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FIRE HAZARDS ANALYSIS OF THE
RADIOACTIVE WASTE MANAGEMENT COMPLEX
AIR SUPPORT BUILDINGS

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ABSTRACT

This report describes the methods, analyses, results, and conclusions of a fire hazards risk analysis performed for the RWMC Air Support Buildings. An evaluation of the impact for adding a sprinkler system is also presented. Event and fault trees were used to model and analyze the waste storage process. Tables are presented indicating the fire initiators providing the highest potential for release of radioactive materials into the environment. Engineering insights drawn from the data are also provided.

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SUMMARY

This report documents a fire hazards analysis of the two Radioactive Waste Management Complex (RWMC) Air Support Buildings. Scenarios were identified that could lead to release of radiological materials from waste stored within the air support buildings. Probabilistic risk assessment (PRA) techniques were used to develop and quantify the frequency of radioactive releases caused by fires. Fire scenarios were modelled based on observation of facilities operations, review of pertinent documentation, and interviews with cognizant facility personnel. Consequences from using a proposed fire mitigation system compared to using the current mitigation system were also evaluated.

A detailed summary of modelled fire initiators and their effects in terms of relative radioactive release and contamination in the SWEPP C&S building are illustrated in Table S-1. Current release and contamination results are compared to the results after installation of the proposed sprinkler system. Total releases for each damage state are summed and reported along with the differences between the current and proposed fire configurations at the bottom of the table. Fire initiator frequencies and damage state frequencies are all given in frequency per year calculations.

Table S-1. Summary of the SWEPP C&S building fire initiators with end damage states.

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Lightning Fire	0.1	MED REL: 1.58 E-8 SML REL: 3.00 E-4 CONTAMIN: 2.17 E-2	MED REL: 1.58 E-10 SML REL: 3.00 E-4 CONTAMIN: 2.18 E-2
Electric Panel Fire	1.3 E-03	MED REL: 2.00 E-10 SML REL: 3.80 E-6 CONTAMIN: 2.83 E-4	MED REL: 2.00 E-12 SML REL: 3.80 E-6 CONTAMIN: 2.83 E-4
Vehicle Fire	8.3 E-04	MED REL: 3.62 E-8 SML REL: 6.88 E-4 CONTAMIN: 3.12 E-5	MED REL: 3.62 E-10 SML REL: 6.88 E-4 CONTAMIN: 3.12 E-5

Table S-1. (continued)

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
2" Propane Fuel Line Fire	4.1 E-04	MED REL: 2.16 E-8 SML REL: 4.10 E-4 CONTAMIN: -----	MED REL: 2.16 E-10 SML REL: 4.10 E-4 CONTAMIN: -----
Vehicle Fuel Leak	1.6 E-04	MED REL: 8.43 E-9 SML REL: 1.60 E-4 CONTAMIN: -----	MED REL: 8.43 E-11 SML REL: 1.60 E-4 CONTAMIN: -----
Earthquake	2.0 E-05	MED REL: 1.05 E-9 SML REL: 2.00 E-5 CONTAMIN: -----	MED REL: 1.05 E-11 SML REL: 2.0 E-5 CONTAMIN: -----
Inflation Unit Fan Fire	4.1 E-06	MED REL: 2.16 E-10 SML REL: 4.10 E-6 CONTAMIN: -----	MED REL: 2.16 E-12 SML REL: 4.10 E-6 CONTAMIN: -----
Waste Storage Container Fire	1.2 E-06	MED REL: 6.32 E-11 SML REL: 1.20 E-6 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Heating and Inflation Unit Fire	1.2 E-06	MED REL: 6.32 E-11 SML REL: 1.20 E-6 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Spurious Activation of Sprinkler Heads	-----		CONTAMIN: 2.18 E-2
TOTAL DAMAGE STATE FREQUENCIES		MED REL: 8.36 E-8 SML REL: 1.59 E-3 CONTAMIN: 2.20 E-2	MED REL: 8.36 E-10 SML REL: 1.59 E-3 CONTAMIN: 4.38 E-2
TOTAL CHANGE IN DAMAGE STATE FREQUENCIES		MED REL: -8.28 E-8 SML REL: 0.0 CONTAMIN: +2.18 E-2	

Based on this analysis, adding a sprinkler system to the SWEPP C&S building would not result in significantly lower radioactive release or contamination frequencies caused from fires. Results in Table S-1 indicate that small releases caused by fires are not improved with the addition of a sprinkler system, while the contamination frequency is increased because of possible spurious activation of the sprinkler system resulting in waste wash down. When waste is washed down, contamination can spread into the facility with a potential for spread outside of the air supported building. Medium releases are reduced by the implementation of a sprinkler system in the C&S building, however, a decrease of 8.28 E-8/year is insignificant considering the 15-year operating life of the facility.

A detailed summary of identified fire initiators and their effects in terms of radioactive release and contamination in the RWMC ASB2 building is shown in Table S-2. Current release and contamination results are compared to the results after installation of the proposed sprinkler system. Totals for each damage state are summed and reported along with the differences between the current and proposed fire configurations at the bottom of the table. Fire initiator frequencies and damage state frequencies are all given in frequency per year calculations.

Table S-2. Summary of the RWMC ASB2 building fire initiators with end damage states.

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Lightning Fire	0.1	MED REL: 2.78 E-4 SML REL: 2.22 E-5 CONTAMIN: 4.13 E-4	MED REL: 1.58 E-10 SML REL: 3.00 E-4 CONTAMIN: 5.58 E-3
Electric Panel Fire	1.3 E-03	MED REL: 3.52 E-6 SML REL: 2.81 E-7 CONTAMIN: 5.28 E-6	MED REL: 2.00 E-12 SML REL: 3.80 E-6 CONTAMIN: 7.26 E-5
Vehicle Fire	8.3 E-04	MED REL: 6.37 E-4 SML REL: 5.09 E-5 CONTAMIN: 5.93 E-7	MED REL: 3.62 E-10 SML REL: 6.88 E-4 CONTAMIN: 8.00 E-6

Table S-2. (continued)

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
2" Propane Fuel Line Fire	4.1 E-04	MED REL: 3.80 E-4 SML REL: 3.03 E-5 CONTAMIN: -----	MED REL: 2.16 E-10 SML REL: 4.10 E-4 CONTAMIN: -----
Vehicle Fuel Leak	1.6 E-04	MED REL: 1.48 E-4 SML REL: 1.18 E-5 CONTAMIN: -----	MED REL: 8.43 E-11 SML REL: 1.60 E-4 CONTAMIN: -----
Earthquake	2.0 E-05	MED REL: 1.85 E-5 SML REL: 1.48 E-6 CONTAMIN: -----	MED REL: 1.05 E-11 SML REL: 2.0 E-5 CONTAMIN: -----
Inflation Unit Fan Fire	4.1 E-06	MED REL: 3.80 E-6 SML REL: 3.03 E-7 CONTAMIN: -----	MED REL: 2.16 E-12 SML REL: 4.10 E-6 CONTAMIN: -----
Waste Storage Container Fire	1.2 E-06	MED REL: 1.11 E-6 SML REL: 8.88 E-8 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Heating and Inflation Unit Fire	1.2 E-06	MED REL: 1.11 E-6 SML REL: 8.88 E-8 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Spurious Activation of Sprinkler Heads	-----		CONTAMIN: 5.60 E-3
TOTAL DAMAGE STATE FREQUENCIES		MED REL: 1.47 E-3 SML REL: 1.17 E-4 CONTAMIN: 4.19 E-4	MED REL: 8.36 E-10 SML REL: 1.59 E-3 CONTAMIN: 1.13 E-2
TOTAL CHANGE IN DAMAGE STATE FREQUENCIES		MED REL: -1.47 E-3 SML REL: +1.47 E-3 CONTAMIN: +1.08 E-2	

Table S-2 shows a decrease in the total frequency of medium releases caused by fires in the RWMC ASB2 building, and an identical increase in the total frequency of small releases. The frequency for radioactive contamination is also significantly increased. For the RWMC ASB2 building proposed sprinkler analysis, a fire detection system like the one in the SWEPP C&S building was added also. The overwhelming reason for the decrease in the frequency of medium releases is in quicker fire detection time, not in the addition of the sprinkler system.

Comparison of the two buildings total damage state frequencies indicates that the RWMC ASB2 building has a much higher frequency for a medium release (approximately five orders of magnitude) than the SWEPP C&S building, though the frequency for small releases and contamination spread are lower. This phenomena occurs because more of the postulated fires in the RWMC ASB2 building are expected to produce a medium release resulting from the lack of a smoke or fire detection system. Small release frequencies are lower in the RWMC ASB2 building relative to the C&S building because of the increase in fires contributing to a medium release. Contamination frequencies are less in the RWMC ASB2 building because at the time of analysis, no fiberglass covered plywood boxes were stored in the ASB2 building.

Four fire initiators contributed to the overall fire and damage frequencies. These fire initiators are listed in Table S-3 with recommendations for reducing risk. In both ASWS building analyses, the contamination frequency for washing down waste containers was increased. Frequency increase is predominantly caused by spurious activation of the sprinkler head, and is listed also in Table S-3 with recommendations for decreasing frequency.

Table S-3. Summary of dominant radiological release contributors and recommendations for reducing the event frequency.

<u>Dominant Events</u>	<u>Mitigation of Radiological Release</u>
1. Lightning Fire	Install a lightning rod on top of both buildings.
2. Vehicle Fire/ Vehicle Fuel Leak	Purchase electric vehicles that can handle all normal and maintenance activities, and remove all fossil fueled vehicles from the ASWS building air locks.
3. Propane Fuel Line Fire	Build a cage around all exposed line that could be damaged by maintenance activities such as snow removal.
4. Spurious Activation of Sprinkler Heads	Remove all fiberglass-covered plywood storage boxes from the C&S building.

Large releases were analyzed but not included in Tables S-1 and S-2 because neither Large Release considered could be mitigated with the installation of a sprinkler system. The two events that could cause Large releases identified in this analysis are a:

1. Propane Tank BLEVE (Boiling Liquid Expanding Vapor Explosion), and (1.2 E-6/yr)
2. An Uncontrolled Desert Fire. (5.9 E-4/yr)

The results of this analysis indicate that the addition of fire sprinkler systems does not significantly affect the fire hazard potential in either air supported building. In addition, the sprinkler system could add to the potential spread of contamination through spurious activation of sprinkler heads.

FIRE HAZARDS ANALYSIS OF THE
RADIOACTIVE WASTE MANAGEMENT COMPLEX
AIR SUPPORT BUILDINGS

1. INTRODUCTION

The Radioactive Waste Management Complex (RWMC), located at the Idaho National Engineering Laboratory (INEL), currently stores transuranic (TRU) and low-level waste (LLW) received from Rocky Flats at Golden, Colorado, and from site generators (including other buried or stored RWMC waste received during the 1960s from Rocky Flats). Waste is temporarily stored in two inflated fabric buildings at RWMC known as the Air-Supported Weather Shield (ASWS) Waste Storage Buildings. The larger ASWS is known as the C&S (Certified and Segregated) Building. The smaller ASWS is known as the ASB2 Waste Storage Building.

Waste is accepted and stored in 55-gallon steel drums, steel boxes, and fiberglass-covered plywood boxes. The waste is retained in the ASWS buildings until it may either be sent directly to the Waste Isolation Pilot Plant (WIPP) in New Mexico or until the waste that is not WIPP-certifiable may be sent to the Process Experimental Pilot Plant (PREPP) for processing and repackaging in a form acceptable for storage at WIPP. Waste that is not WIPP-certified is examined using radiography at the Stored Waste Experimental Pilot Plant to determine whether it is WIPP or PREPP bound. Figure 1 is a flow diagram of the waste processing and disposition.

