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Ms. Judith M. Espinosa, Secretary
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P.O. Box 26110
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Dear Ms. Espinosa:

Enclosed for your information is a copy of DOE/WIPP 91-031, "WIPP Fire Hazards and Risk Analysis."

If you have any questions concerning this report, please contact Jerry Carr of my staff.

Sincerely,

Arlen Hunt
Project Manager

Enclosure

cc w/o enclosure:
C&C File
G. Gonzales, NMED
P. McCasland, NMED/WIPP
B. Garcia, NMED
K. Sisneros, NMED
J. Lytle, DOE-HQ
M. Frei, DOE-HQ
J. Arthur, DOE-AL
R. Wise, DOE-WPO
J. Mewhinney, DOE-WPO
J. Carr, DOE-WPO
R. Farrell, WID

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WIPP Fire Hazards and Risk Analysis

Waste Isolation Pilot Plant

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WIPP FIRE HAZARDS AND RISK ANALYSIS

Westinghouse Electric Corporation
May 1991

Prepared under Subcontract 75-WBA-34490-IZ
by the Nuclear and Advanced Technology Division
for the Waste Isolation Pilot Plant

Approved by: Leslie L. Reed
L. L. Reed, Manager
Environment, Safety and Health

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WIPP FIRE HAZARDS AND RISK ANALYSIS

Westinghouse Electric Corporation
May 1991

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EXECUTIVE SUMMARY

The purpose of this analysis was to conduct a fire hazards and risk analysis of the Transuranic (TRU) contact-handled waste receipt, emplacement, and disposal activities at the Waste Isolation Pilot Plant (WIPP). The technical bases and safety envelope for these operations are defined in the approved WIPP Final Safety Analysis Report (FSAR) [1].

Although the safety documentation for the initial phase of the Test Program, the dry bin scale tests, has not yet been approved by the Department of Energy (DOE), reviews of the draft to date, including those by the Advisory Committee on Nuclear Facility Safety (ACNFS), have concluded that the dry bin scale tests present no significant risks in excess of those estimated in the approved WIPP FSAR. It is the opinion of the authors and reviewers of this analysis, based on sound engineering judgement and knowledge of the WIPP operations, that a Fire Hazards and Risk Analysis specific to the dry bin scale test program is not warranted prior to first waste receipt. This conclusion is further supported by the risk analysis presented in this document which demonstrates the level of risk to WIPP operations posed by fire to be extremely low.

In addition, the potential for a fire during the dry Test Phase bin scale tests, and fire propagation between bins is further restricted by the following Test Phase conditions:

- A Limiting Condition of Operation (LCO) has been established which restricts the accumulation of flammable gases in the bins to less than the lower flammability limit (LFL) with an action statement at 50% of the LFL

- Full characterization of the test wastes, e.g., head space gas analyses for all layers of containment, real-time radiography, and visual inspection of drum wastes

- A lower than average radionuclide inventory, per drum equivalent, than assumed in the FSAR

- A significantly lower throughput of waste than estimated in the FSAR

---

[1] Final Safety Analysis Report, May 1990

In spite of the above, it appears prudent that this Fire Hazards and Risk Analysis should be reviewed during the Test Phase to determine the need and value of its revision.

This Fire Hazards and Risk Analysis report relies heavily on a previously completed WIPP risk assessment, the Integrated Risk Assessment (IRA)[2]. This assessment identifies, analyzes, and quantifies the accessible public health risks posed by the operation of the WIPP, including those contributions from potential fires. The bulk of the IRA was prepared in 1989, reviewed for consistency with the plant configuration in May 1990 and again in May 1991. Those elements of the IRA that are pertinent to fire risks are used in Section 4.0 of this document as the Probabilistic Risk Assessment (PRA). While both the IRA and PRA uses the draft FSAR[3] and the FEIS[4], reviews have concluded that the PRA represents a conservative approach with regard to plant configuration, plant operations, and the safety envelope as represented by the now approved FSAR and FSEIS[5].

This Fire Hazard and Risk Analysis has two parts. The first part uses the Hazards and Operability (HAZOPS) approach to screen potential fire hazards and determine the highest ranking hazards for further analysis in part two, the PRA. The second part employs the PRA, as discussed above, to focus on the highest ranked fire hazards. These hazards are then quantified to determine the risk to the public. This risk is measured in terms of cancer fatalities within a 50 mile radius of the Waste Isolation Pilot Plant.

The hazards ranked highest in terms of a potential off-site release of radioactivity, injury to worker, and stoppage of waste handling operations are given in Table E-1. The first seven hazard entries include the potential for off-site radiation release and are further investigated in the PRA. The seven recommendations resulting from the HAZOPS were incorporated into the PRA. All recommendations from the PRA have been completed. The potential impacts of hazard entries 8 through 15 are less severe and therefore, are not analyzed further in the PRA. Based on our review, the WIPP has operational procedures, recovery plans, and arrangements with the local power company to preclude further risk analyses of these entries; however, specific responses and recommendations to these hazards are included in the conclusion and recommendation and given in Section 3.3.

---

[2]WIPP Integrated Risk Assessment, DOE/WIPP 89-010, May 1990
[3]Draft WIPP FSAR, dated 1988
[4]FEIS, dated 1980
[5]Final Supplement Environmental Impact Statement, January, 1990

TABLE E-1

RECOMMENDATIONS BASED ON SPECIFIC HAZOPS ENTRIES

No.	Table 3.2-1 Ref. #	C*	F*	Potential Actions	Potential Hazard Consequences
1	5	5	2	Administrative control of transient combustibles	Radiological release to the environment (3 drums involved)
2	8	5	1	Periodic inspection and maintenance on electrical components.	Radiological release to the environment (28 drums involved)
3	9	5	1	Periodic inspection and testing	Radiological release to the environment (28 drums involved)
4	10	5	1	Periodic inspection and maintenance and higher flash point fluid	Radiological release to the environment (28 drums involved)
5	13	5	2	Periodic inspection and maintenance of brakes and exhaust systems	Radiological release to the environment (28 drums involved)
6	14, 17	5	2	Administrative control of under-ground traffic. Stop unnecessary traffic and install signal system	Radiological release to the environment (28 drums involved)
7	15	5	2	Periodic inspection and maintenance of fuel and lubrication systems	Radiological release to the environment (90 drums involved)
8	24	4	3	Administrative controls on welding activities	Worker injuries and slowdown of waste handling
9	26	4	3	Spare circuit breakers for all substations.	Loss of ventilation and shutdown of waste handling operations
10	27	4	2	Spare transformer for utility substation	Loss of ventilation and shutdown of waste handling operations
11	28	4	3	Fire segregation or protection between generators	Shutdown of waste handling operations
12	29	4	2	Fire segregation or protection between generators	Shutdown of waste handling operations
13	34	4	3	Review procedures to reduce recovery time; additional preventative maintenance	Shutdown of waste handling operations
14	38	4	3	Periodic inspection and maintenance	Shutdown of waste handling operations
15	35	4	2	Review procedures to reduce recovery time; additional preventative maintenance on transformer	Shutdown of waste handling operations

*C - Consequence
*F - Frequency

The other two accident scenarios were included in the analysis to model the nonfire risk at WIPP. This allows for a comparison of the risk from fire to total plant risk. In the PRA, five major accident scenarios are developed from the first seven HAZOPS entries. Three of these (2, 4, and 5) involve fire. The accident scenarios are:

(1) A1(R3D): Breach of drum above ground in Waste Handling Building (3 drums involved)

(2) A2(R3D): Fire above ground in Waste Handling Building (3 drums involved)

(3) U1B(R3D): Breach of drum underground (3 drums involved)

(4) U2(R90): Underground Transport Fire (90 drums involved)

(5) LPU(R28): Loss of Electric to Waste Hoist from fire (28 drums involved)

These accident scenarios were quantified using event tree and fault tree modeling. The impacts to the public from these postulated radioactive material releases were determined with the Sandia MACCS consequence code. Results were presented in terms of cancer fatalities per year for the 100,000 people living within 50 miles of the WIPP.

Table E-2 presents the risk by accident initiator. The original IRA estimates the total number of potential cancer fatalities within a 50 mile radius attributable to WIPP CH operations to be significantly less than one potential cancer fatality per year. The results of the PRA supports this assessment.

This minimum risk can be understood by comparing the 2.7E-7 yearly rate increase against the normal yearly rate of cancer deaths in New Mexico, which is 141 cancer deaths per 100,000 people[6]. A comparison of the yearly risk posed from the WIPP and other voluntary and involuntary risks per 100,000 people is found in Table E-3.

6 National Data Book and Guide to Sources, Statistical Abstract of the United States 1989, 109th Edition, G. W. Blackburn, P. G. Oden editors, U. S. Government Printing Office.

The IRA identified certain enhancements, which have been completed, that further reduced the potential for risk to the public. The improvements in the Fire Detection and Suppression Systems (FDSS) included:

- increased underground vehicle fire suppression functional testing from annual to semi-annual
- locked open valves for pump pressure sensors
- redirected one underground fuel supply area dry chemical discharge nozzle
- relocated a manual pull station in the Exhaust Filter Building
- increased Halon inspection frequency in Central Monitoring Room from quarterly to monthly

Conclusions and Recommendations

The results of the Fire Hazards and Risk Analysis conclude that the fire risks associated with CH waste receipt, handling, and emplacement operations at the WIPP present an acceptable level of risk to the public. The potential contributions from fire hazards are less than 1.4% of the total plant risk, which, is orders of magnitude below other voluntary and involuntary risks to which the public may be exposed.

As noted the recommendations made in the original WIPP IRA have been completed. Table E-1 summarizes the recommendations based on the HAZOPS entries from this analysis. The first seven entries did not result in any additional actions that need to be completed prior to waste receipt as these were incorporated into the IRA and since then have been completed. However, entries 8-15 contain eight waste receipt actions, including five assessment activities (NOs. 9, 10, 13, 14, and 15.), one administrative action (NO. 8), and two plant modifications (NOs. 11 and 12). Actions are currently underway at the WIPP to address these eight waste receipt items and they have been added to the WIPP Commitment Tracking System to assure their closure prior to waste receipt.

Table E-2
PLANT RISK BY INITIATOR

Frequency x Consequence = Risk

Initiator	Frequency (events/yr)	Total Cancer* Fatality Cases Within 50 Miles	Risk of Cancer Fatality (per year)
A1 (R3D)	5.4E-05	4.8E-03	2.6E-07
A2 (R3D)	3.0E-10	4.8E-03	1.4E-12
U1B (R3D)	9.1E-07	4.8E-03	4.3E-09
U2 (R90)	4.0E-07	9.3E-03	3.7E-09
LPU (R28)	6.9E-13	4.4E-04	3.0E-16
		TOTAL PLANT RISK	2.7E-07 (0.00000027)

Contribution from fire = sum of dominate fire risk ÷ total plant risk
3.7E-09 ÷ 2.7E-07 = 0.014 = 1.4%

A1 (R3D) - Breach of drum above ground in Waste Handling Building (3 drums involved)
A2 (R3D) - Fire above ground in Waste Handling Building (3 drums involved)
U1B (R3D) - Breach of drum underground (3 drums involved)
U2 (R90) - Underground Transport Fire (90 drums involved)
LPU (R28) - Loss of Electric to Waste Hoist from fire (28 drums involved)

*Mean consequence value of cancer fatality cases for population of 100,000 based on 70-year committed effective dose.

Table E-3

RISK FACTOR COMPARISONS

Fatalities Per Year

(per 100,000 people exposed to or engaged in activities)

Cause of Fatality	Per 100,000 People/Per Year
Cigarette Smoking	360.0 (US)
Diseases of the Heart	193.4 (NM)
Cancer - All Causes	140.7 (NM)
Accidents - All Causes	55.0 (NM)
Pneumonia and Flu	23.3 (NM)
Alcohol, Light Drinker	2.0 (US)
Electrocution	0.53 (US)
*WIPP CH Accidents - Cancer	0.00000027

(NM) New Mexico
(US) United States

*Population within 50-mile radius of the WIPP site.

Source for United States statistics: "Risk Assessment and Comparison," Chapter 14, Carcinogen Risk Assessment, Edited by C. C. Travis, Plenum Press, 1988.

Source for New Mexico statistics: National Data Book and Guide to Sources, Statistical Abstract of the United States 1989, 109th edition, G. W. Blackburn, P. G. Oden, editors, Superintendent of Documents, U.S. Government Printing Office.

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SUMMARY OF ABBREVIATIONS AND ACRONYMS USED IN THIS REPORT

A/L	- Air lock
AIS	- Air Intake Shaft
AMS	- Atmospheric Monitoring Station
ANSI	- American National Standards Institute
AQMS	- Air Quality Monitoring System
ARM	- Area Radiation Monitor
ASME	- American Society of Mechanical Engineers
BLDG	- Building
CAM	- Continuous Air Monitor (for airborne radiological particulates)
CB	- Circuit Breaker
CCDF	- Complementary Cumulative Distribution Functions
CCF	- Common Cause Failure
CEDE	- Committed Effective Dose Equivalent
cfm	- cubic foot minute
CH	- Contact-Handled (Waste)
CMR	- Central Monitoring Room
CMS	- Central Monitoring System
CPU	- Central Processing Unit
CR	- Computer Room
CRT	- Cathode Ray Tube
CSC	- Car-Sealed-Closed (locked closed)
CSO	- Car-Sealed-Open (locked open)
DBE	- Design Basis Earthquake
DCF	- Dose Conversion Factor
DG	- Diesel Generator
DHC	- Data Highway Controller
DOE	- Department of Energy
DOT	- Department of Transportation
DP	- Differential Pressure
DSF	- Damage State Frequency
DYNAPAR	- Digital Decelerator
EFB	- Exhaust Filter Building
EMS	- Effluent Monitoring System

EOC	- Engineering Operations Center
EPA	- Environmental Protection Agency
FAS	- Fixed Air Sampler (for airborne radiological particulates)
FDSS	- Fire Detection and Suppression System
FEIS	- Final Environmental Impact Statement
FSAR	- Final Safety Analysis Report
FTA	- Fault Tree Analysis
FW	- Fire Water
GE	- General Electric
GM	- Gieger-Mueller (tubes)
HE	- Human Error
HEP	- Human Error Probability
HEPA	- High Efficiency Particulate Air (filters)
HMS	- Hydrogen Monitoring System
hp	- Horsepower
HSR	- Historical Storage and Retrieval
HVAC	- Heating Ventilation and Air Conditioning
I/O	- Input/Output
ICRP	- International Commission on Radiological Protection
ID	- Identifier
IE	- Initiating Event
IED	- Instrumentation and Equipment Division
IEEE	- Institute of Electrical and Electronic Engineers
INEL	- Idaho National Engineering Laboratory
IRA	- Integrated Risk Assessment
IREP	- Interim Reliability Evaluation Program
kVA	- Kilovolt-ampere
LCO	- Limiting Condition for Operation
LOP	- Loss of Power
LPET	- Loss of Power Event Tree
LPU	- Local Processing Unit
M	- 512k RAM Bubble Memory
MACCS	- MELCOR Accident Consequence Code System
MAG	- Manual Above Ground
MBU	- Process I/O Board
MGL	- Multiple Greek Letter

MMS	- Meteorological Monitoring System
MMS	- Meteorological Monitoring System
mrem	- Millirem
MSHA	- Mining Safety and Health Act
MTBF	- Mean Time Between Failures
MTTR	- Mean Time To Repair
NFPA	- National Fire Protection Association
NIST	- National Institute of Technology
NQA	- Nuclear Quality Assurance
NR	- No Release
NRC	- U.S. Nuclear Regulatory Commission
NREP	- National Reliability Evaluation Program
P&ID	- Process and Instrumentation Diagram
PA	- Public Address (system)
PE-Ci	- Plutonium Equivalent Curies
PM	- Preventative Maintenance
PRA	- Probabilistic Risk Assessment
PS	- LPU Power Supply
PSI	- Pounds per Square Inch
QA	- Quality Assurance
RCA	- Radiological Control Area
RH	- Remote-Handled (Waste)
RMA	- Radiological Materials Area
RMS	- Radiation Monitoring System
RPM	- Rotations Per Minute
SAR	- Safety Analysis Report
SB	- Support Building
SCBA	- Self Contained Breathing Apparatus
SCFM	- Standard Cubic Feet per Minute
SEIS	- Supplement Environmental Impact Statement
SH	- Salt Handling (Hoist)
SMS	- Seismic Monitoring System
SP	- Serial Port I/O Board
SPS	- Southwestern Public Service
SW	- Switch
TMF	- TRUPACT Maintenance Facility

TR	- Transformer
TRU	- Transuranic (Waste)
TVA	- Tennessee Valley Authority
U/G	- Underground
UBF	- Underground Booster Fan
UFS	- Underground Fuel Station
UFVS	- Underground Filtration and Ventilation System
UPS	- Uninterruptible Power Supply
V	- Volts
WAC	- Waste Acceptance Criteria
WCS	- WLINK© Code System
WDPF	- Westinghouse Distributed Processing Family
WE	- Weight Engine
WHB	- Waste Handling Building
WHS	- Waste Hoist System
WIPP	- Waste Isolation Pilot Plant

GLOSSARY

Accessible Public - For the purpose of this document this is defined as the public living within a 50-mile radius of the WIPP site.

Accident Initiator or Initiating Event - An event or series of events that may result in an off-site release of radiological materials.

Accident Sequence - A sequence of events defined by an accident initiator and the failure of a system or systems needed to mitigate the effects of the initiator. Accident sequences with similar results are grouped into consequence categories.

Consequence Category (also known as Damage State) - The results of an accident sequence defined by the amount of radioactive material potentially released as a result of the accident sequence. The consequence categories or damage states for this analysis are R3D, R28, and R90. These are the consequence categories of damaging three drums, 28 drums, and 90 drums, respectively.

Consequences - The potential effects of a release of radioactive materials on the communities surrounding the WIPP site. For the purposes of this study, consequences are defined in terms of the potential for cancer deaths in the surrounding population from an accident resulting in an off-site release. Consequence is one of the components of risk, defined below.

CH TRU Waste - Contact-handled transuranic waste is packaged TRU waste whose external surface dose rate does not exceed 200 mrem per hour.

Critical System - Systems defined for use in this analysis by the WIPP as necessary for the confinement or measure of the release of radioactive materials.

Cut-set - The smallest group of components whose simultaneous failure will cause failure of the system. A single-order cut-set contains exactly one component; a second-order cut-set contains two components, etc.

Event Tree - A logic model used to combine an accident initiator with the systems necessary to mitigate the effects of the initiator. An event tree defines the accident sequences for each initiator.

Fault Tree - A logic model used to quantify the unavailability of a system (the probability of failure of the system to perform its intended function) and to identify the cut-sets, i.e., the component or set of components whose failure would cause failure of the identified system.

Mitigative Systems - Those critical systems whose operation is necessary to prevent or mitigate the effects of an accident initiator. The mitigative systems are modeled using fault trees.

Plutonium Equivalent Curies (PE-Ci) - A radioactive hazard index factor that relates the radiotoxicity of TRU radionuclides to that of Plutonium-239. For additional information, see discussion of PE-Ci derivation in Section 3.3.

RH TRU Waste - Remote-handled transuranic waste. Packaged TRU waste whose external surface dose rate exceeds 200 mrem per hour, but not greater than 1000 rem per hour.

Risk - The frequency of an accident sequence multiplied by the resultant consequences. In this study, risk is defined in terms of potential cancer deaths/year.

TRU Waste - Transuranic waste. Without regard to source or form, waste that is contaminated with alpha-emitting transuranium radionuclides with a half-life greater than 20 years and concentrations greater than 100 nCi/g at the time of assay.

TRUPACT-II - TRUPACT-II is the package designed to transport CH TRU waste to the WIPP site. It is a cylinder with a flat bottom and a domed top that is transported in the upright position. The major components of the TRUPACT-II are an inner, sealed, stainless steel containment vessel within an outer, sealed stainless steel containment vessel. Each containment vessel is nonvented and capable of withstanding 50 pounds of pressure per square inch (psi). The inner containment vessel cavity is approximately six feet in diameter and six feet tall, with a capability of transporting fourteen 55-gallon drums or two standard waste boxes.

WLINK© - The WLINK© computer code, developed by Westinghouse, uses Boolean logic to combine the frequency of the IE with the unavailability and cut-sets of each of the appropriate mitigative systems in each event tree. The result is the frequency of each damage state.

SECTION 1
INTRODUCTION

1.1 BACKGROUND

This study was conducted to address a recommendation by the Advisory Committee on Nuclear Facility Safety as submitted in their letter report to the Secretary of Energy on December 11, 1989. The recommendation from the committee was that a fire risk analysis be performed on pre-closure operations of WIPP.

1.2 SCOPE

The scope of this study was to evaluate the fire hazards associated with the expected CH waste disposal operations at the WIPP site and does not include the test phase activities. It is expected that a risk analysis will be prepared on the test phase in the near future. The study utilized both a Hazard and Operability Study (HAZOPS) and a quantified probabilistic risk assessment (see Appendix A, C & D). The HAZOPS is used as a screening tool to evaluate possible fire hazards. The risk assessment then focuses on the particular hazard.

1.3 METHODOLOGY

To manage risk in a plant, facility, or operation, hazards such as fire, explosion, or toxic materials release have historically been evaluated by conventional tools, such as the Hazards and Operability Study (HAZOPS). These studies have been effective in identifying hazards according to initiating events and possible mitigation methods, but are often limited in determining the impact and effectiveness of such items as mitigation systems, internal controls, and management controls.

Westinghouse combines the use of HAZOPS with fault tree analysis to quantitatively evaluate the present state of a hazard in terms of internal and external initiating event frequencies, the effectiveness of internal controls, operator actions, plant mitigation systems, and the impact of management controls and operations within the plant, facility, or system(s).

For this study, the standard HAZOPS process was used to identify hazards and internal initiating events within the systems selected for evaluation. For this task, the technical leader of the Westinghouse investigation team supervised the HAZOPS.

The study team consisted of the following people:

- Mickey Lovell — Westinghouse Waste Isolation Division, WIPP Fire Protection Engineer
- Ray Godfrey — Westinghouse Waste Isolation Division, WIPP Operations Engineer
- Sam Savorelli — Westinghouse Hazard Management, Flooding & Fire PRA Engineer
- Shelag Morandini — Westinghouse Hazard Management, Flooding, Fire PRA Engineer
- John Iacovino — Westinghouse Hazard Management, (Technical Leader), PRA Project Engineer

The hazards identified in the HAZOPS have been ranked according to both frequency of occurrence and impact to the general public, workers and shutdown of operations. The most significant hazards are then further investigated in a format probabilistic risk assessment. Dominant contributors to risk are identified and recommendations to mitigate the risk are made.

1.4 GUIDELINES

Certain ground rules were necessary to establish the scope of the analysis and to ensure consistent work. These ground rules and guidelines, developed with the WIPP staff, form the basis for this analysis and are detailed in Appendix A. Specific assumptions on HAZOPS and fault and event tree development are found in Sections 3 and 4.

1.5 ORGANIZATION

Section 2 contains the WIPP system descriptions and process flow information.

Section 3 contains the basic HAZOPS screening study and recommendations. Section 4 details the probabilistic risk assessment for significant fire risks.

Appendix A provides the general guidelines and ground rules. Appendix B presents the P&IDs used. A guide to fault tree development is given in Appendix C. Treatment of Common Cause is found in Appendix D. Appendix E is the Fire Detection and Suppression System fault trees. Appendix F contains the biographies of the HAZOPS Study Team members.

SECTION 2
SYSTEM DESCRIPTIONS

2.1 SUMMARY DESCRIPTION

2.1.1 LOCATION AND FACILITY LAYOUT

The WIPP facility is located in Eddy County 26 miles east of Carlsbad, New Mexico. It covers 10,240 acres (16 Sections) (Figure 2.1-1 and 2.1-2). The surface structures (Figure 2.1-3 and explanation to Figure 2.1-3) are located near the center of the facility. Beneath the surface structures, and extending to the boundary, are the subsurface structures. A layout of the planned storage horizon is shown in Figure 2.1-4.

Access to the WIPP facility is provided by two access roads that connect with U.S. Highway 62/180 13 miles to the north and New Mexico Highway 128, four miles to the south (Figure 2.1-1). Rail access is provided from a spur of the Atchison, Topeka & Santa Fe railroad near the Western Ag Minerals Nash Draw mine which is about six miles to the southwest of the WIPP facility (Figure 2.1-1).

2.1.2 PRINCIPAL FEATURES

2.1.2.1 Facility Boundary

The facility (Figure 2.1-3) is surrounded by an eight-feet high chain-link fence and topped by three strands of barbed wire for a total height of nine feet, which encloses all surface structures except the salt storage area. Entrance is through controlled gates. Public access in this area is restricted. Only employees and visitors with proper identification are admitted.

2.1.2.2 Restricted Areas

An area of the facility has been designated as a restricted area for the purpose of radiation protection. This area is located in the southern portion of the WIPP facility including the Waste Handling Building. This area is called the Radiologically Controlled Area (RCA) and includes surface areas where waste handling activities may occur (as

shown by heavy dashed line on Figure 2.1-3). Access to this area is controlled by Administrative Procedures.

2.1.2.3 Facility Utility Supplies and Systems

Figure 2.1-5 shows the location of local utilities in the vicinity of the WIPP facility and the routing of these utilities to the WIPP facility.

Water is supplied from the Double Eagle Water Company. Electric power is supplied by the Southwestern Public Service Company. A 115-kV overhead transmission line operating at 69kV connects the WIPP facility to the Potash Junction-Kerrmac transmission line located about nine miles north of the site. The WIPP facility main Southwestern Public Service (SPS) utility substation is shown in Figure 2.1-3. One diesel generator and an identical backup generator are installed to provide limited electric power in case of an external power outage.

2.1.2.4 Storage Facilities (Utilities)

The WIPP facility surface structures are shown in Figure 2.1-3. These structures include two above ground 180,000-gallon (each) water storage tanks located near the water pumphouse, and two 8,000-gallon (each) buried fuel storage tanks, located near the vehicle service building. These underground storage tanks have been registered with the New Mexico Environmental Improvement Division in accordance with regulations promulgated by the U.S. Environmental Protection Agency in 40CFR 280.

A one shift (300 gallon) supply of diesel fuel is stored underground in a portable trailer mounted tank.

2.1.2.5 Exhaust System

WIPP has four exhaust systems which are part of the ventilation systems and potential radiological release pathways. One system serves the Waste Handling Building and three systems serve the Underground (two systems are in use during normal operation and one system during filtration operation). An elevation view of each exhaust system is shown in Figure 2.1-2.

2.1.2.6 Underground Facilities

The subsurface structures are located on the storage horizon (2,150 feet below the surface). The four shafts extend from the surface to the storage horizon. Waste storage areas are located on the storage horizon along with underground support structures for both waste storage and mining operations. Figure 2.1-4 shows the planned layout of the storage horizon.

2.1.3 SURFACE STRUCTURES

The WIPP facility surface structures accommodate the personnel, equipment, and support services required for the receipt, preparation, and transfer of waste from the surface to the underground. The surface structures are located in an area (approximately 35 acres) within a perimeter security fence. (Figure 2.1-2 and 2.1-3)

2.1.3.1 Waste Handling Building

The primary surface operations at the WIPP facility are conducted at the Waste Handling Building (WHB) (Figure 2.1-6A&B), which is divided into several separate areas: the CH TRU waste handling area, the RH TRU waste handling area, the transuranic package transporter (TRUPACT II) maintenance facility (TMF), and support areas. It should be noted that the TMF is not an actual or planned maintenance facility but is rather an office area for health physics technicians and waste handling with some storage.

The CH TRU waste handling area includes an outdoor truck loading and offloading area, a shielded storage room, an inventory and preparation area, and an overpack and repair room.

Decontamination of a TRUPACT II (Figure 2.1-7), if required, would be accomplished in the decon enclosure located in the Overpack and Repair Room.

Other areas within the WHB include: heating, ventilation, and air conditioning (HVAC) equipment area; and mechanical equipment areas.

2.1.3.2 Exhaust Filter Building

The Exhaust Filter Building (Figure 2.1-8) contains banks of high efficiency particulate air (HEPA) filters that will be used to filter contaminated air from the underground in the unlikely event of a release. The underground ventilation system fans are located outside, adjacent to this building.

2.1.3.3 Water Pumphouse

The Water Pumphouse is located adjacent to the two water storage tanks (Figure 2.1-3). The pumphouse contains two fire pumps (one electric and one diesel) and three electric domestic water pumps, as well as space for water chlorination equipment and chemical storage.

2.1.3.4 Support Building

The Support Building provides office space, analytical chemistry laboratories, change rooms, and houses the CMS computer.

2.1.3.5 Compressor Building

The Compressor Building provides weather protection for the two air compressors which are the primary compressed air supply for the surface structures and the underground. An air receiver and deliquescent air dryer are also housed within the building.

2.1.3.6 Other Surface Structures

The other surface structures include the Warehouse Buildings, the Guard and Security Building, the Vehicle Service Building, a sewage treatment plant, and other auxiliary buildings.

2.1.4 SHAFTS AND SUBSURFACE STRUCTURES

2.1.4.1 General Description

WIPP has four vertical shafts that extend from the surface to the underground horizon. These are: the Waste Shaft, the Salt Handling (SH) shaft, the Exhaust Shaft, and the Air Intake Shaft (AIS) Figure 2.1-2.

The shafts are lined from the shaft collar to the top of the salt formation (about 850 feet below the surface), but are unlined through the salt formation. The shaft lining is designed to withstand water pressure associated with the full piezometric head in any water-bearing units encountered.

2.1.4.2 Waste Shaft

The Waste Shaft is located between the CH TRU and RH TRU areas in the WHB (Figure 2.1-10). It is nominally 19 feet in diameter and is serviced by a hoist utilizing a hoist cage that is primarily used for transportation of CH TRU and RH TRU wastes from the surface to underground storage areas. This shaft may also be used to transport diesel fuel, materials, and large equipment.

2.1.4.3 Salt Handling (SH) Shaft

The SH shaft is located north of the waste shaft (Figure 2.1-2). It is nominally 10 feet in diameter and has a combined mancage/bottom dump salt handling skip. This shaft provides the only means of removing mined materials from the underground. It serves as the secondary supply air duct for the underground areas. The SH shaft is a route for some power, control, monitoring and communication cables with the remainder of the cables goind down the other shafts. Personnel are transported in this shaft.

2.1.4.4 Exhaust Shaft

The exhaust shaft is located adjacent to the Exhaust Filter Building (Figure 2.1-2). It is nominally 14 feet in diameter and serves as the exhaust air duct for the underground areas. The exhaust shaft is used as the opening to exhaust air from the underground storage areas to the surface.

2.1.4.5 Air Intake Shaft (AIS)

The AIS is located to the west of the salt handling shaft. It is a 16-foot-diameter shaft and is the primary supply of fresh air underground.

2.1.4.6 Underground Structures

2.1.4.6.1 General Structures

The underground structures are located on the storage horizon and consist of the waste storage area, and the shaft pillar area that contains the underground support area.

2.1.4.6.2 Waste Storage Area

The storage area has two main entries (one entry for fresh air and one entry for return air) and a number of storage rooms (Figure 2.1-4). The layout of the shafts and entries will allow mining and storage operations to proceed simultaneously; however, administrative controls are in place to prohibit mining and handling waste during the same shift. The first storage panel is used to store waste while the next panel is being mined. Successive stages follow in a similar manner.

A typical storage panel consists of up to seven storage rooms. Each room is 33 feet wide, 13 feet high, and 300 feet long. The storage rooms are separated by pillars of salt 100 feet wide and 300 feet long. Panel entries at each end of these storage rooms are also 33 feet wide and 13 feet high. These panel entries will also be used to store waste, except in the first 200 feet from the main entries, which are of smaller size (22 feet by 14 feet) and will be used to install the panel seal plugs.

