide system, duplex chains, sprockets and equalizing beam. A detailed description is given in Section 4.4.2.5.3.

The incredible event of dropping an FSC from its maximum height of 275" on to the MVDS vault floor has been analyzed (Ref. 11). This analysis concludes that the FSC containment is not breached, the nuclear safety of the fuel elements is maintained, and that the FSC is retrievable.

<u>Operator Errors</u>

The CHM operator activates the grapple release with the FSC suspended outside the permitted release band. The grapple jaws are prevented from disengaging by a mechanical locking plate when the load is suspended. This event also is protected against by the use of two electrical interlocks (position limit switches) that prevent power from being supplied to the grapple solenoid when the grapple is outside the permitted release band. A full description of the grapple operation is contained in Section 4, Appendix A4-2.

The failure probability of both limit switches and the mechanical interlock is estimated as 7.9E-7/demand (Ref. 4). The probability of an operator error is estimated at 1.0E-3/operation (Ref. 2). Thus, the probability of a FSC drop from the CHM grapple outside of the grapple release band is approximately 7.9E-10/operation. Assuming four raise/lower movements per CHM operation and one CHM operation per year for FSC maintenance or repair results in an event probability of 3.2E-9/year. Assuming 252 CHM operations per year for unloading operations results in an event probability of 8.0E-7/year.

Grapple Failure

The grapple design complies with the requirements of ANSI/ASME NOG-1 (Ref. 3) and provides assurance that failure of a single component will not cause loss of load. There are two load carriers providing a dual load path and a jaw locking feature. The work or duty service on the grapple is low and under these conditions the failure probability is negligible.

The minimum safety factors in normal handling are commensurate with the suspension system safety factors, i.e. a factor of 5 for each load carrier. The grab system and raise/lower mechanism is proof loaded to the requirements of NOG-1 and maintenance carried out to the requirements of ANSI B30.2 (Ref. 8).

Seismic Damage Causes Grapple to Release

The grapple jaws cannot release while the mechanical lock is in place and hence while the load is being carried. The lateral loads imposed by a seismic event on the grapple are small compared to the normal operating loads.

All components in the load support chain and grapple locking system are designed against 12,000 lb load resulting from a 'Hangmans drop' situation. The vertical seismic loads imposed on the system do not exceed the 'Hangmans drop' criterion (see Appendix A8-2).

Suspension System Failure

The raise/lower mechanism is double suspension designed to the requirements of ANSI/ASME NOG-1 (Ref. 3) where applicable. The minimum safety factor under the design load is 18 under normal conditions when two chains are acting.

Protection is provided against 'Hangman's drop' by two underload hoist trips. An analysis is given in Section 4, Appendix A4-2.5 for a postulated drop of 0.3 inches after snag release. Under these conditions, the minimum factor of safety in each chain is 7.5. The probability of a 'Hangman's drop' is estimated as 1.2E-8/operations (Ref. 10). Assuming one FSC lowering operation per year for FSC maintenance or repair results in an event probability of 1.2E-8/year. Assuming 252 FSC lowering operations per year for unloading operations results in an event probability of 3.0E-6/year.

Protection is provided against failure of a single chain by the double suspension system (see Section 4.4.2.5.3). Under this non-mechanistic worst case fault, the minimum safety factor in the remaining chain is 3.3 (see Section 4, Appendix A4-2.5). This means that the proof load of the chain, which is one-third the breaking load, is not exceeded.

8.2.3.2. Accident Analysis

This is a Design Event IV category (see Section 8.0).

An analysis is given in Appendix A8-6 for the vertical drop of a loaded FSC onto a concrete surface from a height of 4 inches, where it is shown that the FSC containment is not breached. The analysis height of 4 inches is twice the maximum credible drop of a FSC within the grapple release band. Outside of this release band, analysis is not considered necessary due to the integrity of the CHM raise/lower mechanism and the low probability of such an accident.

The dropping of a loaded FSC into a transfer cask, vault module, or SSW from twice the maximum credible drop height will not result in secondary failure of the transfer cask support collar, the FSC support stool, or the SSW containment. An analysis of the three conditions is given in Appendices A8-6 and A8-8.

Consideration has also been given to possible drop of an empty FSC, internally contaminated, after its lid has been removed (Ref. 14). It is considered that empty FSCs will be returned to the ISFSI during defueling operations, and the empty FSCs are expected to be contaminated. It is planned to store these containers in the vault modules until such time as they are either decontaminated, or removed and disposed of as radioactive waste. A release of radioactivity could occur should an empty FSC be dropped during handling when its lid has been removed, which could possibly occur during ISFSI decommissioning.

8.2.3.3. Accident Dose Calculations

The loaded FSC can be removed to a SSW following any drop. Inspect and evaluate the loaded FSC prior to storage in a vault module. Perform corrective actions as dictated by the evaluation.

There are no radiological consequences arising from this accident.

In order to assess the consequences of postulated drop of an empty FSC, it was conservatively assumed (Ref. 14) that the internals of the dropped FSC are contaminated to a level of 1.0 E+8 dpm/100 cm^2 with activity consisting of the same radionuclides and their concentration ratios as that actually measured on the internal surfaces of the fuel handling machine at the FSV plant (Ref. 15). The FSCs have an internal diameter of 1.5 ft. and are 16.6 ft. high, for an internal surface area of approximately 75,000 cm^2. Thus, a FSC is assumed to contain 3.38 E-2 curies of removable activity. It is assumed that the postulated drop accident results in 1.0% of this activity becoming airborne. Doses to an individual stationed at the emergency planning zone boundary (100 meters from the ISFSI) for the duration of the release, using a worst case dispersion factor of 3.53 E-2 sec/m^3 (representative of a 1 mph wind speed and stability class G - Ref. 16, Section 3.4.2), were calculated to be less than 1 mrem to the whole body and to the lungs (Ref. 14). Due to the extremely high activity concentration assumed, it is considered that the consequences of this drop accident envelope those involving other contaminated equipment items that could occur at the ISFSI.

8.2.4. Fire and Explosions

8.2.4.1. Cause of Accident

Only minor local fires are considered possible within the ISFSI facility. (See Section 3.3.6)

No means of propagating internal explosions are foreseen and loading from such explosions are not considered.