TRU and LLW handled at RWMC are not packaged in large enough quantities to present a significant radiological hazard to the general public. The hazard is generally limited to the operating personnel involved in handling the waste. The most significant consequence associated with release of radioactive material is the public perception of such an event, not any actual damage to the facility or workers.

The analysis documented in this report was performed to identify operations and facility vulnerabilities to the spread of contamination in the

Figure 1. Waste process flow for storage at the RWMC air support buildings.

ASWS buildings resulting from fire and to quantify the associated risk from possible radionuclide release and contamination. Facility management can use the analysis results to develop new administrative and procedural controls or to evaluate building design changes based on risk. The analysis assesses whether a dry sprinkler system installed in the ASWS buildings can significantly decrease the risk for spread of radiological contamination or whether the sprinkler system would, in fact, increase the risk of radiological release by adding a transport mechanism for breached containers. To quantify the addition of a sprinkler system, a baseline risk of contamination spread caused fires in the ASWS buildings is calculated and compared to the calculated risk of contamination with the dry sprinkler system installed.

Historically, probabilistic risk assessments (PRAs) have been used to evaluate the risk and consequences associated with the production of nuclear power. However, PRA application in other nuclear facilities has been increasing as the need for a better understanding of risk has become more important.

2. METHODOLOGY

The analysis presented in this report identifies and quantifies the possible fire scenarios leading to the release of radioactive waste at the RWMC ASWS buildings. The analysis was divided into four tasks.

First, the facility was toured and discussions were held with cognizant site facility personnel. Facility personnel intimately familiar with facility operations assisted the analyst facility operations and helped ensure completeness of the model.

Second, PRA techniques were used to construct logic models of fire vulnerabilities in regard to the facility operation, based on the information gathered during the familiarization task. A combined event/fault tree approach was chosen as the most appropriate PRA tool. The fault tree model allows for many diverse short sequential fire scenarios, while the event tree

adequately models the longer scenario for mitigation of a fire in an ASWS building.

Third, data were collected was then performed to obtain failure or rate of occurrence information for the events identified in the logic models. The data collected for the events depicted in the trees used generic failure rate data sources for the hardware related failures where available, and standardized human failure probability information. When generic data was not available for the postulated hardware failures, estimation techniques and expert opinion were used to derive the needed failure rates.

Fourth, logic models and failure-related data were then analyzed and quantified so that fire scenarios were identified as well as their relative importance to fire hazards at the RWMC ASWS buildings. Fault tree analysis, reduction, and quantification was accomplished using the Integrated Reliability and Risk Analysis System (IRRAS)¹. Event trees were constructed using ETA-II, developed at Science Application International Corporation ².

3. FACILITY DESCRIPTION

This section describes the two ASWS buildings and briefly characterizes the waste stored in the two buildings. The discussion shows the similarities and differences of each building and shows how the C&S building results in the higher risk of the two buildings in terms of contamination.

3.1 Stored Waste Configuration

Most of the waste stored in the ASWS buildings originated at Rocky Flats. Rocky Flats waste primarily consists of sludge-like materials adhering to cloth, glass, metal, plastic, etc. Chemically, the transuranics in the waste are in the form of nitrates, oxides, hydrides, and fluorides. Very small amounts of plutonium metal may also be present. The water content of the waste packages intended for storage in the air support buildings is limited to less than one-half gallon per barrel.³

3.2 The C&S Building

The main ASWS building, known as the Certified and Segregated or C&S Waste Storage Building, is a 650-foot by 150-foot asphalt slab with a steel skeletal structure providing backup support for an inflated fabric weather shield. The non-flammable fabric weather shield is manufactured by the Seaman Corporation.⁴ It has a design life of 13 years, after which deterioration can become significant and holes can develop. Though the fabric is non-flammable, it will burn if subjected to a direct flame. Propane powered heaters in each air support building provide warm supply air to electrically driven fans for building inflation and snow removal. A 30,000-gallon propane storage tank provides propane to both of the heating units in a two inch underground line. Furnace fuel contained in the 30,000-gallon propane tank is located approximately 200 feet away from the C&S building (Figure 2).

Two airlocks are located on the west side of the C&S building on either side of the Stored Waste Experimental Pilot Plant (SWEPP) facility. The airlocks allow waste to be loaded into C&S without loss of air pressure. During normal operation, large quantities of waste are loaded into the airlock from outside the facility or from SWEPP. Once the waste is in the airlock, the outside doors are sealed; then, waste transportation equipment is used to move and stack waste inside the C&S building. Typically, 30 or more barrels are residing inside a C&S airlock at any given time.

At the time of this analysis, the C&S building contained approximately 20,000 Department of Transportation (DOT) 55-gallon steel drums, and 1200 boxes (Figure 3 and Figure 4). Boxes are made of steel or fiberglass-coated plywood: 500 of the 1200 boxes are assumed to be the fiberglass-coated plywood boxes. Waste containers are stored on 8- by 8-foot grids. Each grid can contain 16 drums or two boxes on each layer, and the grids may be stacked up to 5 layers high. Each layer is separated by 4 sheets of fire-retardant plywood stacked 2 sheets high and two sheets wide. A total of 1,170 grids are designated for use in the C&S building arranged 78-grids long and 15-grids wide.

Figure 2. Diagram of the RMC air support buildings.

Figure 3. Department of Transportation 17C/17H drum assembly.

Figure 4. Department of Transportation 7A fiberglass reinforced plywood box.

3.3 The ASB2 Building

The Secondary ASWS building (ASB2), is constructed on an asphalt slab 150-feet long and 150-feet wide. While the building consists of an inflated fabric weather shield, as in the C&S building, there is no steel skeletal support structure. As discussed above, a propane powered heater provides a warm air supply to electrically driven fans for building inflation and snow removal. Currently, the ASB2 building is used as an overflow building for waste containers that have not been certified or vented. One airlock is located on the north side of the ASB2 to facilitate transportation of stored waste.

At the time of this analysis, the ASB2 building contained approximately 1300 DOT 55-gallon steel drums. No fiberglass-coated plywood boxes or steel boxes were contained in the building. The grid structure for the ASB2 building is the same as in the C&S building, with the exception that there are fewer grid spaces (225 total).

3.4 The Proposed Dry-Pipe Sprinkler System

A dry-pipe sprinkler system has been proposed for installation in the C&S building by the INEL fire inspector, Ken Phillips. Although a design has not been selected, the following section will detail the generic characteristics of a dry-pipe sprinkler system.

A dry-pipe sprinkler system comprises of several heat-sensing sprinkler heads and connecting piping. Pipes are filled with pressurized air, supplied by an air compressor. Pipe air is pressurized above the normal water pressure to prevent introduction of water until required in a fire situation. In the event of a fire, each sprinkler head that senses heat will melt the fusible link, air will bleed out of the pipe, and the water pump will activate to maintain water pressure in the sprinkler heads. Water will flow through the pipes in the system, but water will only emerge from independently activated sprinkler heads. Fusible links melt at 165 degrees Fahrenheit and can take about a minute to melt, depending on the heat intensity of the fire. An

additional lag time of 45 seconds to a minute and a half will occur as the air bleeds through the half-inch orifice and the header pipe fills with water.

Four separate dry-pipe systems will be needed to adequately cover the C&S building, since a dry-pipe system typically covers approximately 30,000 square feet and the C&S building is about 100,000 square feet. During a fire, only the quadrants affected by the fire will be activated. Spurious activation of a sprinkler head would result in the release of water through only the affected head. A failure in the air compressor would allow water into the pipe system. However, water would not be released to the building unless a sprinkler head ruptures.

4. FACILITY OPERATION

The mission of the two ASWS buildings is to temporarily store barrels and boxes of radioactive waste. Therefore, the routine activity of the facility is moving and stacking of barrels and boxes. The maximum daily workload is for one forklift to perform the moving and stacking for up to 6 hours. Normal storage operations are performed with electrically driven forklifts to eliminate vehicle exhaust which can set off the smoke detection equipment. Maintenance operations include changing light bulbs and fire detector heads. Maintenance activities typically use fossil-fueled boom trucks, bucket trucks, or cherry pickers. Abnormal operations could include moving all waste containers completely out of the buildings to change the building fabric. Waste containers may also be moved in large quantities during decontamination efforts. Abnormal operations would include a much higher workload for forklift equipment and might include use of propane-, diesel-, or gas-fueled forklifts.

5. SYSTEM MODEL

Event trees were constructed to model the present fire detection system and the proposed fire mitigation system, for each building. A fault tree that considered fires initiation involving stored waste supported the event tree analysis. After the facility familiarization was completed, the C&S was chosen as the upper bounding case of two buildings for the fault tree portion of the analysis. The C&S building presents more potential for fire initiation because (a) fiberglass-covered plywood boxes are stored in the C&S building only, (b) there is more activity in the C&S building, (c) more waste is stored in the C&S building, (d) there are more electric panels in the C&S building, and (e) no vehicles are stored in the ASB2 airlock.

5.1 Event Tree Model

Nine fires were used in the event tree models, see Table 1 for a list of these fires. The probability for each fire was used as the initiated event for in the event trees. Two event trees were constructed for each initiating fire, one modelling the current fire mitigation configuration and one modelling the proposed fire mitigation system, and each of these models were constructed for each ASWS building. All 36 event trees are shown in Appendix A.

Table 1. Initiating fires and probabilities for fires involving stored waste.

<u>INITIATING FIRE</u>	<u>PROBABILITY OF FIRE INVOLVING STORED WASTE</u> ¹	<u>FREQUENCY OF FIRE (PER YEAR)</u> ^{2,4}	<u>PROBABILITY OF INVOLVING WASTE</u> ³
Lightning Fire	3.00 E-4	1.00 E-1	3.00 E-3
Electric Panel Fire	3.80 E-6	1.30 E-3	2.92 E-3
Vehicle Fire	6.88 E-4	8.31 E-4	8.28 E-1
Propane Fuel Line Fire	4.10 E-4	4.10 E-4	1.00
Vehicle Fuel Leak Fire	1.60 E-4	1.60 E-4	1.00
Earthquake Fire	2.00 E-5	2.00 E-5	1.00
Fan Overheat Fire	4.10 E-6	4.10 E-6	1.00
Stored Waste Package Fire	1.20 E-6	1.20 E-6	1.00
Heating and Inflation Unit Fire	1.20 E-6	1.20 E-6	1.00

1 - Values obtained from the fault tree cut sets, see Table A-1 in Appendix A, "Fault tree cut sets for fire involving stored waste".

2 - Values obtained from the fault tree cut sets, see Table A-2 in Appendix A, "Fault tree cut sets for initiating fires".

3 - Values calculated by dividing column 2, "Probability of fire", by column 1, "Probability of fire involving stored waste".

4 - Initiating fires are defined as fires starting in or propagated inside the C&S building. For example Fan Overheat Initiating Fire is the probability that a fan fire occurs outside the C&S building, plus the probability that the fire isn't extinguished, plus the probability that there is kindling available outside the C&S building that a fan fire can ignite in order to propagate the fire inside the C&S building.

Figures 5 through 8 present four example event trees detailing the current fire mitigation system, and the proposed dry-piped fire mitigation system for each building. Note that at each decision point on the trees, the occurrence of the top event is downward. Sequence probabilities are listed at the end of each event tree branch. To the right of the sequence probabilities, the sequence class otherwise known as a Damage State, is listed. Damage states for this analysis are a large release of radioactive nuclides into the environment, a medium release, a small release, and spread of nuclide contamination from the washdown of waste materials during a fire. It was beyond the scope of this analysis to quantify the magnitudes of the releases in terms of curie content. Event tree branches leading to no damage were titled "No Damage" or "Self Extinguishing". Each of the damage states are defined below.