The underground station located at the lower end of the waste shaft provides access for personnel and equipment to handle the waste (Figure 2.1-4). Radiological control stations are located to control entry and exit from the radiologically controlled area.

2.1.4.6.3 Underground Support Areas

A workshop and warehouse area is located in the shaft pillar area at the storage horizon. Shops consist of a repair bay, a welding bay, a lubrication bay, an electrical shop, several parking areas, and a warehouse. An office, electrical substation, designated lunch room, and sanitary facilities are also located at the storage horizon.

2.1.5 GENERAL DESCRIPTION OF OPERATIONS AT THE WIPP FACILITY

2.1.5.1 General Description

Operations at the WIPP facility entail receiving, unloading, and transferring of radioactive waste from the surface of the site to the underground storage rooms. Transporters carrying radioactive waste arrive at the WIPP facility and are staged outside the Waste Handling Building (WHB) (Figure 2.1-9). The shipments are surveyed for external contamination prior to their movement to the WHB for unloading.

The operational philosophy at the WIPP facility is to start radiologically clean and stay radiologically clean. Consequently, any containers of waste that are found to be externally contaminated or damaged will be decontaminated or placed in a larger container (overpacked), as required. Also, any local area of contamination will be isolated and/or decontaminated prior to continuation of the waste handling process.

CH TRU waste will be shipped to the WIPP facility in Nuclear Regulatory Commission (NRC)-certified shipping containers. After the CH TRU waste shipping container is inspected for contamination, the loaded shipping container is moved into the WHB and placed on a handling dock. The container is opened, surveyed for radiation and contamination levels, and the waste in its storage container is removed and placed on a facility pallet. This pallet is then transferred to the cage loading car, which is moved into the hoist cage used in the Waste Shaft for transfer to the storage horizon.

Following receipt of TRU waste in NRC-licensed shipping containers, the primary operations at the WIPP facility are the handling and subsequent underground emplacement of radioactive waste. On the surface, this operation is conducted within the Radioactive Materials Area (RMA), the portion of the Radiologically Controlled Area (RCA) that is located inside the Waste Handling Building (WHB).

All other surface structures at the WIPP facility support the primary function of waste handling operations. WIPP surface structures are discussed under two general headings: the Waste Handling Building and the Support Structures.

2.1.5.2 Waste Handling Building

The primary function of the WHB, and its associated systems, is to provide a structure to unload waste from the incoming shipping containers and to transfer the waste to the underground storage area via the waste shaft. The WHB is divided into the four functional areas: the CH TRU Waste Handling Area; the RH Waste Handling Area; the WHB Support Area; and the Waste Hoist. The general layout of the building is shown in Figure 2.1-6A & B.

2.1.5.2.1 CH TRU Waste Handling Area

The CH TRU side of the WHB is a lowbay area which includes space and equipment for the unloading of TRUPACT II shipping containers and subsequent transfer of palletized waste containers to the waste hoist for transfer underground. It includes air locks; an Inventory and Preparation Area; an Overpack and Repair Room, and CH TRU support facilities. The major divisions within the CH TRU waste handling area are shown in Figure 2.1-6A & B.

2.1.5.2.2 Entrance Air Locks

TRUPACT II shipping containers, which are unloaded from the transport trailers in the RCA external to the WHB, are transferred into the inventory and preparation area of the WHB via air locks. Three air locks provide for waste receipt entry into the CH TRU side of the WHB while personnel airlocks are provided at specific locations. The air locks function to maintain the interior of the WHB at a pressure lower than atmospheric. The doors at each end of the air lock are interlocked to prevent both doors from being open simultaneously.

2.1.5.2.3 Inventory and Preparation Area

The inventory and preparation area on the CH TRU side of the WHB is the primary area for surface CH TRU waste handling operations. To accommodate the TRUPACT II

shipping container, bays on either side of the central air lock are equipped with a dock and overhead crane for opening and unloading the TRUPACT II shipping container, see Figure 2.1-9.

An area within the Inventory and Preparation Area is provided for recharging waste handling equipment batteries. Batteries are not normally removed during recharging operations. In the event that the WIPP facility is operated for more than one waste handling shift per day, batteries may be exchanged for charging, as required.

2.1.5.2.4 Overpack and Repair Room

An Overpack and Repair Room (OP&RR) provides space and facilities for opening and unloading TRUPACT II shipping containers, should they be found to have internal contamination during unloading operations. Should radiological conditions dictate, the shipping container will be transferred from the dock, or unloading area, to the OP&RR for subsequent operations.

2.1.5.2.5 TRUPACT Maintenance Facility (TMF)

The TRUPACT Maintenance Facility (TMF) is Design Class IIIA, however the structural portions of the building are Design Class II because of its interface with the WHB. The TMF provides space and equipment for minor scheduled and unscheduled maintenance activities. However, current plans do not include maintenance activities but rather office and storage space. The process to reflect this change in the FSAR has been initiated. The TMF includes a 25-ton overhead crane.

2.1.5.2.6 WHB Support Areas

WHB support areas, include the waste hoist support areas and the general HVAC support required by the WHB.

The hoist control room provides space and equipment for operation of the waste hoist. From this location, the waste hoist can be operated in a manual or automatic mode.

The primary WHB support area not previously described satisfies heating, ventilation, and air conditioning (HVAC) for the WHB. This equipment is contained within the main

mechanical equipment room of the WHB, located on a second level above the OP&RR and the site-generated waste room. This area houses the exhaust fans, HEPA filters (except for the hot cell HEPA filters, which are located adjacent to the hot cell), and associated ducting that control ventilation flow within the WHB.

2.1.5.2.7 Fire Protection

Within the CH TRU waste handling area, fire barriers exist at the cage loading and shaft areas, the overpack and repair room, shielded storage room, site-generated waste room, and walls enclosing stairwells. In addition, the mechanical equipment room has fire barriers that separate this room from other areas of the WHB.

An automatic sprinkler system is provided throughout the WHB. Trenches are provided in the CH and RH TRU waste handling areas for collecting water from the sprinkler system. On the CH side, the trenches drain to the waste accumulation sump, which houses the waste accumulation tank. The combined capacity of the trenches, tank, and sump is approximately 21,000 gallons. On the RH side, there are a number of different sized trenches with a combined capacity of approximately 12,000 gallons. Wastewater is retained within these trenches until it can be tested for possible contamination and then disposed of as appropriate.

In addition to a sprinkler system, the CH TRU and RH TRU waste handling areas are provided with interior fire hose connections and portable extinguishers.

2.1.5.3 Exhaust Filter Building

The Exhaust Filter Building is located adjacent to the Exhaust Shaft. The primary function of this building is to house the filtration equipment associated with the underground ventilation system. Under normal conditions, two exhaust fans draw air from underground areas, up the exhaust shaft, and discharge it to the atmosphere. During normal operation, there is no measurable radiological contamination in the air stream, and the HEPA filtration units are bypassed. In the event of an underground radiological accident, airflow from the underground is reduced to approximately one-seventh of normal flow and is diverted through the HEPA filtration units located in this building in order to remove airborne radioactive particulates from the air stream. Figure 2.1-8 shows the building layout.

2.1.5.4 Salt Handling Shaft Headframe and Hoist House

The Salt Handling (SH) Shaft headframe consists of an open steel tower (20 feet square and 101 feet high) with backlegs anchored on concrete pads about 74 feet from the headframe. The headframe has a salt dump chute, skip dumping scrolls, salt surgepad, salt retaining wall, and a platform around the hoist rope head sheave. The shaft conveyance is guided by fixed wooden guides. The headframe is supported at grade level by a foundation that extends to rock.

The Hoist House is a separate steel framed building enclosed with insulated metal roofing and siding that contains a hoist room and an attached electrical equipment room. Lightning protection and grounding systems are provided for the headframe and Hoist House. The headframe and Hoist House are constructed of noncombustible materials.

2.1.5.5 Air Intake Shaft Headframe and Hoist House

The Air Intake Shaft (AIS) headframe (Figure 2.1-2) consists of an open steel tower (8 feet x 12 feet and 51 feet high) with backlegs anchored on concrete pads about 30 feet from the headframe. The shaft conveyance is guided by rope guides. The headframe is mounted on top of the air intake plenum. The headframe is designed to allow placement of the emergency escape hoist to be positioned over the AIS.

The hoist house is a separate steel framed building enclosed with insulated metal roofing and siding that contains a hoist room and an electrical equipment room.

2.1.6 SHAFTS AND SUBSURFACE FACILITIES

2.1.6.1 Shafts and Hoists

2.1.6.1.1 General Shaft Features

The principal components of each shaft are the shaft collar (extending from above the ground surface to the top of the rock), the shaft lining (extending from the bottom of the collar to the top of the salt formation at about 850 feet below the surface), and the key

section that terminates the lining in the salt formation. The remainder of each shaft is unlined.

2.1.6.1.2 General Hoist Features

The conveyances in the Waste Shaft and AIS are guided by steel cables (guide ropes). The Salt Handling Shaft conveyance is guided by fixed wooden guides and is equipped with safety dogs. There is no hoist at the exhaust shaft. The Waste Shaft is equipped with catch sprags in the hoist tower to prevent the conveyance or counterweight from falling into the shaft should it run against the upper crash beam and cause the hoist ropes to break. All hoist towers are made of structural steel.

The waste and SH hoists have two sets of brakes each which are designed so that either brake acting alone can stop the fully loaded conveyance under all emergency conditions. In the event of a power failure, the brakes will set automatically. The AIS hoist is also equipped with two independent sets of brakes.

2.1.6.2 Specific Design Features

2.1.6.2.1 Waste Shaft and Hoist

The Waste Shaft is used to transport radioactive waste, underground mining equipment, and materials between the surface and the underground horizon. The conveyance contains an upper and lower deck. The inside diameter of the lined upper portion of this shaft is 19 feet. The shaft lining is unreinforced concrete. Figure 2.1-2 shows the Waste Shaft and hoist arrangements. The waste hoist conveyance (outside dimensions) is 30 feet high by 10 feet wide by 14 feet deep and carries a payload of 45 tons. During loading and unloading operations, the conveyance is steadied by fixed guides. The hoist's maximum rope speed is 500 ft/min. A counter-weight of 50 tons is used to balance the waste hoist conveyance.

2.1.6.2.2 Air Intake Shaft and Hoist

The AIS is used primarily to supply the fresh air to the underground areas. It is also used for emergency egress of personnel from the underground horizon.

The air intake shaft is currently equipped with a hoist conveyance that is 10 feet high by 5 feet wide by 4.2 feet deep and has a capacity to hold seven people. The cage payload is 1,200 pounds. The hoist system is a single drum hoist, operating in an unbalanced mode with a single cage conveyance. The maximum rope speed is 800 ft/min. Cage safety catches are provided to catch the cage against the guide ropes if needed.

2.1.6.3 Subsurface Structures

2.1.6.3.1 General Design

The subsurface structures in the storage horizon located at 2,150 feet below the surface include the waste storage, experimental and support areas. The underground support areas comprise the facilities to service and maintain all underground equipment for mining and storage operations, to monitor for radioactive contamination, and to allow limited decontamination of personnel and equipment. The mining and waste storage areas are isolated from each other by air locks and bulkheads.

The support facilities on the storage side consist of a radiological control station, maintenance area, vehicle parking area with plug-in battery charging, and a waste transfer station.

The support facilities on the mining side consist of a vehicle parking area, electrical substation, mechanical shop, welding shop, warehouse, offices, materials storage area, emergency vehicle parking alcoves, and a fueling station for diesel equipment.

2.1.6.3.1.1 Electrical Utility Services

There are three power supply sources: normal utility power, backup power from on-site diesel generators, and uninterrupted power from batteries.

Normal and backup electrical power is available for selected underground facilities through the 13.8 kV feeders.

A 1100 kw diesel power generator will be manually started, at the generator control panel, following a utility power failure.

A second 1100 kw diesel power generator will be on standby if the first unit is out of service or fails to respond.

2.1.6.3.1.2 Subsurface Structure Features

Radiological protection for the mining operations is provided by complete physical separation of the mining operations from the storage operations. Separate ventilation supplies are provided, with pressure differentials maintained to ensure that any ventilation leakage is from the mining areas to the storage areas until they join for exhausting.

Personnel access for storage operations is through the storage ventilation supply entry. Waste is emplaced in such a way that personnel are working upstream of the waste in the ventilation airflow. This prevents exposing waste handling personnel to any potential airborne contamination from the stored waste containers. Storage areas are continuously monitored for radiation or radiological contamination.

Vapor from diesel fuel constitutes the principal risk of an underground explosion, but normal ventilation dilutes and exhausts the vapor safely in accordance with MSHA policy. A diesel fuel storage location provided with localized ventilation systems, alarms and automatic fire suppression systems to alleviate this hazard is also in the underground. Vehicle refueling is terminated in the event of a ventilation or power outage.

2.1.6.3.1.3 Mining Area Support Structures

The underground vehicle parking areas provide parking spaces for mining vehicles.

The mechanical shop occupies a separate cross-cut. It contains a 10-ton underhung bridge crane, repair stations for underground equipment, portable welder, secure storage areas for supplies, and associated employee facilities. The welding shop is the portion of the mechanical shop near the exhaust entry.

The mining area fuel dispensing room is in a room off the mining exhaust entry which allows ventilation air to exhaust directly to the exhaust entry. This fuel dispensing room provides a location and pumping facilities for a portable fuel tank. This tank is sized for equipment fuel requirements for one shift's operation minimum. All portable tank hoisting is done in the Waste Shaft at times when waste and personnel are not being transported,

or in the SH shaft when waste is being transported. A dry chemical fire suppression system connected to a manually activated reserve supply is provided in the fueling area. Fire-generated smoke and fumes would be exhausted directly to the exhaust shaft.

The warehouse is in a separate cross-cut and contains storage bins for small parts and an office.

The storage horizon emergency vehicle alcoves provide parking spaces for an ambulance and fire truck. The alcoves are near the Salt Handling Shaft.

2.1.6.3.1.4 CH TRU Waste Storage Area

The storage area provides space for 6.2 x 10^6 ft^3 of CH TRU waste material. This area also includes the four main entries and the cross-cuts that provide access and ventilation for these storage rooms.

The main entries link the shaft pillar/service area with the storage area and are separated by pillars. Normal entries are 12 feet high; one is 25 feet wide and the remaining three are 14 feet wide. Within a panel, the storage rooms are a minimum of 13 feet high by 33 feet wide and are 300 feet long and are separated by 100-foot wide pillars.

Panels 1 and 2 will consist of the seven rooms as mentioned above and additional test alcoves. These alcoves will be 14 feet high by 25 feet wide by 100 feet long and will be accessed by a smaller access drift off of the respective panel. Current planning is for Panel 1 to have four such alcoves located to the north of the panel and Panel 2 to have two such alcoves located within the panel. These alcoves are designed to hold up to 1,050 drums of CH TRU waste.

Based on the design of the TRUPACT II shipping container, CH TRU waste will be received at the WIPP facility in a seven-pack configuration or in Standard Waste Boxes (SWB). These waste package assemblies will be stacked three high across the width of the room in an interlocking triangular pitch. This mode of waste emplacement provides for about 168 ft^3 of waste per linear foot of drift.

2.1.7 SERVICE AND UTILITY SYSTEMS

2.1.7.1 Ventilation Systems

2.1.7.1.1 Surface Support Structures Ventilation Systems

The ventilation systems for the WIPP facility are designed to confine potential radioactive contamination releases within the plant, and to provide the heating, ventilating, and air conditioning (HVAC) necessary for personnel comfort and satisfactory equipment operation.

The total ventilation system for the WIPP facility consists of independent ventilation systems which supply the Waste Handling Building (WHB), Exhaust Filter Building, surface support structures, and subsurface structures.

The ventilation systems serving potentially contaminated areas are once-through system discharging to a monitored exhaust stack. The path of the ventilating air in the potentially contaminated areas is from areas of low contamination potential towards areas of higher contamination potential.

2.1.7.1.2 Subsurface Facilities Ventilation System

2.1.7.1.2.1 General

The ventilation system for the underground facilities is designed to provide a suitable environment for personnel and equipment during normal activities. It is also designed to provide confinement and channeling of potential airborne radioactive material in the event of an accidental release, or fumes from an underground fire.

The main underground ventilation system is divided into three separate flows. One flow serves the mining areas, a second flow serves the experimental areas and the third flow serves the storage areas. The three flows are recombined near the bottom of the exhaust shaft that serves as a common exhaust route from the underground level to the surface.

A small quantity of air is drawn down the Waste Shaft to offset natural updraft convection currents and minimize the potential of any radioactive particles escaping up the shaft.

This small quantity of air is immediately routed to the bottom of the exhaust shaft, in order to avoid mixing potentially contaminated air with air being circulated throughout the underground.

The ventilation system is designed as an exhaust system in which the working environment is maintained below atmospheric pressure.

2.1.7.1.2.2 System Description

The ventilation system consists of five centrifugal exhaust fans arranged in parallel, two identical HEPA filter assemblies arranged in parallel, isolation and back draft dampers, filter bypass arrangement, and associated ductwork (Figure 2.1-8).

The five fans are divided into two groups. One group consists of two fans which are used during normal operation to provide the underground flow of 425,000 CFM. These fans are located near the exhaust shaft. The remaining three fans, rated at 60,000 CFM each and located at the Exhaust Filter Building, form the other group and are capable of being used during the filtered mode of operation. However, this mode of operation requires the use of only one of the three fans at any given time. All other fans (four total) are stopped and isolated.

Each filter assembly consists of two banks of prefilters and two banks of high efficiency particulate air (HEPA) filters arranged in series. Each assembly will handle 50 percent of the filtered mode airflow (60,000 CFM total).

2.1.8 ELECTRICAL SYSTEM

2.1.8.1 General

The basic design philosophy of the WIPP facility electrical system is to use normal electrical power (utility power) supplied to the WIPP facility by Southwestern Public Service (SPS). In the event of loss of normal utility power, on-site diesel generators will provide AC power to important WIPP facility electrical loads. Uninterruptible power supply (UPS) units are also on line providing power to critical monitoring systems. From an electric perspective, the WIPP facility design is fail-safe; essential systems are uninterruptible. On loss of utility power, the Exhaust Filter Building goes into isolation mode and waste

handling and other operations cease; therefore, there will be minimal impact to public or operator safety due to a power outage.

2.1.8.2 Major Components and Operating Characteristics

There are three sources of power at the WIPP facility: normal power, backup power, and uninterruptible power supply (UPS). Normal power and backup power are the only sources discussed in this document.

2.1.8.2.1 Normal Power Source

The WIPP facility normal power is supplied by a public utility company. This is the preferred power source and is capable of supplying power to the WIPP facility at all times.

The utility power is supplied by Southwestern Public Service Company from their 69-kV Potash Junction/Kerrmac transmission line. The utility company's Potash Junction Substation has two feeders from multiple generating stations. Power failure from one utility generating source does not interrupt power to the WIPP facility.

2.1.8.2.2 Backup Power Source

In case of a loss of utility power, backup power to selected loads can be supplied by either of the two on-site 1100 kilowatt diesel generators. These units provide 480-V backup power. Backup power (480-V) is fed from buses A and B (Figure 2.1-11) with the tie breaker closed. Each of the diesel generators can carry all preselected monitoring loads plus operation of the AIS hoist for personnel evacuation and other selected backup loads in accordance with procedures in the Facility Operations Manual.

Upon loss of normal power, the generator(s) is started manually by the Facility Operator using the electric starter/batteries. The starter system is a 24 V battery system with a 300 amp-hour capacity. The on-site fuel storage capacity is sufficient for the operation of the one generator for three days. Additional fuel supplies are readily available within a few hours by tank truck allowing on-line refueling and continued operation.

Selected loads have been provided with UPS as backup power sources.

2.1.8.2.3 System Description

The general configuration of the electrical distribution system is shown in the simplified single-line diagram in Figure 2.1-11. The 69kV normal supply is reduced to 13.8kV through a stepdown transformer feeding the normal 13.8kV bus. All the normal loads are fed from the 13.8kV normal bus through several load centers.

The underground power supply feeder system consists of three 13.8kV feeders: one feeder through the Waste Shaft, one feeder through the SH Shaft, and one feeder through the Exhaust Shaft.

2.1.8.2.4 Utility Power Failure

In the event that the utility power fails, the relay at the 13.8kV main bus senses the loss of supply and activates an alarm at the CMR.

Whenever normal power fails, the diesel generators would be started manually. Monitoring loads connected to the UPS system shall continue to receive power from UPS batteries during the transition period until generator power becomes available.

A loss of power to the main bus is sensed at the CMR, and the following sequential operations would take place:

- Breakers between the utility power and main bus are opened.
- All 13.8kV breakers of the main switchgear are opened.
- The diesel generators are manually started.
- The 13.8kV bus is connected to the backup power from the diesel generators through the 480V/13.8kV transformers of the backup substation by closing the generator breakers at the generator panels and the 480V switchgear.

If the generators are running, the manually switched backup loads are switched on in controlled sequence, assuring that the total load is within the capacity of each generator.

2.1.9 FIRE PROTECTION SYSTEM

2.1.9.1 Fire Water Distribution System

The fire water distribution system (Figure 2.1-12) consists of two water storage tanks, with the capacity to handle the maximum credible fire. Fire water storage is reserved and provides 1,500 gal/minute at 125 pounds per square inch (psi) for two hours. The flow rate is based on the calculated water estimated for fire control.

A small jockey pump is provided to automatically maintain the desired static pressure on the water supply system and minimize unnecessary operation of the main pumps.

The pumps have flooded suction from the storage tanks. They discharge water into a 10-inch fire loop equipped with sectionalizing valves. All sectional and control valves are locked, sealed, and visually checked monthly. In addition, the valves are also exercised annually to help ensure proper operation.

2.1.9.2 Fire Protection and Suppression Systems

The following Fire Protection Systems are provided in the specified areas:

Waste Handling Building

- Automatic Wet Pipe Sprinklers in all areas except:
  Hot Cell (all elevations)

- Interior Fire Hose Connections in all areas except:
  Hot Cell (all elevations)

- Fire Detection in the following areas:
  RH Area
  Hot Cell (all elevations)
  Waste Hoist Tower (5th floor)
  Shielded Storage Room

- Manual Pull Stations

- Portable Fire Extinguishers

Exhaust Filter Building

- Automatic Wet Pipe Sprinklers & Water Flow Alarm
- Interior Fire Hose Connections
- Manual Pull Stations
- Portable Fire Extinguishers

Water Pumphouse

- Automatic Wet Pipe Sprinklers & Water Flow Alarm
- Interior Fire Hose Connections
- Manual Pull Stations
- Portable Fire Extinguishers

Underground Support Areas*

- Automatic Dry Chemical Extinguishing System at the Fuel Stations #1 and #2 (actuated by thermal detectors)
- Smoke Detector at Electrical Substations
- Manual Pull Stations
- Thermal Detector at S700 and S1000
- Portable Fire Extinguishers

Salt Handling Hoist House and Head Frame

* Diesel oil fire fighting capability consists of a fire truck stationed underground that carries a Dry Chemical extinguisher system as well as an Aqueous Film Forming Foam (AFFF) extinguishing system, designed specifically for combating combustible liquid fires.

- Automatic Wet Pipe Sprinklers & Water Flow Alarm

- Manual Pull Stations
- Portable Fire Extinguishers

AIS Hoist House and Head Frame

- Automatic Wet Pipe Sprinklers & Water Flow Alarm
- Manual Pull Stations
- Portable Fire Extinguishers

2.1.10 WATER SYSTEM

The primary function of the WIPP facility water system is to supply water for domestic use and fire protection.

The water source is drilled wells located about 30 miles north of the WIPP facility. Water is supplied by gravity flow through a 24-inch diameter pipeline to a junction point about 13 miles north of the site.

At the WIPP facility, the water is chlorinated by a hypochlorinator before it enters two 180,000-gallon above-ground storage tanks located adjacent to the pump house (Figure 2.1-12). These tanks are 32 feet in diameter and are constructed of welded steel. The water level in each tank is monitored locally and in the Central Monitoring Room (CMR) in the Support Building.

2.1.11 CENTRAL MONITORING SYSTEM

The Central Monitoring System (CMS) is a computerized system which collects, records, and displays data for all selected plant instrumentation. The system consists of operating consoles, a data network, local processing units with their associated detectors, and a central computer.

The CMS monitors the following systems:

- Fire Alarm System, including system status parameters
- Radiation Monitoring, with input from the area radiation monitoring system (ARMS) detectors and continuous air monitoring systems (CAMS) including those associated with the Effluent Monitoring System
- Electrical Power status, including backup diesel operation
- Ventilation System, including damper position, blower status, flow measurement, and filter differential pressure
- Facility Systems, including air compressors, vacuum pumps, and storage tank levels
- Meteorological Data, including wind speed and direction, temperature, and barometric pressure

2.1.12 CH TRU WASTE HANDLING SYSTEM

2.1.12.1 Process Description

This chapter addresses WIPP facility operation relative to design bases (e.g., 25-year operational life, design storage capacity and throughputs, etc.). Operational plans currently include a Test Phase during which time the quantities stored will likely be significantly less than the design capabilities. Process descriptions in this chapter are independent of the actual quantity of waste handled.

2.1.12.2 Functional Descriptions

The function of the CH TRU waste handling system is to receive the TRUPACT II shipping containers, take them into the Waste Handling Building (WHB), remove and inspect the waste packages, and move the packages to the underground storage area. Damaged or contaminated packages are overpacked or decontaminated as appropriate Figure 2.1-16. The CH TRU loading/unloading dock area consists of two docks, each capable of unloading up to two TRUPACT IIs at a time. The loading/unloading area can be accessed by any of the three air locks, although, only the middle air lock is normally used.

2.1.12.2.1 CH TRU Waste Receiving

Each incoming shipment is given a receipt inspection, which involves checking the shipment manifest, verifying the shipment contents, performing a security check, and

performing an exterior radiological survey of the shipment as it arrives on the site (Figure 2.1-14).

Following turnover of the shipping documentation, the driver transports and parks the trailer outside the Radiological Controlled Area (RCA) in the Security Yard Receiving Area. The driver is then released. The trailer is then attached to a yard tractor and brought into the RCA by Operations personnel. After unloading, empty TRUPACT IIs, loaded on the trailer are returned to the Security Yard Receiving area following radiological surveys and release. This action is also performed by operations personnel using the yard tractor.

The TRUPACT IIs are off-loaded from trailers outdoors in the RCA using 13-ton electric forklifts, transported through the air lock, and placed in a vacant unloading dock position. The electric forklift is used to minimize the impact of diesel exhaust particulates on the WHB HEPA filters and eliminate a potential fire fuel source. The physical arrangement and location of the air locks and docks is shown in Figure 2.1-9. Each air lock is sized to accommodate a TRUPACT II on a 13-ton electric forklift.

2.1.12.2.2 Inventory/Preparation Area

After entry into the WHB, the shipping container is placed on an unloading dock, the container opened, and the waste packages removed (see Figure 2.1-15). Before the packages are removed from the shipping container, radiological surveys are conducted on all accessible surfaces. As the packages are removed, further radiological surveys are conducted. If contaminated or damaged packages are found, the radiological conditions are reviewed and a decision made to decontaminate at the unloading dock location or close the shipping container and transfer it to the overpack and repair room for unloading under more controlled conditions in accordance with procedures in the WIPP Radiation Safety Manual, WP 12-5. The decision depends upon the magnitude and nature of the contamination found. If no contamination levels above those specified by operating procedures (WAC) are noted, the unloading sequence continues.

The unloading dock provides a work platform for personnel to access the closure mechanism on the TRUPACT II. When the container is properly placed on the dock, personnel have a full 360 degree access to it.

The outer lid tamper seal is first removed and recorded. The atmosphere between the inner lid and outer lid is vented through HEPA and assessment filters. The filters are subsequently checked for contamination. If no contamination is detected, the closure mechanism is released. The outer lid is removed and set aside with the aid of an overhead bridge crane and specially designed lifting fixture. The process is repeated for the inner lid; the inner cavity atmosphere is vented through HEPA filters. The filters are subsequently checked for contamination. If no contamination is detected, the closure mechanism is released and the lid is removed and set aside using the same overhead bridge crane and lifting fixture. The contents of the container is surveyed for contamination. If no contamination is detected, the overhead bridge crane and lifting device is attached to a TRUPACT II pallet in the bottom of the container and the entire contents of the container are removed. The contents are placed on a facility pallet near the dock and the lifting device removed. A typical TRUPACT II contains fourteen 55-gallon drums that are stretch wrapped or banded together into two seven-packs. Each seven-pack, or assembly, sets on a molded slip sheet that is made of high molecular density polyethylene. A second unmolded slip sheet is placed on top of the seven-pack and the entire assembly is held together by stretch wrap or steel banding.

The facility pallet is designed to hold two TRUPACT II pallets and their contents (28 drums or 4 standard waste boxes). These pallets (Figure 2.1-17) are placed in recesses in the facility pallet using the overhead bridge crane. Final contamination surveys are conducted and the assembly IDs are recorded using a bar code reader system that is linked to the inventory tracking system. The loaded facility pallet is transported, using a 13-ton electric forklift, to the conveyance loading car inside the conveyance loading room air lock at the waste shaft.

2.1.12.2.3 Overpack Operation

As required, TRUPACT II shipping containers holding contaminated or damaged CH TRU waste packages are moved into the Overpack and Repair Room (OP&RR) through an air lock. A separate HEPA-filtered enclosure, sized to accommodate a TRUPACT II and also to permit controlled unloading is contained within OP&RR. The TRUPACT II is opened under appropriate radiological controls and the contaminated waste packages unloaded. The packages are decontaminated or overpacked, as needed. Operational experience at interim storage sites indicates that breached packages are not expected during normal

transportation. Consequently, the waste packages are expected to be intact and contamination free.

The activities in the overpack/repair area primarily involve handling contaminated material. The area contains radiation monitors, continuous air monitors, and alarms; personnel must wear appropriate anti-contamination equipment. Access to the area is limited to minimize unnecessary exposure.

2.1.12.2.4 Shielded Storage Area

Arriving CH TRU waste packages that have surface dose rates in excess of 100 mrem/hr are given expeditious transfer to the cage loading area. If they must remain on the surface for an extended period of time, the containers are placed in the shielded storage area, which contains radiation detection equipment and personnel shielding to help protect personnel. This area is posted as a Radiation Area and locked when waste is stored inside the enclosure.

2.1.12.2.5 Cage Loading Airlock

The room adjacent to the waste shaft is an air lock. Pallets of waste packages are moved by forklift into this air lock and placed on the conveyance loading car (Figure 2.13). With the outer air lock door closed, this car moves the pallets onto the hoist cage. The conveyance loading car is designed to transfer the pallets on or off the pallet support stands provided in the waste hoist cage. Normally two TRUPACT II loads will be carried at a time. The drum handling load is 28; the number of non-drum containers depends upon the size of the specific waste packages (for SWBs, the quantity is four). The hoist lowers the waste packages to the storage horizon.

2.1.12.2.6 CH TRU Waste Transfer Area (Waste Shaft Station)

At the waste shaft station, the underground waste transporter backs up to the waste hoist cage, and the pallet is winched onto the transporter (Figure 2.1-18). The transporter then moves the waste packages to the waste storage room.

2.1.12.2.7 CH TRU Waste Storage Area

At the waste storage room the waste packages are removed from the transporter and stacked in the storage face. Drummed waste in seven-packs are stacked three high and five wide across the room. The box stacking configuration depends upon the box size (Figure 2.1-19). Seven-packs and boxes are intermixed, as practical. For stability, overpack containers in four-pack assemblies are added to the waste stack always on the top row. After the waste packages are removed from the facility pallets, the pallets are returned to the surface for reuse. The ventilation flow in the storage room moves from the working area over the waste stack and into the exhaust drift.