8.2.4.2. Accident Analysis

This is a Category IV Design Event (see Section 8.0). The MVDS is constructed from steel and concrete, and there is no stored amount of combustible material for creating a major fire hazard. Minor local fires may occur and will be dealt with by local portable extinguishers. There are no foreseeable situations where these types of minor fires can compromise the long term integrity of the fuel and its protective systems.

Consideration was given to potential effects of a fire on radioactive materials other than spent fuel that are authorized to be stored at the ISFSI, discussed in Section 7.6.4. Radioactive sources are stored in a fire-rated cabinet against the south wall of the charge face, designed to protect the sources against the effects of fires, and no release of radioactivity would occur from the sources (Ref. 14). In the event the depleted uranium plugs (DUPs) were exposed to a fire, no significant release of U-238 would be anticipated. Uranium metal is only pyrophoric when it is finely divided. The DUPs consist of solid, machined, depleted uranium that is nickel plated, and the uranium in this form would not be expected to burn, even if it were exposed to a fire. In order to reduce the potential for involvement of the DUPs in a fire, any storage areas for low-level radioactive waste are required to be separated from the DUPs by a minimum horizontal distance of 20 feet (Ref. 14).

As discussed in Section 7.6.4, low-level radioactive waste temporarily stored at the ISFSI awaiting disposal is expected to consist primarily of dry radioactive waste, such as rags or paper wipes, and anti-contamination clothing. This waste will be stored in 55 gallon steel drums. The steel drums would afford some protection of the contents against the effects of fires. However, a calculation was performed to assess the dose consequences that could result in the event of a fire, assuming the maximum inventory of low-level waste expected to be stored at the ISFSI were involved in the postulated fire, with no credit for protection by the packaging. The results of this calculation are described below.

Spent fuel shipping casks are required to be shown capable of withstanding exposure to a fire lasting at least 30 minutes with temperatures of 1,475 degrees F (10 CFR 71.73(c)(3)). In order to assure that loaded spent fuel shipping casks will not be exposed to a fire involving low-level radioactive waste at the ISFSI, low-level radioactive waste is not permitted to be staged in the transfer cask reception bay when a cask containing spent fuel is in the cask load/unload port (CLUP).

Externally initiated explosions (see Section 3.3.6) are considered to be bounded by the tornado generated missile load analysis presented in Section 8.2.1.

8.2.4.3. Accident Dose Calculations

Minor fires within the MVDS facility will not compromise the integrity of the fuel and its protective systems. There are no releases of radioactivity from the FSCs resulting from this accident.

A calculation was performed to assess the dose consequences that could result in the event of a fire, assuming low-level waste authorized to be temporarily stored at the ISFSI for disposal were involved in a fire. Neglecting the protection against fires afforded by the 55 gallon steel drums that would contain low-level radioactive waste, it was conservatively assumed that low-level radioactive waste material containing 1.0 curie of activity was burned (Ref. 14). The waste material was assumed to have the same radionuclides and concentration ratios as that identified inside the FSV plant fuel handling machine (FHM) before it was decommissioned (Ref. 15). The release fraction from the fire was assumed to be the same as that used in NUREG/CR-0672 (Reference 17) for a combustible waste fire, 1.5 E-4. Resultant doses at the ISFSI 100 meter emergency planning zone boundary, assuming a ground level release and a dispersion factor of 3.53 E-2 sec/m^3 (worst case value based on a wind speed of 1 mile per hour and Stability Class G - Reference 16, Section 3.4.2), were calculated to be less than 1.0 mrem to the whole body and to the lungs, which received the highest organ dose.

8.2.5. Drop of a Transfer Cask

8.2.5.1. Cause of Accident

The MVDS crane is not a high integrity device and is equipped with limited protection systems. An uncontrolled lowering (dropping) of a transfer cask is postulated to occur during unloading operations. A more detailed description of the crane is given in Sections 3.2.5.3 and 4.4.2.1.

The probability of an uncontrolled lowering of a transfer cask is estimated to be 1.7E-5/operation (Ref. 5). Assuming one transfer cask operation per year for FSC maintenance or repair results in an event probability of 1.7E-5/year. Assuming 252 transfer cask operations per year for unloading operations results in an event probability of 4.3E-3/year.

8.2.5.2. Accident Analysis

This is a Design Event III category (see Section 8.0).

During the raise and traverse of the transfer cask, the maximum possible drop height from the MVDS crane onto the reception bay floor is approximately 7 feet (base of transfer cask to floor). The transfer cask may topple following impact with the reception bay floor.

The TN-FSV casks have been licensed under 10 CFR Part 71 and will be used to transfer loaded FSCs from the ISFSI during defueling operations. The TN-FSV casks can withstand a 7 foot drop onto the cask bottom in the ISFSI cask receiving bay, followed by a topple, without breach of the containment vessel, assuming the impact limiters are not installed. Reference 13 contains the drop analysis for the TN-FSV casks. Since the TN-FSV casks will maintain their integrity in the event of a cask drop accident, such an event would not result in the release of significant amounts of radioactivity to the atmosphere. However, the FSC contained inside the transfer cask is not guaranteed for drops in excess of 4 inches, and damage may result in releasing radioactive particulates and gas into the transfer cask.

The TCRB floor could be damaged by a drop of the transfer cask from the MVDS crane, but the integrity of the vault module is not affected. See Section 4, Appendix A4-1 and Appendix A8-8.

8.2.5.3. Accident Dose Calculations

There is no immediate radiological hazard resulting from this accident. The cask is handled at the ISFSI site using appropriate radiation protection precautions. Inspect and evaluate the cask and FSC. Perform corrective actions as dictated by the evaluations.

8.2.6. Impacts on Charge Face Structure

8.2.6.1. Cause of Accident

The charge face structure and shield plugs form the primary shielding boundary for the FSCs.

There are two equipment impact cases as addressed below:

1. Those equipment impacts onto the charge face structure and shield plugs from equipment drops. The worst case equipment drop onto the overall charge face structure is the dropping of an isolation valve (25,000 lbs) from a height of 7" from the MVDS crane. The probability of an uncontrolled lowering (drop) of an isolation valve is estimated at 1.7E-5/operation (Ref. 5).

2. Those equipment impacts onto the charge face shield plugs from local impacts. Local equipment impacts on the shield plugs are bounded by the tornado generated missiles A, B, C, and E which can enter the charge hall by penetrating the roof or wall cladding. The probability of a direct impact onto the charge face structure and shield plug is estimated at approximately 1.0E-7/year (see Section 8.2.1).