A Large Release is that amount of radioactive nuclides generated from an uncontained fire that completely destroys either of the two ASWS buildings and their contents. This definition assumes that no intervention is successful by RWMC personnel or the Central Facilities firemen. Credible fire scenarios that could lead to a large release include: propane tank Boiling Liquid Expanding Vapor Explosion (BLEVE), or an uncontrolled desert fire.

A Medium Release is that amount of radioactive nuclides generated from the largest credible fire within the air support buildings. Waste storage configuration and small amount of combustible material stored in the buildings limit the size of a fire. The RWMC Safety Analysis (DRAFT February 1989) assumes two rows of fire retardant plywood (FRP) boxes stacked five high represent the most severe stacking arrangement. A total of 0.17 Curies would be released to the environment. The storage arrangement precludes fire spread to additional storage arrays.

A Small Release is that amount of radioactive nuclides generated from a fire that is contained by the RWMC Fire Brigade or the Central Facilities firemen before the entire waste stack is consumed. One or more of the FRP boxes are assumed to have been breached by this fire.

Contamination is defined as radioactive nuclides that can be washed away from breached steel waste containers or fiberglass-covered plywood boxes by water run off from fire suppression activities. In the past, the fiberglass-covered plywood boxes stored at the Transuranic Storage Area-Retrieved (TSA-R) have been known to leak alpha contamination when washed down with rainwater; therefore, all of the stored plywood boxes are considered to leak if washed down with water.

5.1.1 C&S Building Event Tree Models

Top events for the C&S building current fire mitigation system (Figure 5) event tree are as follows:

1. Type if fire initiated (different for each tree),
2. Stored Materials Involved,
3. Fire Detection Fails,
4. Emergency Fire Brigade Fails,
5. Central Response Fails, and
6. Breached Stored Materials or Plywood Boxes Present.

Frequencies for the event tree initiators were calculated using fault tree information as displayed in Table 1. Initiating fire frequencies were taken from the fault tree cut sets shown in Table A-1 in Appendix A.

Probabilities for the top events, "Stored Materials Involved", were calculated by dividing the fire frequencies of fire (see Table 1) by the frequencies for fire involving stored waste. Frequency values for all fire scenarios were obtained from the fault tree cut set data, see Tables A-1 and A-2 in Appendix A. The probability for stored materials not being involved in a fire is the complement $(1-x)$ of the probability number for stored materials involved as shown in Figures 5.

The probability for "Fire Detection Fails" was calculated by determining the probability of a fire signal not reaching the Central Facilities Fire Department. The possibility of the actual fire detector heads not detecting

Figure 6. Example event tree model for the SWEPP C&S Building, proposed fire mitigation system.

fire was considered, but not evaluated. Historically, the fire detectors in the C&S building fail in the alarm state, thus sending a signal to the Central Facilities Fire Department when one was not needed. Furthermore, each fire detector head is independent, and the probability of multiple heads failing when needed is very remote.

The probability for "Emergency Fire Brigade Fails" was calculated based on the amount of time an Emergency Brigade would be available. Since the RWMC has people available 10 hours a day, 5 days a week, the probability of failure was calculated to be 0.70. It was assumed that the Emergency Brigade would respond to all fires that were alarmed while Emergency Brigade personnel were on duty.

The probability for "Central Response Fails" was found in the Accident Sequence Evaluation Program Human Reliability Analysis Procedure (ASEP) manual for human errors.⁵ Given that the Central Facility Fire Department facility receives an alarm signal, it is unlikely that they would fail to respond. Central facilities fire department can respond to a fire alarm at the RWMC within 10 minutes given that a fire truck is available. There are two fire trucks at the Central Facilities fire station, and if both trucks were out on another fire alarm response, it could take 30 to 45 minutes for a fire truck to respond. There were 547 fire alarm responses in 1988, and all fire motor vehicles were out for a total of 740 hours. All three fire stations have a total of four fire engines, three brush fire units (for brush fires), one rescue unit, four ambulances, four 4 X 4 personnel carriers, one tanker (for the brush fire units), and one car for the fire chief. Eighteen vehicles over 740 hours averages 41 hours a year per vehicle, so both fire trucks at central would be out on the average of 82 hours per year. The amount of time that both central fire trucks are out on a call together would be even lower.

The top event "Breached Stored Materials or Plywood Boxes Present" considers spread of contamination by the water used to mitigate a fire. This event considers only stored waste that is not involved in a fire. Several assumptions were made in the final calculation of this number:

1. A 50- by 50-foot area is considered the affected wash down area by either the sprinkler system, the Emergency Fire Brigade, or the Central Facilities Fire Department.
2. A 2500-square-foot area can contain up to 560 barrels.
3. There is an 82% chance of washing down steel barrels or boxes and an 18% chance of washing down plywood boxes, based on the probability of finding steel barrels versus plywood boxes in any given 50- by 50 foot area and given that one plywood box occupies the same area as 8 barrels. Therefore, of the 560 barrels, 101 could be boxes and 464 could be barrels.
4. At any given time, 1 out of 10,000 barrels could be breached, based on engineering judgment and UOR breached plywood box experience.
5. From past experience, the probability of spreading contamination by washing down plywood boxes is close to 1.0.
6. Even though the probability of spreading contamination by washing down a breached steel container is less than with plywood, it is still assumed to be 1.0.

The top probability for "Breached Stored Materials or Plywood Boxes Present" was calculated by multiplying the probability of washing down a barrel (0.82) times the probability of any barrel encountered being breached (464/10,000) plus the probability of a box being washed down (0.18) times the probability of a washed down box contaminating the run-off water (1.0).

An event tree was developed for the proposed dry-piped fire mitigation configuration containing the same top events as for the current fire mitigation configuration event tree, with the addition of "Sprinkler System Fails" (Figure 6). A dry-piped sprinkler system will provide 24-hour protection against larger fires, though the system will not activate in less time than the Central Facility Fire Department if the fire has low heat output, such as in the case of a smoldering fire. Additionally, if the fire

is a fast hot fire, the sprinkler system may only be able to contain rather than extinguish the fire. The dry-pipe system can take up to 3 minutes to activate once the heat produced in the fire reaches the sprinkler head at 165 degrees Fahrenheit. The value for the dry-pipe system failing on demand was assumed to be, 0.01, based on engineering judgment after talking to several cognizant fire experts including Ken Phillips.

5.1.2 ASB2 Building Event Tree Models

Figure 7 shows the event tree used for modelling the current fire mitigation configuration in the ASB2 building. Top event headings for Figure 7 are identical to the event tree in Figure 5 showing the current fire mitigation configuration for the C&S building. However, there are subtle differences between the two building models.

For the top event, "Fire Detection Fails," the probability for failure is increased to 0.926. No smoke detectors are installed in the ASB2, so early detection can only occur when people are in the ASB2 at the time a fire starts. It has been estimated that people occupy the ASB2 an average of 25% of the working day. However, crews will usually be working in the building all day for several days or not at all for several days. The RWMC staff works a split shift of four ten-hour days, either Monday through Thursday or Tuesday through Friday. Therefore, 25% of 50 hours per week, people are expected to be within the ASB2 building. Assuming that a person working within the air supported waste storage building were able to detect an incipient fire 100% of the time, the probability for no detection is still 0.926 because no one is within the ASB2 so much of the week.

For the top event, "Breached Stored Materials Present," the probability has been considerably reduced to 0.056, reflecting that no fiberglass covered plywood boxes are stored in the C&S building. Assumptions 1, 2, 3, and 6 for "Breached Stored Materials Present" in the C&S building (see page 9) still apply.

In addition to the damage states listed in the event tree, the probability for spurious activation was also calculated and added to the probability for contamination in the proposed fire mitigation system event trees. A spurious activation was assumed to be 0.1/year by engineering judgment after talking to cognizant fire experts. This number was multiplied by the probability for a sprinkler head being present in the vicinity of a breached steel barrel or plywood boxes [0.2181 for the C&S building and 0.056

LIGHTENING FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB .	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						2.09E-03	NO DAMAG
					5.60E-02 BR WASTE	1.24E-04	CONTAMIN
						4.88E-03	NO DAMAG
					5.60E-02 BR WASTE	2.89E-04	CONTAMIN
						5.16E-08	NO DAMAG
						9.23E-02	SELF EXT
						6.66E-06	SML REL
						1.55E-05	SML REL
						1.55E-10	MED REL
						2.78E-04	MED REL
1.00E-01 FIRE		9.26E-01 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT			
	3.00E-03 WASTE	9.26E-01 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT			

Figure 7. Example event tree model for the RWMC ASB2 Building, current fire mitigation system.

for the ASB2 building (see the calculation for "Breached Stored Materials Present" for each building event tree model)].

5.2 Fault Tree Model

A fault tree was developed to identify the combinations of events (termed basic events) necessary to cause the undesired top event, "Fire Inside the RWMC C&S Building Involves Stored Waste Materials." Combinations of these events will be referred to as cut sets. The frequency at which this undesired top event occurs was used to calculate both the initiating event tree frequency, "Fire Initiated in the C&S Building" and top event "Stored Materials Involved" for all of the event trees, as discussed earlier. Basic event descriptions of all basic events are presented in Section 6.0. Sections 5.2.1 through 5.2.8 discuss details of the fault tree development and the associated assumptions involved with the analysis. Initially, all scenarios were examined; then, the fault trees were scrutinized and appropriately pruned to reflect incidents most likely to occur. Note that the fault trees were analyzed for fires involving, because the sprinklers would not be activated for small fires such as a waste container fire. Therefore, if the fire wasn't big enough to involve stored materials, it probably wouldn't be large enough to activate the sprinkler system.

5.2.1 Fire Inside the RWMC C&S Building Involving Stored Waste Material

Figure 9 shows that an internal C&S building fire was developed from two major scenarios, "Fires started inside the C&S building," and "Fires started outside the C&S building."

"Fires started inside the C&S building" was logically split into "Operationally dependant fires," "Electrically started fires," and "Fires resulting from storage of hazardous waste."

Figure 9. Fire inside the SWEPP C&S building involves stored waste.

"Operationally dependant fire" were further subdivided into "Fires started during normal operations," "Fires started during maintenance operations," and "Fires started during abnormal operations."

Each of these sub-top events are developed on subsequent pages, and the probabilities for these events are incorporated into the initial fault tree to arrive at the top event probability of "Fire Inside the RWMC C&S Building Involves Stored Waste Materials."

5.2.2 Externally Caused Fire in C&S building

Fault trees developed for externally caused fires are shown in Figures 10 and 11. An externally caused fire may be started by man-made fire sources or natural fire sources. There are three man-made fire scenarios considered in this analysis. The first scenario requires that a break in the fuel line running from the propane tank to the heating and inflation unit occur in conjunction with an ignition source, while the fan closest to the piping is operating. If a fire does occur, this scenario provides a transport mechanism (the fan) to spread the fire into C&S building. Corrosion of the piping was initially considered as a source for a break in the piping, but was eliminated from the fault tree for two reasons:

1. Galvanized steel plated with zinc does not easily rust; therefore, yearly inspection of the piping would reveal corrosion before a pipe could rust through.
2. Maintenance personnel check the heating and inflation (H&I) unit daily and would notice a small leak (resulting from the noxious fumes associated with propane) before a major leak could occur.

In the second scenario, fire can occur when a heating and inflation unit fire happens in conjunction with kindling being present next to the unit. Kindling is considered to consist of tumbleweeds from the desert. This kindling acts as the transport mechanism for the fire to spread from the

Figure 10. Fire inside the SWEPP C&S building caused by external fire.

Figure 11. Heating and inflation unit fire external to the SWEPP C&S building.

heating and inflation unit into the C&S building. Kindling exposed to hot duct work on the H&I unit was also postulated to start a fire, but was eliminated as none of the exposed surfaces are hot to the touch.