2.1.12.2.8 Interface Between Mining and Waste Storage Activities

Separate mining ventilation and storage ventilation circuits are maintained by means of temporary and permanent bulkheads. Air pressure in the mining side is maintained higher than in the storage side to ensure that any leakage results in airflow to the storage side.

Rooms being mined are within the mining ventilation circuit. Similarly, rooms under storage are within the storage ventilation circuit.

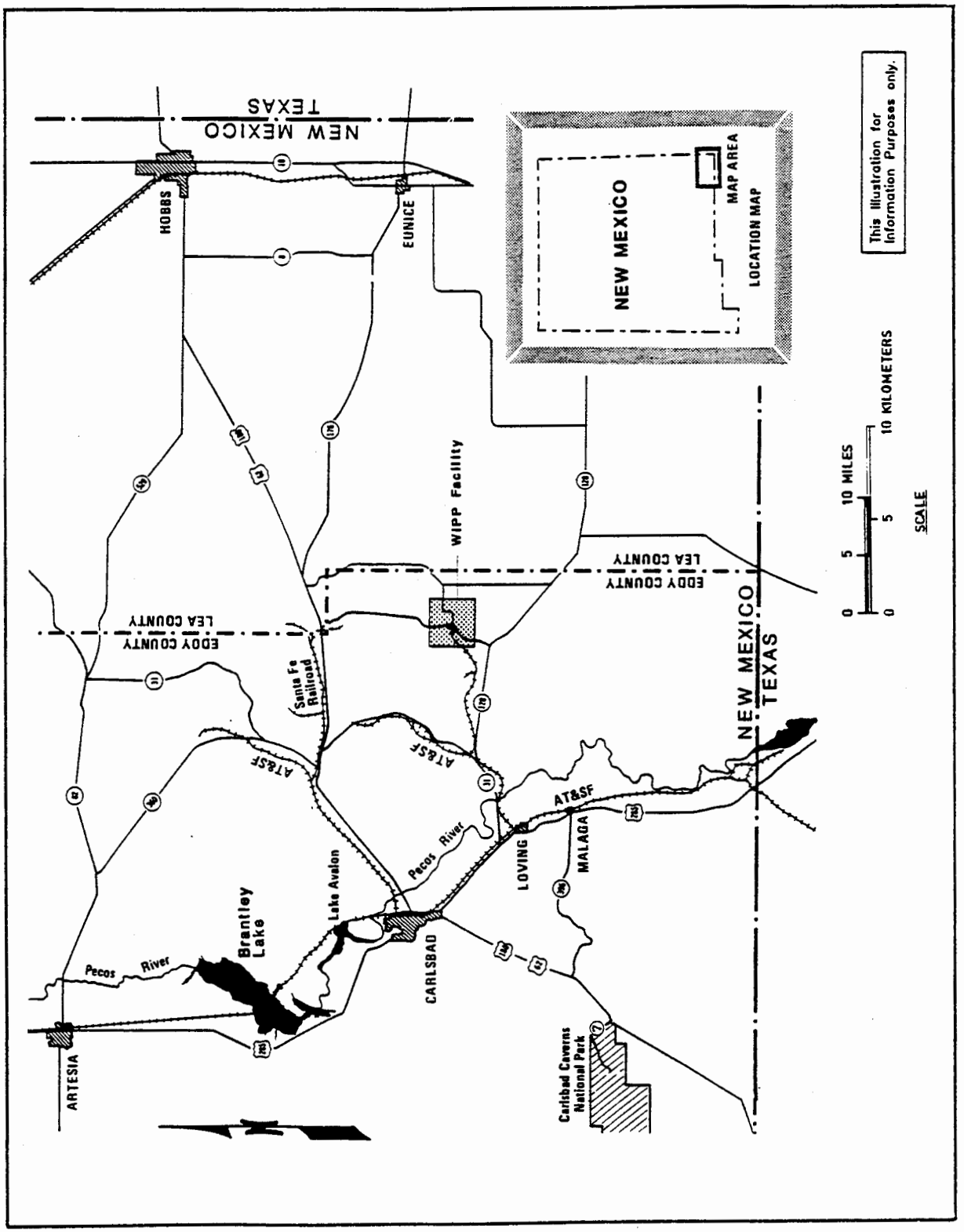


FIGURE 2.1-1. General Location of the WIPP Facility

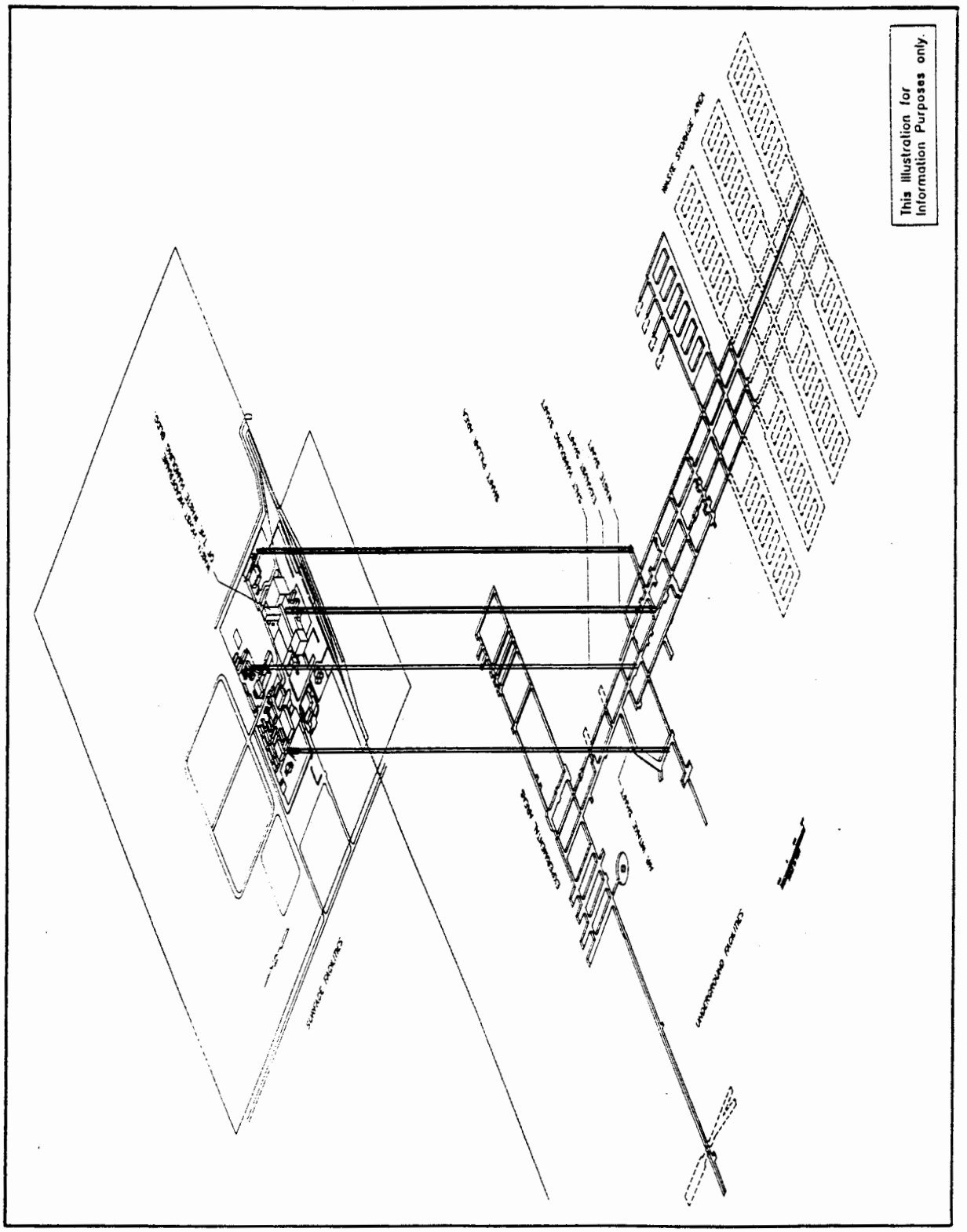


FIGURE 2.1-2. Spatial View of the WIPP Facility

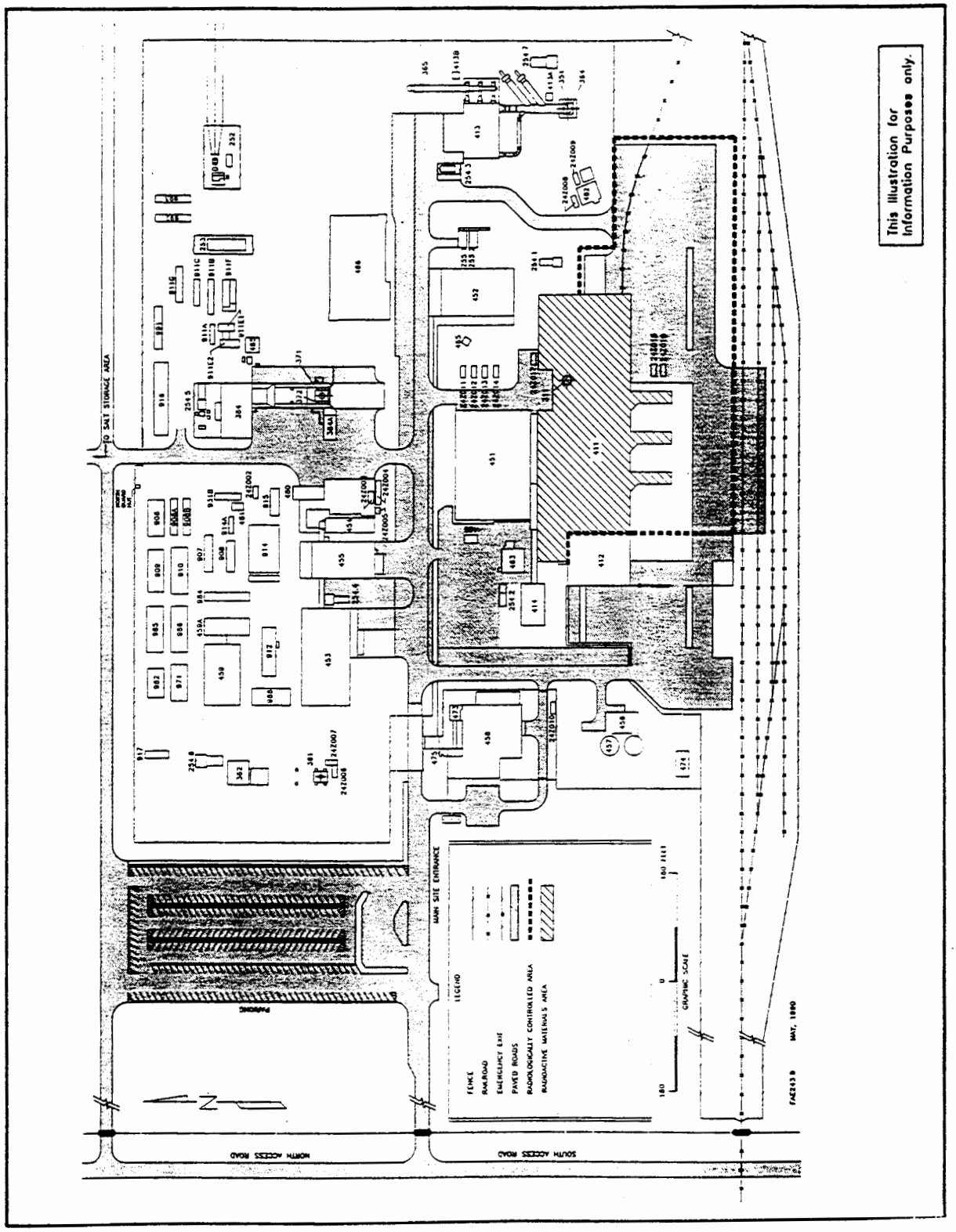


FIGURE 2.1-3. WIPP Surface Structures

FACILITIES, USAGE AND STRUCTURE NUMBERS (FY 1990)

SPS UTILITY SUBSTATION	FAC 252
13.8 KV SWITCHGEAR 25P-SWG15/1	FAC 253
AREA SUBSTATION NO.1 25P-SW15.1	FAC 254.1
AREA SUBSTATION NO.2 25P-SW15.2	FAC 254.2
AREA SUBSTATION NO.3 25P-SW15.3	FAC 254.3
AREA SUBSTATION NO.4 25P-SW15.4	FAC 254.4
AREA SUBSTATION NO.5 25P-SW15.5	FAC 254.5
AREA SUBSTATION NO.6 25P-SW15.6	FAC 254.6
AREA SUBSTATION NO.7 25P-SW15.7	FAC 254.7
ON-SITE GENERATOR #1 25-PE 503	FAC 255.1
ON-SITE GENERATOR #2 25-PE 504	FAC 255.2
WASTE SHAFT	FAC 311
EXHAUST SHAFT	FAC 351
AIR INTAKE SHAFT	FAC 361
AIR INTAKE SHAFT/WINCH HOUSE	FAC 362
EFFLUENT MONITORING INSTRUMENT SHED - "A"	FAC 364
EFFLUENT MONITORING INSTRUMENT SHED - "B"	FAC 365
SALT HANDLING SHAFT	FAC 371
SALT HANDLING SHAFT HEADFRAME	FAC 372
SALT HANDLING SHAFT HOISTHOUSE	FAC 384
UNDERGROUND SERVICES OFFICE	FAC 384A
WASTE HANDLING BUILDING	BLD 411
TRUPACT MAINTENANCE BUILDING	BLD 412
EXHAUST SHAFT FILTER BUILDING	BLD 413
MONITORING STATION A	BLD 413A
MONITORING STATION B	BLD 413B
WATER CHILLER FACILITY	FAC 414
SUPPORT BUILDING - OFFICES, ETC.	BLD 451
SAFETY & EMERGENCY SERVICES FACILITIES	BLD 452
WAREHOUSE/SHOPS BUILDING	BLD 453
VEHICLE SERVICE BUILDING	BLD 454
AUXILIARY WAREHOUSE BUILDING - MAINTENANCE	BLD 455
WATER PUMPHOUSE	BLD 456
WATER TANKS (2)	FAC 457
GUARD AND SECURITY BUILDING	BLD 458
CORE STORAGE BUILDING	BLD 459
DBL. WIDE TRAILER - OFFICE	BLD 459A
MAINTENANCE STORAGE	BLD 461
COMPRESSOR BUILDING	BLD 463
AUXILIARY AIR INTAKE	FAC 465
TELEPHONE HUT	BLD 468
ARMORY BUILDING - ARMORY AND LOCK SHOP	BLD 473
HAZARDOUS WASTE STORAGE BUILDING	BLD 474
GATEHOUSE - MAIN SITE ENTRANCE/EXIT	BLD 475
VEHICLE FUEL STATION	FAC 480
EXHAUST SHAFT HOIST EQUIPMENT WAREHOUSE	BLD 482
SULLAIR COMPRESSOR BUILDING	BLD 485
ADMINISTRATION BUILDING	BLD 486
DBL. WIDE TRAILER	TRL 906
SINGLE WIDE TRAILER - OFFICE	TRL 907
SINGLE WIDE TRAILER - OFFICE	TRL 908
SINGLE WIDE TRAILER - CABLE FABRICATION	TRL 908A
SINGLE WIDE TRAILER - LAB AND CABLE FABRICATION	TRL 908B
DBL. WIDE TRAILER - OFFICE	TRL 909
DBL. WIDE TRAILER - OFFICE AND LAB	TRL 910
SINGLE WIDE TRAILER - VACANT - TO BE EXCESSED	TRL 911A
SINGLE WIDE TRAILER - OFFICE	TRL 911B
SINGLE WIDE TRAILER - OFFICE	TRL 911C
SINGLE WIDE TRAILER - AIS STAGING	TRL 911E1
SINGLE WIDE TRAILER - VACANT - TO BE EXCESSED	TRL 911E2
DBL. WIDE TRAILER - COMPUTER CENTER	TRL 911F
SINGLE WIDE TRAILER - CABLE FABRICATION	TRL 911G
DBL. WIDE TRAILER - OFFICE AND CLASSROOMS	TRL 912
TRAILER COMPLEX (7) - OFFICE	TRL 914
SINGLE WIDE TRAILER - OFFICE	TRL 914A
SINGLE WIDE TRAILER - OFFICE	TRL 915
TRAILER COMPLEX (4) - OFFICE	TRL 916
SINGLE WIDE TRAILER - AIS DATA AQUISITION	TRL 917
SINGLE WIDE TRAILER - CHANGE ROOM	TRL 931B
DBL. WIDE TRAILER - OFFICE	TRL 971
DBL. WIDE TRAILER - OFFICE	TRL 982
SINGLE WIDE TRAILER - OFFICE	TRL 984
DBL. WIDE TRAILER - OFFICE	TRL 985
DBL. WIDE TRAILER - OFFICE	TRL 986
DBL. WIDE TRAILER - OFFICE	TRL 988
SINGLE WIDE TRAILER - OFFICE	TRL 991
SINGLE WIDE TRAILER - LAB	TRL 992
SINGLE WIDE TRAILER - LAB	TPL 993
MOBILE STORAGE BUILDINGS	24Z002 THRU 24Z017

FAE259.9-1 CURRENT AS OF MAY, 1990

This Illustration for Information Purposes only.

Explanation to Figure 2.1-3

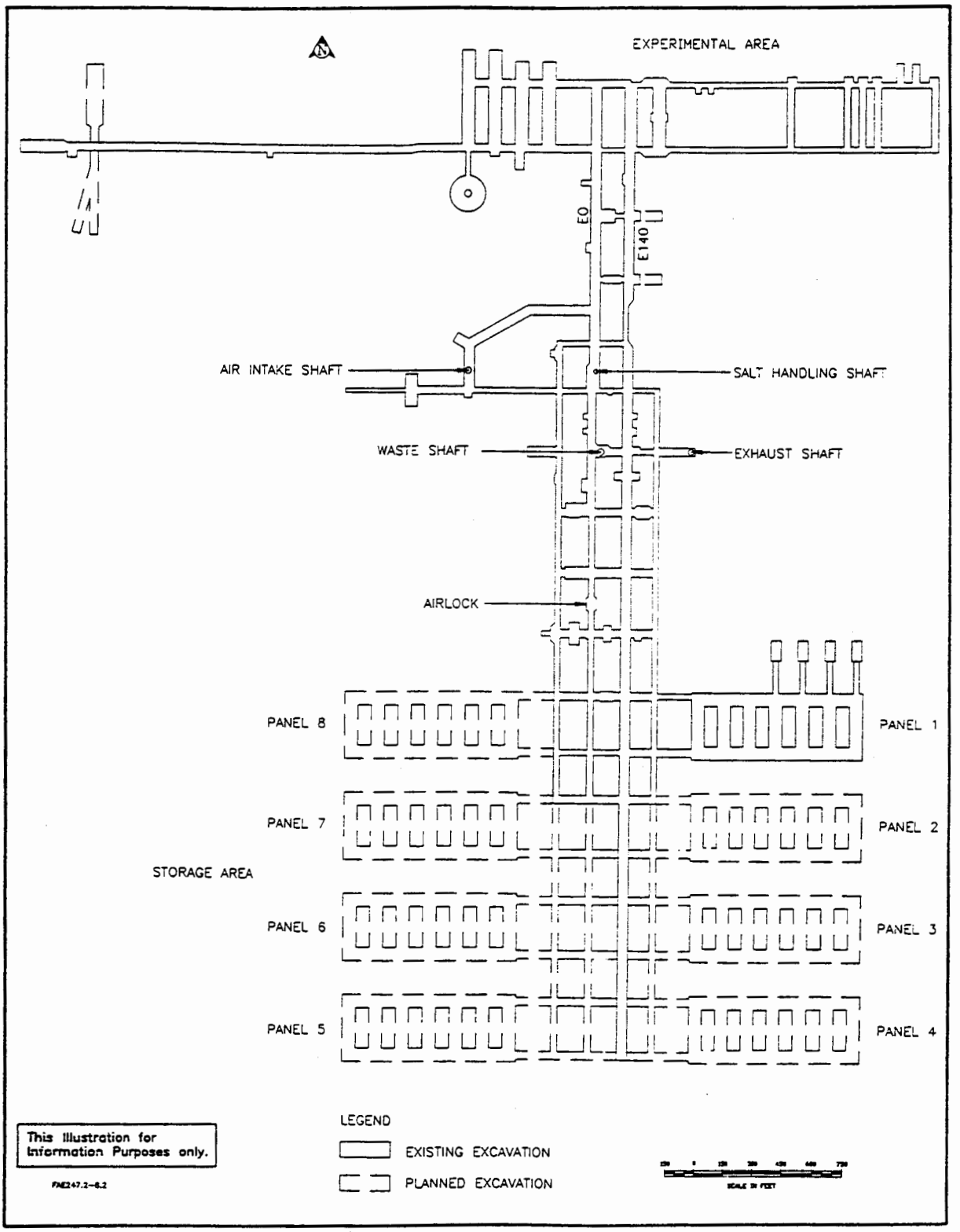


FIGURE 2.1-4. Storage Horizon

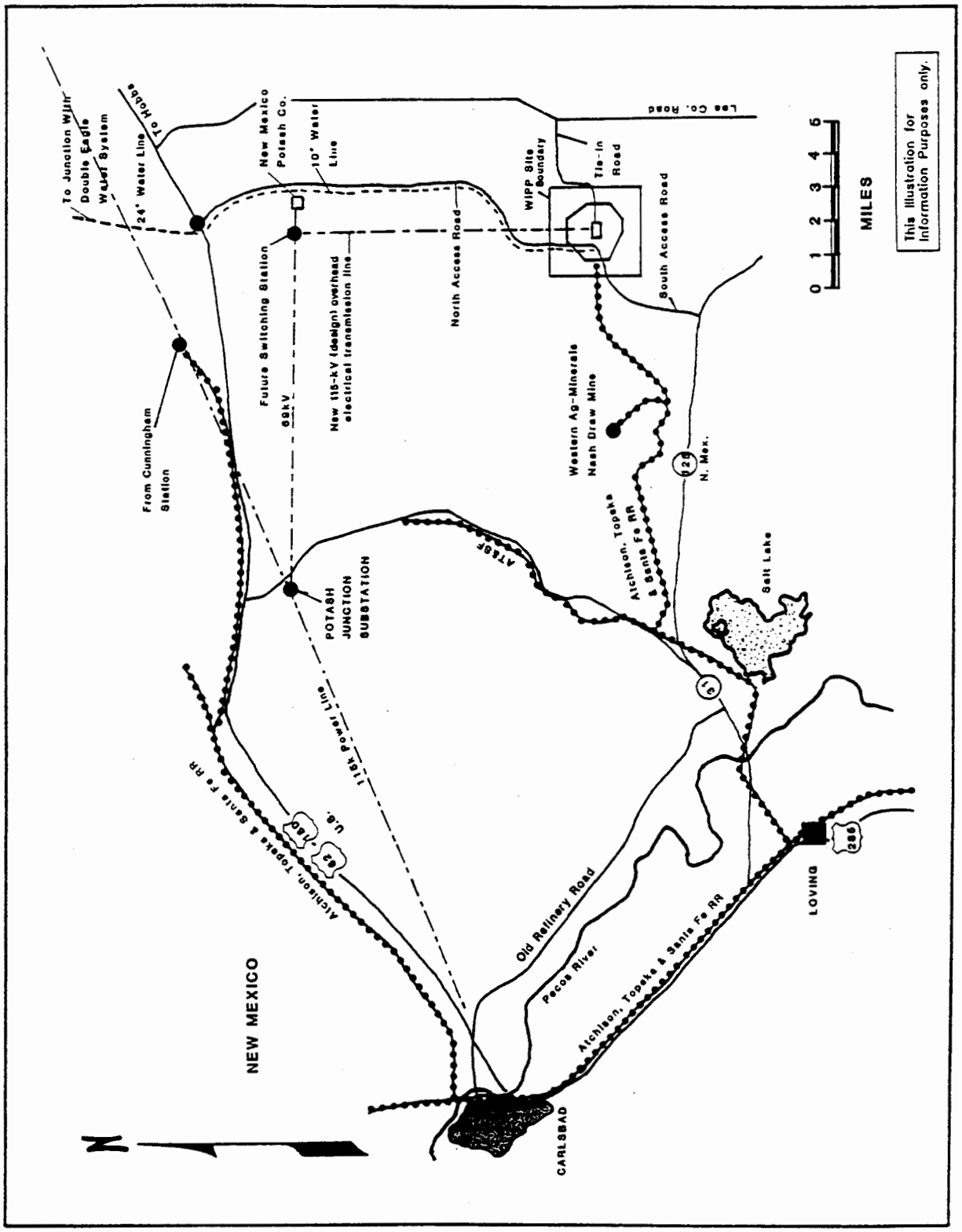


FIGURE 2.1-5. WIPP Facility Access and Utilities

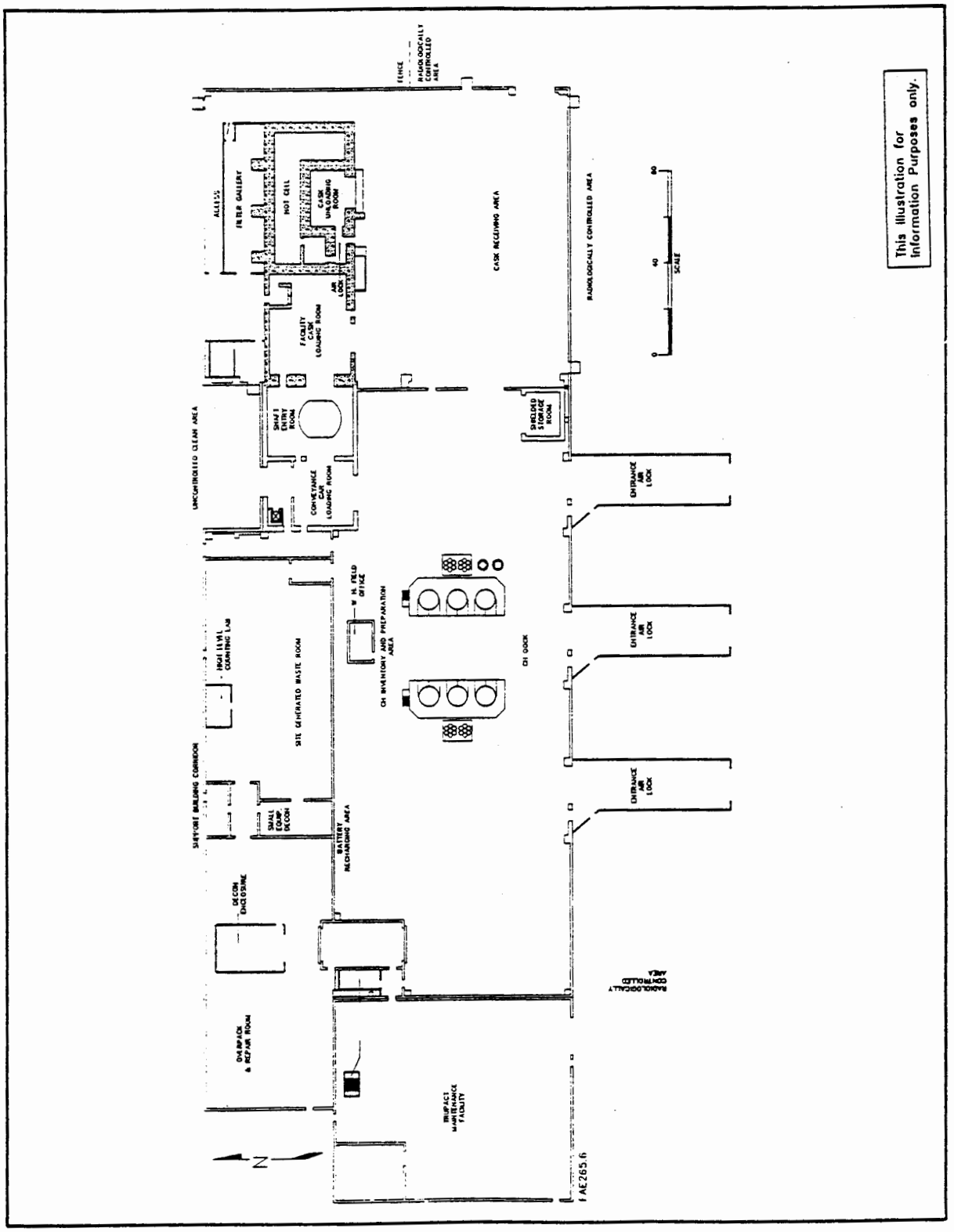


FIGURE 2.1-6A. Waste Handling Building Plan (Ground Floor)

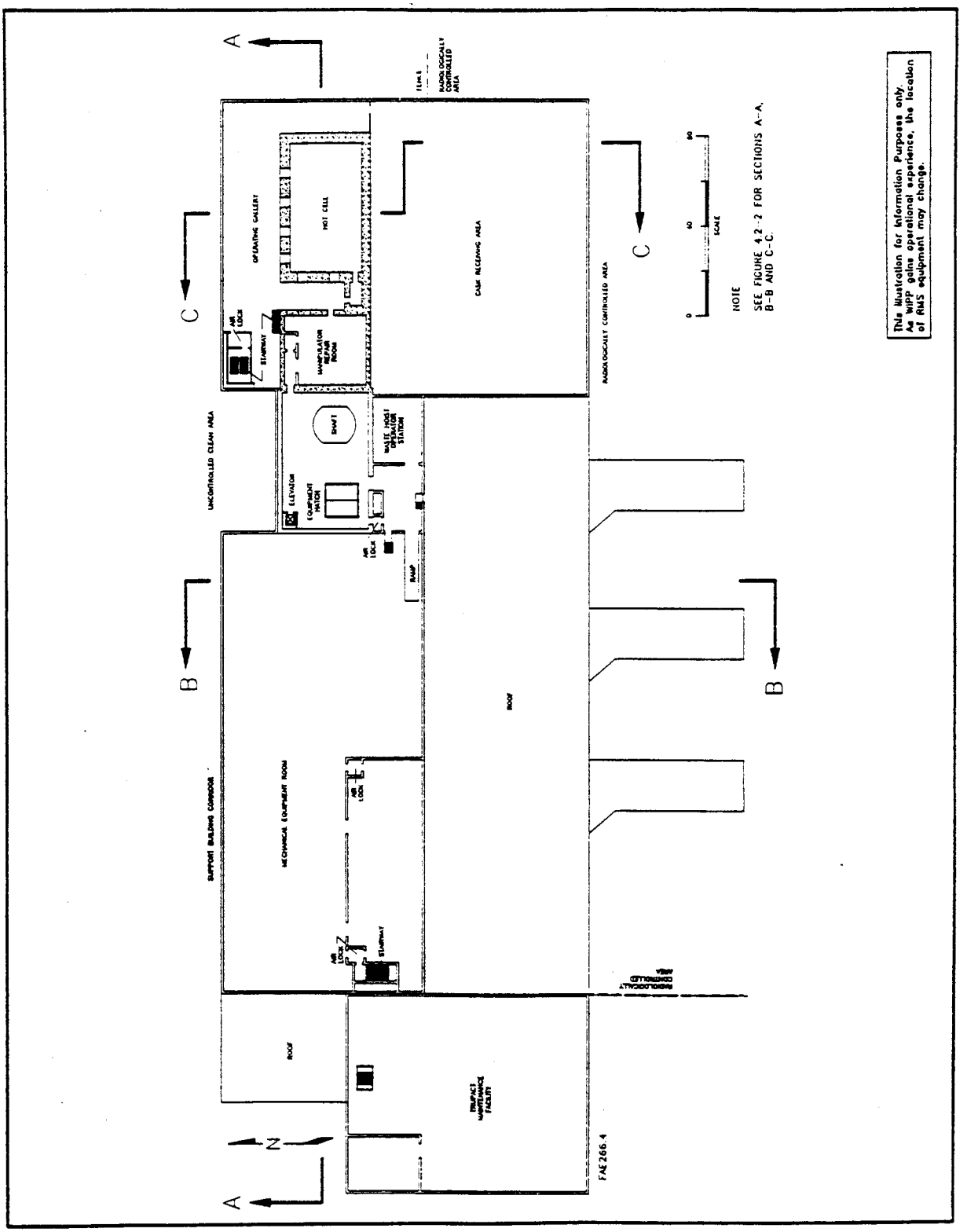


FIGURE 2.1-6B. Waste Handling Building Plan (Upper Floor)