8.2.6.2. Accident Analysis

This is a Design Event III category (see Section 8.0).

An analysis of impacts on the charge face structure and the charge face shield plugs from equipment drops and tornado generated missiles is given in Appendix A8-3.

The shielding integrity of the charge face structure is maintained and the FSCs stored within the vault module will not be affected by these worst case impacts.

8.2.6.3. Accident Dose Calculations

There are no radiological consequences resulting from this accident. The charge face structure will not be breached from these impacts nor will any damage occur to the FSC.

8.2.7. Long Term Loss of AC Electrical Power

8.2.7.1. Cause of Accident

This postulated accident considers the long term loss (> 1 hour) of AC electrical power to the ISFSI facility. All other components are assumed to be in their normal condition.

The cause of this accident is the major failure in the power utility network.

8.2.7.2. Analysis of Accident

This is a Design Event III category (see Section 8.0).

Table 8.2-1 lists all the equipment normally operated by external power and identifies those whose functions may be carried out manually.

The major effect of a loss of AC electrical power will be a prolonged interruption in fuel handling operations.

The long term steady state temperatures have been assessed as part of the normal (but conservative) temperature history. See Section 3, Appendix A3-1.4. With the FSC or a fuel element partially inserted into the charge face or any position intermediate between the CHM and the transfer cask, SSW, or vault module, the ability of the FSC/element to reject its decay heat output will be impaired to some degree. In these intermediate locations the limiting case is provided by the adiabatic temperature response of a fuel element - average rated fuel element 2.9 degrees Fahrenheit/hr, peak rated fuel element 5.1 degrees Fahrenheit/hr. This heat up rate has been substantially reduced because of the additional decay from June 1992 to the present. The steady state temperatures in the CHM and transfer cask allow indefinite storage periods and the conservative adiabatic transient response demonstrates that significant time periods are available for recovery operations.

Loss of AC power with the FSC or fuel element fully in the CHM or FSC fully in the transfer cask results in much lower peak temperatures and is bounded by the above case.

8.2.7.3. Accident Dose Calculations

There are no radiological consequences resulting from this accident.

8.2.8. Full or Partial Blockage of Outlet to Vault Module

8.2.8.1. Cause of Accident

Due to the height above ground level, the outlet may be blocked by airborne debris but this is much less likely to occur than the blockage of the inlet (Section 8.1.2). The outlet is double sided and while it is possible for a light weight plastic sheet to completely block the upwind outlet, it is incredible that another sheet could be blown simultaneously onto the downwind side. Blockage of the upwind side of the outlet will not impair the cooling flow.

A blockage of 10% of the outlet is postulated to occur for the collection of leaves and debris on the outlet. A probability of once per year is assumed.

Blockage by a snowdrift is considered to be incredible since a 70 foot drift is required. A snowdrift on the roof may build up and block one side of the outlet under extreme conditions, however the remaining side will still remain clear. Snow can be blown onto the mesh and build up eventually causing a blockage if the snow is sufficiently wet. The large size of the mesh will make this unlikely and as such would only cause a single sided blockage.

As discussed in Section 8.1.2, frost formation has been observed to occur on the screens ("bird mesh") in the outlet ducts, though not to the extent observed at the inlet ducts where heavy frost has at times almost completely covered the inlet screens. The frost is very delicate and pores exist through which some air can flow. Blockage due to the formation of ice on the outlet screens, such as due to freezing rain, would be very unlikely since the roof over the screens would offer protection, and ice buildup would only be expected to occur on the upwind side. In the unlikely event that frost or ice buildup blocks 95% or more of the outlet screens, actions would be taken as necessary to remove the blockage within 24 hours, as required by the Technical Specifications.

A blockage caused by tornado generated missiles entering the duct is not considered due to the very low probability of a missile entering the stack (see Section 8.2.1). However, the physical size of the largest missile able to reach the stack top, would not constitute more than a 30% blockage of a single module outlet, were it to enter the stack.

Although outlet blockage resulting from displaced cladding from the stack canopy is unlikely due to the suction forces created by the tornado, it will not result in a blockage of greater than 95% of the total MVDS stack outlet.

8.2.8.2. Accident Analysis

This is a Design Event IV category (see Section 8.0).

Four cases of partial inlet blockage are considered in Appendix A8-11. These are a 50%, 75%, 90%, and 95% blockage. One case of partial outlet blockage is considered in Appendix A8-11, 95% blockage. The 95% inlet and outlet blockage cases are analyzed to show that although no credible cause of prolonged blockage to this extent exists, the safety of the facility is not compromised.

As discussed in Section 8.1.2, there was an occurrence of inlet duct blockage estimated to be approximately 96% due to ice formation over the wire mesh in the inlet duct. This occurred due to uncontrolled water drainage from melting snow on the roof of the inlet duct structure. A steel gutter was installed on this roof to collect and drain water to the side of the MVDS structure, preventing the water from contacting the inlet duct wire mesh. This is considered to remove the mechanism for ice formation, and prolonged 95% blockage of the inlet or outlet ducts is not considered to be credible. Nevertheless, analyses of inlet duct blockages greater than 95%, and up to 99%, have been performed and the results are summarized in Appendix A8-11. As discussed in Reference 12, maximum allowable temperatures for accident conditions of the fuel, FSCs, and concrete would not be reached until after 14 days, 9.7 days, and 14 days respectively with 100% blockage of the inlet or outlet ducts, conservatively assuming peak rated fuel with only 600 days decay (150 Watts per element). However, since fuel was loaded in June 1992, an additional decay of greater than 6,000 days has occurred. Hence, a surveillance interval of 7 days is acceptable.

8.2.8.3. Accident Dose Consequences

There are no radiological consequences of this accident.

8.2.9. Tornado Generated Missile Impact on the Transfer Cask in the Transfer Cask Reception Bay or Cask Load/Unload Port

8.2.9.1. Cause of Accident

Tornado missiles A, B, C, D and E (Table 3.2-1) may enter the TCRB via the roller shutter door. In the process, they will lose much or most of their energy before hitting the transfer cask.

The probability of this event is less frequent than the DBT (1.0E-7). The transfer cask is a small target and the probability of an impact on the transfer cask during a DBT is considered to be similar to the value of 3.0E-3/year estimated for an impact on the CHM (Section 8.2.10). There will be no transfer casks in the TCRB for a significant fraction of the year (maximum of 252 transfer casks loaded per year). The probability of this accident is estimated to be less than 1.0E-10 per year and is considered to be below a level where further analysis is necessary.