The final man-made fire scenario involves a propane refueling accident. No transport mechanism is given as there would be enough fuel present to completely knock down the C&S building in a Boiling Liquid Expanding Vapor Explosion (BLEVE). Additionally, a fire resulting from improper maintenance of the propane tank was postulated, but eliminated as no maintenance has yet been performed on the propane tank other than refueling.

Natural fire sources include lightning strikes, desert fires, and earthquake initiated fires. Lightning strikes would be propagated to the waste by initiating an electric panel fire with kindling near by. Desert fires with sufficient magnitude need no further kindling sources to propagate to inside the C&S building. Earthquakes postulated are of sufficient magnitude (modified Mercalli scale intensity of 7 to 8) to rupture propane fuel lines.

Fires can enter the C&S building only if the firemen fail to prevent it, with the exception of lightning-initiated fires that ignite electric panels. Firemen may fail to respond to a fire if the MIPS system is inoperable, or the fire might be too big for the firemen to arrest.

5.2.3 Internal Fire Caused by Electrical System Failure

Two scenarios have been postulated for an electrical system failure leading to a fire (see Figure 12). The first scenario involves ignition of an electric panel in the presence of combustible materials that could spread to boxes or barrels. Kindling sources are needed to spread a fire to the stored waste, and include plywood spacers that may be stacked near electric panels. Asphalt will burn only given a self-sustaining fire on it's surface, is not considered a propagating kindling source.

Figure 12. Fire inside the SWEPP C&S Building caused by an electrical system failure or a fire in the airlocks.

The second scenario involves a fuel line leak of a vehicle stored in the air lock of the C&S leading to a fire ignition. Three propane forklifts are stored in an airlock at the C&S. An undetected leak of fuel from these vehicles could result in a sizeable fire that could spread to waste containers stored in the air lock. In this fire scenario, a fire initiates in the electric airlock motors used for opening and closing the airlock doors. Experience indicates that, at most, these motors might spark but not ignite. Since the motors are approximately 50 feet above any possible combustible materials, sparks could not ignite the postulated combustible materials stored within the airlock.

5.2.4 Internal Fire Caused by Storage of Hazardous Waste

One scenario was postulated for internal fires caused by storing waste (Figure 13): spontaneous combustion of a barrel resulting from the receipt of a waste package not intended for the C&S or WMC. There are barrels containing waste that have a low probability of spontaneously igniting, but these barrels are stored at the Hazardous Waste Storage Facility. It is remotely possible for the C&S to accidentally receive one of these packages.

Another scenario was postulated that modelled a container leaking liquid waste with a flash point at room temperature, but this scenario was eliminated as each barrel contains no more than one half gallon of liquid, and the flash point of gasoline, a highly volatile liquid, is greater than 400 degrees Fahrenheit. Yet another scenario was considered and eliminated: container fires originating from spontaneous combustion of stored oily rags. After consulting INEL fire experts, this scenario was eliminated because though oily rags may spontaneously combust, without oxygen the fire will smother. The net effect would be to slightly raise the temperature of the stored container.

Figure 13. Fire inside the SWEPP C&S building caused by the storage of hazardous waste.

5.2.5 Internal Fire Caused During Normal Operation

One scenario is postulated for fires occurring during normal operation (Figure 14)--fires initiated by an electric forklift. In order for waste to be ignited, the forklift must be transporting waste container or be located next to stored waste containers. Since there is no fossil fuel to burn on this transportation vehicle, a kindling source must also be present to propagate a fire to the stored waste. Kindling sources considered are fire-retardant coated plywood spacers, fiberglass-covered plywood boxes, and breached steel drums.

One other kindling source was also considered in this scenario: vehicle combustibles such as upholstery or oily rags. Even though these kindling sources could indeed ignite, the fire produced would not be sufficient to spread to the stored waste materials unless the driver purposely ran the forklift into a stack of stored materials. Sabotage is outside the scope of this report.

Another fire scenario was considered and eliminated; a spark from the electric forklift motor igniting combustible gasses present. There are three sources for combustible gasses: hydrogen produced from the battery of the electric forklift, propane gas from the heating and inflation unit, and hydrogen from barrels stored in the C&S. Hydrogen produced from the electric forklift battery could never build up to 4% volume in air within a building as large as the C&S building because the C&S building has several air changes per day. Propane was postulated to enter the building through the H&I unit, but because of the way that the heating and inflation unit works, even if the pilot light was extinguished only a small amount of propane would be drawn into the building. This small amount of propane would not be sufficient to sustain a fire. The RWMC Safety analysis credits one air change per hour in the C&S building and one air change every 1.3 hours in the ASWS-II. The number of air changes per hour, coupled with the large volume of the buildings preclude any explosive concentrations of propane or hydrogen building up in the air support buildings. Each barrel is vented for hydrogen gas and left on

Figure 14. Fire inside the SWEPP C&S building during normal operations.

the Transuranic Storage Area (TSA) pad outside for eight weeks. During that time, hydrogen would be sufficiently dispersed to prevent a buildup to 4% volume in air around any storage area within the C&S building.

5.2.6 Internal Fire Caused During Maintenance Operations

In this fault tree (Figure 15), the postulated scenario is similar to the previous fault tree in that waste transportation equipment is the ignition source for a fire. During maintenance operations, however, propane-fueled vehicles are used instead of electric powered vehicles, so kindling does not have to be present to involve stored waste material. Additionally, moving waste is not a maintenance activity, so the branch of the Normal Operations tree that considers "Waste Ignited During Transport" was eliminated.

Welding or Cutting maintenance activities were originally considered in this fault tree, but were eliminated. Though there is a very good chance of a fire being produced during welding or acetylene cutting activities, there is always at least one fire watch person armed with a fire extinguisher present during such activities.

5.2.7 Internal Fire Caused During Abnormal Maintenance Operations

In this scenario (Figure 16), abnormal maintenance operations include vehicles fueled by propane, diesel, or gasoline. This fault tree is very similar to the previous two fault trees. A vehicle fire can ignite the waste being transported on the forklift, or can ignite stored waste if it is running within proximity to the waste.

5.2.8 Combustible Waste Materials

Three sources of combustible stored waste are considered in this fault tree (Figure 17), plywood spacers, breached steel containers, and fiberglass-covered plywood boxes. The plywood spacers are fire retardant, but the spacers will still burn and propagate a fire if the fire affecting the spacers

Figure 15. Fire inside the SWEPP C&S building during maintenance operations.

Figure 16. Fire inside the SWEPP C&S building during abnormal maintenance operations.

is very hot. A breached steel container would probably ignite if combustibles were present inside, or if the plywood spacer underneath or on top of the steel container was ignited. The fiberglass-covered plywood boxes could ignite if a fire melted the fiberglass. Tests at the RWMC have determined that fiberglass-covered boxes take 30 minutes to ignite from a constant flame at ambient temperatures of 20 degrees Fahrenheit.

Figure 17. Combustible materials fault tree.

6. DATA COLLECTION

Data were collected for each of the basic events in the fault tree, and for the top events in the event trees. A list of basic events, the trees in which they appear, and a brief description of the basic event is provided in Table 1. A list of the failure probabilities and the assumptions that were used in determining the failure probabilities for each event is provided in Table 2.

Table 2. Fire Hazards Fault Tree Basic Event Data.

<u>TREE</u>	<u>EVENT</u>	<u>DESCRIPTION</u>
EXTFR	DESERTFIRE-I	A desert fire occurs within the vicinity of the RWMC. There is a 200-ft fire break between the C&S building and the desert.
	EARTHQUAKE-I	An earthquake becomes an ignition source for a fire outside the ASWS buildings by rupturing fuel lines from the propane tank.
	FIREMEN-FTC-B	The firemen fail to contain the fire before it enters the C&S building because the fire is too large.
	FIREMEN-FTR-B	The firemen fail to respond to the fire alarm in sufficient time to prevent the fire from entering the C&S building.
	ASWI-FLRUPT-HE-I	The propane supply line is ruptured at the heating unit because of human error as in snow removal activities.
	ASWI-FP-RN-B	The H&I primary fan is running next to the exposed fuel line.
	ASWI-HT-RN-B	Outside the C&S, the heater in the H&I unit is running.
	ASWI-FP-SP-B	Outside the C&S, the primary fan continuously emits internal sparks.
	ASWI-KDHNIU-HK-B	Outside the C&S building, kindling such as tumbleweeds or trash have accumulated against the heating and inflation unit. The kindling provides a medium for a spark or ignition source to enter the buildings.
	ASWM-PR-PR-I	A propane fire results from failure to follow procedures while refueling the propane tank, results in a BLEVE.
	LIGHTNINGFIRE-I	A lightning strike to power lines starts a fire in an electric panel inside the C&S and acts as an ignition source for fire.

Table 2. (continued)

<u>TREE</u>	<u>EVENT</u>	<u>DESCRIPTION</u>
EXTFR	ICSI-KDEP-HK-B	Inside the C&S building, independent of operational status, kindling is stacked near an electric panel. The kindling becomes the medium to spread a fire from an electrical panel fire. Plywood spacers are considered to be the predominant kindling source.
	ICSI-PROP-B	10% of fires originating in electric panels are large enough to propagate to the kindling. Number derived from engineering judgement.
EXTFR2	ASWN-PF-IG-I	Outside of the C&S building, the H&I unit catches fire during normal operations, providing an ignition source for kindling that can spread a fire inside either building.
	ASWN-FU-OH-I	Outside the ASWS buildings, the H&I primary or secondary fan overheats, providing an ignition source for kindling that can spread a fire inside a building.
ELECFR	ICSI-EP-SH-I	Inside the C&S building, independent of operational status, an electric panel shorts, creating an ignition source. Kindling is needed to spread the fire to waste storage crates.
	ICSI-KDEP-HK-B	Inside the C&S building, independent of operational status, kindling is stacked near an electric panel. The kindling becomes the medium to spread a fire from an electric panel short.
	ICSI-PROP-B	10% of fires originating in electric panels are large enough to propagate to the kindling (number derived from engineering judgement).
	ACSI-MVFL-RP-I	Inside the C&S airlock, independent of operational status, a stored vehicle fuel line ruptures and leaks (propane or gasoline).

Table 2. (continued)

<u>TREE</u>	<u>EVENT</u>	<u>DESCRIPTION</u>
ELECFR	ACSI-MVST-HE-B	Inside the C&S airlock, independent of operational status, an operator does not detect a fuel line leak and starts a vehicle also stored in the air lock.
	ACSI-RADMAT-B	Inside the C&S airlock, waste is temporarily stored.
WASTFR	ICSI-CT-SP-I	Inside the C&S building, independent of operational status, a waste package not intended for storage in the C&S building spontaneously ignites causing radiological damage.
NORMFR	ICSN-EF-IG-I	Inside the C&S building, an electric forklift ignites. Kindling would be required in the near proximity to propagate the fire.
	ICSN-KDEFL-HK-B	Inside the C&S building, during normal operation, kindling is present next to a forklift providing a medium for an electric forklift fire to be spread to the stored waste.
	WASTE-TRANSPORT	Inside the C&S building, during abnormal operations, a non-electric forklift is transporting waste containers.
	BRDRUM-TRANSPORT	Forklift transporting steel drum or box.
	FRP-TRANSPORT	Forklift transporting FRP box.
	ICSI-SDBRCH-IG-B	Inside the C&S building, independent of operational status, previously breached steel drums containing stored waste are ignited by a fire.
	PROXIMITY	Forklifts are operating close enough to the stored waste to ignite the waste with a forklift fire.
MAINTFR	ICSM-GV-ML-I	Inside the C&S building, during maintenance operations, a gas vehicle ignites.