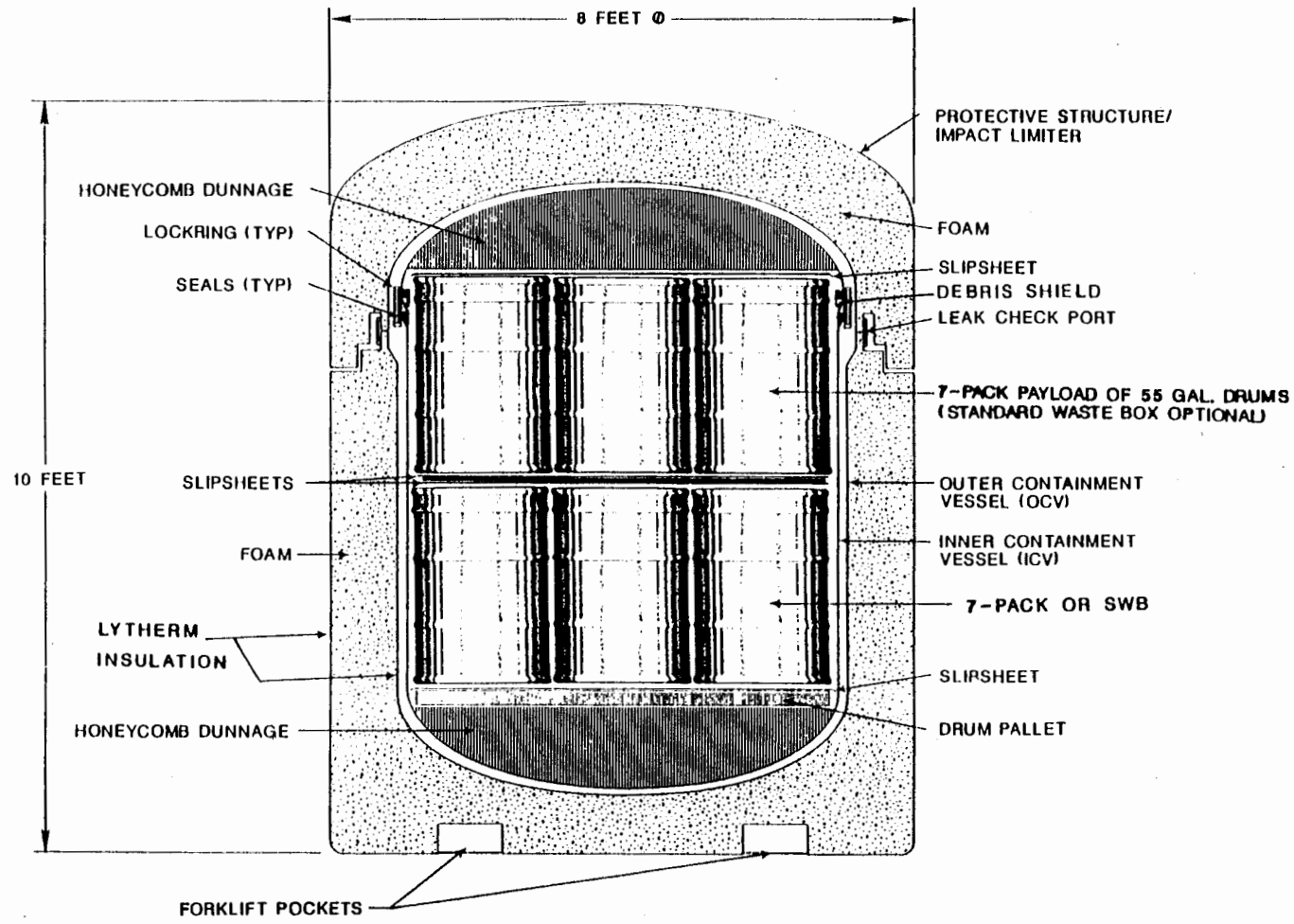


FIGURE 2.1-7. TRUPACT II Packaging Showing Configuration with Seven-Packs

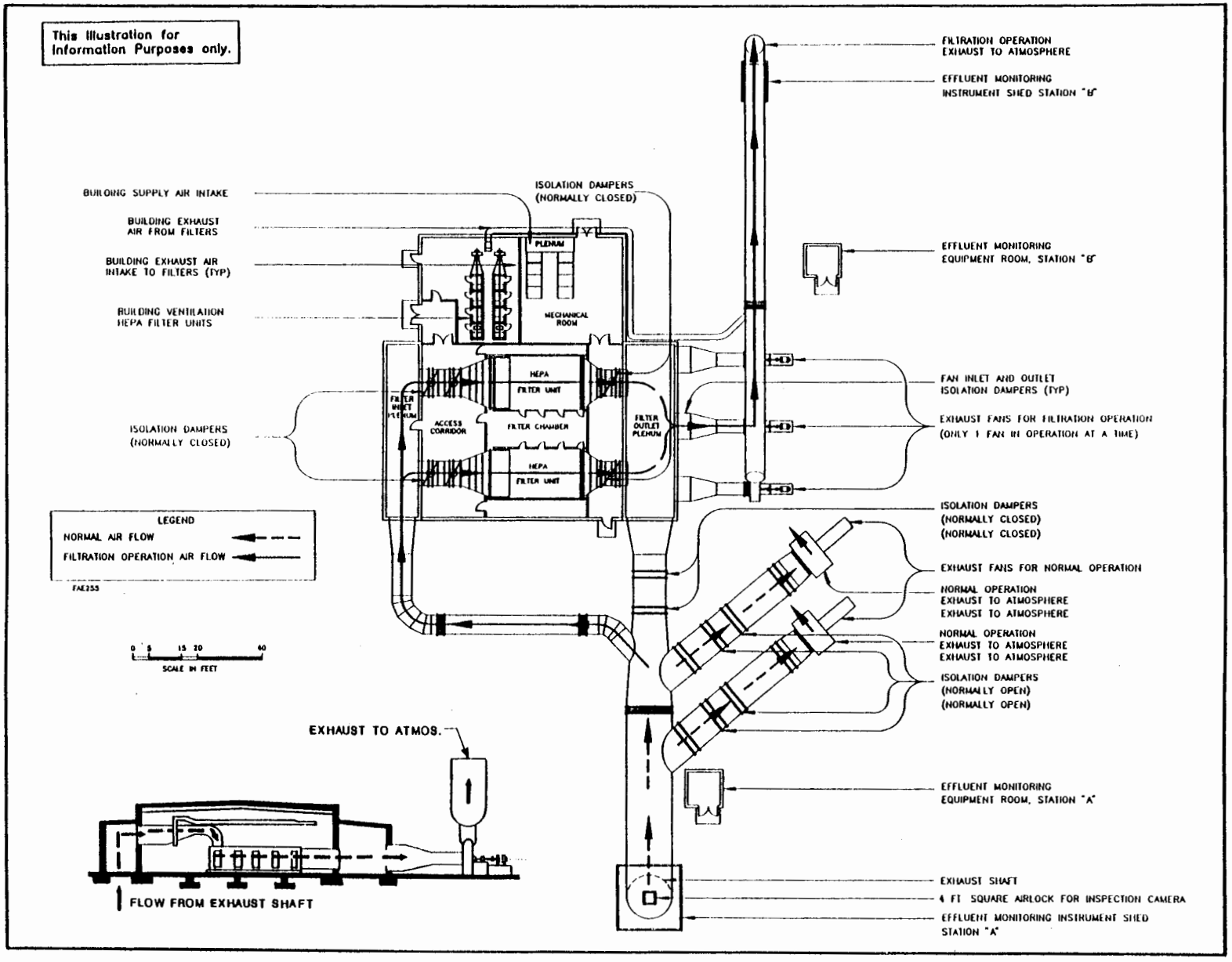


FIGURE 2.1-8. Exhaust Filter Building

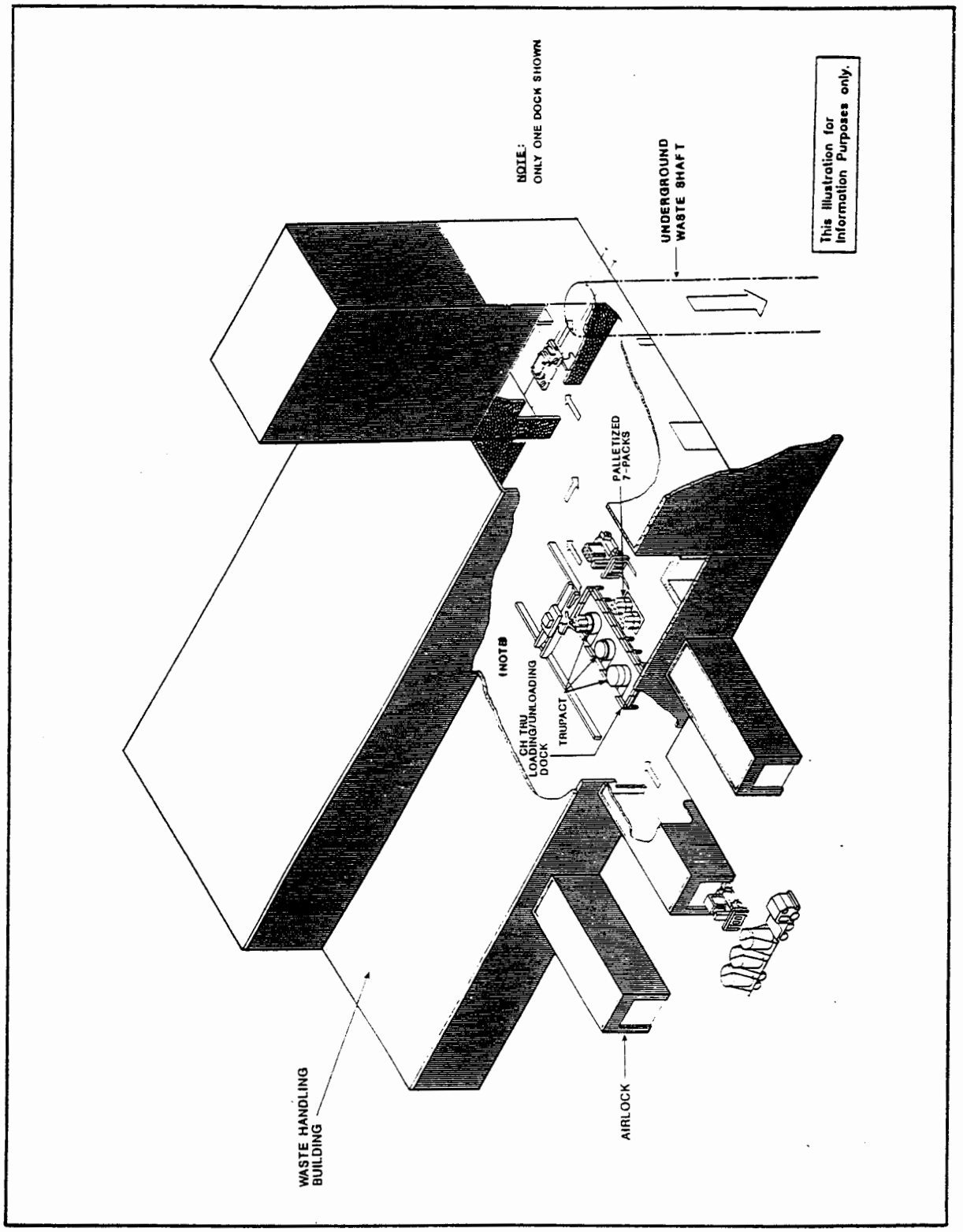


FIGURE 2.1-9. CH TRU Waste Handling

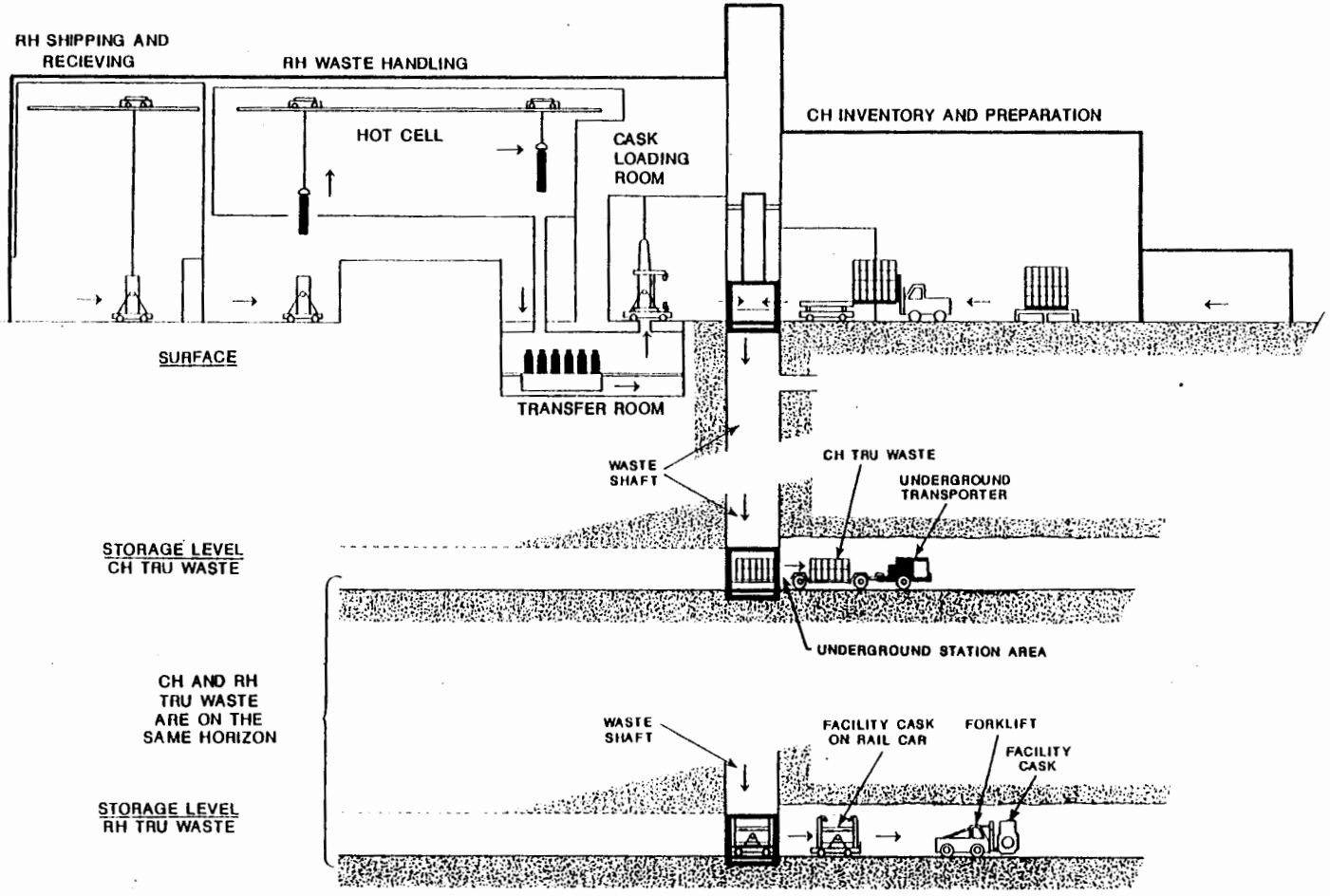


FIGURE 2.1-10. Waste Shaft Area

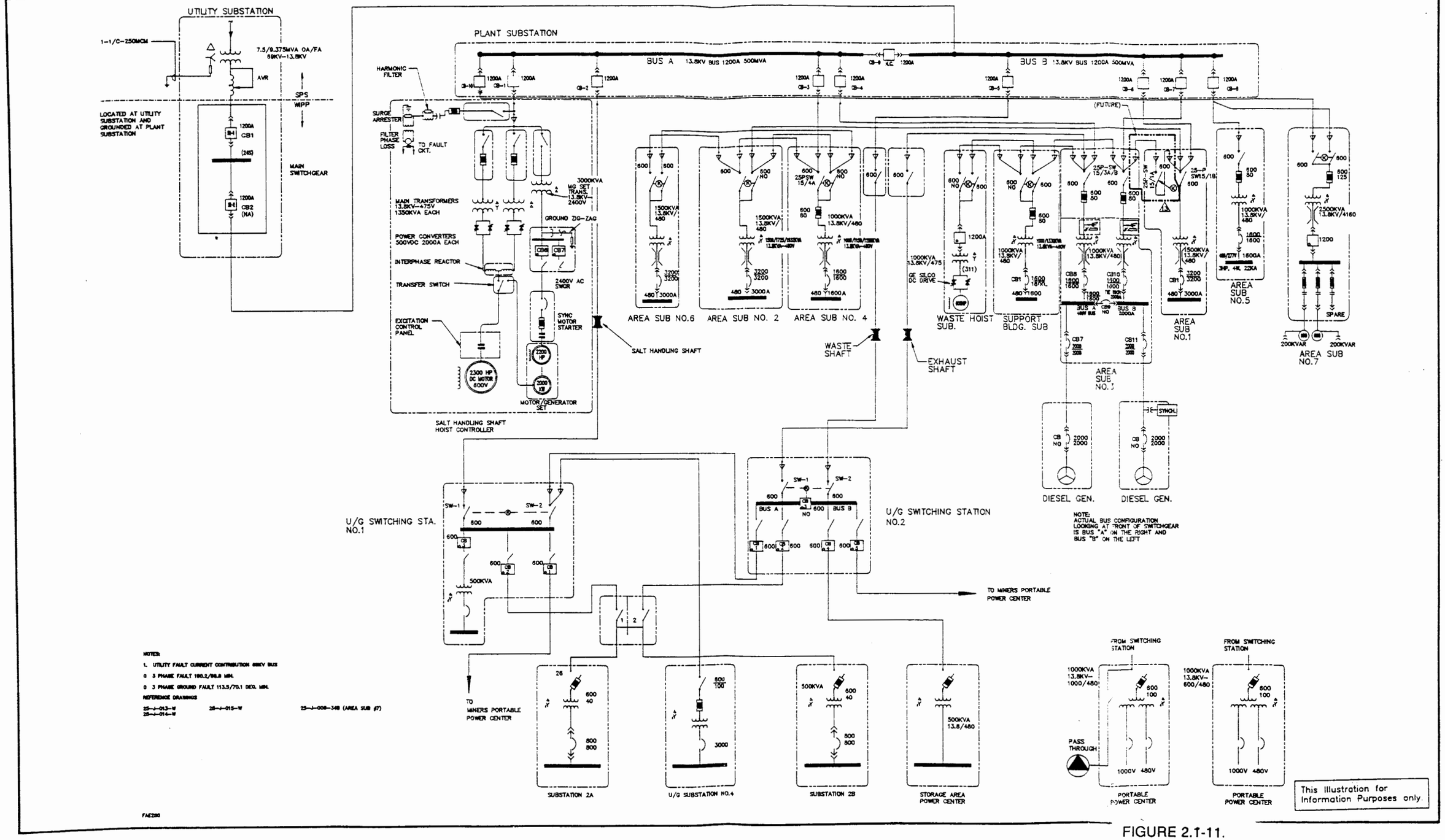


FIGURE 2.1-11.
13.8KV Power Distribution System
Single Line Diagram

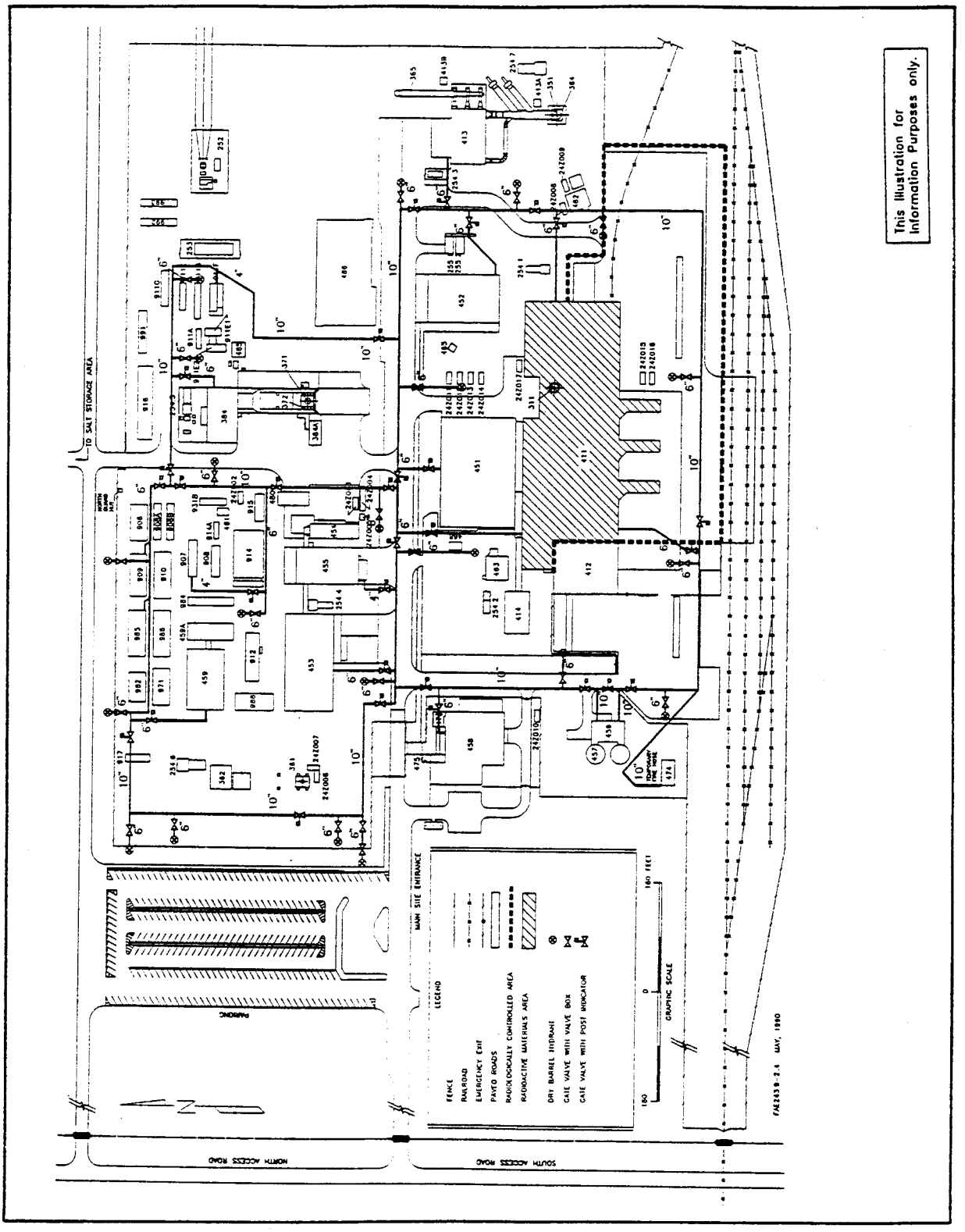


FIGURE 2.1-12. Fire Water Distribution System

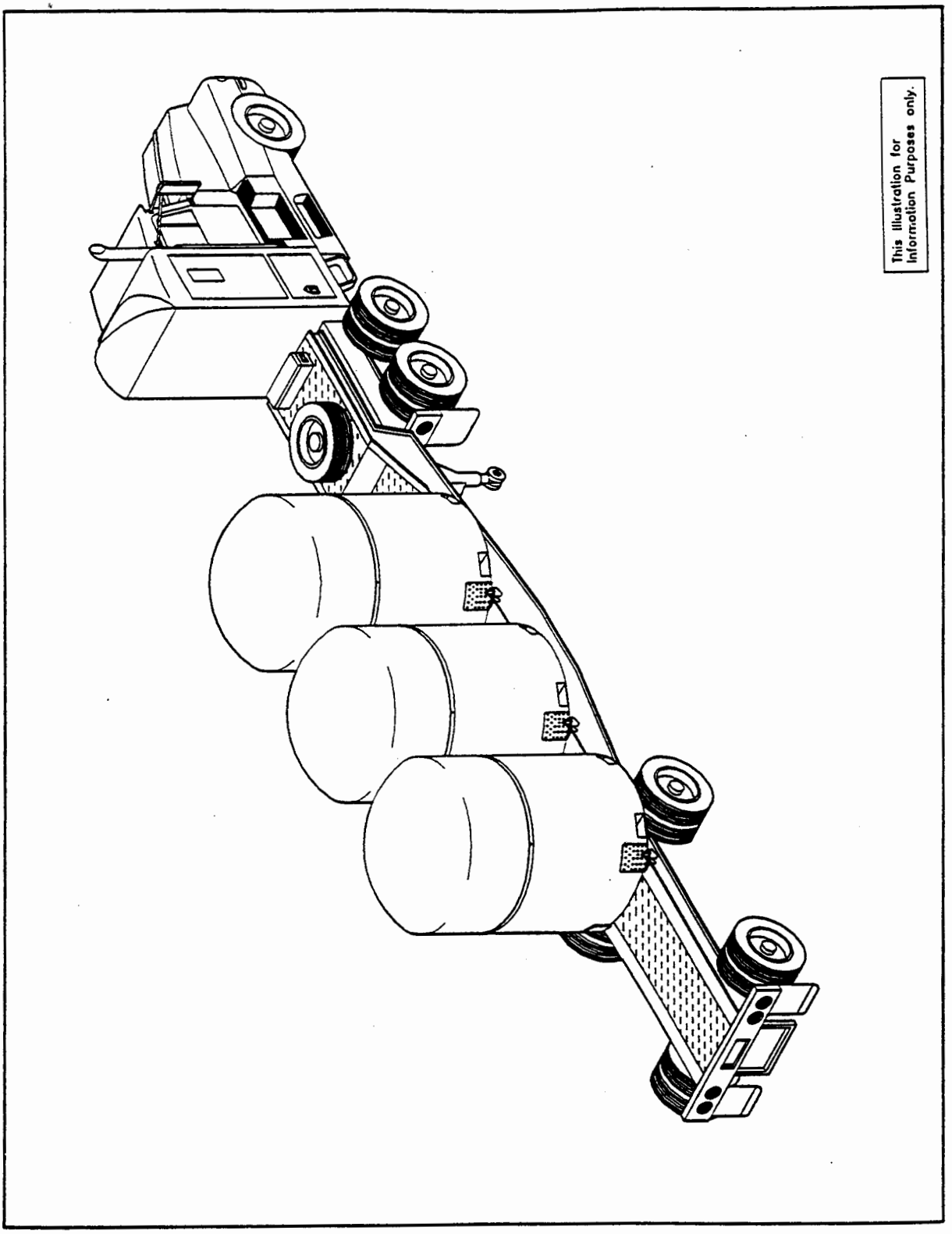


FIGURE 2.1-13. TRUPACT II Shipping Container on Trailer

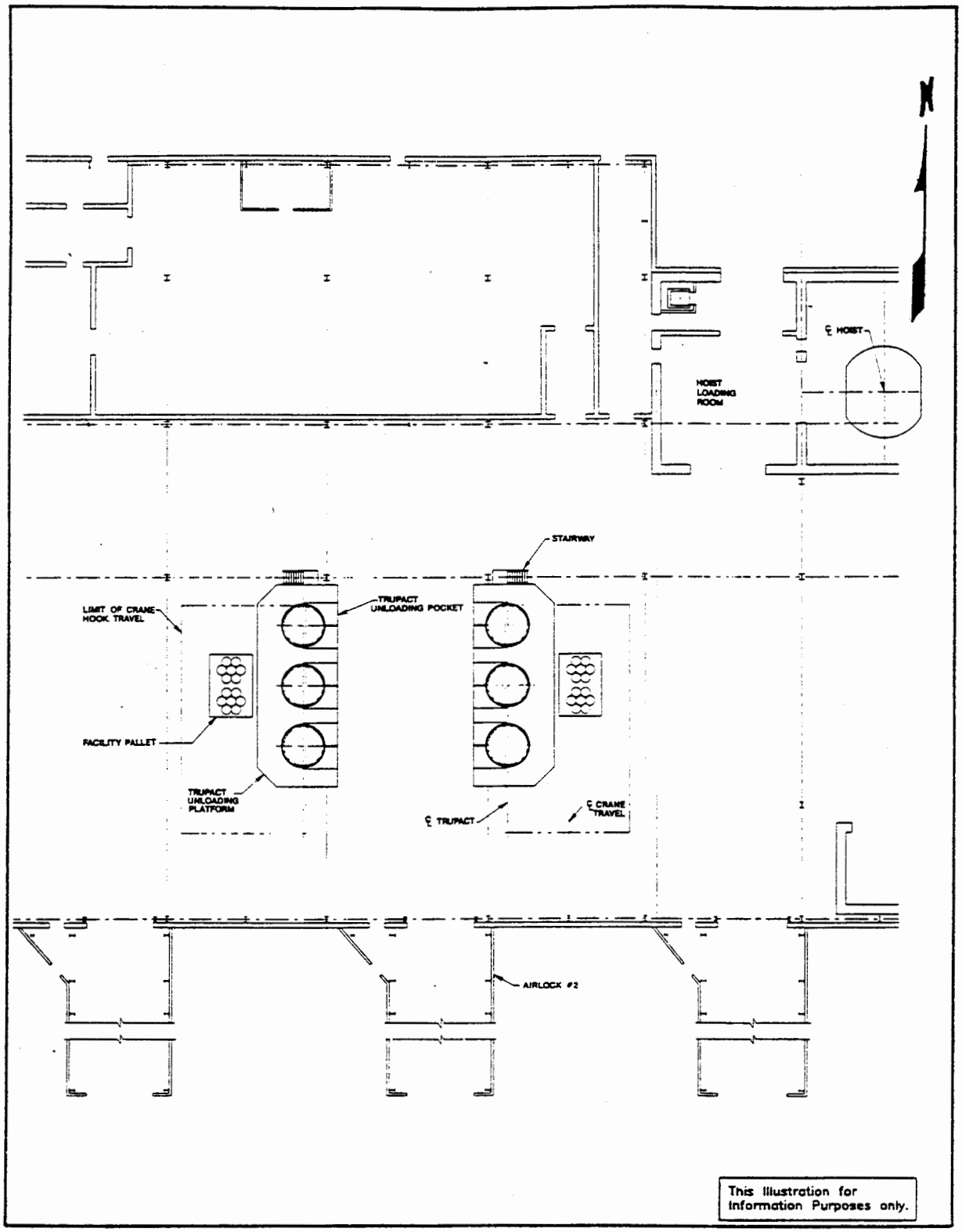


FIGURE 2.1-14. Configuration of CH TRU Waste Unloading Docks in Waste Handling Building