8.2.10. Tornado Generated Missile Impact on Container Handling Machine

8.2.10.1. Cause of Accident

Missiles A, B, C, and E may penetrate the MVDS building cladding above the 30 foot level (see Section 8.2.1) and impact the CHM.

The analysis in Appendix A8-7 shows the probability of a missile strike on the CHM when loaded to be conservatively estimated at less than 1.0E-10/year.

This low probability is considered to be below a level where further analysis of the consequences is necessary.

However, if handling operations are in progress one of the following actions will be taken to ensure that the FSC/element is in the best practical position allowed. The MVDS crane is mechanically restrained in its stopped position by the automatic application of the restraint system which prevents crane movement during a tornado event (see Sections 1.3.2.9 and 4.4.2.1).

1. If a FSC is being lowered or raised by the CHM over a vault module or SSW
2. Continue the operation and close the isolation valve or the CHM valve as applicable.
3. If a full FSC is being lowered into a transfer cask

   Continue to lower the FSC into the transfer cask and close the CHM valve.
4. If the CHM is full and in transit

Protection is provided by the CHM tornado clamps on the MVDS building crane and MVDS crane hoist failure (see Section 8.2.1.2.1).

8.2.11. Lifting of Equipment Out of Sequence

8.2.11.1. Container Handling Machine Lifted with both Container Handling Machine Valve and Isolation Valve Open

8.2.11.1.1. Cause of Accident

The postulated cause of this accident is the premature removal of the crane pendant key from the CHM valve allowing the crane to be mobilized. A full description of the CHM key interlock system is contained in Section 4, Appendix A4-2.

Premature removal of the crane pendant key is conservatively estimated as 2.0E-8/operation (Ref. 10). The operator failing to shut the isolation valve prior to attempting key removal is estimated as 1.0E-3/operation (Ref. 2). Assuming two CHM lifts per transfer cask operation and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 4.0E-11/year. Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 1.0E-8/year. . These are considered to be below a level where further analysis is necessary.

8.2.11.2. Shield Plug Handling Device Lifted with Isolation Valve Open

8.2.11.2.1. Cause of Accident

The SPHD is lowered onto the isolation valve and disconnected from the MVDS crane. It is then rotated to engage the three valve location dowels into the isolation valve. An interlock pin on the isolation valve open/shut mechanism mechanically interlocks the SPHD to the isolation valve when the isolation valve is not fully closed.

The postulated cause of this accident is a failure of the mechanical interlock, and an out of sequence rotation of the SPHD by the operator(s).

8.2.11.2.2. Accident Analysis

This is a Design Event IV category (see Section 8.0).

No credible cause of interlock failure is identified. The interlock pin and valve location dowels are not subject to any undue shear or tensile forces. The low usage rate and material specification ensures that wear rate is not significant.

If an attempt is made to lift the SPHD while the isolation valve is open, the mechanical interlock will prevent the valve location dowels from being unlocked. In the event of an attempted lift, the valve location dowel tensile strength will prevent lifting (see Section 4, Appendix A4-2).

8.2.11.2.3. Accident Dose Calculations

Since the analysis has shown that the SPHD cannot be lifted for this accident condition, there are no radiological dose consequences.

8.2.11.3. Isolation Valve Lifted off Charge Face Structure, Standby Storage Wells, or Cask Load/Unload Port after Shield Plug Removed

8.2.11.3.1. Cause of Accident

The isolation valve is bolted down into position on the charge face over the vault module, and SSW, or transfer cask prior to any handling operations.

The removal of a bolted isolation valve is by administrative control.

The postulated cause of this accident is the unscheduled removal of an isolation valve from a vault module position.

8.2.11.3.2. Accident Analysis

This accident has the potential for a direct radiation dose to the operator and is a Design Event IV (see Section 8.0). To ensure this potential is minimized, Health Physics monitoring of radiation levels at the interface between the isolation valve and the unplugged channel is carried out during lifting operations. If radiation levels above background are detected, the isolation valve is lowered and the equipment status is examined.

8.2.11.3.3. Accident Dose Calculations

Appendix A8-10 calculates that the peak dose rate of an unplugged channel is 310 rem/hr at the vault module position centerline at the charge face level. On lifting the isolation valve, a shine path can exist between the base of the isolation valve and top of the surrounding shield plugs. Any radiation shine is detected by Health Physics monitoring and the isolation valve is lowered. The maximum clearance between the isolation valve is 4 inches resulting in a dose rate at the outside edge of the isolation valve of 12.6 rem/hr (see Appendix A8-10). Conservatively assuming it takes two minutes to detect the radiation and lower the isolation valve, a maximum exposure to the operator is 0.4 rem.

8.2.12. Close Isolation Valve onto Partially Inserted Fuel Storage Container or Fuel Element

8.2.12.1. Cause of Accident

Closing the isolation valve and CHM valve onto a partially inserted FSC/element is prevented by the use of a key interlock system. The isolation valve is mechanically prevented from being closed via the operator handwind unless the CHM raise/lower mechanism control key is inserted into the CHM valve. This control key is only released from the CHM raise/lower mechanism control panel when the grapple is at upper datum (FSC/element fully inserted into CHM). The upper datum position is protected by the use of two limit switches. A full description of the

CHM key interlock system and the raise/lower mechanism interlocks is contained in Section 4, Appendix A4-2.

The probability of the isolation valves being shut onto a FSC or fuel element to cause significant damage is conservatively estimated to be 2.4E-10/operation (Ref. 10). Assuming two isolation valve closure operations per FSC and 252 full FSCs are handled per year, this results in an event probability of 1.2E-7/year. This is reduced to 4.8E-10/year assuming only one fuel element handling operation per year. These are considered to be below a level where further analysis of the consequences is necessary.

8.2.13. Deposit Fuel Storage Container/Fuel Element on the Charge Face

8.2.13.1. Cause of Accident

The CHM is regularly moved with storage containers on board (252 storage container operations per year) and occasionally with fuel elements (one operation per year). This latter assumed event frequency is very conservative, based on the fuel storage design features. During transit, the CHM isolation valve is mechanically locked shut by a keyswitch operated locking bolt. The CHM isolation valve is opened by being mechanically driven by isolation valve #1. The CHM isolation valve has no built in open/shut drive of its own. A full description of the CHM key interlock system and the raise/lower mechanism interlocks is contained in Section 4, Appendix A4-2.