Table 2. (continued)

<u>TREE</u>	<u>EVENT</u>	<u>DESCRIPTION</u>
MAINTFR	WASTE-TRANSPORT	Inside the C&S building, during abnormal operations, a non-electric forklift is transporting waste containers.
	ICSI-SDBRCH-IG-B	Inside the C&S building, independent of operational status, previously breached steel drums containing stored waste are ignited by a fire.
	PROXIMITY	Forklifts are operating close enough to the stored waste to ignite the waste with a forklift fire.
ABOPFR	ICSA-MV-ML-I	Inside the C&S building, during abnormal operations, a diesel, gas, or propane vehicle ignites (caused by an electrical or mechanical malfunction) in the presence of combustible material.
	WASTE-TRANSPORT	Inside the C&S building, during abnormal operations, a non-electric forklift is transporting waste containers.
	BRDRUM-TRANSPORT	Forklift transporting steel drum or box.
	FRP-TRANSPORT	Forklift transporting FRP box.
	ICSI-SDBRCH-IG-B	Inside the C&S building, independent of operational status, previously breached steel drums containing stored waste are ignited by a fire.
	PROXIMITY	Forklifts are operating close enough to the stored waste to ignite the waste with a forklift fire.
	ICSI-PB-IG-B	Inside the C&S building, independent of operational status, fiberglass-covered plywood waste storage boxes are ignited by a fire.
COMBMAT	ICSI-PS-IG-B	Inside the C&S building, independent of operational status, fire retardant plywood spacers are ignited by a fire.

Table 2. (continued)

ICSI-SDBRCH-IG-B	Inside the C&S building, independent of operational status, previously breached steel drums containing stored waste are ignited by a fire.
ICSI-PB-IG-B	Inside the C&S building, independent of operational status, fiberglass covered plywood waste storage boxes are ignited by a fire.

Table 3. Fire Hazard Basic Event Failure Probabilities.

<u>EVENT</u>	<u>FAILURE PROBABILITY</u>	<u>ASSUMPTIONS</u>
DESERTFIRE-I	2.949 E-02/yr	29 fires have occurred within the boundaries of the INEL in 11 years of recorded data. None have occurred at the RWMC but this number assumes a ratio of the area of RWMC (10 sq mi) shares the INEL incidents of fires.
EARTHQUAKE-I	1.0 E-03/yr	There have been 4 recorded earthquakes at the INEL in 17 years, all with a magnitude of less than 1.0 on the richter scale. Maximum credible is 6.5 north of NRF. This assumes a return period of 1000 years based on an earthquake felt at RWMC of a Modified Mercalli Intensity of 7 to 8, which corresponds to a 0.2 g ground acceleration.
FIREMEN-FTC-B	0.02	All 29 fires in 11 years have been contained. Assumed noninformed prior distribution, $r=0$, $n=29$ fires. ⁵
FIREMEN-FTR-B	1 E-05/alarm	Failure to respond to an alarm in time to stop the fire from entering the C&S building. Value obtained from ASEP. ⁵
ASWN-PF-IG-I	4.10 E-04/yr	Engineering judgment assumes that if 1000 of these furnaces ran for one year, one would expect 1 furnace to catch on fire. Divide the 1 by the number of furnaces and the number of hours in a year, then multiply by the number of hours the RWMC furnace operates (3500 hours approximately).
ASWN-FU-OH-I	1.384 E-03/yr	Based on Seabrook data for a fan failing during operation, one could expect that 1 of 50 fan failures is the result of overheating. ⁶
ICSI-EP-SH-I	1.27 E-03/yr	Based on IEEE Standard 500 number for metal-enclosed electric switch gear overheating, times 6 electric panels, multiplied by 8760 hours in a year. ⁷

Table 3. (continued)

<u>EVENT</u>	<u>FAILURE PROBABILITY</u>	<u>ASSUMPTIONS</u>
ICSI-KDEP-HK-B	0.03	Plywood spacers are considered to be the predominant kindling source. It is assumed that container stacking occurs in the vicinity of electric panels 30% of the time, and that one of every ten times an operator stacks plywood against an electric panel.
ICSI-PROP-B	0.10	Based on engineering judgement.
ACSI-MVFL-RP-I	5.39 E-03/yr	Three propane-fueled vehicles are stored in the air locks at night. The number is based on the DOE data base Safety Performance Measurement System 1979 DOE DE-AC07-76ID01570 Dr. R. J. Nertney. ⁸
ASWI-FLRUPT-HE-I	2.9 E-02/yr	Fuel lines are inspected quarterly for leakage; no leaks have been found in 8 years. Used noninformed prior, $r=0$, $n=8$ years. ASEP screening value includes errors of omission/commission, equal to 0.03. ⁵
ASWI-FP-RN-B	0.50	One of the two fans is located next to exposed fuel line piping. The fans are run on alternate months, so 50% of the time one would expect the critical fan to run.
ASWI-HT-RN-B	0.42	The heater is operating 5 months of the year, November through March for most years.
ASWI-FP-SP-B	1.0	Any motor-driven component will emit sparks internally.

Table 3. (continued)

<u>EVENT</u>	<u>FAILURE PROBABILITY</u>	<u>ASSUMPTIONS</u>
ASWI-KDHNIU-HK-B	0.148	Tumbleweeds are the only source abundant enough to provide adequate kindling. Tumbleweeds are considered capable of being blown next to the H&I unit 3 months per year (September to November). During this period tumbleweeds were considered to be present 60% of the time, allowing that the wind blew 1 of every three days, and tumbleweeds were allowed to accumulate up to 1 week.
ASWM-PR-PR-I	2.0 E-6/yr	Based on the assumption by a propane fire expert (Dick Thatcher) that there are approximately 50,000 30K Gallon Propane Tanks in the U.S., and he would expect to see a BLEVE every 10 years. ¹¹
LIGHTNINGFIRE-I	0.1/yr	Between 40,000 and 50,000 strikes were recorded last year within the South East reporting district. One struck at RWMC last year, but not on the C&S building. Assume that 10% of RWMC strikes at the RWMC hit the C&S building. Based on one year of data from the Bureau of Land Management.
ICSI-KDEP-HK-B	0.03	Container stacking could occur in the vicinity of electric panels 30% of the time, and that one of every ten times an operator stacks plywood against an electric panel. There are no procedures against stacking plywood spacers against electric panels.
ACSI-MVST-HE-B	0.03	Includes failure to detect propane, gas, or diesel leak in air lock. ASEP screening value. ⁵
ACSI-RADMAT-B	1.0	There are 20 to 30 containers stored in the airlocks at any given time. Conservative estimate.

Table 3. (continued)

<u>EVENT</u>	<u>FAILURE PROBABILITY</u>	<u>ASSUMPTIONS</u>
ICSI-CT-SP-I	1.0 E-06/yr	This number is obtained by engineering judgment. To have this event occur, manufacturer packaging human error, shipping human error, and chemical reaction leading to spontaneous combustion has to occur.
ICSN-EF-IG-I	3.29 E-05/yr	Based on SPMS forklift fire data. Assumes 1 of 10 forklift fires is an electric forklift. Used binomial distribution.
ICSN-KDEFL-HK-B	0.25	Percentage availability based on forklift moving boxes or plywood spacers 50% of the time, and half of the forklift moving time is with an empty load.
PROXIMITY	0.85	Based on engineering judgement. It is considered that 85% of forklift operations occur within close enough proximity of the stored waste for a forklift fire to ignite the waste.
ICSM-GV-ML-I	3.816 E-05/yr	Binomial distribution used with SPMS DOE facility information on forklift fires.

Table 3. (continued)

<u>EVENT</u>	<u>FAILURE PROBABILITY</u>	<u>ASSUMPTIONS</u>
ICSA-MV-ML-I	7.56 E-04/yr	Binomial distribution used with SPMS DOE facility information on forklift fires.
WASTE-TRANSPORT	0.5	During waste transport, 50% of the time the forklift is carrying waste.
BRDRUM-TRANSPORT	0.976	20,700 waste containers in the C&S building inventory are a steel drum or box.
FRP-TRANSPORT	2.36 E-02	500 waste containers in the C&S building inventory are FRP boxes.
ICSI-PS-IG-B	1.0	Conservative estimate that assumes all fires big enough to ignite plywood.
ICSI-SDBRCH-IG-B	1 E-4	Probability of a barrel being breached at any point in time 2/20,000 based on previous UOR experience. Conservative Estimate.
ICSI-PB-IG-B	1.0	Conservative estimate that assumes all fires large enough to reach plywood boxes, will ignite plywood boxes.

7.0 RESULTS AND RECOMMENDATIONS

Risk is defined generally as the probability of occurrence of an undesired event (in units of events/year) multiplied by the consequences (or damage) created by that event. Consequences can include equipment downtime, property damage, environmental damage, and injuries or fatalities to employees or the public. Determining risk provides a quantitative basis for making policy decisions and for choosing between possible alternatives for risk improvement. Risk can be reduced by:

- a) decreasing the frequency of the undesired event,
- b) decreasing the probability of mitigating system failure,
- c) increasing the reliability or adding new barriers, or
- d) decreasing the consequences of an event.

The following sections describe the results of the RWMC fire hazards analysis. Engineering insights based on the results of this analysis are also presented.

7.1 Event Tree Analysis Results

The results of the event tree analysis, shown in Tables 4 and 5, compare the frequency of occurrence for medium and small releases caused by fire, and an estimated frequency for water damage (presented as contamination frequency) for the current and proposed fire mitigation system for each building. These results are a summation of the damage states discussed earlier in section 5.1. To fully use these results, facility personnel will have to estimate clean-up costs associated with each release category so that risk can be expressed in dollars per year. This cost analysis was beyond the scope of this report. Iteration of the damage state definitions is provided below.

A Large Release is that amount of radioactive nuclides generated from an uncontained fire that completely destroys either of the two ASWS buildings and their contents. This definition assumes that no intervention is successful by RWMC personnel or the Central Facilities firemen. Credible fire scenarios that could lead to a large release include: propane tank Boiling Liquid Expanding Vapor Explosion (BLEVE), or an uncontrolled desert fire.

A Medium Release is that amount of radioactive nuclides generated from the largest credible fire within the air support buildings. Waste storage configuration and small amount of combustible material stored in the buildings limit the size of a fire. The RWMC Safety Analysis (DRAFT February 1989) assumes two rows of fire retardant plywood (FRP) boxes stacked five high represent the most severe stacking arrangement. A total of 0.17 Curies would be released to the environment. The storage arrangement precludes fire spread to additional storage arrays.

A Small Release is that amount of radioactive nuclides generated from a fire that is contained by the RWMC Fire Brigade or the Central Facilities firemen before the entire waste stack is consumed. One or more of the FRP boxes are assumed to have been breached by this fire.

Contamination is defined as radioactive nuclides that can be washed away from breached steel waste containers or fiberglass-covered plywood boxes by water run off from fire suppression activities. In the past, the fiberglass-covered plywood boxes stored at the Transuranic Storage Area-Retrieved (TSA-R) have been known to leak alpha contamination when washed down with rainwater; therefore, all of the stored plywood boxes are considered to leak if washed down with water.

7.1.2 C&S Building Event Tree Analysis Results

Table 4 shows a detailed summary of modelled fire initiators and their effects in terms of relative radioactive release and contamination in the SWEPP C&S building. Current release and contamination results are compared to the results after installation of the proposed sprinkler system. Totals for each damage state are summed and reported along with the differences between the current and proposed fire configurations at the bottom of the table. Fire initiator frequencies and damage state frequencies are all given in frequency per year calculations.

Table 4. Summary of the SWEPP C&S building fire initiators with end damage states.