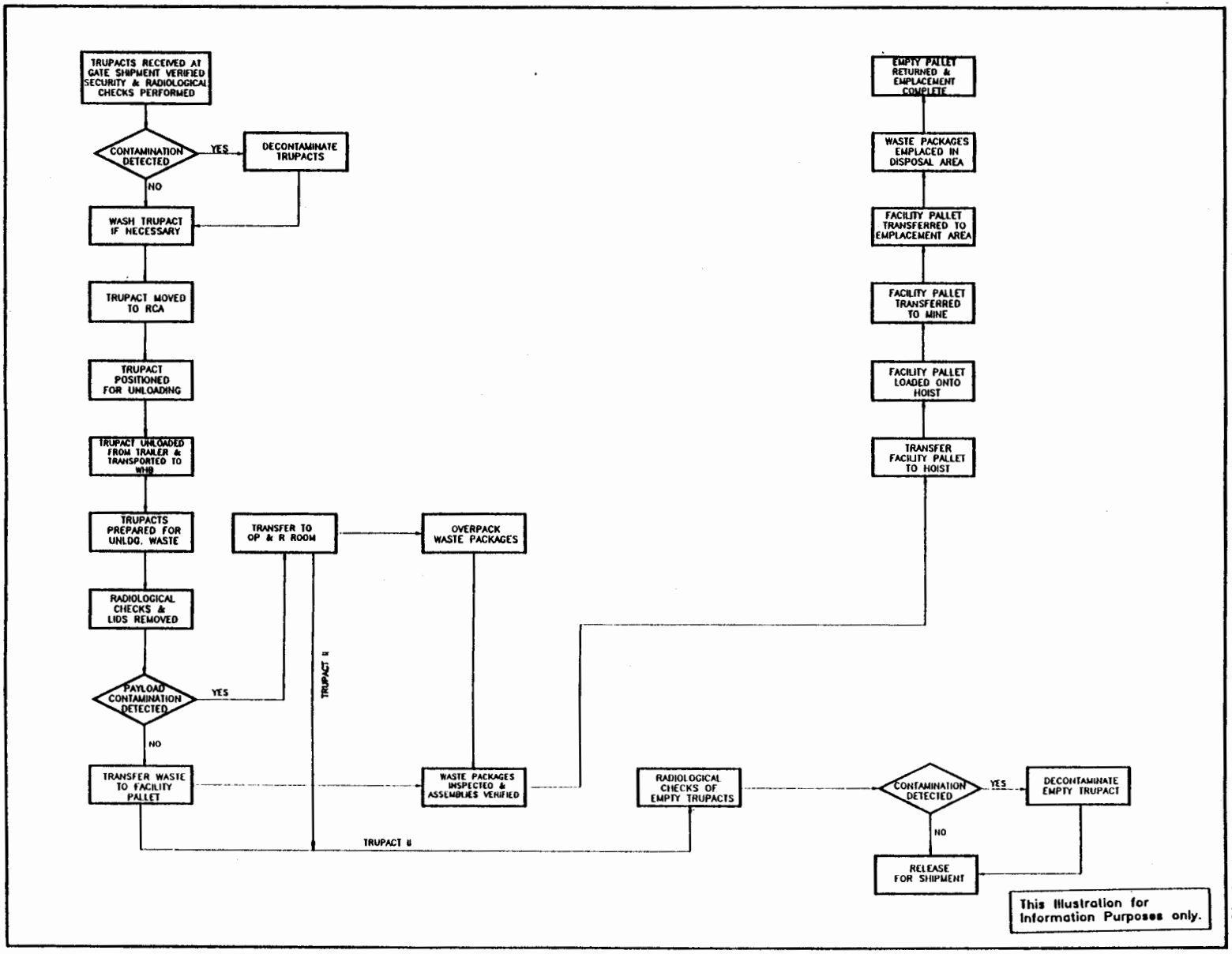


FIGURE 2.1-15. WIPP Facility Surface and Underground CH Waste Flow Diagram

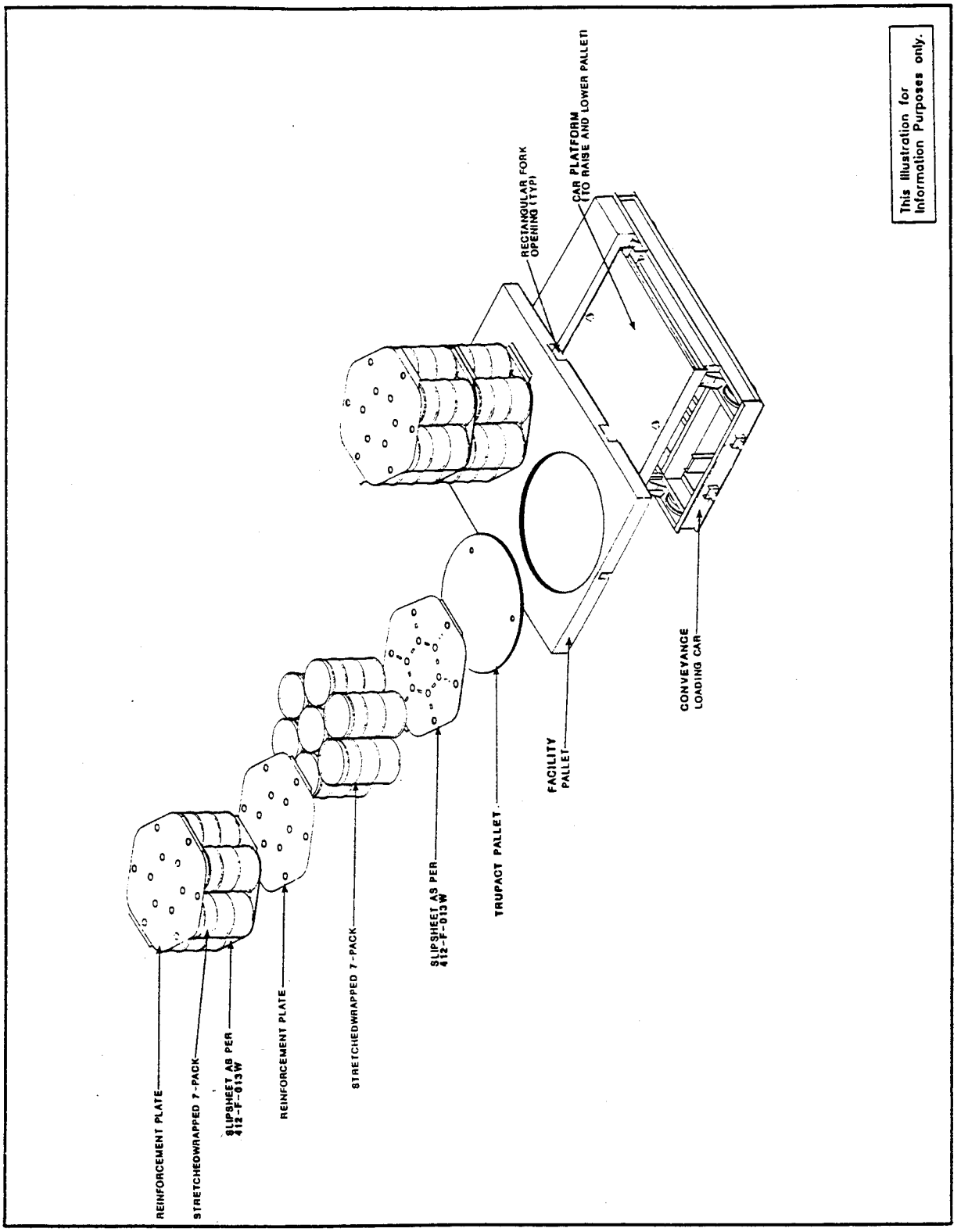


FIGURE 2.1-16. CH Waste Pallet on Conveyance Loading Car

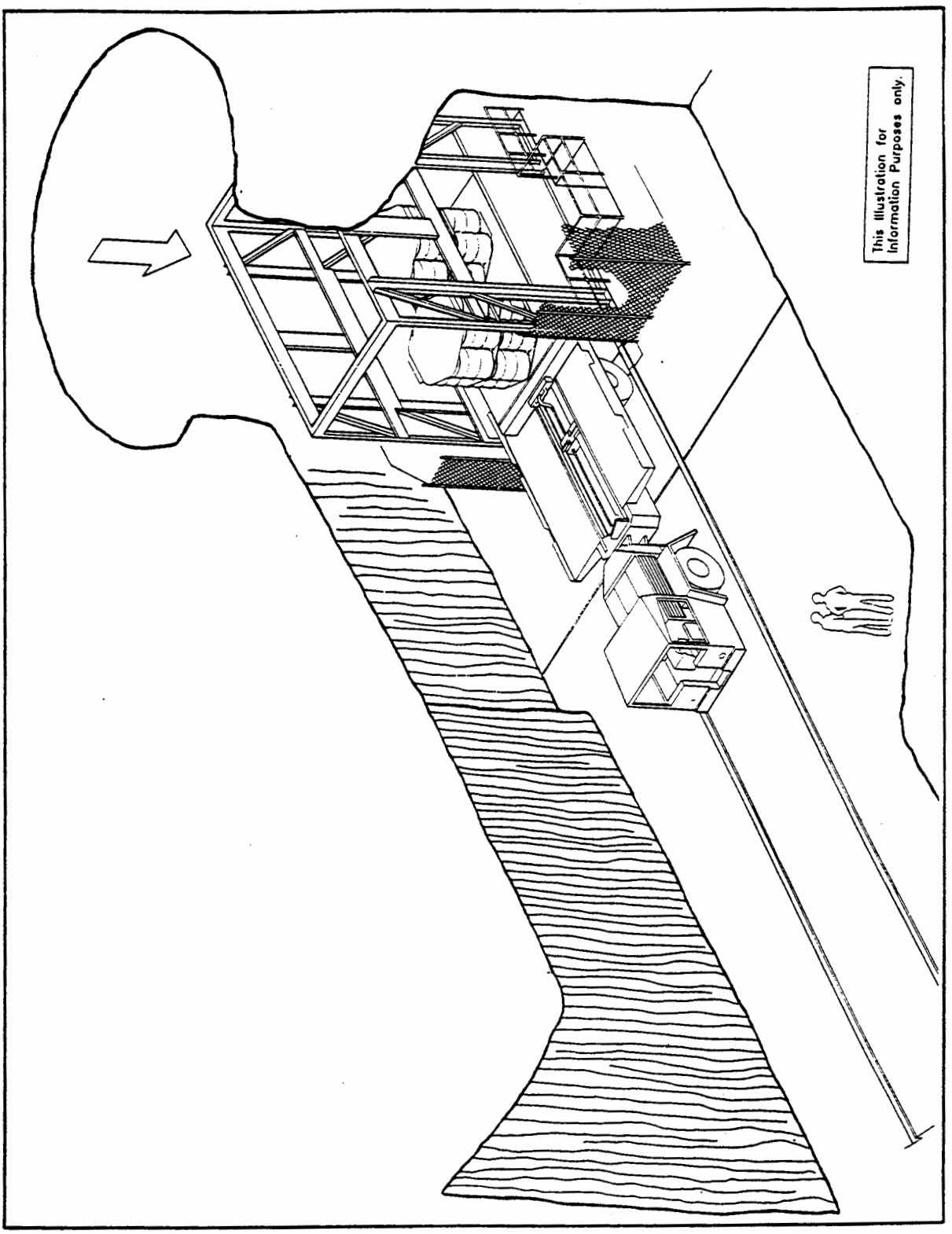


FIGURE 2.1-17. CH TRU Waste Transfer Cage to Transporter

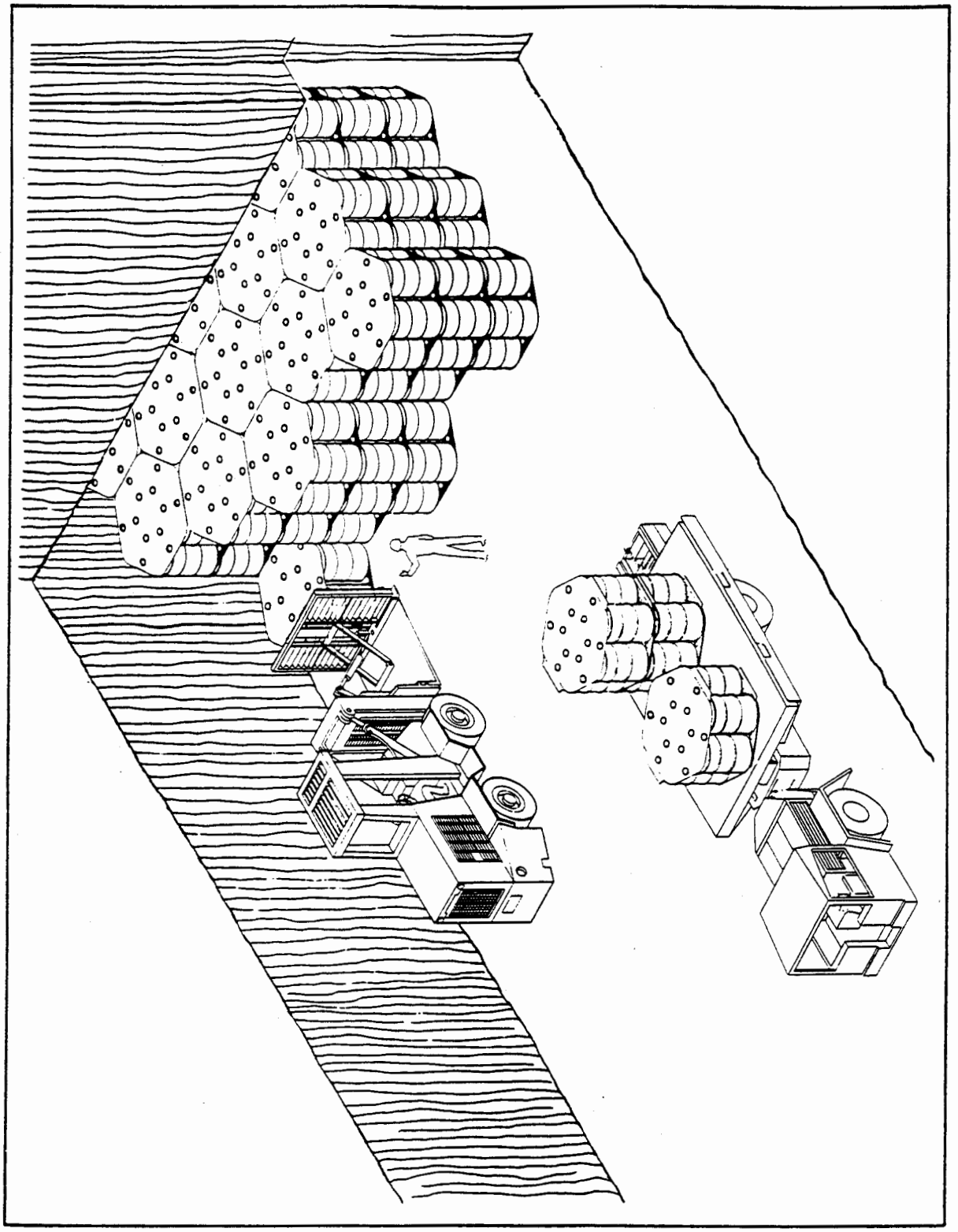


FIGURE 2.1-18. CH TRU Waste Emplacement in Storage Room

SECTION 3
HAZARD AND OPERABILITY STUDY

This section offers a brief summary of Hazard and Operability Study (HAZOPS) methodology; the resultant fire HAZOPS tables and the screened recommendations.

3.1 HAZOPS METHODOLOGY

The objective of this Hazard and Operability Study (HAZOPS) is to identify existing fire hazards, probable hazard frequencies, and possible consequences at WIPP, that may result from failures in its operation (e.g., plant configuration, process, maintenance procedure, etc.).

The first goal of a HAZOPS is to identify probable hazards having consequences of concern at a plant or system. The examination of hazards for the WIPP was limited to internally generated events; external events such as earthquakes, flooding or airplane crashes were not considered as initiators, which is consistent with Section 7.1, Accident Classification, of the FSAR.

The concept of HAZOPS utilizes a full description of the process and evaluates possible deviations from the intention of the design. This allows the study group to postulate various consequences of the deviation. The deviations are evaluated by using the design criteria on a critical component by critical component basis and applying a series of guide words to the process stream/system description. The guide words, their definitions, and examples are detailed in Table 3.1-1. Since WIPP does not operate on a process flow basis such as a refinery, many of these guide words were not used. Additionally, the HAZOPS methodology allows the use of specialized guide words for unique processes. A HAZOPS sequence flow is presented as Figure 3.1-1.

Once the guide word is applied, and a consequence of concern is identified (i.e., meets the definition of a hazard as defined in the scope of the study), possible reasons or causes for the deviation (hazard initiators) are investigated.

TABLE 3.1-1
HAZARD AND OPERABILITY STUDY GUIDE WORDS

Guide Word	Meaning	Example (use)
NO or NOT	Negation of Intention	No flow of A (pump P2 stops)
MORE	Quantity Increased	Flow of A greater than design (control valve V2 fails open)
LESS	Quantity Decreased	Less of A (Flow sensor for valve V2 fails high)
COLLISION	Vehicle Collision	Lube oil truck collides with transporter resulting in a fire
EXPLOSION	Explosion of Component	Explosion of substation transformer causing loss-of-offsite power
OVERHEATED COMPONENT	Fire Caused by Overheated Component in System	Overheated motor in conveyance car causes fire and disables car
ELECTRICAL SHORT	Electrical Short in Cabling	Electrical short in air lock circuit disables door
RUPTURE	Breach Failure	Diesel fuel ruptures from storage tank (Heat failure)

The hazards identified may be the result of many different and varied occurrences. In practical application, the hazards considered are typically limited to internally initiated hazards which may be the result of a hardware failure, operator error, or maintenance malfunction. Limiting the scope of a study to these areas allows the analyst or study team to concentrate on areas which present the greatest risk of controllable loss to the facility.

A listing of assumptions used in the HAZOPS is shown in Table 3.1-2.

For the purpose of this study, to facilitate prioritization of an identified hazard and possible action, a general ranking was assigned to the consequence and probability of each

TABLE 3.1-2
ASSUMPTIONS USED IN HAZOPS

1. This analysis is limited to on-site CH waste receipt, emplacement, and disposal activities and associated support systems. Examples of support systems are exhaust filter building, compressor building, substations, salt hoist, water pump house, and diesel generators used for auxiliary power.

2. The operational flow of this analysis begins when the TRUPACT container enters the air lock. The analysis does not consider the unloading of the trailer outside of the Waste Handling Building because that accident is already bound by the TRUPACT certification documentation.

3. The TRUPACT container is not considered to be damaged during any operation in which the container is handled. Therefore, no scenarios involving the TRUPACT trailer are discussed.

4. No external events such as seismic events, flooding, or airplane crashes are considered applicable to this analysis.

5. Two general classes of hazards resulting from fire have been identified:
   - Off-site radiological impacts
   - On-site hazards; such as worker injuries and deaths, and/or loss of facility operation

6. All vessels, piping, ducting, and the like are designed to withstand the maximum and minimum temperatures in which they would be exposed to during normal operating conditions.

7. For this analysis, it is assumed that Fuel Station No. 1 will not be in service and only Fuel Station No. 2 will be used. (Since issuance of the FSAR, Fuel Station No. 1 has been administratively removed from service.)

8. It is assumed that fire in one diesel generator will result in disabling of both diesel generators that are used for providing auxiliary power.

identified hazard. Both are ranked on a scale of 1 to 5. For consequence, the HAZOPS Team developed a ranking of relative consequences. This is as follows:

Relative Consequence Rankings (Represented by C in Tables)

Rank	Consequence
1	Maintenance/repair required
2	Operations slowdown
3	Potential for worker injury or slowdown of waste handling operations
4	Potential for multiple injuries or shutdown of waste handling operations
5	Potential for worker fatalities or substantial damage to facility or off-site release of radioactivity

The HAZOPS team also developed a relative frequency level. This is shown below.

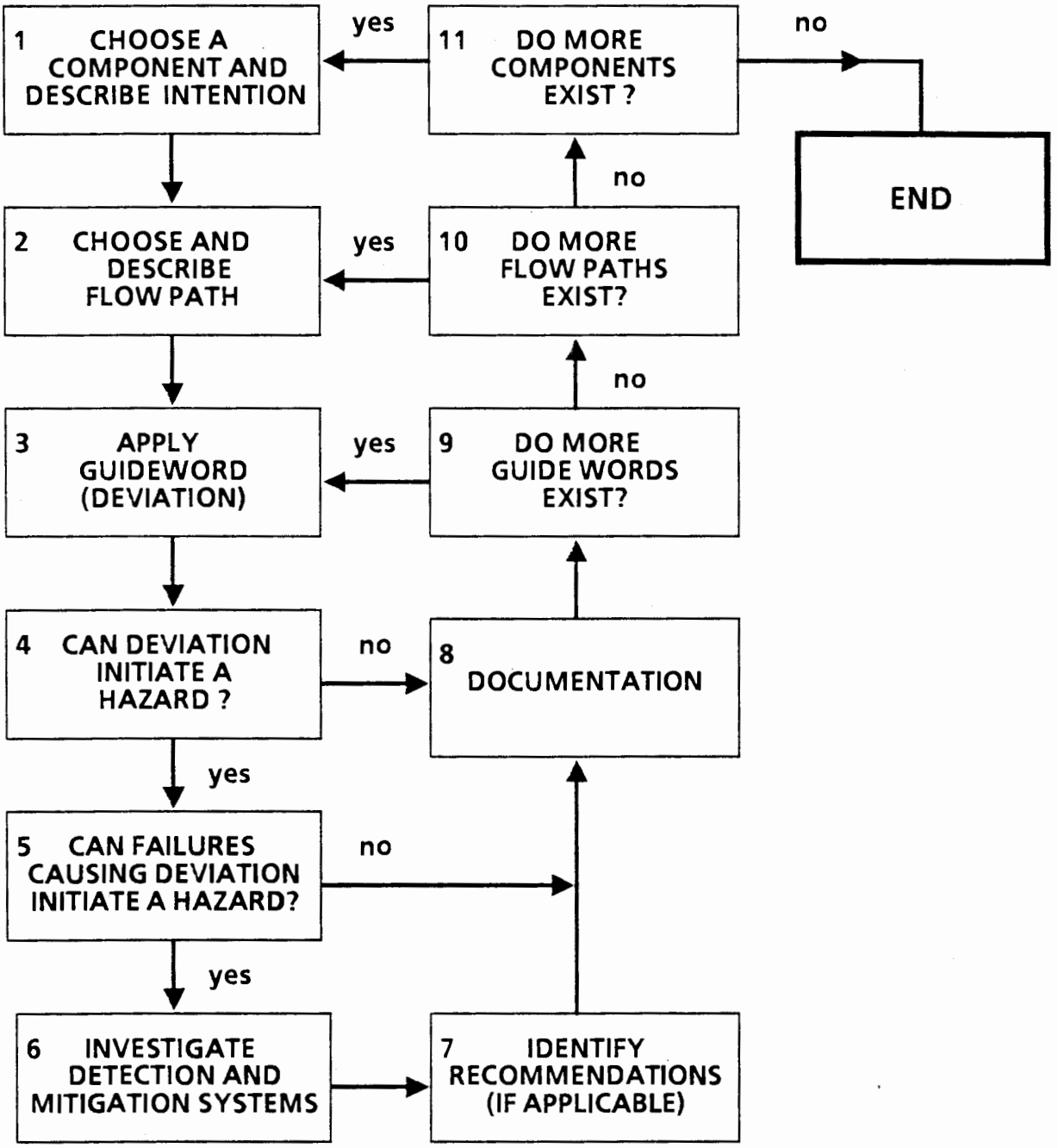
Relative Frequency Rankings (Represented by F in Tables)

Rank*	Frequency
1	Event has been postulated, planned for, but not known to have occurred
2	Has happened very infrequently in the past, on the order of once per facility life
3	Has happened relatively infrequently in the past, equal to or greater than once every five years
4	Has happened relatively frequently in the past, equal to or greater than once per year
5	Has happened frequently in the past, equal to or greater than once per month

* This ranking system may not correlate to the rankings assigned in other WIPP documentation, e.g. FSAR.

FIGURE 3.1-1

SAMPLE HAZOPS PROCESS FLOW



The frequency ranking is based on the HAZOP team's engineering and operating experience judgment and represents the probability that the initiator (cause) may result in the possible consequence(s) with consideration for detection and mitigation systems (e.g., relief valves, operator actions, etc.).

The ranking for each may then be multiplied to develop a ranking or priority to provide a general risk ranking of the recommendations. For example, if a hazard is identified to have a consequence of 2 and a frequency of 5, the ranking of 10, when compared with other identified hazard rankings, allows management to place a general priority on any required actions. Once the consequence and cause are determined, remedial action or recommendations, if identified, are offered.

Following identification of a hazard, specific actions may be necessary to address the hazard. Actions taken can be anything from a complete redesign to recognizing that there may be no effective alternatives -- no action identified. The action taken often correlates the frequency of an event and its consequences with management perspective.

If the hazard identified has a relatively high probability of occurrence, with high possible consequences, the problem should be addressed as soon as possible.

The recommendations and areas of concentration for this study are based on general severity screening criteria adopted by the team in its discussions, in which scenarios which had the highest risk, as determined by informal team consensus, received the most attention.

Special emphasis was placed in public safety as in keeping with DOE and Westinghouse policy. Therefore any hazard assigned to a consequence ranking of 5 due to off-site release of radioactivity was assigned the highest risk level. This was independent of its frequency of occurrence. As expected, frequencies of accidents involving off-site radioactive releases were very low (either 1 of 2 on the relative frequency ranking).

Also any hazards assigned to a consequence ranking of 4, due to potential for multiple injuries or shutdown of waste handling operations, was assigned the next highest risk level. The combination of these hazards are included in Table 3.3-1.

This screening method, although based on engineering judgment and experience, should not be considered to be a substitute for, nor take the place of, a quantified hazards assessment using quantitative techniques (e.g., fault and event trees). The use of these techniques allows the ranking of hazards and hazard sequences based on probabilistic techniques. These techniques consider the estimated frequency of an initiating event and the simultaneous failure probabilities of any detection and mitigation systems or operator errors. The most significant hazards identified will be quantified in a formal Probabilistic Risk Assessment in Section 4.

3.2 HAZOPS TABLES

Table 3.2-1 documents the potential deviations that were discussed during the HAZOPS sessions. For those deviations for which hazards were identified, recommendations are indicated in Table 3.3-1, and these recommendations are summarized, by relative priority, in Section 3.3.

TABLE 3.2-1 (1 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Battery Recharger in CH Area of Waste Handling Bldg. **REFERENCE/P&ID: Refer to applicable forklift O&M manual**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
1	Battery charging	Electrical short/H_2 fire	Explosion/fire could lead to loss of charger plus forklift as well as cause potential injury due to explosion. Could cause slowdown if no other charger is available	While charging batteries on forklift, charging equipment develops short or over chargers batteries resulting in explosion	Post more explicit operating instructions plus provide access to extra charger Assess operational training	3	3

TABLE 3.2-1 (2 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Waste Handling Building Electric-Driven Forklift **REFERENCE/P&ID: 41-H-012 (O&M Manual)**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
2	Forklift operation	Electrical short/fire explosion	All forklifts operation will be restricted. Waste handling will be suspended until problem has been investigated. Possible worker injury due to battery explosion.	Electrical short in forklift circuitry causing battery explosion	Assess periodic inspection and maintenance	3	2

TABLE 3.2-1 (3 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Waste Handling Building Entrance Air Lock Door **REFERENCE/P&ID: 41-K-026-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
3	Air lock door operations	Electrical short	While the disabled door remains open, the other door is closed. Other air locks available for waste handling. Door can be manually operated. Minimal consequence.	Electrical short in air lock circuit causes electrical fire disabling one door	No recommendation	1	2

TABLE 3.2-1 (4 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: CH Dock Bridge Crane **REFERENCE/P&ID: 41-T-151 A/B**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
4	Crane drum handling	Electrical short	Slowdown of waste handling operation and potential for worker injury. Drums will not drop because brake is mechanically set.	CH dock bridge crane electrical short causing fire in crane motor while lifting drums from TRUPACT.	Assess periodic inspection and maintenance	3	2

TABLE 3.2-1 (5 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Floor of CH Loading Area of Waste Handling Bldg **REFERENCE/P&ID: 41-G-501-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
5	Miscellaneous loading area activities	Leak/spontaneous ignition	Fire will cause radiological release involving 3 drums	Combustible material under pallet or flammable concentrations of gases. Material ignites causing contents of one drum to burn and not more than two adjacent drums will pressurize and burst because of heat.	Administrative control of transient combustibles. No smoking area	5	2

TABLE 3.2-1 (6 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Overpack & Repair Room Bridge Crane **REFERENCE/P&ID: 41-G-501-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
6	Crane drum handling	Electrical Short	Some potential for worker injury plus minimal slowdown of waste handling. Waste handling can still be done. Mechanical brake sets.	Electrical short in crane motor causes fire and disables crane while crane is lifting drums.	Assess periodic inspection and maintenance	3	2

TABLE 3.2-1 (7 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Electric-Driven Conveyance Loading Car **REFERENCE/P&ID: 41-H-018 (O&M Manual)**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
7	Conveyance loading operations	Overheated component	Fire is contained under pallet. Waste handling is suspended.	Electric-driven conveyance loading car has overheated motor producing fire. Car is loading facility pallet containing 28 drums.	Need alternative loading car or maintain spare parts inventory. Also, assess periodic inspection & maintenance.	3	2

TABLE 3.2-1 (8 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Waste Hoist Control Room **REFERENCE/P&ID: 31-J-542-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
8	Waste hoist operations	Electrical short	Radiological release involving 28 drums underground plus shutdown of facility	Electrical short in panels causes fire and malfunctioning controls causing hoist to drop drums after crashing into upper headframe	Assess periodic inspection & testing.	5	1

TABLE 3.2-1 (8 of 32)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Electrical Cables Between Control Room & Motor Room **REFERENCE/P&ID: 31-J-543-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
9	Waste hoist operations	Electrical Short	Radiological release involving 28 drums plus shutdown of facility.	Electrical short in cables. Hoist malfunctions causing 28 drums to drop after crashing into upper headframe	Assess periodic inspection and testing.	5	1

TABLE 3.2-1 (10 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Hoist Motor Room **REFERENCE/P&ID: 41-G-507-014**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
10	Waste hoist operations	Overheated component	Radiological release involving 28 drums plus shutdown of facility	Overheated motor results in fire with hydraulic fluid supplying combustibles. Hoist malfunctions causing 28 drums to drop after crashing into upper head frame.	Assess periodic inspection & maintenance, also review the possibility of a higher flash point hydraulic fluid	5	1

TABLE 3.2-1 (11 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Battery Charging Equipment

REFERENCE/P&ID: Refer to applicable forklift O&M manual

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
11	Battery charging	Electrical short/H_2 fire	Explosion/fire could lead to loss of charger plus forklift as well as cause potential injury due to explosion. Could cause slowdown if no other charger is available.	While charging electric forklift/cart, equipment sustains electrical short or overcharges batteries causing explosion/fire	Post more explicit operating instructions plus providing access to extra charger	3	3

TABLE 3.2-1 (12 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Fuel Trailer

REFERENCE/P&ID: 53-F-130-01E
53-D-016

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
12	Underground refueling	Leak/rupture	Suspension of waste handling, shutdown U/G ventilation, possible electrical outage, potential salt hoist failure	Diesel fuel is leaking from trailer fuel tank while it is being brought down salt shaft. After it is unloaded, it ignites.	Another trailer is available as backup. Assess periodic inspection of trailer for leaks or weakened structure	3	2