For this accident to occur, a number of coincidental events are necessary: failure of the locking bolt arrangement, some external mechanism to open the CHM isolation valve and a lowering of the CHM raise/lower mechanism.

The probability of a FSC or fuel element being exposed is estimated as 7.4E-14/operation (Ref. 10). Assuming 252 FSC and one fuel element handling operation per year, this results in event probabilities of 1.9E-11/year and 7.4E-14/year, respectively. These are considered to be below a level where further analysis of the consequences is necessary.

8.2.14. Traverse Container Handling Machine with Load Partially Inserted

8.2.14.1. Cause of Accident

Section 8.2.12 discusses the accident in which the isolation valve is closed onto a partially inserted FSC or fuel element. Because of the CHM key interlock system design, the probability of this event is extremely low (2.4E-10/operation).

For the accident in this section, the postulated cause is the premature removal of the MVDS crane interlock key from the open CHM valve, following the events discussed in 8.2.12, permitting the movement of the CHM away from the isolation valve in which a partially inserted FSC/element is trapped. A full description of the CHM key interlock system and the raise/lower mechanism interlocks is contained in Section 4, Appendix A4-2.

The probability of this accident is estimated as 1.0E-18 (Ref. 10), involving a number of events in addition to those in Section 8.2.12. Assuming two CHM lift/traverse movements per transfer cask and one transfer cask operation per year for FSC maintenance or repair, this results in an event probability of 2.0E-18/year. Assuming 252 transfer cask operations per year for unloading operations, this results in an event probability of 5.0E-16/year. These are considered to be below a level where further analysis of the consequences is necessary.

8.2.15. Maximum Credible Accident

8.2.15.1. Cause of Accident

The "Maximum Credible Accident" is the radiological consequences at the site boundary (approximately 100 meters) resulting from the leak of one FSC in a vault module. The release is via the leak path from the MVDS stack (height of 80 ft 6 inches).

There are two postulated failure modes causing this accident. First is the failure of the redundant metal O-ring seals. Secondly is the failure of the FSC due to corrosion. Due to the design of the FSC's redundant seals and the corrosion protection afforded in the FSC design, (see Section 4.2.3.2) no credible failure mechanism for these design features is identified. Thus, both of these failure modes are considered low probability events.

8.2.15.2. Accident Analysis

This is a Design Event IV category (see Section 8.0).

The release from a failed FSC is assumed to occur into the storage vault module over a 10 minute period, chosen to represent an instantaneous loss of containment. Following this release the gaseous and particulate matter are assumed to be released to the atmosphere via the outlet cooling stack and that no filtration of the release occurs.

8.2.15.3. Accident Dose Calculations

The radiological consequences at the controlled area boundary for one leaking FSC are within the requirements of 10 CFR 72.106 (Ref. 8). Appendix A8-9 contains the radiological release assessment for this accident.

Table 8.2-1. Powered Equipment

EQUIPMENT	MANUAL OPERATION
MVDS Crane	Long transverse, cross traverse, raise, lower
CHM raise/lower mechanism	Lower, grab release at isolation valve level
Isolation valves - CHM on isolation valve #1 or isolation valve #2	None (loss of power disables interlock system and valves are locked as set).
CHM HEPA filtration system	None
Lights	None (battery powered emergency lights exist)
Heaters/ventilation fans	None

8.3 Site Characteristics Affecting Safety Analysis

All site characteristics affecting the safety analysis presented in this SAR are noted where they apply.

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8.4 References

1. Regulatory Guide 3.62, February 1989, "Standard Format and Content for the Safety Analysis Report for Onsite Storage of Spent Fuel Storage Casks."
2. Handbook of Human Reliability Analysis, NUREG/CR-1278, August 1983.
3. ANSI/ASME - NOG-1 - 1983, "Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)."
4. Smith, David J., "Reliability and Maintainability in Perspective," McMillan Education, 1988, Third Edition.
5. NCSR/GR/64, "Reliability techniques used in the assessment of cranes," March 1985.
6. ANSI B30.2-1976, "Overhead and Gantry Cranes (Top Running Bridge, Single or Multiple Girder, Top Running Trolley Hoist)."
7. ANSI/ANS-57.9 - 1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)."
8. Code of Federal Regulations, Title 10, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."
9. Code of Federal Regulations, Title 10, Part 20, "Standards For Protection Against Radiation."
10. GEC Alsthom Engineering Systems Ltd., Design Calculation, Fort St. Vrain MVDS Chapter 8 SAR, Reference 2879 Chapter 8 Calc 1., May 10, 1990 and Calc 2, March 8, 1990.
11. PSC letter dated May 24, 1991 (P-91177), Crawford to Ruffin (NRC); Subject: "Fort St. Vrain Independent Spent Fuel Storage Installation; Request for Additional Information."
12. GEC Alsthom Engineering Systems Ltd. Report, "Fort St. Vrain ISFSI, Thermal Analysis for a Range of Inlet Duct Blockage Situations"; November, 1992. Submitted to the NRC by PSC letter, Warembourg to Sturz, dated December 15, 1992 (P-92310).
13. Transnuclear, Inc. Report, "Engineering Report, TN-FSV Cask Drop Analysis in the ISFSI Cask Receiving Bay"; June, 1995.

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14. PSC letter dated December 12, 1995 (P-95103), Crawford to Travers (NRC); Subject: "Request License Amendment to Permit Certain Radioactive Materials at the FSV ISFSI, Necessary to Conduct Licensed Activities."

15. PSC letter dated January 11, 1995 (P-95005), Fisher to Austin (NRC); Subject: "Response to Comments Regarding the Final Survey Plan for Site Release."

16. Fort St. Vrain Decommissioning Plan, Public Service Company of Colorado, November 5, 1990; Approved by the NRC in November 1992; Latest Revision - December 26, 1995.

17. NUREG/CR-0672, "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station," Prepared by Pacific Northwest Laboratory, June 1980.

Appendix A8-1

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APPENDIX A8-9

RADIOLOGICAL RELEASE ASSESSMENT

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RADIOLOGICAL RELEASE ASSESSMENT: FSC LEAKAGE (Maximum Credible Event)

Calculations have been performed to determine the maximum dose that will be received outside the MVDS site boundary following the maximum credible release from the MVDS stack (height 80 ft 6 in). This release occurs as a consequence of the gross leakage of a single FSC in a VM.