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Lightning Fire	0.1	MED REL: 1.58 E-8 SML REL: 3.00 E-4 CONTAMIN: 2.17 E-2	MED REL: 1.58 E-10 SML REL: 3.00 E-4 CONTAMIN: 2.18 E-2
Electric Panel Fire	1.3 E-03	MED REL: 2.00 E-10 SML REL: 3.80 E-6 CONTAMIN: 2.83 E-4	MED REL: 2.00 E-12 SML REL: 3.80 E-6 CONTAMIN: 2.83 E-4
Vehicle Fire	8.3 E-04	MED REL: 3.62 E-8 SML REL: 6.88 E-4 CONTAMIN: 3.12 E-5	MED REL: 3.62 E-10 SML REL: 6.88 E-4 CONTAMIN: 3.12 E-5
2" Propane Fuel Line Fire	4.1 E-04	MED REL: 2.16 E-8 SML REL: 4.10 E-4 CONTAMIN: -----	MED REL: 2.16 E-10 SML REL: 4.10 E-4 CONTAMIN: -----
Vehicle Fuel Leak	1.6 E-04	MED REL: 8.43 E-9 SML REL: 1.60 E-4 CONTAMIN: -----	MED REL: 8.43 E-11 SML REL: 1.60 E-4 CONTAMIN: -----
Earthquake	2.0 E-05	MED REL: 1.05 E-9 SML REL: 2.00 E-5 CONTAMIN: -----	MED REL: 1.05 E-11 SML REL: 2.0 E-5 CONTAMIN: -----

Table 4. (continued)

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Inflation Unit Fan Fire	4.1 E-06	MED REL: 2.16 E-10 SML REL: 4.10 E-6 CONTAMIN: -----	MED REL: 2.16 E-12 SML REL: 4.10 E-6 CONTAMIN: -----
Waste Storage Container Fire	1.2 E-06	MED REL: 6.32 E-11 SML REL: 1.20 E-6 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Heating and Inflation Unit Fire	1.2 E-06	MED REL: 6.32 E-11 SML REL: 1.20 E-6 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Spurious Activation of Sprinkler Heads	-----		CONTAMIN: 2.18 E-2
TOTAL DAMAGE STATE FREQUENCIES		MED REL: 8.36 E-8 SML REL: 1.59 E-3 CONTAMIN: 2.20 E-2	MED REL: 8.36 E-10 SML REL: 1.59 E-3 CONTAMIN: 4.38 E-2
TOTAL CHANGE IN DAMAGE STATE FREQUENCIES		MED REL: -8.28 E-8 SML REL: 0.0 CONTAMIN: +2.18 E-2	

Based on this analysis, adding a sprinkler system to the SWEPP C&S building would not result in significantly lower radioactive release or contamination frequencies caused from fires. Table 4 results show that small releases caused by fires are not improved with the addition of a sprinkler system, while the contamination frequency is increased because of possible spurious activation of the sprinkler system resulting in waste wash down. When waste is washed down, contamination can spread into the facility with a potential for spread outside of the air supported building. Medium releases

are reduced by the implementation of a sprinkler system in the C&S building, however, a decrease of $8.28 \text{ E-}8/\text{year}$ is insignificant considering the operating life of the facility, approximately 15 years.

7.1.3 ASB2 Building Event Tree Analysis Results

Table 5 shows a detailed summary of modelled fire initiators and their effects in terms of radioactive release and contamination in the RWMC ASB2 building. Current release and contamination results are compared to the results after installation of the proposed sprinkler system. Totals for each damage state are summed and reported along with the differences between the current and proposed fire configurations at the bottom of the table. Fire initiator frequencies and damage state frequencies are all given in frequency per year calculations.

Table 5. Summary of the RWMC ASB2 building fire initiators with end damage states.

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Lightning Fire	0.1	MED REL: $2.78 \text{ E-}4$ SML REL: $2.22 \text{ E-}5$ CONTAMIN: $4.13 \text{ E-}4$	MED REL: $1.58 \text{ E-}10$ SML REL: $3.00 \text{ E-}4$ CONTAMIN: $5.58 \text{ E-}3$
Electric Panel Fire	$1.3 \text{ E-}03$	MED REL: $3.52 \text{ E-}6$ SML REL: $2.81 \text{ E-}7$ CONTAMIN: $5.28 \text{ E-}6$	MED REL: $2.00 \text{ E-}12$ SML REL: $3.80 \text{ E-}6$ CONTAMIN: $7.26 \text{ E-}5$
Vehicle Fire	$8.3 \text{ E-}04$	MED REL: $6.37 \text{ E-}4$ SML REL: $5.09 \text{ E-}5$ CONTAMIN: $5.93 \text{ E-}7$	MED REL: $3.62 \text{ E-}10$ SML REL: $6.88 \text{ E-}4$ CONTAMIN: $8.00 \text{ E-}6$
2" Propane Fuel Line Fire	$4.1 \text{ E-}04$	MED REL: $3.80 \text{ E-}4$ SML REL: $3.03 \text{ E-}5$ CONTAMIN: -----	MED REL: $2.16 \text{ E-}10$ SML REL: $4.10 \text{ E-}4$ CONTAMIN: -----
Vehicle Fuel Leak	$1.6 \text{ E-}04$	MED REL: $1.48 \text{ E-}4$ SML REL: $1.18 \text{ E-}5$ CONTAMIN: -----	MED REL: $8.43 \text{ E-}11$ SML REL: $1.60 \text{ E-}4$ CONTAMIN: -----

Table 5. (continued)

<u>Fire Initiator</u>	<u>Frequency (per Year)</u>	<u>Damage States (w/o Sprinkler)</u>	<u>Damage States (Sprinkler)</u>
Earthquake	2.0 E-05	MED REL: 1.85 E-5 SML REL: 1.48 E-6 CONTAMIN: -----	MED REL: 1.05 E-11 SML REL: 2.0 E-5 CONTAMIN: -----
Inflation Unit Fan Fire	4.1 E-06	MED REL: 3.80 E-6 SML REL: 3.03 E-7 CONTAMIN: -----	MED REL: 2.16 E-12 SML REL: 4.10 E-6 CONTAMIN: -----
Waste Storage Container Fire	1.2 E-06	MED REL: 1.11 E-6 SML REL: 8.88 E-8 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Heating and Inflation Unit Fire	1.2 E-06	MED REL: 1.11 E-6 SML REL: 8.88 E-8 CONTAMIN: -----	MED REL: 6.32 E-13 SML REL: 1.20 E-6 CONTAMIN: -----
Spurious Activation of Sprinkler Heads	-----		CONTAMIN: 5.60 E-3
TOTAL DAMAGE STATE FREQUENCIES		MED REL: 1.47 E-3 SML REL: 1.17 E-4 CONTAMIN: 4.19 E-4	MED REL: 8.36 E-10 SML REL: 1.59 E-3 CONTAMIN: 1.13 E-2
TOTAL CHANGE IN DAMAGE STATE FREQUENCIES		MED REL: -1.47 E-3 SML REL: +1.47 E-3 CONTAMIN: +1.08 E-2	

Table 5 shows a decrease in the total frequency of medium releases caused by fires in the RWMC ASB2 building, and an identical increase in the total frequency of small releases. The frequency for radioactive contamination is also significantly increased. For the RWMC ASB2 building proposed sprinkler analysis, a fire detection system like the one in the SWEPP C&S building was added also. The overwhelming reason for the decrease in the

frequency of medium releases is in quicker fire detection time, not in the addition of the sprinkler system.

In comparing the two buildings total damage state frequencies we find that the RWMC ASB2 building has a much higher frequency for a medium release (approximately five orders of magnitude) than the SWEPP C&S building, though the frequency for small releases and contamination spread are lower. This phenomena occurs because more of the postulated fires in the RWMC ASB2 building are expected to end in a medium release resulting from to the lack of a smoke or fire detection system. Small release frequencies are lower in the RWMC ASB2 building relative to the C&S building because of the increase in fires contributing to a medium release. Contamination frequencies are less in the RWMC ASB2 building because at the time of analysis, no fiberglass covered plywood boxes were stored in the ASB2 building.

Four fire initiators contributed to the overall fire and damage frequencies. These fire initiators are listed in Table 6 with recommendations for reducing risk. In both ASWS building analyses, the contamination frequency for washing down waste containers was increased. Frequency increase is predominantly caused by spurious activation of the sprinkler head, and is listed also in Table 6 with recommendations for decreasing frequency.

Table 6. Summary of dominant radiological release contributors and recommendations for reducing the event frequency.

	<u>Dominant Events</u>	<u>Mitigation of Radiological Release</u>
1.	Lightning Fire	Install a lightning rod on top of both buildings.
2.	Vehicle Fire/ Vehicle Fuel Leak	Purchase electric vehicles that can handle all normal and maintenance activities, and remove all fossil fueled vehicles from the ASWS building air locks.
3.	Propane Fuel Line Fire	Build a cage around all exposed line that could be damaged by maintenance activities such as snow removal.
4.	Spurious Activation of Sprinkler Heads	Remove all fiberglass-covered plywood storage boxes from the C&S building.

Large releases were analyzed but not included in Tables 4 and 5 because neither large releases considered could be mitigated with the installation of a sprinkler system. The two events that could cause large releases identified in this analysis are a:

1. Propane Tank BLEVE (Boiling Liquid Expanding Vapor Explosion), and (1.2 E-6/yr)
2. An Uncontrolled Desert Fire. (5.9 E-4/yr)

As a result of this analysis, we can see that the addition of fire sprinkler systems does not significantly affect the fire hazard potential in either air supported building. In addition, the sprinkler system could add to the potential spread of contamination through spurious activation of sprinkler heads.

In conclusion, the analysis has identified facility vulnerabilities to fire hazards that can be used as guidance in facility modifications to improve the facility fire protection. The results and recommendations should be quantified on a cost basis before being used as a guidance tool (outside the scope of this analysis). When a final dry-pipe sprinkler system is chosen, this report can be updated to reflect the more detailed information.

7.2 Recommendations For Further Analysis

In order to correctly assess the need for a sprinkler system, an analysis of the curie content associated with each magnitude for release, and a cost analysis for clean up efforts associated with each category for release should be assessed. If there is a significant decrease in the amount of airborne alpha-contamination released between a medium and small release, a dry pipe sprinkler system may be warranted even though the frequency of occurrence for a fire that involves stored waste materials is about once every thousand years. Similarly, if the cost to clean up a fire associated with a medium release was approximately the same as for a small release, additional fire mitigation systems would not be warranted.

8. REFERENCES

1. K. D. Russell, Integrated Reliability and Risk Analysis System, NUREG/CR-5111, EG&G Idaho., Inc, Idaho Falls, 1988.
2. ETA-II, Science Applications International Corporation, Los Altos, 1987.
3. R. W. Passmore, Safety Analysis For the Radioactive Waste Management Complex at the Idaho National Engineering Laboratory, WM-PD-86-011, Rev. 2, EG&G Idaho, 1986.
4. 8028 FR LTC DC-6 White 56 in. fabric, manufactured by Seaman Corporation, Millersburg, 1984.
5. A. D. Swain, Accident Sequence Evaluation Program Human Reliability Analysis Procedure, NUREG/CR-4772, SAND86-1996, February 1987.
6. PRA Procedures Guide: A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants, NUREG-CR 2300.VI, pg. 5-47, 1983.
7. Seabrook Station Probabilistic Safety Assessment, December 1983.
8. IEEE Nuclear Reliability Data Manual, 1977.
9. R. J. Nertney, Safety Performance Measurement System, DOE DE-AC07-76ID01570, 1979.
10. M. L. Davis, D. G. Satterwhite, et. al, Summary Procedures Guide For Application of Risk and Hazards Analysis Techniques, EG&G Idaho, 1988.
11. Telephone conversation with Dick Thatcher, noted Propane Tank Fire Expert, July 17, 1989.

Appendix A

Fault Tree Quantification

Table A-1. Fault Tree Cut Sets for Fire Involving Stored Waste.