TABLE 3.2-1 (13 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Diesel-Powered CH Transporter **REFERENCE/P&ID: 52-H-008 (O&M Manual)**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
13	Underground transport	Leak/rupture/ overheated engine	Shutdown of waste handling, worker injury, potential radiological release involving 28 drums	Diesel truck engine fire while transporter is moving 28 drums from waste hoist to panels. Fire is not near panels.	Assess periodic inspection & maintenance	5	2
14	Underground transport	Collision	Shutdown of waste handling, worker injuries and potential radiological release involving 28 drums	Lube oil truck collides with CH transporter at junction of E140 and S1950 spilling diesel oil and igniting it. Transporter has 28 drums.	Assess shutting down traffic while transporter is moving to panels through administrative procedures. Assess traffic monitoring capability.	5	2
15	Underground transport	Leak/rupture/ overheated engine	Shutdown of waste handling, worker injuries and potential radiological release involving 90 drums	Transporter has moved toward panel diesel truck engine fire ignites fuel tank and ignites 90 drum face.	Periodic inspection & maintenance	5	2

TABLE 3.2-1 (14 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Getman Lube Truck **REFERENCE/P&ID: 74-UE-060 (O&M Manual)**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
16	Underground maintenance	Leak/rupture/ overheated engine	Waste handling will be suspended. Possible worker injury	Diesel truck engine fire while truck is in an area that is isolated from the waste drums.	Assess periodic inspection & maintenance	3	2
17	Underground maintenance	Collision/leak	Covered in accident description No. 14	Lube truck collides with CH transporter scenario is covered in transporter accident description No. 14.	Covered accident description No. 14	-	-
18	Underground maintenance	Collision/leak	Waste handling will be suspended. Potential worker injury.	Lube truck collides with some other vehicle besides transporter causing fire and burns diesel.	Assess periodic training in traffic potential accident awareness. Also review the need to increase major junction visibility	3	2

TABLE 3.2-1 (15 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Diesel-Powered Fork Lift

REFERENCE/P&ID: 52-H-007B (O&M Manual)
52-H-005

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
19	Underground handling	Leak/rupture/ overheated engine	Waste handling will be suspended. Possible worker injury	Diesel forklift engine fire. Fork lift is not near waste drums.	Assess periodic inspection & maintenance	3	2

TABLE 3.2-1 (16 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Electric-Driven Forklift

REFERENCE/P&ID: 74-H-010A (O&M Manual)

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
20	Underground maintenance	Electrical short/ explosion	Electrical short causes explosion near battery and disables forklift, slowdown of operation	During maintenance activities, spark from battery connection ignites diesel or hydraulic fluid causing fire	Assess the maintenance procedures plus the use of alternate forklift	2	2

TABLE 3.2-1 (17 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: All Other U/G Diesel-Driven Equipment **REFERENCE/P&ID: 74-U-039 (O&M Manual)**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
21	Miscellaneous underground transport operations	Leak/rupture	Waste handling will be suspended. Possible worker injury.	Diesel truck engine fire. Equipment is located in mining area.	Assess periodic inspection & maintenance	3	2

TABLE 3.2-1 (18 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Electrical Substation and Switching Station **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
22	Underground power supply	Electrical short	Loss of bulkhead door operations, lighting, and radiation monitoring. Waste handling activities underground will be suspended	Electrical short in circuit breaker causing loss of U/G bulkhead door operation, lighting, and radiation monitoring	Review the procedures to reduce recovery time plus assess preventive maintenance	3	3
23	Underground power supply	Explosion	Loss of bulkhead door operations, lighting, and radiation monitoring. Waste handling activities underground will be suspended	Transformer explosion due to breakdown of insulation causing loss of U/G bulkhead door operations, lighting, and radiation monitoring	Review the procedures to reduce recovery time plus assess preventive maintenance	3	2

TABLE 3.2-1 (19 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Maintenance Shop **REFERENCE/P&ID: 54-W-005-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
24	Underground maintenance (welding/cutting torches)	Explosion/welding	Potential worker injuries and slowdown of waste handling	Leaking oxygen and acetylene coupled with leaking diesel from lube truck in shop. Explosion from welding follows and fire ensues	Assess administrative and physical controls on work activities	4	3

TABLE 3.2-1 (20 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: U/G Office Area/Conex REFERENCE/P&ID: 54-W-005-W

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
25	Underground support activities	Electrical short	Potential for filling drift with smoke. Potential for injury to personnel working in the area. Would cause slowdown of waste handling activities.	Electrical short in appliances, or components causing fire in office area/conex.	Assess the inspection frequency and criteria on wiring and housekeeping	3	3

TABLE 3.2-1 (21 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Utility Substation 252 **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
26	Site power distribution	Electrical short	Loss of ventilation and shutdown of waste handling operations.	Electrical short in main circuit breaker (1 of 2) causing loss-of-offsite power	Assess the need to provide spare circuit breakers	4	3
27	Site power distribution	Explosion	Loss of ventilation and shutdown of waste handling operations.	Transformer explosion due to breakdown of insulation causing loss-of-offsite power	Assess the need to provide spare transformer	4	2

TABLE 3.2-1 (22 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Diesel Generators (Fac 255.1 & 255.2) **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
28	Site backup power	Leak/rupture	Shutdown of above and underground waste handling operation	Diesel oil fire knocks out both diesel generators. Offsite power is available.	Assess the need to further segregate or protect the backup generators	4	3
29	Site backup power	Leak/rupture	Shutdown of above and underground waste handling operation	Loss-of-offsite power followed by diesel oil fire which knocks out both diesel generators	Assess the need to further segregate or protect the backup generators	4	2

TABLE 3.2-1 (23 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Facility Substations 254.1 & 254.2 **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
30	Site power distribution	Electrical short	Loss of power to WHB and suspension of waste handling activities. Crane could be in middle of lifting drums.	Electrical short in circuit breaker causing loss of electrical power to WHB HVAC, lighting, and crane power	Review the procedures to reduce recovery time plus assess preventive maintenance	3	3
31	Site power distribution	Explosion	Loss of power to WHB and suspension of waste handling activities. Crane could be in middle of lifting drums.	Transformer explosion due to breakdown of insulation causing loss of electrical power to WHB HVAC, lighting, and crane power	Review the procedures to reduce recovery time plus assess preventive maintenance	3	2

TABLE 3.2-1 (24 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Facility Substation 254.3 for Exhaust Filter Bldg **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
32	Electric supply to ventilation	Electrical short	Loss of underground exhaust ventilation plus waste handling activities until electrical power is reconfigured	Electrical short in main circuit breaker (1 of 2) causing loss of underground exhaust ventilation	Review the procedures to reduce recovery time plus assess preventive maintenance	3	3
33	Electric supply to ventilation	Explosion	Loss of underground exhaust ventilation plus waste handling activities until electrical power is reconfigured	Transformer explosion due to breakdown of insulation causing loss of underground exhaust ventilation	Review the procedures to reduce recovery time plus assess preventive maintenance	3	2

TABLE 3.2-1 (25 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Facility Substation 254.5 for Salt Hoist **REFERENCE/P&ID: 25-J-020-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
34	Power to salt hoist	Electrical short	Loss of salt hoist would shutdown waste handling because salt hoist is main egress.	Electrical short in circuit breaker causing loss of salt hoist	Review the procedures to reduce recovery time plus assess preventive maintenance	4	3
35	Power to salt hoist	Explosion	Loss of salt hoist would shutdown waste handling because salt hoist is main egress.	Transformer explosion due to insulation breakdown causing loss of salt hoist	Review the procedures to reduce recovery time plus assess preventive maintenance	4	2

TABLE 3.2-1 (26 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Facility Substation in Bldg 451 (Support Bldg) REFERENCE/P&ID: 25-J-020-W

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
36	Support building power	Electrical short	Suspension of waste handling	Electrical short in circuit breaker causing loss of power to support bldg plus lighting to waste tower	Review the procedures to reduce recovery time plus assess preventive maintenance	3	3
37	Support building power	Explosion	Suspension of waste handling	Transformer explosion due to breakdown of insulation causing loss of power to support bldg plus lighting to waste tower	Review the procedures to reduce recovery time plus assess preventive maintenance	3	2

TABLE 3.2-1 (27 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Salt Handling Shaft Bldg 384 **REFERENCE/P&ID: 38-J-027-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
38	Salt handling hoist operations	Overheated components	Loss of salt hoist would shutdown waste handling because salt hoist is main egress.	Overheated components causing motor to be disabled causing loss of salt hoist	Assess periodic inspection & maintenance	4	3

TABLE 3.2-1 (28 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: TRUPACT Maintenance Facility 412 REFERENCE/P&ID: 41-J-656-021

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
39	Miscellaneous maintenance activities	Overheated components	Fire could cause slowdown, potential burn through of CH area wall	Space heater fire followed by complete combustion of storage contents	Assess the need for a fire rated separation between the CH bay and the TMF area.	2	2

TABLE 3.2-1 (29 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Compressor Bldg (Bldg 463) **REFERENCE/P&ID: 41-D-001-W**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
40	Site compressed air service	Leak/rupture	Disables both compressors stopping operations.	Leaking oil from compressor ignites	Review the need for a fire separation between compressors and/or add sprinkler system	2	2

TABLE 3.2-1 (30 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Diesel-Driven Fire Pump in Water Pump House **REFERENCE/P&ID: 45-G-101-010**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
41	Fire water system	Leak/rupture	Fire water capacity is maintained from jockey & electric-driven pump. No major consequence.	Diesel oil fire knocks out diesel fire pump. Does not affect electric-driven fire pump. Pumps are separated by more than 20 ft. Cables to electric pump are protected.	Continue availability of electric while repairing diesel.	1	2

TABLE 3.2-1 (31 of 31)

WIPP HAZARD & OPERABILITY PROBLEM IDENTIFICATION TABLE

SYSTEM/VESSEL: Electric-Powered Fire Pump in Water Pump House **REFERENCE/P&ID: 45-G-101-010**

No.	Line Identification	Deviation	Potential Hazard Consequences	Possible Causes (Accident Scenario)	Potential Actions	C	F
42	Fire water system	Overheated components	Fire disables electric driven pump & jockey pump. Diesel will automatically kick on.	Overheated motor causes fire which disables pump and potentially disables jockey pump	Assess periodic inspection & maintenance	1	2

3.3 SUMMARY OF RESULTS

The WIPP CH waste fire HAZOPS resulted in the identification of a number of potential hazards, for which the HAZOPS team has made recommendations for design or operating procedure modifications. The recommendations for the top 15 risks from the HAZOPS are summarized in Table 3.3-1 and discussed here. The balance of the HAZOPS entries in Table 3.2-1 were not recommended for further evaluation. The relative risk-associated with these potential hazards was not sufficiently great to warrant further study as determined by the HAZOPS team.

3.3.1 Specific Recommendations

The first seven entries in the HAZOPS Table 3.3-1 represent potential releases of radioactivity off-site as a result of a fire/explosion. All these accident scenarios will be bounded in consequence or quantified by formal Probabilistic Risk Methods in Section 4.

The following are the recommendations or responses for entries 8 through 15 in Table 3.3-1.

No. 8 <u>Welding Activities</u>

At the present time, all hot work activities underground are controlled by administrative procedures. Welding and other hot work is performed only by qualified personnel. Safety precautions associated with welding include the use of a fire watch, with portable fire extinguisher, removal of combustible and flammable materials within the work area where welding or hot work is being performed.

Quantitative analysis on this event is not deemed necessary because of established administrative controls.

Recommendation: Administratively restrict welding or other hot work that would be performed in the vicinity of waste.

No. 9 <u>Circuit Breakers</u>

The project has two backup diesel generators for use in the event that electrical power is interrupted. These generators are capable of providing electrical power to selected systems. In addition, an agreement exists between the local utility,

Southwest Public Service (SPS) and the WIPP that the utility will respond and provide replacements in the event of equipment damage.

Quantitative analysis on this event is not deemed necessary because corrective action is in process.

Recommendation: Ensure the availability of spare circuit breakers for utility substation.

No. 10 Transformers

Due to current arrangement with local utility company, it is not necessary to store a spare transformer on-site. Local utility company provides all maintenance to the main power supply. The diesel generators are available to supply the site with power, if the transformer is lost.

Quantitative analysis on this event is not deemed necessary because corrective action is in process.

Recommendation: None

No. 11 Electrical Supply

The Final Safety Analysis Report includes as a limiting condition of operations that at least one backup diesel generator and associated electrical distribution system shall be operable and available for use. This applies at all times personnel are underground. Loss of both diesel generators would result in suspension of all underground activity. All waste handling would be suspended. Since off-site power is still available, this would cause no problem. All waste handling activities would be placed in a safe condition, until backup power was available.

Quantitative analysis on this event is not deemed necessary because the corrective action is already specified.

Recommendation: Assess the need to provide further fire segregation or protection between the generators.

No. 12 Backup Generators

The probability of a fire disabling both generators concurrent with a loss of off-site power is postulated to be very low. However, because of the close proximity of the two generators, further review of the fire protection needs to be accomplished. The generators are currently located in separate metal buildings approximately ten feet apart.

Quantitative analysis on this event is not deemed necessary because the corrective action is already specified.

Recommendation: Assess the need to provide further fire segregation or protection between the generators.

No. 13 SH Power

Potential for electrical short, causing the breaker on Substation 254.5 to fail does exist. At present time, recovery procedures are in place to address this issue. The current configuration allows for the salt hoist to be lowered during loss of power so personnel could be evacuated to a safe place. The hoist braking is such that sudden stops do not occur and emergency stops are gradual.

Quantitative analysis on this event is not deemed necessary because the corrective action is already specified.

Recommendation: Assess the recovery procedures for adequacy and completeness.

No. 14 SH Hoist Operations

The salt hoist has daily operability check as well as periodic inspections to ensure that all safety features are in proper working operation. Additional safety precautions are provided to insure personnel safety. Material cannot be transported in the same cage with personnel. Further precautions require that all personnel going underground attend a safety briefing prior to their first trip.

Current procedures do address potential power outages to the salt hoist. Loss of breakers could possibly be addressed by providing for a crossfed from another substation. Current configuration does allow for lowering the salt hoist, during loss-

of-power, so personnel could be evacuated on the waste hoist, or the Air Intake Shaft.

Quantitative analysis on this event is not deemed necessary because the corrective action is already specified.

Recommendation: Assess the inspection and maintenance procedures associated with the electrical system supplying the SH hoist.

No. 15 SH Substation

Potential for transformer explosion exists. At present time, recovery procedures are in place to address this issue. The current configuration allows for the salt hoist to be lowered during loss of power so personnel could be evacuated to a safe place. The hoist braking is such that sudden stops do not occur and emergency stops are gradual.

Quantitative analysis on this event is not deemed necessary because the corrective action is already specified.

Recommendation: Assess the recovery procedures for adequacy and completeness.

TABLE 3.3-1

RECOMMENDATIONS BASED ON SPECIFIC HAZOPS ENTRIES

No.	Table 3.2-1 Ref. #	C*	F*	Potential Actions	Potential Hazard Consequences
1	5	5	2	Administrative control of transient combustibles	Radiological release to the environment (3 drums involved)
2	8	5	1	Periodic inspection and maintenance on electrical components.	Radiological release to the environment (28 drums involved)
3	9	5	1	Periodic inspection and testing	Radiological release to the environment (28 drums involved)
4	10	5	1	Periodic inspection and maintenance and higher flash point fluid	Radiological release to the environment (28 drums involved)
5	13	5	2	Periodic inspection and maintenance of brakes and exhaust systems	Radiological release to the environment (28 drums involved)
6	14, 17	5	2	Administrative control of under-ground traffic. Stop unnecessary traffic and install signal system	Radiological release to the environment (28 drums involved)
7	15	5	2	Periodic inspection and maintenance of fuel and lubrication systems	Radiological release to the environment (90 drums involved)
8	24	4	3	Administrative controls on welding activities	Worker injuries and slowdown of waste handling
9	26	4	3	Spare circuit breakers for all substations.	Loss of ventilation and shutdown of waste handling operations
10	27	4	2	Spare transformer for utility substation	Loss of ventilation and shutdown of waste handling operations
11	28	4	3	Fire segregation or protection between generators	Shutdown of waste handling operations
12	29	4	2	Fire segregation or protection between generators	Shutdown of waste handling operations
13	34	4	3	Review procedures to reduce recovery time; additional preventative maintenance	Shutdown of waste handling operations
14	38	4	3	Periodic inspection and maintenance	Shutdown of waste handling operations
15	35	4	2	Review procedures to reduce recovery time; additional preventative maintenance on transformer	Shutdown of waste handling operations

*C - Consequence
*F - Frequency

SECTION 4
RISK QUANTIFICATION (PRA)

4.1 INTRODUCTION

This section identifies, analyzes, and quantifies the health risk to the public due to postulated contact-handled (CH) waste accidents at WIPP.

Seven HAZOPS entries from Table 3.3-1 have been identified as having potential off-site radiological impact. In the probabilistic risk assessment (PRA), they are grouped into 3 categories. These are:

Table 3.3-1 No.	PRA	HAZOPS Identification
	3 drum surface fire	
1		Miscellaneous loading area activities (3 drum fire)
	28 drum waste hoist scenario	
2		Waste Hoist Operations (28 drums involved)
3		Waste Hoist Operations (28 drums involved)
4		Waste Hoist Operations (28 drums involved)
	90 drum transport/storage face scenario	
5		Underground Transport (28 drums involved)
6		Underground Transport (28 drums involved)
7		Underground Transport (90 drums involved)

The accidents scenarios in the PRA are further labeled. The scenarios relevant to fire are:

	Event Tree Designation	Consequence Designator
3 drum surface fire	A2 fire above ground	R3D three drums damaged
28 drum waste hoist scenario	LPU loss of electric power	R28 twenty-eight drums damaged
90 drum transport/storage face scenario	U2 underground fire	R90 ninety drums damaged

In addition two other non-fire-induced accident scenarios round out the five PRA accident scenarios. These are: an above ground breach involving three drums designated A1 as an event tree, and an underground breach involving three drums designated U1B.

In the PRA analysis, the two scenarios involving 28 drums being transported underground are lumped together with the 90 drum case. This will be discussed in Section 4.2.2.2.

The balance of this section describes the PRA process and results.

4.1.1 SCOPE AND OBJECTIVES

The objective of the PRA is to identify, analyze, and quantify the risk of off-site airborne radiological releases, and their consequences, as a result of the CH waste receipt and emplacement process at the WIPP site. This risk assessment includes the analysis of systems determined by the analysts to be critical to the public health or safety, particularly those systems used in the confinement or measurement of the release of radioactive materials.

The specific systems identified as being critical to public health or safety are listed on Table 4.1-1. Support systems relied on by the systems in Table 4.1-1 are shown in Table 4.1-2.

The results of this analysis provide a quantification of the total risk of the WIPP facility for CH waste receipt and emplacement including the following:

- Total risk to the human population in the area surrounding the site boundary
- An identification of the dominant contributors to risk
- Insight into the significance of the dominant contributors, and recommendations, if appropriate.

4.1.2 METHODOLOGY

This risk assessment is performed in a series of steps as follows:

- Systems whose failure may cause a release of radiological material or whose success may mitigate the effects of such a release are identified. These systems are listed on Table 4.1-1. Support systems relied on by the systems in Table 4.1-1 are shown in Table 4.1-2.
- Each of the release prevention or mitigation systems identified in Table 4.1-1 is analyzed using fault tree analysis. Failure modes of the system and the unavailability of the system are derived.
- A number of accident initiators (events potentially causing a release of radioactive materials - explained in Section 4.2.0) are identified (listed in Table 4.1-3). A lengthy list of identified initiators (both internal and external events) are reviewed for the potential to contribute to an on-site release of CH waste particulates. Most of the initiators are pared from the list in Table 4.1-3, since they are not deemed capable of CH waste releases or potentially occur with such low frequency as to add minimally to the total public risk.
- Event trees are constructed to model the potential initiator and the systems necessary to mitigate the effects of the accident and to identify the accident sequences associated with each initiator. The results of this modeling are grouped into a number of release categories. (These categories are defined by the amount of radioactive material that could be involved and whether the potential release is filtered or unfiltered).

- A fault tree linking code, WLINK©©, is used to combine the accident initiators and their mitigative systems, identified in each accident sequence, into an overall frequency of potential release of radioactive materials from the WIPP site. The dominant contributors to this overall probability are also identified in this process.

- The results of the fault tree linking process are combined with the consequence analysis results to identify the total risk to the population in the area surrounding the WIPP.

The quality assurance (QA) steps in this report are in compliance with the Westinghouse Nuclear and Advanced Technology Division Quality Assurance Program as well as NQA-1 1983, Addendum 1A criteria.

Uncertainty analysis was not part of the scope of this program. With the limited scope of the PRA, a decision was made to put off uncertainty analysis until initial results were calculated. Once these results were calculated, they were of such low risk magnitude that an analysis of uncertainty was not technically mandated.

All systems analyzed in the PRA were walked down by the system analyst and cognizant WIPP engineers. All systems were modeled in the WIPP facility configuration as of January 1989, with a review for consistency with current plant configuration occurring in May 1991 for this fire analysis.

4.1.3 UNIQUE PLANT FEATURES AFFECTING RISK ASSESSMENT

The scope of this PRA is limited to the CH waste drum handling aspects of the WIPP facility. Because of this scope, many features of the plant are not included in the analysis, or are analyzed only to the extent that they impact the CH waste drum handling process. Some of the plant features excluded from or limited in this analysis include the RH waste receipt, handling, and emplacement aspects of the WIPP and many of the other selected systems.

The WIPP site is a waste handling and storage facility; TRU waste is brought to the site and emplaced in the storage rooms U/G. There are no processing or treatment facilities on the site. Because this is not a processing facility, detailed analysis is limited to the

areas where CH waste is handled, i.e., the WHB (and its HVAC system), the waste hoist, the U/G storage area (and its HVAC system) and appropriate support systems.

Table 4.1-1

SYSTEMS DIRECTLY RELATED TO ACCIDENT ANALYSIS

- Fire Detection and Suppression Systems
  - Manual, Aboveground System
  - Manual, Underground System
  - Dry Chemical System
  - Fire Water System
- Waste Handling Building HVAC System
- U/G Air Filtration System (located in EFB)
- Waste Hoist Braking System

Table 4.1-2

SUPPORT SYSTEMS

- Compressed Air System
- Radiation Monitoring System
- Central Monitoring System
- Electric Power Systems

Table 4.1-3

ACCIDENT INITIATORS

- Aboveground Breach of Waste Drums – A1(R3D)
- Aboveground Fire – A2(R3D)
- U/G Breach of Drums – U1B(R3D)
- U/G Fire – U2(R90)
- Loss of Electrical Power (U/G Release) – LPU(R28)

4.2 ACCIDENT SEQUENCE MODELING INTRODUCTION

This section develops a number of event tree models that couple identified IEs with failure of appropriate mitigative features to represent accident sequences. The event tree model also identified the various damage states (consequence categories) resulting from the combination of the accident initiating event (IE) and mitigation system failures. There are five event trees developed. These are:

- Aboveground Breach of Drums (A1ET, Figure 4.2-1)
- Aboveground Fire (A2ET, Figure 4.2-2)
- U/G Drum Failure (Storage Room) (U1BET, Figure 4.2-3)
- U/G Fire (Waste Storage Room) (U2ET, Figure 4.2-4)
- Loss of Power to Hoist Motor (LPUET, Figure 4.2-5)

Each of these accident sequences is determined to be capable of initiating a radioactive release with potential health effects off the site.

From the event tree, specific accident sequences are derived and categorized by consequence category. Section 4.2.1 documents the development of the accident scenarios. This includes identification of potential sources of a CH release and the appropriate mitigative/protective response features. Section 4.2.2 documents the development of the event trees and the quantification of the IEs.

4.2.1 DEVELOPMENT OF ACCIDENT SCENARIOS

4.2.1.1 Objectives and Scope

As part of the PRA, all important safety systems have undergone a rigorous analysis. A system is identified as critical to public safety or health if it is necessary for the confinement or measure of the release of radioactive materials. This specific accident sequence modeling task will identify potential IEs (hazards) and determine the ability of the plant's safety systems to prevent or mitigate the release of radionuclides. A specific analysis of the consequences is also performed as part of the PRA. Risk is quantified by combining the probability of a release with its associated consequence (impact).

Section 4.2.1 documents the development of the accident scenarios that could result in an off-site airborne radiological release. This includes identifying significant potential sources of a CH release and appropriate mitigative/protective features. In this section, each of the accidents postulated in the draft WIPP FSAR, the WIPP Final Environmental Impact Statement (FEIS), and the draft WIPP Supplemental Environmental Impact Statement (SEIS) are addressed and all the accident scenarios analyzed in this risk assessment are defined.

Section 4.2.2 documents the development of the event trees and the quantification of the IEs. In this section, event trees are developed by linking each of the five accident initiators identified in Section 4.2.1 with the systems needed to mitigate the effects of each of these IEs. After the event trees are developed, the frequency of occurrence for each of the five IEs is calculated.

The accident sequence evaluation includes the development of an event tree model that couples each identified IE with failure of appropriate mitigative features. The event tree model also identifies the various damage states (consequence categories) resulting from the combination of the accident IE and mitigation system failures. From the event tree, specific accident sequences are derived and categorized by consequence category according to the amount of radioactive material potentially released in each sequence.

4.2.1.2 Discussion of Potential Accident Scenarios

The identification of potential accident scenarios for consideration in WIPP safety assessments has been mandated and guided by Department of Energy (DOE) Orders 6430.1 and AL 5481.1B. The guidance from DOE Order AL 5481.1B is as follows:

> For the purpose of the AL Safety Analysis Program, risk will be determined in the following manner unless otherwise agreed to by the Director, Site and Preliminary Design:
>
> - The accident analyses shall provide a quantitative risk assessment of various postulated accident scenarios to the public, workers, property, or the environment. If the analysis determines that a particular scenario is not credible [probability <1.0 E-6, the analysis will not be included in the Safety Analysis Report (SAR)], but a statement shall be made that the scenario was

evaluated and determined not to be credible. That analysis shall be available for review by the DOE.

- If it is determined that a quantitative analysis is not practical, then an analysis will be performed using qualitative descriptors for accident severity and probability of occurrence.

- A table that summarizes the risks associated with the accident analyses is provided in the FSAR.

These guidelines were used to determine the development of accident scenarios in the WIPP FSAR. In addition, the following guidance was used as a probabilistic approach.

> Probabilistic analysis considers those events whose annual probability of occurrence exceeds 1.0E-6.

This guidance was used in the PRA to judge whether a postulated accident sequence is credible and should be analyzed for its consequences.

The FSAR applies the 1.0E-6 per year limit to judge whether an accident resulting in on-site release of radioactive particulates is credible. Although the PRA is concerned with off-site releases of radioactivity, this analysis will likewise consider credible those accidents that release radioactive particulates on the site with a frequency less than 1.0E-6 per year.

The identification of potential accident scenarios began with a review of the accident scenarios identified in the FEIS (Table 4.2-1) and in the FSAR (Table 4.2-2). A facility walk down was performed to provide additional input for development of accident sequences. Although new sequences were identified, the PRA did identify sequences that were not considered credible by the WIPP FSAR.

Postulated Accident Scenarios That Are Not Analyzed Quantitatively

The following FEIS and FSAR scenarios (See Tables 4.2-1 and 4.2-2, respectively) are specifically evaluated with respect to their impact on plant risk. These scenarios are

found to be noncontributors to risk, for reasons explained below, and are not analyzed further or included in the accident sequence evaluation.

- FEIS scenarios C1 and C2 and FSAR scenarios C0 and C1 postulate the TRUPACT-II container suffering a collision with a vehicle or a fall from the forklift. Since the TRUPACT-II container is an NRC Type B container, it is designed to withstand a fall from a height of 30 feet. Each of these scenarios would result in a fall of less than six feet and would, therefore, cause no damage to the TRUPACT-II that could release radioactive materials. Therefore, these scenarios are not included in the accident sequence evaluation for the WIPP.

- FEIS scenario C6 postulates drum failure from excessive internal pressure. The Waste Acceptance Criteria (WAC), WIPP DOE-069 Rev. 3, states "For purposes of transportation and emplacement (short term) there will be no mixture of gases or vapors in any package which could, through any credible increase of heat or pressure, or through an explosion, significantly reduce the effectiveness of the packaging." Therefore, this scenario is not included in the accident sequence evaluation.

- FEIS scenarios C8, C12, C14, C20, and C22 and FSAR scenarios C7 and C10 each postulate fire caused by internal combustion in the drum. The WAC, however, states that pyrophoric materials (i.e., those that may ignite spontaneously under the ambient conditions of shipment or storage in the WIPP) shall be rendered safe by mixing with chemically stable materials (e.g., concrete, glass, etc.) or processed to remove their hazardous properties. No more than one percent by weight of the waste in each package may be pyrophoric forms of radionuclides, and these shall be generally dispersed in the waste." The criterion further states, "because experimental evidence supplemented by operational history supports the conclusion that there is no danger of sustained combustion of packaged TRU waste due to spontaneous internal ignition, the fire hazard to the WIPP facility is limited to exposure of waste packages to external fires." Because of this criterion, accident scenarios involving spontaneous internal combustion in the drums will not be considered in this analysis.

- FEIS scenarios C9 and C10 include drum failure on the way to repair. CH waste handling procedures call for drums needing overpacking or repair to be transported from the CH dock to the overpack and repair room in a closed TRUPACT-II container. Therefore, these scenarios will not be included in the WIPP accident analyses evaluation.

- FEIS scenario C16 involves the puncturing of a drum U/G by the forklift. At the WIPP site, however, the "forklift" used U/G to move the drums from the transporter to the waste storage area is not a conventional forklift with "tines." This U/G forklift has a solid platform in lieu of the tines. The tines on a forklift are the mechanism expected to cause a puncture; since this special forklift has no such tines it seems unlikely to be able to puncture the drums, and this accident sequence is already bounded by accident sequence U1B. For this reason this scenario is not included in the WIPP analysis. Analyses of other equipment U/G causing puncturing is included in Accident Q6.

- FEIS scenario C18 addresses the possibility of a rock fall from the mineshaft rib (walls) causing damage to the drums. The top of the shaft, through the rock layer, is lined with a concrete sleeve to prevent rock falls. This scenario, therefore, is not applicable to the WIPP site and will not be included in this WIPP analysis.

- FEIS scenario C13 and FSAR scenario C8 postulate a catastrophic hoist failure due to failure of all six hoist cables. From Reference 7, the frequency of this scenario is calculated to be 2.4E-10 per year. Since this is an incredible event, this scenario will not be included as an initiator in the PRA.

The probability of the five-ton overhead crane in the CH bay dropping a load of waste drums is not considered credible. The crane is designed to hold its load in a loss of power (LOP) event. Operator errors are minimized through testing and qualification of crane users. In addition, there are two sets of spring release brakes that will not release if power to the crane is not available. Therefore, this accident is not included in the accident sequence analysis.

As is explained in the SEIS, a roof failure in the waste storage room and a criticality accident are each considered incredible accidents and, therefore, are not analyzed in this evaluation.

A criticality accident is considered an incredible event because all WIPP waste must meet the WAC and TRU payload compliance criteria and all possible criticality accident scenarios were analyzed in DOE/WIPP 88-0014, Criticality Safety Analysis for CH Waste at the WIPP.

Note that the WIPP WAC states that "TRU waste shall not be in free-liquid form," thereby precluding the possibility of contamination from a liquid spill of waste.

The probability of an accident whereby the keyway (concrete reinforcing structure surrounding the shaft at the start of the salt layer) is crushed by formation pressure and falling cement and rock cause damage to drums on the hoist, and is considered incredible. The keyway design has been verified to be adequately robust to prevent such an occurrence (WIPP Design Validation Final Report, October 1986, DOE/WIPP-86-010, Sections 8.3.2.2 and 8.3.3.2).