The inventory of fission products contained in a maximum powered fuel block is assumed to be a factor of 1.76 greater than that calculated using ORIGEN-S for an average powered fuel block (Reference 1).

The releasable inventory of fission products from a single FSC containing six maximum powered fuel blocks of 600-day decay is defined as 0.001% of the solids, 50% of the halogens and 100% of the noble gases of the failed fuel particle fraction of 0.25% (Reference 7). The assumption that 0.001% of the solids are released is considered highly conservative as this value is about 100 times higher than the respirable fraction of particulates which are expected to be released in a severe spent fuel transportation accident (Reference 4). It is assumed that no filtration of the release occurs.

Calculations to predict the consequences of the release have been performed using the computer code MARC-1 (Reference 2). This code uses a Gaussian plume model for the atmospheric dispersion calculation. The results of the atmospheric dispersion calculation are used to determine the whole body and critical organ doses due to the following sources: external irradiation from the plume, activity deposited on the ground, beta irradiation from activity deposited on the skin, and internal irradiation from radioactive material taken into the body via inhalation.

The plume dispersion parameters assumed for the release calculations are based on the recommendations of Reference 5. Constant weather conditions of Pasquill Stability Class F with a wind speed of 1 ms^{-1} have been modeled. The release is assumed to occur at ground level into a building wake with no plume rise characteristics modeled. A 10 minute release period has been chosen to represent an instantaneous release from an FSC. A ground roughness of 1.0E-3 m has been used in the modeling to represent a "sandy desert" terrain (Reference 3).

The maximum calculated doses occur at the site boundary.

The maximum cloud gamma dose at the site boundary is calculated as less than 0.01 mrem. The maximum individual organ doses for adults resulting from inhalation are presented in Table 1. Doses to other organs not presented (thyroid, liver. etc) have also been calculated, but were not found to be significant when compared to the doses to the lungs and the bones. Inhalation and cloud gamma doses will be a maximum with no rainfall.

The effect of precipitation on the calculated doses has been investigated for the maximum measured rainfall rate at Fort St Vrain of 2.46 inches in a single hour (Reference 6). The gamma dose and skin beta dose attributed to the maximum calculated ground radioactivity deposited will both be a maximum at this rainfall rate. The calculated skin dose resulting from beta irradiation following the maximum credible release, which is assumed to occur during this period of maximum rainfall, assuming contamination of the skin exists for 4 days following the accident, is 71 mrem (or 18 mrem per day). The corresponding maximum calculated dose from activity deposited on the ground for an individual positioned at the site boundary for 7 days following a release is 0.3 mrem.

It should be noted that the doses calculated assuming wet deposition are intended as a guide only as the coefficients used in the calculation are dependent on particle size and are based on limited data for high rainfall rates.

It is therefore assumed that the 50 year committed dose consists of the effective committed dose due to inhalation, the dose from external irradiation from the plume and the dose resulting from 7 days exposure to the activity deposited on the ground adjacent to the site boundary with the maximum rainfall occurring during the release. This method of assessment results in a 50 year effective committed dose of approximately 1 mrem to this hypothetical individual.

Ingestion via the food chain has not been quantified in this assessment. It is judged that the contribution from this route will not significantly increase the calculated 50 year effective committed dose.

The results which are presented above are based on conservative assumptions and demonstrate that following the maximum credible release, the requirements of 10 CFR 72.106 are met. Specifically the requirement is that "any individual located on or beyond the nearest boundary of the controlled area shall not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident". The calculated dose of l mrem achieves the criterion with a substantial margin.

TABLE 1. MAXIMUM INDIVIDUAL ORGAN DOSES

ORGAN	INHALED DOSE (mrem)
LUNGS	4.0
BONE MARROW	0.6
BONE SURFACE	1.3
EFFECTIVE COMMITTED DOSE	0.6

RADIOLOGICAL RELEASE ASSESSMENT: FSC LID REMOVAL

Conservative hand calculations have been performed to determine the worst case operator dose resulting from a 'puff release' at the charge face via the CHM following the lid closure removal from a FSC.

The assumptions made regarding the releasable inventory of fission products for this case are the same as those made for the FSC vault leakage accident presented previously in this Appendix. It is assumed that the release is into a 1,000 cubic meters volume, which is representative of the charge hall volume, and that one operator is present on charge face for 30 minutes following the release.

There are two distinct contributions to the operator dose from this release: an internal dose arising from inhalation and an external gamma dose from the cloud.

The inhalation dose has been analyzed assuming the standard man described in ICRP 2 (Reference 9) inhaling 10^7 cc in an 8 hour working day. It is assumed that the release is uniformly distributed within the 1000 m^3 volume and that there are no air changes in the volume.

The contribution to the inhalation dose from each nuclide has been estimated based on the inhalation dose conversion factors for adults presented in Reference 6. The whole body dose calculated from inhalation is 310 mrem, largely resulting from the inhalation of Sr-90.

The external gamma dose is mainly due to the presence of Kr-85. The external gamma dose is found to be negligible compared to the inhalation dose.

The puff release into the charge face volume will only gradually escape by leakage from this volume to the environment, as there are no well defined leakage paths. The release of this inventory from the charge hall volume to the environment will effectively originate from a level of about half the height of the building and will be of a longer duration than the release resulting from a FSC leakage in the vault, hence the off site consequences will be bound by the analysis presented previously in this Appendix.

REFERENCES

1. 'Fort St Vrain MVDS Project Data File' GECA ESL Drawing No 362F0001 Issue D.

2. 'NRPB Methodology for Assessing the Radiological Consequences of Accidental Releases of Radionuclides to Atmosphere - MARC-l' M D Hill. J R Simonds and J A Jones NRPB-R224 (September 1989).

3. 'A Model for Short and Medium Range Dispersion of Radionuclides Released to the Atmosphere' R H Clarke NRPB-R91 (September 1979).

4. PSC letter dated January 18, 1991 (P-91039), Crawford to Roberts (NRC), Subject: "Fort St. Vrain Independent Spent Fuel Installation; Accident Analysis Assumptions."

5. 'Assumptions Used for Evaluating the Potential Radiological Consequences of a loss of coolant accident for Pressurized Water Reactors' US NRC Regulatory Guide 1.4, Revision 2. June 1974.

6. 'Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10CFR Part 50, Appendix I'. USNRC Regulatory Guide 1.109, Revision 1, October 1977.