Mincut Upper Bound 2.191E-003

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	29.3	29.3	6.4E-004	ICSA-MV-ML-I, ICSI-PB-IG-B, ICSI-PS-IG-B, PROXIMITY
2	56.2	26.9	5.9E-004	DESERTFIRE-I, FIREMEN-FTC-B
3	69.9	13.6	3.0E-004	ICSI-PB-IG-B, ICSI-PROP-B, ICSI-PS-IG-B, ICSI-KDEP-HK-B, LIGHTENINGFIRE-I
4	83.3	13.4	2.9E-004	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-PF-SP-B, FIREMEN-FTC-B
5	90.7	7.3	1.6E-004	ACSI-MVFL-RP-I, ACSI-MVST-HE-B, ACSI-RADMAT-B
6	96.3	5.6	1.2E-004	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-HT-RN-B, FIREMEN-FTC-B
7	97.8	1.4	3.2E-005	ICSI-PB-IG-B, ICSI-PS-IG-B, ICSM-GV-ML-I, PROXIMITY
8	98.7	0.9	2.0E-005	EARTHQUAKE-I, FIREMEN-FTC-B
9	99.1	0.4	8.9E-006	FRP-TRANSPORT, ICSA-MV-ML-I, ICSI-PB-IG-B, WASTE-TRANSPORT
10	99.4	0.3	6.9E-006	ICSI-PB-IG-B, ICSI-PS-IG-B, ICSN-EF-IG-I, ICSN-KDEFL-HK-B, PROXIMITY
11	99.6	0.1	4.1E-006	ASWI-KDHNIU-HK-B, ASWM-FU-OH-I, FIREMEN-FTC-B
12	99.8	0.1	3.8E-006	ICSI-EP-SH-I, ICSI-KDEP-HK-B, ICSI-PB-IG-B, ICSI-PROP-B, ICSI-PS-IG-B
13	99.9	0.0	2.0E-006	ASWM-PR-PR-I
14	100.0	0.0	1.2E-006	ICSI-CT-SP-I
15	100.0	0.0	1.2E-006	ASWI-KDHNIU-HK-B, ASWN-PF-IG-I, FIREMEN-FTC-B
16	100.0	0.0	2.9E-007	DESERTFIRE-I, FIREMEN-FTR-B
17	100.0	0.0	1.4E-007	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-PF-SP-B, FIREMEN-FTR-B

Table A-1. Fault Tree Cut Sets for Fire Involving Stored Waste.

Mincut Upper Bound 2.191E-003

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
18	100.0	0.0	9.7E-008	FRP-TRANSPORT, ICSI-PB-IG-B, ICSN-EF-IG-I, ICSN-KDEFL-HK-B, WASTE-TRANSPORT
19	100.0	0.0	6.4E-008	ICSA-MV-ML-I, ICSI-PS-IG-B, ICSI-SDBRCH-IG-B, PROXIMITY
20	100.0	0.0	6.1E-008	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-HT-RN-B, FIREMEN-FTR-B
21	100.0	0.0	3.6E-008	BRDRUM-TRANSPORT, ICSA-MV-ML-I, ICSI-SDBRCH-IG-B, WASTE-TRANSPORT
22	100.0	0.0	3.0E-008	ICSI-PROP-B, ICSI-PS-IG-B, ICSI-SDBRCH-IG-B, ICSI-KDEP-HK-B, LIGHTENINGFIRE-I
23	100.0	0.0	1.0E-008	EARTHQUAKE-I, FIREMEN-FTR-B
24	100.0	0.0	3.2E-009	ICSI-PS-IG-B, ICSI-SDBRCH-IG-B, ICSM-GV-ML-I, PROXIMITY
25	100.0	0.0	2.0E-009	ASWI-KDHNIU-HK-B, ASWM-FU-OH-I, FIREMEN-FTR-B
26	100.0	0.0	6.9E-010	ICSI-PS-IG-B, ICSI-SDBRCH-IG-B, ICSN-EF-IG-I, ICSN-KDEFL-HK-B, PROXIMITY
27	100.0	0.0	6.0E-010	ASWI-KDHNIU-HK-B, ASWN-PF-IG-I, FIREMEN-FTR-B
28	100.0	0.0	4.0E-010	BRDRUM-TRANSPORT, ICSI-SDBRCH-IG-B, ICSN-EF-IG-I, ICSN-KDEFL-HK-B, WASTE-TRANSPORT
29	100.0	0.0	3.8E-010	ICSI-EP-SH-I, ICSI-KDEP-HK-B, ICSI-PROP-B,

Table A-2. Fault Tree Cut Sets for Initiating Fires.

Mincut Upper Bound 1.030E-001

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	97.1	97.1	1.0E-001	LIGHTENINGFIRE-I
2	98.4	1.2	1.3E-003	ICSI-EP-SH-I
3	99.1	0.7	7.6E-004	ICSA-MV-ML-I
4	99.7	0.6	5.9E-004	DESERTFIRE-I, FIREMEN-FTC-B
5	99.9	0.3	2.9E-004	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-PF-SP-B, FIREMEN-FTC-B
6	100.0	0.2	1.6E-004	ACSI-MVFL-RP-I, ACSI-MVST-HE-B, ACSI-RADMAT-B
7	100.0	0.1	1.2E-004	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-HT-RN-B, FIREMEN-FTC-B
8	100.0	0.0	3.8E-005	ICSM-GV-ML-I
9	100.0	0.0	3.3E-005	ICSN-EF-IG-I
10	100.0	0.0	2.0E-005	EARTHQUAKE-I, FIREMEN-FTC-B
11	100.0	0.0	4.1E-006	ASWI-KDHNIU-HK-B, ASWM-FU-OH-I, FIREMEN-FTC-B
12	100.0	0.0	2.0E-006	ASWM-PR-PR-I
13	100.0	0.0	1.2E-006	ICSI-CT-SP-I
14	100.0	0.0	1.2E-006	ASWI-KDHNIU-HK-B, ASWN-PF-IG-I, FIREMEN-FTC-B
15	100.0	0.0	2.9E-007	DESERTFIRE-I, FIREMEN-FTR-B
16	100.0	0.0	1.5E-007	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-PF-SP-B, FIREMEN-FTR-B
17	100.0	0.0	6.2E-008	ASWI-FLRUPT-HE-I, ASWI-FP-RN-B, ASWI-HT-RN-B, FIREMEN-FTR-B
18	100.0	0.0	1.0E-008	EARTHQUAKE-I, FIREMEN-FTR-B
19	100.0	0.0	2.0E-009	ASWI-KDHNIU-HK-B, ASWM-FU-OH-I, FIREMEN-FTR-B
20	100.0	0.0	6.1E-010	ASWI-KDHNIU-HK-B, ASWN-PF-IG-I, FIREMEN-FTR-B

APPENDIX B
EVENT TREE QUANTIFICATION

LIGHTNING FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB .	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						2.34E-02	NO DAMAG
					2.18E-01 BR WASTE	6.52E-03	CONTAMIN
						5.46E-02	NO DAMAG
					2.18E-01 BR WASTE	1.52E-02	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		6.98E-07	NO DAMAG
		4.57E-05 DETECTION				4.56E-06	SELF EXT
1.00E-01 FIRE						9.00E-05	SML REL
	3.00E-03 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		2.10E-04	SML REL
		4.57E-05 DETECTION				2.10E-09	MED REL
						1.37E-08	MED REL

Figure B-1. Lightning initiated fire for the current C&S building configuration.

ELECTRIC PANEL FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
1.30E-03 FIRE		4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	3.04E-04	NO DAMAG
						8.48E-05	CONTAMIN
						7.10E-04	NO DAMAG
						1.98E-04	CONTAMIN
						9.07E-09	NO DAMAG
						5.92E-08	SELF EXT
						1.14E-06	SML REL
						2.66E-06	SML REL
						2.66E-11	MED REL
						1.73E-10	MED REL
	2.92E-03 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT			

Figure B-2. Electric panel fire for the current C&S building configuration.

VEHICLE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						3.35E-05	NO DAMAG
					2.18E-01 BR WASTE	9.35E-06	CONTAMIN
						7.82E-05	NO DAMAG
					2.18E-01 BR WASTE	2.18E-05	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		1.00E-09	NO DAMAG
8.31E-04 FIRE		4.57E-05 DETECTION				6.53E-09	SELF EXT
						2.06E-04	SML REL
						4.82E-04	MED REL
	8.28E-01 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		4.82E-09	MED REL
		4.57E-05 DETECTION				3.14E-08	MED REL

Figure B-3. Vehicle initiated fire for the current C&S building configuration.

PROPANE FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
		4.57E-05 DETECTION				0.00E+00	SELF EXT
4.10E-04 FIRE						1.23E-04	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		2.87E-04	SML REL
		4.57E-05 DETECTION				2.87E-09	MED REL
						1.87E-08	MED REL

Figure B-4. Propane fuel line fire for the current C&S building configuration.

VEHICLE FUEL LEAK	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	0.00E+00	CONTAMIN
		4.57E-05 DETECTION				0.00E+00	NO DAMAG
1.60E-04 FIRE						0.00E+00	SELF EXT
						4.80E-05	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		1.12E-04	SML REL
		4.57E-05 DETECTION				1.12E-09	MED REL
						7.31E-09	MED REL

Figure B-5. Vehicle fuel line leak initiated fire for the current C&S building configuration.

EARTHQUAKE LEADING TO FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
2.00E-05 FIRE	1.00E+00 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	0.00E+00	NO DAMAG
						0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
						0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
						0.00E+00	SELF EXT
2.00E-05 FIRE	1.00E+00 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	6.00E-06	SML REL
						1.40E-05	SML REL
						1.40E-10	MED REL
						9.14E-10	MED REL

Figure B-6. Earthquake initiated fire for the current C&S building configuration.

H&I UNIT FAN OVERHEATS	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
4.10E-05 FIRE		4.57E-05 DETECTION				0.00E+00	SELF EXT
						1.23E-06	SML REL
						2.87E-06	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		2.87E-11	MED REL
		4.57E-05 DETECTION				1.87E-10	MED REL

Figure B-7. Inflation unit fan fire for the current C&S building configuration.

WASTE CONTAINER COMBUSTION	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE		2.18E-01 BR WASTE	0.00E+00	CONTAMIN
				1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		4.57E-05 DETECTION				0.00E+00	SELF EXT
1.20E-06 FIRE						3.60E-07	SML REL
						8.40E-07	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE			8.40E-12	MED REL
		4.57E-05 DETECTION		1.00E-05 FIRE DEPT		5.48E-11	MED REL

Figure B-8. Waste storage container fire for the current C&S building configuration.

HEATING AND INFLATION UNIT FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
					2.18E-01 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		4.57E-05 DETECTION				0.00E+00	SELF EXT
1.20E-05 FIRE						3.60E-07	SML REL
						8.40E-07	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		8.40E-12	MED REL
		4.57E-05 DETECTION				5.48E-11	MED REL

Figure B-9. Heating and inflation unit fire for the current C&S building configuration.

LIGHTNING FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
1.00E-01 FIRE	3.00E-03 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	2.34E-02	NO DAMAG
							6.52E-03	CONTAMIN
							5.40E-02	NO DAMAG
							1.51E-02	CONTAMIN
							5.46E-04	NO DAMAG
							1.52E-04	CONTAMIN
							6.98E-09	NO DAMAG
							3.53E-06	NO DAMAG
							9.83E-07	CONTAMIN
							4.56E-08	SELF EXT
1.00E-01 FIRE	3.00E-03 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	9.00E-05	SML REL
							2.08E-04	SML REL
							2.10E-06	SML REL
							2.10E-11	MED REL
1.00E-01 FIRE	3.00E-03 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	1.36E-08	SML REL
							1.37E-10	MED REL

Figure B-10. Lightning initiated fire for the proposed C&S building.