Analyses of Accident Initiators

After studying the FEIS and FSAR postulated accident scenarios and performing a walk down/talk through of the CH waste receipt and handling process, a number of accident initiators were identified (see Table 4.2-3). These initiators are grouped into accident categories according to the consequences of each accident. Assumptions of the extent of damage and release are based on Section 9.5 of the FEIS for the appropriate accident category, and are presented below. (The accidents considered in the PRA are numbered Q1, Q2, etc., to minimize confusion with the FEIS and FSAR accident identifiers.)

- Accident Category A1: Surface Container Failure (Accidents Q1, Q2) - An operator error results in a forklift hitting a stack of CH waste drums. It is conservatively assumed that two drums are punctured by the tines of the forklift and that the lid of a third drum is knocked off as it falls from the stack. It is assumed that the drums become disengaged from the forks. Since not all of the waste is expected to fall out of the damaged drums, it is assumed that 25 percent of the radioactivity content is released from the drum that lost a lid and

ten percent is released from each punctured drum. (These values are consistent with those in Section 9.5.1 of the FEIS.)

- Accident Category A2: Surface Fire (Accident Q3) - The limited quantity of flammable materials in the WHB makes the following assumption reasonable: if a fire occurs in the CH bay, the overpack and repair room, or the shielded storage area, not more than the contents of one drum will burn and not more than two adjacent drums will pressurize and burst because of the heat. Despite the unlikelihood of having flammable material in this area, it is postulated that a small puddle of combustible liquid is spilled under a pallet of waste drums and ignites. Although such a fire would be small, the adjacent drums are assumed to fail and spill half their contents. The contents spilled from the adjacent drums do not burn, and only one percent of the spilled material is in powder form. (These values are consistent with those in Section 9.5.1 of the FEIS.)

- Accident Category LPU: U/G Container Failure (Failure of Hoist) (Q8) - The initiator that could lead to a hoist failure, causing damage to 28 drums of waste, is an LOP event. For the LOP event, a failure of the waste hoist brakes would also have to occur to reach a subsequent failure of waste drums.

  Because the counterweight weighs more than the hoist conveyance loaded with CH waste (54 tons versus approximately 40 tons), this initiator may cause the counterweight to fall; the conveyance would then crash into the headframe. In this scenario, the waste drums are assumed to fall either down the shaft or into the WHB around the shaft, releasing 100 percent of their contents (as assumed in Section 9.5.1 of the FEIS). Since the underground ventilation draws all hoist tower air into the shaft and U/G, each of these initiators would result in an U/G release.

- Accident Category U1B: U/G Container Failure (Accidents Q4, Q5, Q6) - A more plausible accident than U1A but with less severe consequences involves the damaging of approximately two to three drums of waste U/G. In Q4, the transporter is assumed to back into the facility pallet that is still on the hoist, knocking the drums off the pallet; it is assumed that the lid breaks off one drum.

The seven-packs are secured to the facility pallet by a nylon harness forming a four point tie-down to the pallet and also having a lateral strap; the transporter is moved slowly and deliberately, and at least one spotter is present to aid the transporter driver in aligning the transporter with the pallet in the hoist. The effects of this accident are assumed to be the same as that of Q2, the lid of one drum falls off, releasing 25 percent of the drum's contents. (This value is consistent with Section 9.5.1 of the FEIS).

In Q5, a seven-pack of drums is assumed to be knocked off the transporter by the forklift while attempting to grip the seven-pack. The result of this accident is assumed to be the same as that of Q2.

In Q6, a seven-pack of drums is considered to be punctured by "other equipment." Since the U/G forklift does not have standard tines, it is extremely unlikely that the forklift would therefore puncture the drums as in accident Q2. For the purposes of this analysis, it is assumed, however, that the platform under the gripping mechanism could pry open the lids of two drums on a bottom seven-pack while trying to load the top seven-pack.

For this analysis, it is assumed the damage is the same as for Q2 (Category A1) except the release is U/G.

- Accident Category U2: U/G fire (Accident Q7) - Vehicles used in the U/G disposal area are diesel powered and contain sufficient fuel for one shift of operation (about 60 gallons). Because of the high flash point of diesel fuel, the probability of causing a fire with such a vehicle is quite low; such fires, however, have occurred in the past, and a fire is considered credible for this analysis. Even though CH waste is received in metal drums, a portion of the waste is combustible, there is a small probability that the waste packages could be involved in a fire. The following assumptions are made:

  - The combustible material is 60 gallons of diesel fuel contained in the full tank of a diesel-powered vehicle operating in the vicinity of a stored array of CH waste drums.

- A truck engine fire is the initiator. Engine fires are typically electrical. If the dry chemical fire suppression system on the vehicle and manual fire suppression methods fail, the fire is assumed to spread to the fuel tank of the vehicle.

- The heat of the unsuppressed fire then causes the ignition of the waste in the drums. Consistent with the WIPP FEIS, 25 percent of the waste is assumed to be combustible. It is assumed that 100 percent of the combustible material (25 percent of the waste) is consumed in the fire.

Analysis of Fire as an Initiating Event

The initiation of a fire in the WIPP facility can produce various consequences. These consequences can be broadly divided into human losses, financial losses, and environmental releases. For the purpose of this analysis, only fires that could initiate a potential release of radionuclides to the environment are being considered. For this reason, the scope is limited to the area of the facility which is directly associated with the waste handling process, specifically for CH waste.

The WIPP facility is limited to handling waste exclusively inside the WIPP buildings. No chemical processing is required, and there are only small quantities of combustibles in the buildings. All buildings are equipped with lightning protection to prevent damage from lighting strikes, including fires.

Later discussions in the next section analyze externally-induced fires such as fires from lightning strikes and range fires. This section examines internally-induced fires, i.e., fires initiated within the WIPP facilities.

In addition, the WIPP Waste Acceptance Criteria set limits on the amount of residual liquids and pyrophoric materials that can be contained in waste drums shipped to the WIPP.Therefore, it was determined to be very unlikely for a leaky waste drum to contribute to a fire.

The impact of a fire depends on the type and size of the fire, the potential for the fire to propagate, and the capability to detect and suppress the fire once it has started.

- WHB - The WHB is the focal point for receiving CH waste. The waste will be taken from the CH Bay Unloading Area to the U/G storage area via the waste hoist for storage. Propagation of a fire from outside of the WHB into the CH bay is unlikely since the building is constructed of concrete and steel; the CH bay is separated from the unloading pad by airlocks (A/Ls). Fire barriers exist between the CH bay and each of the following: the cage loading and shaft areas, the overpack and repair room, shielded storage room, site-generated waste room, and walls enclosing stairwells. Fire detection and suppression within the WHB consists of automatic sprinkler protection, water for extinguishing fires, and manual methods such as extinguishers, hose reels and fire trucks. Several areas within the WHB are evaluated for potential fire hazards or initiators.

  - Outside Unloading/Staging Areas

    The unloading/staging areas are located adjacent to the WHB. The trucks are backed into a special holding area within the access gate but outside of the locked loading/unloading area. The trailers are pulled into the loading/unloading area by a trailer jockey, one trailer at a time. Here each TRUPACT-II is removed from the trailer and taken by forklift through an A/L into the CH bay. The A/L doors are interlocked such that both doors cannot be opened at the same time. There is a potential for a fire to occur in the loading/ unloading area with the diesel-engine truck or the diesel powered trailer jockey that is transporting the waste. If this were to occur, it is likely that the fire would be restricted to the area outside the A/L. The waste drums would still be contained within the TRUPACT-IIs during this unloading process. Since the TRUPACT-IIs are designed to withstand accidents far greater than any credible scenario in this area, a fire in this area would not initiate a radiological release. Fires external to the drums are addressed in Section 4.2.1.3.

    Propagation of a fire from this area to an adjacent area in the WHB where waste drums are being moved is not considered because of fire barriers. A fire that is ignited outside the WHB will not propagate into the building because of the A/L interlocks, the size of the A/Ls, and the lack of combustible material in the A/L.

Although the WHB A/L interlocks are assumed to preclude the possibility of external fires propagating to the WHB, fires ignited from outside the WHB will be considered in Section 4.2.1.3.

- Entrance A/Ls

Three A/Ls are provided for entry into the CH TRU side of the WHB. These A/Ls receive the TRUPACT-II shipping containers that are off-loaded from the transport trailers external to the WHB.

These A/Ls function to maintain the interior of the WHB at a pressure lower than atmospheric to ensure that air leaks flow into the WHB, thereby minimizing the inadvertent release of airborne radioactive contamination from the WHB. The A/Ls are empty rooms through which a TRUPACT-II container is transported by a battery-powered forklift. The probability of starting a fire in one of these A/Ls is determined to be minimal since the A/L contains no combustible material. The possibility of internal combustion in the drums is discussed in Section 4.2.1.3. Because the likelihood of a fire occurring in this area is minimal, the potential for fire propagating from this area to another area of the WHB is not considered.

- Inventory and Preparation Area (CH Bay)

In the CH bay, a five-ton overhead crane unloads the TRUPACT-IIs and lifts the CH waste drums onto the facility pallet that will be taken to the waste hoist via a battery- powered forklift and conveyance car. Since this crane is designed to hold its load in the event of any LOP, it is assumed that a fire that would disable the crane would not cause the crane to drop an array of drums; the crane would just cease operation. There are two sets of spring release brakes that will not release if power to the crane is not available. Therefore, a fire causing failure of the crane and initiating a release is not considered credible.

Also located within the CH Inventory and Preparation Area (in an area of the building approximately 40 feet from the overhead crane) is a recharging station for the batteries that power the equipment used within this area. This station is equipped with an exhaust hood and ventilation system that will vent any hydrogen produced when charging the batteries. Additionally, there is enough airflow in the area to disperse any hydrogen that would be released into the room such that a buildup would not occur. Also, the amount of hydrogen generated is expected to be minimal since not all of the batteries will be recharged at the same time. It is not probable that a fire would propagate to another area of this room where the waste is being handled, damage drums, and cause a release of radionuclides, given the respective locations within the room and the fact the areas are separated by nothing more than concrete floor. If the HVAC system failed to vent the hydrogen, it is assumed the hydrogen would remain trapped under the exhaust hood or be dispersed into the room since the amount expected to be produced is minimal.

The CH bay contains a very limited quantity of flammable materials. There is no way to ignite a fire in this area unless there is a gross violation of procedures that goes unchecked and uncorrected. Despite the unlikelihood of having flammable material in this area, it is postulated that a small puddle of combustible liquid is spilled under a pallet of waste drums and ignites. Although such a fire is small, the adjacent drums could fail and are assumed to spill half their contents. This scenario is discussed in Section 4.2.1.3 (Category A2) and is explained further and quantified in Sections 4.2.2.1 and 4.2.2.2.

In addition to the above, an examination was made of hydraulic fluid use in the CH Waste Handling Bay for its potential to contribute to a fire. There are currently 18 fluids which are or have been in use on the site with flash points ranging from 285°F to 445°F. It is noted that these flash points may be lower should the fluids become atomized. Flash points in this range classify the hydraulic fluids as Class IIIB Combustible Fluids per the NFPA Fire Protection Handbook, which is the least volatile rating for combustible liquids. The hydraulic fluid with the most conservative

flash point of 285°F will be used in the following discussions of hydraulic fluid contributions to fire analysis.

In the CH waste handling area of the WHB, two sources of hydraulic fluid have been determined: the overhead crane and the electric-driven CH waste transporter.

The hydraulic fluid in the overhead crane is not determined to contribute to a possible fire in the CH waste handling area, since the temperature ratings of automatic sprinklers near the WHB ceiling (100°F to 225°F) fall below the flash points of all hydraulic fluids used at the WIPP.

The hydraulic fluid in CH waste transporters, on the other hand, could be released to contribute to a fire in the vicinity of the CH waste drums. However, there is not a significant amount of hydraulic fluid used in the transporter. The additional fire contribution from the transporter hydraulic fluid is considered minor compared to the envisioned WHB fire source term.

- Waste Hoist Room

The waste hoist room is located at the top of the waste hoist shaft in the WHB (elevation 185' 6"). This area contains the waste hoist motor and the hydraulic braking system for the waste hoist. The area is equipped with a sprinkler system that is located approximately 50 feet above the floor. There is two thermal detectors in the area located on the opposite side of the room from the hoist motor and braking system. This is a controlled access area which can be entered via a personnel elevator or through several locked doors with stairs and ladders between levels. Both entries require a key that is kept in the hoist control room to gain entry to the hoist room.

a. Waste Hoist Motor Area

The waste hoist is powered by an electric motor. It receives power from the waste hoist Substation. If an electrical fire, either

locally or at the substation, were to occur and destroy or damage the waste hoist motor or terminate power to the motor while the hoist was transporting CH waste, the waste hoist would stop. As long as the braking system is functioning, it would remain in the same position as when the motor stopped. Therefore, a fire in this area would not initiate an environmental release of radionuclides unless the hoist braking system failed to maintain the hoist in a stationary position (see Sections 4.2.1.3 and 4.2.2.1). The frequency of this event is considered as part of the frequency of the loss of off-site power event.

In addition, an examination was made of hydraulic fluid use in the waste hoist motor area for its potential to contribute to a fire.

The waste hoist brakes are hydraulically operated, so there is hydraulic fluid present in the waste hoist brake room. It was determined through analyses presented in Section 4.2.1.3 that fire in the waste hoist control room or hoist brake area cannot contribute to failure of the hoist brakes.

A fire in these areas could cause a loss of power to the waste hoist. However, the frequency of fire causing a loss of power has already been incorporated in the initiating event frequency for loss of power to the waste hoist. Since release of hydraulic fluid cannot contribute to a higher frequency of fire, but only to the size and duration of a fire, considering hydraulic fluid would not change the results of the analysis. Therefore, no specific analysis considering the addition of hydraulic fluid is warranted.

b. Waste Hoist Braking System

The waste hoist braking system is located in the same area as the hoist motor. The hoist brakes are hydraulically operated. They will fail in a safe position if the hydraulic fluid pressure drops below 900 psi. A fire in the waste hoist room would cause the hydraulic fluid lines to rupture, resulting in a loss of hydraulic fluid

pressure in the brakes, causing them to set. As a result, such a fire would not lead directly to a release of radionuclides.

- Waste Hoist Control Room

A waste hoist control room exists in the area of the waste hoist motor and braking system. This control room houses both the control and power circuitry for operating the waste hoist. An operator is stationed in the control room at all times when the hoist is operating. This control room is equipped with an emergency stop button for the hoist. Contained in the control room are the control cabinets, breakers, and 475V transformer (TR) for the waste hoist. A fire in the 475V TR will result in an LOP to the waste hoist. The frequency of such a fire will be included as part of the LOP IE frequency. A fire in the power cables or circuitry in the control room is not considered capable of propagating and disabling the controller and contactor functions. These cables are shielded by conduit. As a result, the waste hoist brakes will still remain in a state where they may be set, and hoist failure would be prevented.

- Overpack and Repair Room

The overpack and repair room provides space and facilities for opening and unloading TRUPACT-II containers suspected to have internal contamination during unloading operations. Entry into this room from the CH bay is via an A/L. The HVAC system maintains this room at a negative pressure relative to the inventory and preparation area and the exterior of the WHB. A mobile floor-supported hoist is located within an enclosure in the overpack and repair room for lifting operations. There is an access entry for a six-ton electric lift truck as well.

Initiation of a fire in this area, although unlikely since there are no combustible materials stored in this area, is addressed in Section 4.2.1.3 for a surface fire. Since this area is separated by significant distance from the TRUPACT-II unloading dock, with no combustible materials, propagation of a fire from this area into other areas is not considered a likely occurrence.

- Shielded Storage Room

  A shielded storage room provides for the temporary surface storage of CH TRU waste containers with surface dose rates greater than 100 mrem/hr. This room is shielded by concrete walls and can accommodate several seven-packs of drums. If a fire were to occur in this room, it would be contained by the fire barriers. A fire in this room external to the drums is addressed in Section 4.2.1.3.

- Site-Generated Waste Area

  This area is located in the WHB. It is provided for the handling of radiological waste produced on the site as a result of decontamination operations. There is also a liquid waste collection system that contains an accumulation tank for liquid radwaste. This area is not directly related to the CH waste handling process. The area is located in a separate room in the WHB, which is separated from other areas of the WHB by fire barriers. Access to this area is gained through an A/L from the CH bay. If a fire were to ignite in this area, the potential for it to propagate to the CH Bay is minimal since the area is enclosed by fire barriers.

- U/G Fuel Station (UFS) - The UFS is used to store diesel fuel needed to operate the vehicles used in the U/G area. This area, containing one fuel trailer with a steel tank (built to meet or exceed FHWA 36 CFR Part 393.67 fuel tank standards), is isolated by fire doors and equipped with a dry-chemical fire protection system. This area is located in a separate corridor approximately 1000 feet from the nearest waste storage area and 650 feet from the waste hoist shaft. Even if it is postulated that a fire ignited in this area, the fire would be contained within this area if the door to this area were closed. Even if a fire ignited at the time the door was open, it is unlikely that a fire could propagate to the waste storage rooms or to the waste hoist shaft because of the large distances and lack of combustible materials in the area.

- U/G Support Areas and Experimental Area - A workshop and warehouse area is located in the shaft pillar area at the storage horizon. The U/G support areas consist of a repair bay, a welding bay, a lubrication bay, an electrical shop, several parking areas, and a warehouse. These areas are located outside the RMA. The U/G support area is approximately 900 feet away and the experimental area is approximately 3300 feet away. There is sufficient distance between the areas so that if a fire were to occur in any of these support areas, it is highly unlikely that it would spread to the CH waste emplacement areas and cause a release of radionuclides.

- U/G CH Waste Storage Area - The U/G storage area has several panels each consisting of up to seven storage rooms. The storage rooms are separated by pillars of salt 100 feet wide and 300 feet long. There are panel entries at each end of these storage rooms. The vehicles that are used to transport the waste from the hoist to the U/G storage area are diesel powered. An unsuppressed fire in this area, which ignites on one of the vehicles, is postulated to propagate to the storage area and come in contact with the storage drums. The external fire scenario is discussed under accident category U2 in Section 4.2.1.3 and the IE frequency is calculated in Section 4.2.2.2.

- Exhaust Filter Building - The EFB contains banks of HEPA filters and support equipment that will be used to filter contaminated air from the U/G in the event of a release. The U/G ventilation system fans are located outside, adjacent to this building. A fire in the EFB could not initiate a release of radionuclides or propagate to the WHB because no waste is stored in or near the EFB, and there is sufficient distance (approximately 200 feet) between the buildings. In addition, the HEPA filters are Underwriter Laboratory Class 1 rated, which means they will not contribute fuel to a fire when subjected to a source of ignition, but may not maintain their filtering capability in a fire. The filter room is fully sprinklered. Therefore, a fire in the EFB is not analyzed as an accident initiator.

- Support Building - The Support Building is located adjacent to the WHB with a common main corridor between the buildings. The building houses general support services (administrative, operations control, technical support, and U/G personnel support functions) for all structures and activities at the WIPP facility.

The building is constructed of steel framing and sandwich panel siding. The interface with the WHB is separated by fire rated construction and fire doors. All areas of the Support Building contain sprinklers and manual hose reels. The Computer Room (CR) and Central Monitoring Room (CMR) contain Halon fire suppression systems. Two-hour fire walls with one and one-half-hour rated fire doors on each opening are included around the computer and CMR area. One and one-half-hour rated fire dampers are included for all duct penetrations through the fire walls. The Support Building CMR and computer do not serve any control functions for the waste handling process. They are strictly monitoring devices. The Support Building does not contain any CH waste so if a fire ignited in the Support Building, it could not initiate a radiological release. The potential for a fire propagating to the WHB from the Support Building is very low because of the building construction and the presence of fire barriers.

- Diesel Generators (DGs) - The DGs are the plant backup electrical supply. They will supply power to the plant facilities in the event electric power from the plant substation is unavailable. A postulated fire at this location would only disable the backup electrical power supply. This area is located approximately 100 feet from the RH side of the WHB and a fire propagating from the DGs to this area would not be likely since the area between the buildings does not contain any combustible materials. Since this is a backup power supply, these DGs would not normally be operating; power to the electrically powered waste handling equipment would be supplied from the plant substation.

- Water Pumphouse - The water pumphouse is located adjacent to two water storage tanks. The pumphouse contains the fire pumps and the electric domestic water pumps as well as space for water chlorination equipment and chemical storage. It is an aboveground facility with a steel frame and siding located approximately 300 feet from the WHB. The building contains a wet pipe sprinkler system, portable fire extinguishers, and hose reels. A fire in the water pumphouse could not initiate a release of radionuclides because no waste is stored in or near the water pumphouse. Propagation of a fire from the pumphouse is not considered credible because of the distance to the WHB and there is no combustible material located between the buildings. Therefore, a fire in the water pumphouse is not analyzed as an accident initiator.

- Compressor Building - The compressor building provides weather protection for the two air compressors that provide compressed air to the WHB. An air receiver is also housed within the building. This building is an aboveground, steel frame and siding building located approximately 50 feet west of the Support Building. The compressed air system operates the dampers in the WHB HVAC system. A fire in the compressor building does not impact the waste handling process and would not initiate a radiological release since waste is not stored or handled in or around this building. Additionally, propagation of a fire from this building to the WHB is not considered credible since both of the buildings are of steel construction and the area between them is approximately 50 feet with no combustible material located between them.

- Guard and Security Building - The guard and security building is located on the west side of the WIPP facility. It contains the security control station and office area, an auditorium, a visitor's information center, a lunch room, a kitchen, and locker and toilet facilities. This building is located approximately 300 feet from the WHB. This building is not related to the waste handling process, so given a fire in this area, there is no chance for a radiological release. Because of the distance from this building to any area containing CH waste, it is not probable that a fire could propagate outside of this structure and initiate a radiological release.

- Electrical Substations - There are several electrical substations that supply power to the WIPP facility. Two of these substations, Substations 4 and 5 are located on the north side of the site and do not supply power to any critical functions of the CH waste handling process. These substations are eliminated from the analysis on this basis. Substation 2 is located near the compressor building. Although Substation 2 supplies power to the WHB HVAC system, a fire at the substation could not precipitate an accident. In addition, its location does not present any danger of a fire propagating to the WHB. Substation 1 is located near the WHB on the RH side. A fire at this substation will not propagate to the WHB since the building construction of both the substation and the WHB is noncombustible construction and there are no combustible materials stored between the substation and the WHB. Furthermore, loss of power to Substation 1 could not result in a release of radioactive materials to the environment.

The plant substation is located near the north boundary of the site that is over 1000 feet from the WHB. Therefore, a fire in the plant substation will not propagate to the WHB. Loss of power due to fire in the plant substation could shut down critical systems but would not be capable of initiating a radiological release as explained for individual substations below.

Substation 3 provides power to the EFB HVAC system and the waste hoist. A fire in this substation could result in an LOP to both the waste hoist and the EFB. Although the EFB HVAC system is used to filter air from U/G in the event of a radiological release, an LOP to this building or the HVAC system could not initiate a release of radionuclides. Also, an LOP to the waste hoist would not initiate a radiological release. The waste hoist operation would stop and the brakes would be applied to prevent the hoist from free wheeling up the shaft. LOP events are discussed in Sections 4.2.1.3 and 4.2.2.1. Propagation of a fire from Substation 3 to the WHB is not a likely event. The substation is located next to the EFB and because of the building construction and distance from the WHB, it is not likely that a fire could propagate from this substation to the WHB.

Fire traveling from any of the substations via interconnecting cables is not considered to be a probable event. All building penetrations (including cable penetrations) are protected by fire barriers.

- Telephone Building - The Telephone Building does not affect any control function of the waste handling process. A fire in this building would not initiate any type of radiological release and the potential for propagation to the WHB is not considered to be a credible event.

The results of the screening process indicated that a fire in most support areas related to the CH waste handling process will not initiate a release of radionuclides.

Analysis of External Events and Other Accidents

No external events were included in the analysis. The external event initiators that were screened out in this risk assessment included tornadoes, earthquakes, lightning, thunderstorms, flooding, and range fires.

- Tornadoes - The WIPP FSAR states that the WHB is designed to withstand the design basis tornado with 183 mph winds. The FSAR further states that it is highly improbable that a single missile can penetrate both the WHB structure and waste drums stored inside the building. Since the facility is designed on a single failure basis, the probability of two missiles, one breaching the building and one damaging the drums, was not analyzed. Therefore, it is assumed that a tornado cannot damage waste drums inside the WHB.

  Although a tornado crossing the top of a shaft could damage the HVAC system, it cannot cause a release of material U/G. Therefore, a tornado cannot be an initiator of an U/G breach of drums accident.

  According to the FSAR, Section 1A.1.1.3, tornado damage to Type B containers (i.e., TRUPACT-IIs) "is anticipated to be less severe than postulated transportation and handling accidents, so that the allowable exclusionary boundary limit would not be exceeded."

  Since no credible accident scenario initiated by tornadoes exists for the WIPP facility no tornado event tree has been developed.

- Earthquakes - The maximum ground acceleration for the DBE for the WIPP was 3.2 in/sec^2 (or 0.1g) horizontally and vertically with 10 maximum stress cycles. The structures and components at the WIPP analyzed for the effect of a design basis earthquake (DBE) include surface confinement facilities and equipment, CH waste handling and emplacement equipment, and U/G facilities directly related to the CH waste handling and emplacement process, as follows.

  WHB Structure - According to the WIPP FSAR, the WHB confinement boundary including the hoist tower and the tornado resistant doors are designed to withstand the DBE. The CH unloading overhead crane is designed to hold its load in place in the event of a DBE.

  According to the FEIS, Section 9.5.3.1 "All surface buildings and systems that are essential for the safe handling of radioactive waste are designed to withstand the earthquake-induced ground movement that may be expected to occur at the site during the operational life of the repository. Accordingly,

earthquake-induced releases of radioactivity to the environment are not likely." In addition, the FEIS states, "several Japanese investigators measured earthquake acceleration simultaneously at the depth and surface. The results of these investigations indicated that U/G motion was four to six times less than that at the surface . . . It is therefore expected that for the peak surface accelerations predicted for the WIPP site (0.1 g to 0.2 g), little or no damage to U/G facilities will occur."

Since a DBE would not initiate an off-site release of radiological materials, an earthquake event tree was not developed nor were additional analyses performed for an earthquake as an external IE at the WIPP.

- Lightning - A direct lightning strike to the WIPP site could initiate an LOP (either site wide or local). If power were lost to the waste hoist, the waste hoist braking system would be required to function properly to prevent free wheeling of the conveyance. This scenario is included in Section 4.2.2.1, in the event tree for LOP to hoist motor causing U/G release of radiological materials.

  TRUPACT-IIs are not left outside the WHB unless they are still on their trailers. Since all the trailers and the forklift that would carry the TRUPACT-IIs into the WHB are grounded, a direct lightning strike would not damage the TRUPACT-IIs and cause a radiological release. Therefore there is no event tree for this scenario.

  Lightning could also induce a fire aboveground. However, all WIPP waste handling operations apart from moving TRUPACT-IIs occur indoors. All WIPP buildings are equipped with lightning arrestor systems that are designed to dissipate or ground lightning strikes.

  For these reasons, a fire induced from a lightning strike is not considered to be a threat to the WIPP waste handling operations.

  Lightning would have no direct effect U/G, except to cause a loss of electrical power. Since the loss of electrical power cannot cause a release of radioactive materials (except as referred to above) no additional event trees (beyond those identified above) were developed for lightning as an external IE.

- Thunderstorms - Thunderstorms, with their associated high winds, heavy precipitation, and hail can be a source of potential destruction. The damage, however, would be expected to be less than that caused by tornadoes. All structures essential to safe operations are designed to withstand high winds. As a result, the winds, hail, and precipitation would cause no greater threat to site structures.

- Flooding - The nearest perennial stream to the WIPP site is the Pecos River, which is 14 miles away and the site is located 400 feet above the floodplain. Any flooding of this river will thus have no effect on the WIPP site. At the site only occasionally does a severe storm produce enough rain to cause water to flow over the ground surface. The site has been engineered so that liquid released from a local tank rupture will not result in a flood of sufficient depth to endanger WIPP safety equipment or systems. In conclusion, flooding does not pose any threat to the WIPP facility operation.

- Range Fires - The arid climate and desert vegetation of the region do present the potential of range fires in the area surrounding the WIPP site. During operations, such a range fire would not be expected to cause extensive damage to the WIPP structures because of the buffer zone afforded by clearing vegetation from Control Zone I and the fire protection systems employed at the site. Any impacts of range fires on facility operation and risk to the public are considered to be insignificant.

Other external events such as plane crash and meteor strike are considered noncredible and therefore not analyzed.

4.2.1.3 Mitigation Systems

A summary of mitigation systems discussed in this section is presented in Table 4.2-4.

WHB HVAC

The WHB HVAC functions required to prevent an off-site release during an accident are:

- To filter radioactive particulates from the exhaust air in the event of an accident
- To maintain building in-leakage (i.e., negative pressure)

Automatic Functions Required During Accident: None Required - System Continually Operating

Operator Actions Required During Accident: None Required - System Continually Operating

If the system fails during operation, the operator may have some options for alternative actions or to repair the system. These actions, however, are not modeled as part of the PRA, unless they are explicitly called out in the procedures.

- Support Systems

  Electrical Power

  - For fan operation
  - For continuous air (radiation) monitors
  - For A/L interlocks

  Compressed Air

  The loss of compressed air results in the closure of HVAC air control dampers. This is explicitly modeled within the fault tree for this system.

- Functional Criteria

  WB1 is defined as the successful filtering of WHB air through the HEPA filters, thus preventing the release of significant amounts of airborne radionuclides from an accident directly into the atmosphere. Some of the failures implicit in WB1 result only in termination of HVAC flow and loss of negative pressure in WHB, causing minor leakage. These failures are included in WB1 for conservatism.

Exhaust Filter Building - U/G Filtration System

The primary function of the U/G filtration system is to filter radioactive particulates from the U/G exhaust air in the event of an accident.

Operability of U/G booster fans is not required for preventing or mitigating an off-site release following a release initiator, and these fans are normally not used.

Automatic Functions Required During Accident: The EFB U/G filtration system is activated by an alarm on two separate CAMs that monitor the U/G, or by an alarm on the CAM that monitors the air exiting the U/G. These automatic functions are adequate to provide off-site protection, and are explicitly modeled as part of the EFB Underground Filtration and Ventilation System (UFVS) system analysis.

Operator Actions Required During Accident: None Required - System will actuate automatically.

If the automatic operation fails, the operator may have some options available for alternative actions. These are not modeled unless explicitly identified in the procedures.

- Support Systems

  Electrical Power

  - For fan operation
  - For radiation monitors

Compressed Air

The loss of compressed air results in the closure of HVAC air control dampers. This is explicitly modeled within the fault tree for this system.

Radiation Monitors

- CAMs (Underground)

- Effluent monitoring system (EMS) CAMs at exit from U/G

- Functional Criteria
  UF1 is defined as successful filtration through the EFB HEPA filters, thus preventing the release of significant amounts of airborne radionuclides from an accident directly into the atmosphere.

  UF2 is defined as successfully preventing significant airborne radionuclides from leaving the U/G through the EFB or any other shaft in the event of a fire U/G, thus preventing the release of significant amounts of radionuclides from an accident directly into the atmosphere.