7. FSV ISFSI Predicted Spent Fuel Fission Product Inventories. General Atomics Report No. 910061 NIC 4th May 1990.

8. 'Rainfall Data for Fort St Vrain'. 'Fort St Vrain ISFSI Safety Analysis Report' Figure 2.3-9.

9. ICRP Publication 2, Report of Committee II 'Permissible Dose for Internal Radiation', 1959.

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APPENDIX A8-10

SHIELDING ASSESSMENT OF DIRECT RADIATION DOSE RATES IN ACCIDENT CONDITIONS

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Calculation of Radiation Dose Rates to Operators for Off-normal and Accident Conditions

The code used for the assessment was RANKERN 12 (Reference 1). Data for 400 day decay delay fuel was used, and the results are given with respect to 600 day decay fuel by the application of a conversion factor of 0.76 to the 400 day decay results. The result of the assessment are listed below and are for an average rated fuel block. Values for a peak rated fuel block are higher by a factor of 1.76.

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1. Exposed FSC

   To assess the dose rate from an FSC protruding 21" below the CHM, it was considered that the contribution from the fuel within the CHM was neglible compared to the dose rate for the unshielded sections. Thus the model consisted of a 21" length of fuel block surrounded by a 0.5" thickness of steel FSC. The resultant dose rate at 1 meter from the fuel centerline was calculated as 1,200 rem/hour.

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2. Exposed Fuel Block

   To assess the dose rate from a fuel block protruding 21" below the CHM, the same model as in the previous case (1) was used with the exclusion of the 0.5" steel thickness of the FSC. The dose rate calculated at 1 one meter from the fuel centerline was 1,500 rem/hour.

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3. Unplugged Vault

   To assess the dose rate above an unplugged channel in the charge face, of a full vault, above a position containing a FSC, a model of the charge face structure and the six adjacent FSC's was produced. The dose rates were then calculated at various radial distances from the channel centerline at the top of the charge face level. The calculations gave a peak dose rate of 170 rem/hour at the channel centerline.

   To assess the dose rate above an unplugged channel in the charge face, of a full vault, but at a location which does not contain a FSC, the same model as used previously was used with the exclusion of the central FSC and fuel blocks. The dose rates were then calculated at various radial distances at the top of charge face level. The peak dose rate was 310 rem/hour at the channel centerline.

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4. Clearing of Inlet Ducts Wire Mesh

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This evaluation assesses the dose rate to an operator clearing the blocked wire mesh of the inlet ducts. The analysis gives a peak dose rate of 20 mrem/hour, on the surface of the wire mesh grill at 1.5 meters above the floor. Based on a time of 4 hours per duct and six ducts for the complete MVDS facility, the cumulative dose to an operator is estimated as 480 mrem.

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5. Isolation Valve Lifting from Unplugged Channel

This evaluation assess the cumulative dose to an operator from removing the isolation valve from a full channel before replacement of the shield plug. A streaming dose can occur between the valve underside and the charge face plug tops, (maximum gap of 4").

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Based on the peak dose rate above the empty channel of 310 rem/hour from (3) above, the dose rate to the operator is estimated to be 12.6 rem/hour.

The time for detection of the fault is conservatively assumed to be 2 minutes, thus the cumulative dose to an operator is estimated as 0.4 rem.

REFERENCES

1. “Answers (RANKEN 2). A Point-kernel Integration Code for Complicated Geometry Problems. A User Guide to Version 12".

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APPENDIX A8-11

THERMAL ANALYSIS FOR REDUCED AIR FLOW THROUGH THE MVDS VAULT MODULES

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INTRODUCTION

The MVDS storage vaults have inlet and outlet ducts which allow the circulation of cooling air.

In this Appendix the effect on FSC and fuel element storage temperatures is considered for inlet and outlet blockages postulated in Section 8.

Partial Blockage of Inlet and Outlet Ducts at the MVDS

The method of assessment using the DADS code (Reference 1 and 2) and the assumptions made in the analysis are detailed in Appendix A3-1. The vault modules are assumed to be fully loaded with fuel having a 600-day decay period.

The DADS flow performance calculations have been carried out for a single vault module with a range of wire mesh blockage assumptions. Both the inlet and outlet ducts have, however, interconnecting features which allow the individual vault flow performances to be based on the total overall blockage.

The inlet duct features two large plena, running the length of the MVDS, which act as an inlet manifold. The combined flow area of the plena is in excess of 100 square feet and ensures an even flow distribution without any significant increase in the system flow resistance. The analysis presented therefore embraces both local blockage of an inlet duct wire mesh and total blockage of a number of adjacent vaults.

The same flow redistribution mechanism is also present within the birdmesh screen enclosure of the outlet ducts. The flow area of this communicating plenum is in excess of 50 square feet and will ensure flow redistribution in the event of a complete blockage of an outlet duct wire mesh. Total blockage of both sides of the outlet duct screen is not however considered possible.

The effect of postulated percentages of blockage to the wire mesh of either the inlet ducts or the outlet ducts has been assessed. The inlet duct is the more sensitive to blockage, because of its relatively smaller flow area and hence its higher flow resistance. Results are presented in Table A8-11-1 for a range of postulated inlet duct screen blockages between 0%. and 95% and for an outlet duct screen blockage of 95%. The variation of the FSC and fuel element temperatures with various percentages of blockage for the full vault operating condition are presented in Table A8-11-1. All of the flow rates and temperatures are assessed for calm dry conditions at the maximum ambient temperature of 120 degrees F, which will account for the maximum fuel and FSC temperatures.

Blockages of the MVDS Inlet Duct Greater Than 95%

On March 11, 1992, there was an actual blockage occurrence due to the formation of ice on the inlet duct wire mesh, described in Section 8.1.2. It was estimated that approximately 96% of the inlet duct was blocked. Since this exceeded the 95% previously analyzed, analyses were performed of blockage cases beyond 95%, up to approximately 99% of the inlet duct assumed to be blocked. The DADS code (Ref. 3) was again used to model the thermohydraulics in the ISFSI, and the vault modules were assumed to be fully loaded with fuel having a 600 day decay period. The major differences in assumptions between this analyses and that discussed in the preceding paragraphs are the ambient temperatures. Instead of 120 degrees F, an ambient temperature of 35 degrees F was used to simulate a maximum temperature at which ice could reasonably be postulated to block the inlet ducts. In addition, other cases were analyzed assuming an ambient temperature of 95 degrees F. This was used instead of 120 degrees F, since it is considered to be representative of a maximum average ambient temperature over a period of about 10 days (it would take at least this long for fuel and FSCs to reach maximum temperatures). As in the preceding analyses, no credit was taken for enhancement of cooling due to wind effects, and calm day conditions were assumed. A summary of the analyses is presented here. A detailed discussion of these analyses is contained in Reference 4.