VEHICLE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
8.31E-04 FIRE							3.35E-05	NO DAMAG
							9.35E-06	CONTAMIN
							7.75E-05	NJ DAMAG
							2.16E-05	CONTAMIN
							7.82E-07	NO DAMAG
							2.18E-07	CONTAMIN
							1.00E-11	NO DAMAG
							5.06E-09	NO DAMAG
							1.41E-09	CONTAMIN
							6.53E-11	SELF EXT
							2.06E-04	SML REL
							4.77E-04	SML REL
							4.82E-06	SML REL
							4.82E-11	MED REL
							3.11E-08	SML REL
							3.14E-10	MED REL

Figure B-12. Vehicle initiated fire for the proposed C&S building configuration.

VEHICLE FUEL LEAK LEADING TO FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
							0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
						1.00E-02 SPRINKLER	0.00E+00	NO DAMAG
						1.00E-05 FIRE DEPT	0.00E+00	NO DAMAG
							0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	SELF EXT
							0.00E+00	SML REL
							4.80E-05	SML REL
							1.11E-04	SML REL
							1.12E-06	SML REL
							1.12E-11	MED REL
							7.24E-09	SML REL
							7.31E-11	MED REL

Figure B-14. Vehicle fuel line leak initiated fire for the proposed C&S building configuration.

EARTHQUAKE LEADS TO FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE	0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE			2.18E-01 BR WASTE	0.00E+00	NO DAMAG
				1.00E-02 SPRINKLER		2.18E-01 BR WASTE	0.00E+00	CONTAMIN
					1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		4.57E-05 DETECTION		1.00E-02 SPRINKLER		2.18E-01 BR WASTE	0.00E+00	CONTAMIN
2.00E-05 FIRE							0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE				0.00E+00	SELF EXT
	1.00E+00 WASTE			1.00E-02 SPRINKLER			6.00E-06	SML REL
					1.00E-05 FIRE DEPT		1.39E-05	SML REL
							1.40E-07	SML REL
							1.40E-12	MED REL
		4.57E-05 DETECTION		1.00E-02 SPRINKLER			9.05E-10	SML REL
							9.14E-12	MED REL

Figure B-15. Earthquake initiated fire for the proposed C&S building configuration.

HEATING AND INFLATION UNIT FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE	0.00E+00	NO DAMAG
						2.18E-01 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE			2.18E-01 BR WASTE	0.00E+00	NO DAMAG
				1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	2.18E-01 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	NC DAMAG
							0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
							0.00E+00	NO DAMAG
		4.57E-05 DETECTION		1.00E-02 SPRINKLER		2.18E-01 BR WASTE	0.00E+00	CONTAMIN
1.20E-05 FIRE							0.00E+00	SELF EXT
							3.60E-07	SML REL
							8.32E-07	SML REL
			7.00E-01 EM BRIGADE				8.40E-09	SML REL
	1.00E+00 WASTE			1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT		8.40E-14	MED REL
		4.57E-05 DETECTION					5.43E-11	SML REL
				1.00E-02 SPRINKLER			5.48E-13	MED REL

Figure B-18. Heating and inflation unit fire for the proposed C&S building configuration.

ELECTRIC PANEL FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						2.72E-05	NO DAMAG
					5.60E-02 BR WASTE	1.61E-06	CONTAMIN
						6.34E-05	NO DAMAG
					5.60E-02 BR WASTE	3.76E-06	CONTAMIN
						6.71E-10	NO DAMAG
						1.20E-03	SELF EXT
						8.43E-08	SML REL
						1.97E-07	SML REL
						1.97E-12	MED REL
						3.52E-06	MED REL

Figure B-20. Electric panel fire for the current ASB2 building configuration.

VEHICLE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						3.00E-06	NO DAMAG
					5.60E-02 BR WASTE	1.78E-07	CONTAMIN
						6.99E-06	NO DAMAG
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	4.15E-07	CONTAMIN
						7.40E-11	NO DAMAG
		9.26E-01 DETECTION				1.32E-04	SELF EXT
8.31E-04 FIRE						1.53E-05	SML REL
						3.56E-05	SML REL
	8.28E-01 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		3.56E-10	MED REL
		9.26E-01 DETECTION				6.37E-04	MED REL

Figure B-21. Vehicle initiated fire for the current ASB2 building configuration.

PROPANE FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
4.10E-04 FIRE	1.00E+00 WASTE	9.26E-01 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	0.00E+00	NO DAMAG
						0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
						0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
						0.00E+00	SELF EXT
						9.10E-06	SML REL
						2.12E-05	SML REL
		9.26E-01 DETECTION	7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		2.12E-10	MED REL
						3.80E-04	MED REL

Figure B-22. Propane fuel line fire for the current ASB2 building configuration.

VEHICLE FUEL LEAK LEADING TO FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		9.26E-01 DETECTION				0.00E+00	SELF EXT
1.60E-04 FIRE						3.55E-06	SML REL
						8.29E-06	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		8.29E-11	MED REL
		9.26E-01 DETECTION				1.48E-04	MED REL

Figure B-23. Vehicle fuel line leak initiated fire for the current ASB2 building configuration.

EARTHQUAKE LEADS TO FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
2.00E-05 FIRE		9.26E-01 DETECTION				0.00E+00	SELF EXT
						4.44E-07	SML REL
						1.04E-06	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		1.04E-11	MED REL
		9.26E-01 DETECTION				1.85E-05	MED REL

Figure B-24. Earthquake initiated fire for the current ASB2 building configuration.

H&I UNIT FAN FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		9.26E-01 DETECTION				0.00E+00	SELF EXT
4.10E-06 FIRE						9.10E-08	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		2.12E-07	SML REL
		9.26E-01 DETECTION				2.12E-12	MED REL
						3.80E-06	MED REL

Figure B-25. Inflation unit fan fire for the current ASB2 building configuration.

WASTE CONTAINER COMBUSTION	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	BR WASTE		
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
			7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
		9.26E-01 DETECTION				0.00E+00	SELF EXT
1.20E-06 FIRE						2.65E-08	SML REL
						6.22E-08	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		6.22E-13	MED REL
		9.26E-01 DETECTION				1.11E-06	MED REL

Figure B-26. Waste storage container fire for the current ASB2 building configuration.

HEATING INFLATION UNIT FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	FIRE DEPT	ER WASTE		
						0.00E+00	NO DAMAG
					5.60E-02 BR WASTE	0.00E+00	CONTAMIN
						0.00E+00	NO DAMAG
			7.00E-01 EM BRIGADE		5.60E-02 BR WASTE	0.00E+00	CONTAMIN
				1.00E-05 FIRE DEPT		0.00E+00	NO DAMAG
1.20E-05 FIRE		9.26E-01 DETECTION				0.00E+00	SELF EXT
						2.66E-08	SML REL
						6.22E-08	SML REL
	1.00E+00 WASTE		7.00E-01 EM BRIGADE	1.00E-05 FIRE DEPT		6.22E-13	MED REL
		9.26E-01 DETECTION				1.11E-06	MED REL

Figure B-27. Heating and inflation unit fire for the current ASB2 building configuration.

LIGHTNING FIRE	STORED HAZ WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
							2.82E-02	NO DAMAG
						5.60E-02 BR WASTE	1.67E-03	CONTAMIN
							6.52E-02	NO DAMAG
						5.60E-02 BR WASTE	3.87E-03	CONTAMIN
							6.59E-04	NO DAMAG
						5.60E-02 BR WASTE	3.91E-05	CONTAMIN
							5.98E-09	NO DAMAG
							4.26E-06	NO DAMAG
							2.53E-07	CONTAMIN
							4.56E-08	SELF EXT
							9.00E-05	SML REL
							2.08E-04	SML REL
							2.10E-06	SML REL
							2.10E-11	MED REL
							1.36E-08	SML REL
							1.37E-10	MED REL

Figure B-28. Lightning initiated fire for the proposed ASB2 building configuration.

ELECTRIC PANEL FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
							3.67E-04	NO DAMAG
						5.60E-02 BR WASTE	2.18E-05	CONTAMIN
							8.48E-04	NO DAMAG
						5.60E-02 BR WASTE	5.03E-05	CONTAMIN
							8.56E-06	NO DAMAG
						5.60E-02 BR WASTE	5.08E-07	CONTAMIN
					1.00E-05 FIRE DEPT		9.07E-11	NO DAMAG
				1.00E-02 SPRINKLER			5.54E-08	NO DAMAG
			7.00E-01 EM BRIGADE				3.28E-09	CONTAMIN
		4.57E-05 DETECTION		1.00E-02 SPRINKLER		5.60E-02 BR WASTE	5.92E-10	SELF EXT
1.30E-03 FIRE							1.14E-06	SML REL
							2.63E-06	SML REL
							2.66E-08	SML REL
							2.66E-13	MED REL
	2.92E-03 WASTE		7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT		1.72E-10	SML REL
		4.57E-05 DETECTION		1.00E-02 SPRINKLER			1.73E-12	MED REL

Figure B-29. Electric panel fire for the proposed ASB2 building configuration.

VEHICLE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
B.31E-04 FIRE	B.28E-01 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	4.05E-05	NO DAMAG
						5.60E-02 BR WASTE	2.40E-06	CONTAMIN
						5.60E-02 BR WASTE	9.35E-05	NO DAMAG
						5.60E-02 BR WASTE	5.55E-06	CONTAMIN
						5.60E-02 BR WASTE	9.44E-07	NO DAMAG
						5.60E-02 BR WASTE	5.60E-08	CONTAMIN
	B.28E-01 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	1.00E-11	NO DAMAG
						5.60E-02 BR WASTE	6.10E-09	NO DAMAG
						5.60E-02 BR WASTE	3.62E-10	CONTAMIN
						5.60E-02 BR WASTE	6.53E-11	SELF EXT
						5.60E-02 BR WASTE	2.06E-04	SML REL
						5.60E-02 BR WASTE	4.77E-04	SML REL
B.28E-01 WASTE	B.28E-01 WASTE	4.57E-05 DETECTION	7.00E-01 EM BRIGADE	1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	4.82E-06	SML REL
						5.60E-02 BR WASTE	4.82E-11	MED REL
						5.60E-02 BR WASTE	3.11E-08	SML REL
						5.60E-02 BR WASTE	3.14E-10	MED REL

Figure B-30. Vehicle initiated fire for the proposed ASB2 building configuration.

PROPANE FUEL LINE FIRE	STORED RAD WASTE INVOLVED	FIRE DETECTION FAILS	EMERGENCY FIRE BRIGADE FAILS	SPRINKLER SYSTEM FAILS	CENTRAL FACILITIES RESPONSE FAILS	BREACHED STORED MATERIALS PRESENT	SEQUENCE PROB.	SEQUENCE CLASS
FIRE	WASTE	DETECTION	EM BRIGADE	SPRINKLER	FIRE DEPT	BR WASTE		
			7.00E-01 EM BRIGADE			5.60E-02 BR WASTE	0.00E+00	NO DAMAG
							0.00E+00	CONTAMIN
						5.60E-02 BR WASTE	0.00E+00	NO DAMAG
							0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
				1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT	5.60E-02 BR WASTE	0.00E+00	CONTAMIN
							0.00E+00	NO DAMAG
							0.00E+00	NO DAMAG
		4.57E-05 DETECTION		1.00E-02 SPRINKLER		5.60E-02 BR WASTE	0.00E+00	CONTAMIN
4.10E-04 FIRE							0.00E+00	SELF EXT
							1.23E-04	SML REL
							2.84E-04	SML REL
			7.00E-01 EM BRIGADE				2.87E-05	SML REL
	1.00E+00 WASTE			1.00E-02 SPRINKLER	1.00E-05 FIRE DEPT		2.87E-11	MED REL
		4.57E-05 DETECTION					1.85E-08	SML REL
				1.00E-02 SPRINKLER			1.87E-10	MED REL

Figure B-31. Propane fuel line fire for the proposed ASB2 building configuration.

Figure B-36. Heating and inflation unit fire for the proposed ASB2 building configuration.

END

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