Two separate inlet duct wire mesh screen blockage situations were assessed - front and side inlet duct blockage, described in the following paragraphs:

Front Inlet Duct Blockage

The DADS analysis was carried out for a single, fully loaded vault with a range of inlet duct wire mesh screen blockage assumptions extending to 99%. No account was taken in this analysis of any air flow entering via the two side inlet air flow routes in assessing the increased flow losses due to the blockage. The calculations were carried out for the two specified ambient conditions of 95 degrees F and 35 degrees F and the results are presented in Table A8-11-2, extracted from Reference 4.

Side Inlet Duct Blockage

These cases assume that all of the front inlet and one of the two side inlet duct’s wire mesh screens are completely blocked. The second side inlet is then subjected to 0%, 25%, 50% and 75% blockage of its wire mesh screen which in area terms represents 96%, 97%, 98%, and 99% blockage of the total front and side inlet duct screen flow areas. In this situation, the total air cooling flow for the six vaults is all admitted through this single side inlet. The most onerous cooling scenario occurs for the end vault, the one furthest from the single inlet, and it is this vault location which is assessed in the DADS analysis. The results are presented in Table A8-11-3, extracted from Reference 4.

REFERENCES

1. ESL/TM(85)198 Design-And-Analysis-of-Dry-Stores (DADS) Thermal Design Computer Program. Specification, description and validation, GEC ESL Report December 1985.

2. ESL/TM(90)37 Design-and-Analysis-of-Dry-Stores, Validation of Version C.C. Brown, February 1990.

3. ESL/TM(90)58 Design-and-Analysis-of-Dry-Stores (DAS) Computer Program, Validation of Issue D.

4. GEC Alsthom Engineering Systems Ltd. Report, "Fort St. Vrain ISFSI, Thermal Analysis for a Range of Inlet Duct Blockage Situations"; November, 1992. Submitted to the NRC by PSC letter, Warembourg to Sturz, dated December 15, 1992 (P-P2310).

TABLE A8-11-1

VARIATION OF FUEL ELEMENT AND FSC TEMPERATURES WITH INLET/OUTLET DUCT BLOCKAGES

DUCT BLOCKAGE (%)	COOLING AIR CONDITIONS		AVERAGE FUEL		PEAK FUEL	
	FLOW RATE (lb/s)	OUTLET TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°)
INLET DUCT						
0	8.13	131	156	194	176	235
50	7.91	131	157	195	177	236
75	7.37	132	159	196	180	239
90	5.50	136	169	205	192	250
95	3.77	144	185	221	217	272
OUTLET DUCT						
95	6.15	135	165	202	188	246

Note:I) The fuel temperatures are the maximum centerline values.

ii) The air flow rate is for a single module.

TABLE A8-11-2

COMPARISON OF RESULTS OF THE DADS ANALYSIS FOR A RANGE OF FRONT INLET DUCT WIRE MESH SCREEN BLOCKAGE CASES

DUCT BLOCKAGE (%)	COOLING AIR CONDITIONS		AVERAGE FUEL		PEAK FUEL	
	FLOW RATE (lb/s)	OUTLET TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°)
1200F AMBIENT						
0	8.13	131.0	156.0	194.0	176.0	235.0
95	3.77	144.0	185.0	221.0	217.0	272.0
950F AMBIENT						
0	8.52	105.6	130.6	169.7	150.3	211.2
50	8.30	106.0	131.2	170.2	151.2	212.1
75	7.72	106.7	133.2	172.1	153.9	214.6
90	5.76	110.7	142.5	180.9	167.4	227.0
95	3.95	117.9	158.2	195.6	189.7	247.6
96	3.44	121.3	165.0	202.1	199.4	256.6
97	2.87	126.5	175.5	211.9	214.0	270.0
98	2.18	136.4	194.4	229.7	240.1	294.1
99	1.36	161.4	238.3	271.1	299.5	348.9
350F AMBIENT						
0	9.60	44.4	68.5	111.1	88.3	154.0
50	9.35	44.8	69.3	111.9	89.2	154.9
75	8.69	45.5	71.2	113.7	91.9	157.4
90	6.47	49.1	79.9	121.9	104.0	168.5

DUCT BLOCKAGE (%)	COOLING AIR CONDITIONS		AVERAGE FUEL		PEAK FUEL	
	FLOW RATE (lb/s)	OUTLET TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°)
95	4.44	55.6	94.5	135.6	125.1	188.0
96	3.87	58.5	100.9	141.7	134.2	196.4
97	3.22	63.3	110.8	151.0	148.1	209.2
98	2.45	72.1	128.3	167.5	172.6	231.8
99	1.53	94.3	169.2	206.0	228.4	283.3

Note that no allowance is made in this analysis for any cooling flow through the side inlets.

TABLE A8-11-3

COMPARISON OF RESULTS OF THE DADS ANALYSIS FOR A RANGE OF SIDE INLET DUCT WIRE MESH SCREEN BLOCKAGE CASES

DUCT BLOCKAGE (%)	EQUIV. TOTAL DUCT BLOCKAGE (%)	COOLING AIR		AVERAGE FUEL		PEAK FUEL	
		FLOW RATE (lb/s)	OUTLET TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°F)	FSC TEMP (°F)	FUEL TEMP (°)
950F AMBIENT							
0	96	3.27	122.7	167.9	204.8	203.4	260.3
25	97	2.77	127.6	177.6	213.9	217.0	272.8
50	98	2.13	137.5	196.2	231.5	242.4	296.2
75	99	1.33	162.9	241.0	273.7	302.9	352.1
350F AMBIENT							
0	96	3.72	59.5	102.9	143.6	137.1	199.1
25	97	3.11	64.2	112.8	152.9	151.0	211.9
50	98	2.39	73.0	129.9	169.0	174.9	234.0
75	99	1.49	95.7	171.7	208.4	231.6	286.3

Note that this analysis assumes that the front and one side inlet duct birdmesh screens are completely blocked and all the cooling flow for the six vaults is admitted via the single available side inlet.