Fire Detection and Suppression System

The FDSS functions are to:

- Monitor critical areas of the WIPP site, detect a fire, and provide suitable alarms to plant personnel

- Suppress a fire to protect aboveground and U/G facilities

The following major components of the FDSS are applicable to the CH waste handling process:

- Portable extinguishers, manual hose reels, and fire truck (above and below ground)

- Sprinkler System

- Dry chemical (UFS and U/G diesel - driven vehicles)

Automatic Functions Required During a Fire: The Sprinkler System and Dry Chemical System have automated actuation features from the various sensors involved. The suppression functions of these systems are designed to extinguish a fire prior to major damage occurring and are explicitly modeled as part of the system analysis. Thus, for Sprinkler and Dry Chemical Systems, actuation is assumed to provide protection resulting in no damage to CH Drums.

Operator Actions Required During Accident: Sprinkler and Dry Chemical Systems will actuate automatically. In addition, the dry chemical can be activated manually.

The means of fire suppression at the WIPP are the automatic actuation of a fire suppression systems and manual fire suppression. As in any facility operation, however, it is likely that manual incipient fire suppression activities will be conducted by personnel discovering the fire. Personnel involved in the CH waste handling process and personnel involved in U/G operations are trained in the use of portable fire extinguishers. Even though such manual activities do not constitute primary fire suppression methods, because these actions may occur before activation of the automatic system, they are modeled first in the event trees.

- <u>Support Systems</u>

  Manual Methods (above and below ground)

  - Human or CMR detection of fire

  - Water for manual hose reels

  Fire Water Distribution

  - Water for distribution

  - Electricity for motor driven fire pump

- Diesel fuel for diesel-driven pump
- Heat (from a fire) to activate sprinklers

Dry Chemical System

- Heat (from a fire) to activate the thermal detectors

- Functional Criteria

MAG is defined as the successful suppression of a fire aboveground using manual means prior to damage to the waste drums.

MUG is defined as the successful suppression of a fire U/G using manual means prior to damage to the waste drums.

FW is defined as the successful suppression of a fire by the Fire Water System prior to damage to the waste drums.

CUG is defined as the successful suppression of a fire by the Dry Chemical System prior to damage to the waste drums.

See Table 4.2-4 for mitigation system summary for risk quantification.

4.2.1.4 Key Modeling Assumptions

- Movement of waste on the hoist is a dedicated operation. Personnel and CH waste will not occupy the hoist at the same time.

- No maintenance will be performed on any part of the waste hoist system while CH waste is loaded on the hoist.

- It is assumed that only waste that meets the appropriate acceptance criteria, as described in Rev. 3 of the WIPP WAC, will be shipped to the WIPP site.

- This analysis evaluates only that portion of the WIPP plant involved in the CH waste handling process.

- The structures at the WIPP site meet the design requirements specified in the WIPP FSAR regarding earthquakes, tornadoes, and other natural phenomenon.

- TRUPACT-IIs meet the appropriate design criteria for NRC Type B containers. It is beyond the scope of this study to assess the ability of TRUPACT-IIs to meet appropriate design and licensing requirements.

- The waste hoist headframe is designed to withstand the force of a crash of a loaded hoist conveyance (i.e., the hoist conveyance could crash into the headframe and sustain damage but it is assumed it could not push the headframe out through the roof of the hoist tower).

- It is assumed that each of the fire suppression systems is sized to suppress a fire postulated to occur in that area.

- The waste hoist motor and the EFB HVAC system are both powered via connections at waste hoist Substation. LOP to or failure of both buses of Substation 3, then, would cause both the waste hoist motor and the EFB HVAC system to fail. If the hoist brakes failed, after a catastrophic failure of Substation 3, no filtration of radionuclides released from a loaded hoist drop would be available. However, the LOP to the EFB HVAC system also would stop U/G ventilation, therefore, there would be no driving force to bring radioactive particulates to the surface and no off-site radioactive release.

- Sabotage is beyond the scope of this analysis.

- The overpack and repair room and enclosure each have their own HVAC system with HEPA filters. The analysis of this system is bounded by the WHB HVAC analysis.

- In the event of any emergency condition on or near the waste hoist (such as a fire alarm), the operator will either stop the hoist using the E-stop (the hoist will remain stopped until the unsafe condition has been corrected), or the spring-

activated hoist operator handle will automatically place the control handle in the controlled stop position.

- Transportation of CH waste to the WIPP site is beyond the scope of this analysis. An independent risk assessment of transportation of CH waste to the WIPP site was conducted and the results have been incorporated into Section 5.2.2 of the Final SEIS.

- According to waste handling procedures, drums found to be contaminated externally are removed from the TRUPACT-II in the overpack and repair enclosure and packed inside an overpack drum. These overpack drums are then transported to the U/G storage area. It is assumed these drums are not transported U/G on a pallet with other waste drums.

- It is assumed that adequate surge protection exists to protect the waste hoist braking system from random or lightning-induced power surges.

- The mission time for accident scenario evaluation is assumed to be eight hours. This mission time is conservatively estimated for the accident scenarios as one shift, eight hours in length. This time is not related to the life of a postulated fire, which would be shorter.

- For the fire analysis, it is assumed that penetrations through fire barriers are adequately addressed.

4.2.2 ACCIDENT SEQUENCE EVALUATION

4.2.2.1 Event Tree Development

Event trees were developed for each accident category in order to perform the accident sequence evaluation and identify sequences and consequence categories. Each of these event trees is described in detail in the following subsections.

Aboveground Breach of Drums Event Tree - A1ET

Event Tree Top Events

- Initiator - Aboveground Breach of Drums - A1

  In this initiator, drums of CH waste are damaged while in the WHB, during the unloading of the TRUPACT-II container or while being transported on the facility pallet to the hoist. This accident scenario includes accidents Q1 and Q2 (described in Section 4.2.1.3), drums dropped from forklift and drums punctured by forklift. The event tree for A1 is shown in Figure 4.2-1.

  When actually preparing to move the loaded pallet, the forklift operator is aided by at least one spotter. Additionally, since the transfer of waste drums to the storage rooms U/G will not be an "assembly line process," and thus not quickly handled, the forklift is moved slowly and deliberately. The deliberate pace at which the process proceeds, coupled with the presence of at least one spotter, makes these accidents unlikely, but the accident is analyzed to assess the result.

  Either of these accidents would result in the release of radionuclides from the waste into the atmosphere in the WHB. In order to prevent a significant release off-site, the WHB HVAC system would be required to operate.

- WHB HVAC Filtration - WB1

  The WHB HVAC filtration system functions as required to filter radioactive particulates from the exhaust air. The WHB air is normally vented through the HEPA filters so there is no switchover action or actuation required. This results in a filtered release.

Success Criteria

If the WHB HVAC Filtration mode remains operational, no unfiltered release will occur (Release category FR3).

Accident Sequences

Failure of WB1 will result in an unfiltered release from the WHB. For this accident scenario, three drums are assumed to have been breached (Release category R3D).

Aboveground Fire Event Tree - A2ET

Event Tree Top Events

- Initiator - Fire Aboveground - A2

  In this initiator, drums of CH waste are damaged by an external fire in the CH bay. This scenario includes accident Q3 (described in Section 4.2.1.3). The waste drums are assumed to be exposed to the fire after they have been removed from the TRUPACT-II and before they are removed from the CH bay. The event tree for this scenario is shown in Figure 4.2-2.

  Because of the lack of combustible materials stored in the CH bay, the effects of the fire are assumed to be limited to causing the contents of one drum to burn and two other drums bursting open (but not burning) due to the heat.

- Fire Suppression - Manual (Aboveground) - MAG

  The most probable means of fighting fires in the WIPP facility involves the use of appropriate manual equipment. Therefore, the manual suppression mode is modeled first. In the CH bay, manual means of fire suppression include portable extinguishers, located on the walls, and manual hose reels. Success of the manual fire suppression results in no release (NR) (see Figure 4.2-2).

- Fire Suppression - Water - FW

  If the fire is not suppressed by manual means, the sprinkler system in the CH bay of the WHB will be automatically actuated when the increased temperature from the fire causes the in the sprinklers to open. Success of the sprinkler system is dependent upon success of the Fire Water System to provide water to the sprinkler heads. Success of this node results in NR.

- WHB HVAC Filtration - WB1

  If the fire is not suppressed, radionuclides are assumed to be released into the WHB. The WHB HVAC filtration system functions as required to filter radioactive particles from the exhaust air. The WHB air is always vented through the HEPA filters so there is no switchover action or actuation required. Success of this node results in a filtered release.

Success Criteria

If either MAG or FW succeed, NR occurs.

Accident Sequences

If both of the fire suppression modes fail, radionuclides will be released into the WHB. If, however, WB1 succeeds, the radionuclides will be filtered through the HVAC system (FR3). Failure of WB1 results in an unfiltered release to the atmosphere (R3D). (Although both scenarios A1 and A2 result in damage to three drums of waste, A2 is expected to release 25 percent of each of two drums (no burning of contents) and 25 percent of the contents of one other drum will burn. Since these consequences are more severe than those of A1, R3D and FR3 will be defined as the consequences of A2.)

U/G Drum Failure (Storage Room) Event Tree - U1BET

Event Tree Top Events

- Initiator - U/G Drum Failure (Waste Storage Room) - U1B

  In this initiator, waste drums in the waste storage rooms are assumed to be damaged by handling equipment. This scenario includes accidents Q4, Q5, and Q6, transporter hits pallet in the hoist, drum drops from forklift, and other equipment punctures drum (These accidents are described in more detail in Section 4.2.1.2). The event tree for U1BET is shown in Figure 4.2-3.

When actually preparing to remove the pallet from the hoist or the seven-pack from the transporter, the transporter or forklift operator is aided by at least one spotter making these accidents unlikely, but still credible.

Any of these accidents would result in the release of radionuclides from the waste into the atmosphere in the waste storage rooms U/G. The effects of this scenario are assumed to be the same as that of A1, except U/G. In the absence of personnel actions, the U/G release must be detected by airborne particulate monitors and the EFB UFS would be required to operate.

- U/G Filtration System - UF1

  The UFS functions to filter radionuclides from the U/G exhaust air before it is released to the atmosphere. The filtration of U/G exhaust at the EFB depends on the detection of radiation in the exhaust flow and successful switchover to the filtration mode. Success of UF1 results in a filtered release. Failure of UF1 results in an unfiltered release of radionuclides to the atmosphere.

Success Criteria

If UF1 succeeds, a filtered release occurs (FR3).

Accident Sequences

Failure of UF1 results in an unfiltered release to the atmosphere (R3D).

U/G Fire (Waste Storage Room) Event Tree - U2ET

Event Tree Top Events

- Initiator - U/G Fire (Waste Storage Room) - U2

  In this initiator, waste drums are damaged in a fire in the storage room U/G. This scenario includes accident Q7 (described in Section 4.2.1.3), external fire U/G. The event tree for this scenario is shown in Figure 4.2-4.

In Q7, an external fire is assumed to start in the neighborhood of the stored waste drums in the U/G facility. Since the transporter is required by procedures to be parked at least 30 feet away from the array of drums or around the corner of a drift, and all U/G vehicles have a governor restricting speed to no more than 12 mph, a vehicle collision is not considered to be a high probability event. An engine fire in the transporter, however, could initiate this accident.

According to the FEIS, it is assumed that if a fire is not suppressed, 90 drums of waste would be damaged, burning all combustible material in each of the 90 drums.

- Fire Suppression - Manual (Underground) MUG

  If such a fire did start, fire suppression using manual methods, fire extinguishers on each vehicle and on the walls, is assumed to be the initial response. Success of this system would result in NR of radioactive materials. If MUG fails, CUG would need to be addressed.

- Fire Suppression - Dry Chemical - CUG

  If MUG fails, the dry chemical system on the U/G vehicle would be required to suppress an engine fire. Success of CUG results in NR. Failure of both MUG and CUG results in a release of radionuclides U/G.

- U/G Filtration System - UF2

  The filtration of U/G exhaust at the EFB depends on the detection of radiation in the exhaust flow and successful automatic switchover to the filtration mode (for conservatism, manual activation of filtration was not considered). Success of UF2 results in a filtered release. Failure of UF2 results in an unfiltered release of radionuclides to the atmosphere.

Success Criteria

If MUG succeeds, no release will occur.

If CUG succeeds, no release will occur.

Accident Sequences

If both MUG and CUG fail, UF2 is addressed. Success of UF2 results in a filtered release of the material from 90 drums (FR90).

Failure of MUG, CUG, and UF2 results in an unfiltered release of the material from 90 drums to the atmosphere (R90).

Loss of Power (to Hoist Motor) Event Tree (Underground Release) - LPUET

Event Tree Top Events

- Initiator - LOP - Failure of Drums - LPU

  In this initiator, a LOP is assumed to occur and cause a loaded hoist to crash into the headframe, damaging the drums in the hoist. This scenario includes accident Q8. The event tree for this scenario is shown in Figure 4.2-5.

  In this initiator, the Waste Hoist is assumed to be near the storage horizon and is assumed to have been loaded with a full facility pallet, 28 drums, when it suffers a failure due to a LOP, followed by a failure of the waste hoist braking system (the LOP to the hoist could be caused by lightning, fire, or by a random LOP). The hoist travels upward (due to the weight of the counterweight), hits the headframe, and drops the contents of all 28 drums around and down the waste shaft. The force of the fall causes all 28 drums to break, releasing 100 percent of their contents.

- Hoist Braking System - HB

  The LOP cannot cause the hoist brakes to fail, but they are required to engage to prevent the hoist from travelling freely up the shaft. If the brakes engage properly, the hoist stops at its current position and no release occurs. If HB fails, the availability of the U/G filtration system must be addressed.

- U/G Filtration System - UF1

  If this accident were to occur, the only means of filtering the radionuclides and, thus, mitigating the effects of this accident is the U/G filtration system. The filtration of U/G exhaust at the EFB depends on the detection of radiation in the exhaust flow and successful switchover to the filtration mode. Success of UF1 results in a filtered release. Failure of UF1 results in an unfiltered release of radionuclides to the atmosphere.

Success Criteria

Success of HB results in no release.

Success of UF1 (after failure of HB) results in a filtered release (FR28).

Accident Sequences

Failure of both HB and UF1 results in an unfiltered release of radionuclides to the atmosphere (R28).

Table 4.2-5 identifies the accident sequences by consequence category.

4.2.2.2 Calculation of Initiating Event Frequencies

Initiating Event Frequency for A1 - Breach of Drums Aboveground

The IE A1, Breach of Drums Aboveground, includes accidents Q1 and Q2, as explained in the event tree development section. In Q1, a seven-pack is knocked over or knocked off the pallet by the forklift in the CH bay. In Q2, a seven-pack is punctured by a forklift in the CH bay.

Each waste shipment is assumed to consist of the maximum load of three TRUPACT-IIs (each containing two seven-packs). Three TRUPACT-IIs will require two pallets, but for conservatism we will assume that an average of three pallets will be handled and transported U/G each day (one pallet at a time). In addition, it was assumed that CH waste will only be handled five days per week.

In all CH waste handling operations in the CH bay at WIPP, there is at least one spotter, in addition to the forklift driver, actively involved in the process of helping to handle the waste. As explained above, a pallet loaded with waste will only be handled by a forklift an average of three times per day (in an eight hour shift). This is not, therefore, a rushed process. (In addition, all vehicles associated with the CH waste handling process are equipped with governors that restrict their speed to no more than 11.9 mph. This feature helps prevent the inadvertent running of the forklift at an unsafe speed.) The forklift driver is operating in a normal, low stress environment.

Accounting for each of these factors in the calculation of the IE frequency yields the calculations and results described below.

Probability of operator failing to complete a two step process from oral instructions (the two steps being picking up the pallet and placing the pallet down - Q1, and picking up a seven pack from the transporter and putting it down - Q2) (Reference 8 - Table 20-8, mean value used) is conservatively determined to be as follows:

P(fl) = 5.0E-3 failures per forklift operation

Failure of spotter to correct forklift operator error is determined to be

P(sp) = 1.0E-2 failures of spotter to correct, per action

Number of loaded pallets moved per year (three trips/day * five days/week * 50 weeks/year) (10 holidays assumed)

T = 750 loaded pallets moved per year

F(Q1) = [P(fl) * P(sp)] * T = 0.038/year
F(Q2) = [P(fl) * P(sp)] * T = 0.038/year
F(A1) = F(Q1) + F(Q2) = 0.075/year

F ( ) in this equation represents the frequency of the specific initiating event or group of initiating events.

Initiating Event Frequency for A2 - Aboveground Fire

The initiator in A2 is accident Q3, combustible material pools around the CH waste drums, ignites, and causes the combustible material in one drum to burn and two other drums to burst from the heat. All the vehicles used in the CH bay are battery operated and no diesel or other flammable materials are stored or used in the CH bay area. This is a clean area with no smoking allowed; no oily rags or loose papers are lying around. It is extremely unlikely, therefore, that a fire capable of causing the waste to burn could start in the CH bay.

Considering human factors, the analysis assumes that such a fire could start through a series of unknown, unidentified, ill-considered activities that go unchecked or uncorrected. Since there is no credible way to introduce flammable fuel into the CH bay under normal circumstances, identifying specific activities leading to this event is not plausible. Fires can be initiated by combinations of fire sources and human interaction. Many fires are caused by human activities as well as component failure. To account for events that include a combination of unforeseen human activities, the frequency of a fire associated with HE, 3.0E-2 per year (Reference 9) is assigned for failure to follow proper procedures and a probability of 0.1 (engineering judgment) is assigned that this action is not corrected. We will thus estimate the frequency of this unknown series of activities involved in a fire initiation as 3.0E-3 per year.

Initiating Event Frequency for U1B - U/G Breach of Drums

This initiator, U1B - U/G Breach of Drums, includes accidents Q4, Q5, and Q6. In these accidents, seven-packs of waste are knocked off the transporter, punctured or have their lids pulled off by the U/G forklift, or are damaged by any other equipment while the drums are U/G.

For this analysis an average of three pallets of waste per day (one eight hour shift per day, five days per week) will be transported to the U/G storage room. The transporter would be required to remove a pallet from the waste hoist three times per day (750 times per work year). In order to remove a pallet from the hoist, the transporter is backed up to the hoist cage and a large fixed hook on the bed of the transporter (attached to a horizontal hydraulic screw in the transporter bed) is attached to the side of the pallet. After the hook

is attached, the hydraulic screw is turned, causing the hook to move up the transporter bed dragging the pallet onto the bed.

The transporter driver is assisted by at least one spotter while backing up to the hoist. There is only one way to attach the hook to the pallet; once the hook is attached, the pallet is pulled onto the transporter. Because of the hook and the raised sides of the transporter bed, the pallet cannot fall off the transporter once it is hooked on.

The failure mode for this accident (Q4), then, is the transporter backing up and hitting the pallet, causing the drums to fall from the pallet and to sustain damage.

Probability of the driver failing to carry out an oral instruction (back up to the hoist properly) (Reference 8 - Table 20-8)

P(bu) = 1.25-3 failures per backup operation

Probability of spotter failing to correct driver's error (see Section 4.2.2.2) is judged to be

P(sp) = 1.0E-2 spotter failures per operation

Probability that the transporter hitting the pallet will cause the drums to fall and break (drums are held down with nylon tie-downs and the transporter is geared so that it cannot travel more than 12 mph) is conservatively estimated to be

P(dm) = 1.0E-1

Number of times transporter must pick up pallets per year

T = 750 pallets unloaded per year

P(Q4) = [P(bu) * P(sp) * P(dm)] * T = 9.4E-4/year.

The value for P(dm) is based on engineering judgment by the assessment team.

In accident Q5, the U/G forklift knocks over a seven-pack of drums or pulls the top off of the drums in the lower seven-pack while trying to lift the top seven-pack. While unloading

the pallet in the waste storage room, the forklift driver is assisted by a spotter and the transporter driver. This scenario would be the same as that of accident Q1 (A1), except there are two spotters and there can be as many as four seven-packs to each pallet.

Probability of the forklift driver failing to carry out a two step oral instruction (the two steps being picking up and placing down a seven-pack of drums) (Reference 8 - Table 20-8)

P(fl) = 5.0E-3 failures per unloading operation

Probability of neither assistant correcting the error (for conservatism, no credit is taken for the second spotter, see Section 4.2.2.2) is determined to be

P(sp) = 1.0E-2 spotter failures per unloading operation

Number of seven-packs needing to be picked up

T = 750 * 3 = 2250 seven-packs moved per year

P(Q5) = [P(fl) * P(sp)] * T = 0.11

In accident Q6, another piece of equipment causes damage to the waste drums. During normal operation, no other equipment is expected to be in the waste storage rooms. For conservatism, we will postulate that twelve times per year (once per month) other equipment is in the storage room (maintenance equipment, etc.).

Since we do not know what other kind of equipment would be in this room, we will assume the operator fails to perform the intended function with the same probability as P(fl) above

P(xx) = P(fl) = 5.0E-3 failures per other equipment usage

Probability that operator causes damage to the waste drums while failing to perform intended function is conservatively estimated to be

P(dm) = 1.0E-1 failures per intended function performed

Number of times other equipment is in waste storage rooms

T = 12 times other equipment in storage rooms per year

P(Q6) = P (xx) * P(dm) * T = 6.0E-3

P(U1B) = P(Q4) + P(Q5) + P(Q6) = 9.4E-04 + 0.11 + 0.006 = 0.12

The value for P(dm) is based on engineering judgment by the assessment team.

Initiating Event Frequency for U2 - U/G Fire

The IE, U2 - U/G Fire, corresponds to accident Q7. The scenario for this event is a fire in the waste storage room, external to the drums, of sufficient size to cause the combustible contents of 90 drums to burn and release contamination into the U/G storage area.

Fires in the waste storage area could be initiated by fires on the transporter or by fires on the fork lift (vf) near the drums that have already been placed in the CH storage rooms (approximately 90 drums are assumed to burn in an unsuppressed fire or by a random fire due to unspecified human actions). Flammable material is not expected to be present in the vicinity of the drums and diesel oil spills are not expected to ignite. Hence, a fire spreading from causes unrelated to the transporter and the forklift would only result from a gross breakdown of administrative control (such as storing or leaving combustible material in the vicinity of the drums), [defined as F(rf)]. The frequency of the U/G fire, therefore, is equal to the frequency of a vehicle fire plus the frequency of a random propagating fire (F(U2) = F(vf) + F(rf).

- Frequency of Vehicle Fire

  The fire risk associated with the transporter and fork lift are postulated only for that period of time when either vehicle is used to transport the drums. If drums are not being transported, the vehicles will be moved out of the immediate storage area. These vehicles are assumed to be in operation five days a week for 50 weeks (ten holidays assumed). It is assumed that there will be three trips of 45 minutes each per operation day. Hence, the fraction of each year that the drums are being moved by the vehicles T(vh) is:

T(vh) = 0.75 hours/trip x 3 trips/8 hours x 40 hours/week x 50 weeks/year / 8760 hours/year = 6.4E-2.

The frequency of a vehicle fire, F(vf), is derived from truck fire data taken from the National Fire Protection Association (Reference 11) and from the American Trucking Association (Reference 12). F(vf) is calculated to be 1.3E-3. This includes engine fires as well as collisions. If a fire starts on the vehicle, the fire suppression system on the vehicle would be initiated. A truck fire could occur while the transporter is moving to the waste storage room and thus would only affect the 28 drums on the transporter. For conservatism, however, all truck fires are assumed to occur while the transporter is in the Waste Storage Room. Such a fire could damage 90 drums of waste.

The probability of successful fire suppression, which applies only to the vehicle fire, is included here in the appropriate portions of the calculation. From Section 4.8, the unavailability of the vehicle dry chemical system (CUG) is:

$\overline{CUG}$ = 2.7E-2

In nuclear plant fire analyses, it has been found that unless manual fire suppression is initiated within minutes (if the automatic suppression system fails), the probability of successful suppression is very low. Since the WIPP first response team is expected to reach the site of a fire within approximately ten minutes (provided it has been alarmed), the probability of failure of fire suppression using manual means (MUG) is derived in Section 4.8 and is:

$\overline{MUG}$ = 3.4E-2

Therefore, the probability of unsuccessful fire suppression is

F(fs) = 0.027 x 0.034 = 9.2E-4 per fire

- <u>Frequency of a Random Fire (rf)</u>

Because of the lack of flammable materials in the vicinity of the waste drums, a fire unrelated to the U/G vehicles could only result from a breakdown of

administrative control. Further, this fire would have to propagate to the site of the waste drums to cause damage. As is explained in Section 4.2.2.2, the Fire Initiator, a random fire caused by unspecified, inappropriate human actions, F(hm), is assigned a frequency of 3.0E-2/year. This value must then be combined with the frequency of additional inappropriate unchecked human actions allowing the fire to propagate to the waste drums F(hp). The frequency of the random fire is then

$$F(rf) = F(hm) * F(hp)$$
$$F(rf) = (3.0E\text{-}2) * (3.0E\text{-}3) = 9.0E\text{-}5/year$$

The fire described above includes both a random fire caused by inappropriate human actions, and propagation of that fire. This type of fire, however, is not subjected to the vehicle fire suppression system since it is not a vehicle fire. It is also not considered feasible to take credit for manual fire suppression system use. For these reasons, this aspect of the fire cannot be multiplied by the unavailability of the fire suppression systems. Thus the frequency of the U/G fire is the frequency of the vehicle fire (multiplied by the unavailability of the fire suppression systems and the portion of time the waste would be on the U/G vehicle) plus the frequency of the random fire that propagates (such a fire is not subject to suppression, and could be started any time of the day or night, as a result of some unanticipated action, even when the facility is not in operation). The total frequency is as calculated below.

$$F(U2) = T(vh) * [F(vf) * F(fs)] + F(rf)$$

$$F(U2) = [6.4E\text{-}2 * 1.3E\text{-}3 * 9.2E\text{-}4] + 9.0E\text{-}5 = 9.0E\text{-}5/year$$

<u>Initiating Event Frequency for LPU - Loss of Power Causes Failure of Hoist (underground release)</u>

Accident Q8 could occur as a result of this IE, LOP to the waste hoist tests the hoist brakes. If the hoist brakes fail, the hoist will be pulled into the headframe and drums could break open. The accident results in a release of radioactive material in the waste shaft and U/G, since the waste shaft air is vented through the U/G Ventilation System.

The LOP to the hoist motor and controls includes the frequency of loss of off-site power, component failures and fires in electrical components, since any of these events would require the waste hoist brakes to set to prevent the accident from progressing. A small fault tree was constructed and quantified to calculate the LOP frequency due to the first two contributors above.

The FTA is based on a mission time of 187.5 hours per year. This is the estimated yearly time the waste hoist would be carrying CH waste, according to the following calculation:

> The waste hoist is assumed to be in operation carrying CH waste 45 minutes per day (3 trips/day * 15 minutes/trip), 250 days per year.
>
> Therefore, the number of hours per year the hoist is carrying CH waste is:

$$45 \frac{\text{minutes}}{\text{day}} \times \frac{1 \text{ hour}}{60 \text{ minutes}} \times \frac{5 \text{ days}}{\text{week}} \times \frac{50 \text{ weeks}}{\text{year}} = 187.5 \frac{\text{operating hours}}{\text{year}}$$

For use in the LOP fault tree, the loss of off-site power frequency of 0.2 per year was derived from Section 4.6.3 of Volume II of the WIPP IRA. This yearly frequency for loss of off-site power was converted to an hourly failure frequency for combination with the hourly failure rates of components in the fault tree.

The quantification of the LOP fault tree yielded an annual frequency of failure of electric power to the waste hoist motor of 2.7E-02 per year.

F(lph) = 2.7E-2 per year

The frequency for loss of off-site power includes power failures due to lightning. Therefore, lightning will not be analyzed independently as a LOP initiator.

In addition to loss of off-site power and electrical component failures, two other IEs which could result in a LOP to the hoist motor are a fire in the power cables and a fire in the 475 V TR in the hoist control room. The frequencies of these fires are derived in the following section titled "Fire Causes Loss of Power to Waste Hoist," and the results for each are presented here.

F(pc) = 1.4E-4 per year
F(tf) = 3.4E-4 per year

The total annual frequency of loss of electric power to the hoist motor is the sum of the frequencies from the LOP fault tree and the fire contributors.

F(lp) = F(lph) + F(pc) + F(tf) = 2.8E-2 per year

This sum of potential LOP contributors shows that the contribution from loss of off-site power and component failures dominates the contribution from fire initiators.

- Fire Causes LOP to Waste Hoist

  The analysis of this section addresses the contribution of fires, which result in LOP, to the hoist motor. Two fire areas were identified for examination. These areas are the 475V TR in the hoist control room and the power cables from the hoist control room to the hoist motor.

  - Time at Risk of a Fire

    A fire that occurs in the hoist control room or the cable routing from the control room to the hoist motor could only lead to a LOP to the hoist motor during the period of time the drums are being transported on the hoist. The hoist is assumed to be in operation five days a week for 50 weeks (ten holidays assumed). It is assumed that there will be three trips of 15 minutes each per operation day. Hence, the fraction of each year that the drums are being moved by the hoist T(fr) is

    T(fr) = 0.25 hours/trip x 3 trips/8 hours x 40 hours/week x 50 weeks/year / 8760 hours/year = 2.14E-2

  - Frequency of Fires in Components

    The frequency of fires in components (cables, breakers, and TRs) is based on the Westinghouse data base (Reference 14) which includes 221 fires in 920 cumulative years of nuclear power plant operation.

Frequency of these events are:

cable fires f(c/f): 12/920 years = 0.013/year
breaker fires f(bf): 7/920 years = 0.0076/year
transformer fires f(tf): 8/920 years = 0.0087/year

- Human Interactions

Fires can be initiated by combinations of fire sources and human interaction. Many fires are caused by human activities as well as component failure. To account for events that include a combination of unforeseen human activities, a HE probability of 3.0E-2 (Reference 9) is assigned for failure to follow proper procedures and a probability of 0.1 (engineering judgment) is assigned that this action is not corrected. For example, leaving flammable liquids in the control room would be a failure to follow procedures. If this material is not discovered and removed by inspection (0.1), a means of spreading fire between cabinets is introduced in the control room. Therefore, the probability of a propagating fire as a result of HE, developing after initiation of a fire, P(hp) is 3.0E-3.

An estimated 28 of the 221 fires could be related to events caused by human interactions f(hm) or 28/920 = 3.0E-02/year (Reference 14) is assigned for random human initiation of fires in any of the critical areas.

- Fire Detection and Suppression

Except for large, propagating fires (or explosions and fires), the majority of the fires in nuclear power plants have been put out by portable extinguishers. Portable extinguishers could be used for cabinet fires (or other small nonpropagating random fires) in the control room. Small fires (trash cans, etc.) or cabinet fires would not initiate an event where the hoist operation could not be terminated. Hence, only the worst case fires are addressed.

Sprinkler systems would not activate until the fire had generated sufficient heat. The sprinkler systems will generally suppress a large fire and prevent further fire spread. It is assumed that cable fires would not generate enough heat to activate the sprinkler system.

If the worst case fire considered were to occur, no credit is given for manual fire fighting such as using hose stations. The hose stations would also contribute to water damage in the waste hoist control room. It is possible that hose stations could be used for cable fires, but these would only be used if the sprinkler system failed and it is assumed that major damage would result to the cables before the fire could be extinguished with hose stations.

- Fires in the Control Room F(cr)

The hoist control room contains control cabinets, breakers and a 475 V TR for the hoist motor. A fire in the control cabinets would not cause a LOP to the waste hoist motor or fail the waste hoist braking system. A fire in the 475 V TR (or the breakers adjacent to the TR) could induce a LOP to the hoist motor.

The fire data for breaker and TR fires are equivalent to the breaker and TRs housed in the control room.

Breaker fires f(bf): 7/920 years = 7.6E-3/year
Transformer fires f(tf): 8/920 years = 8.7E-3/year

A fire in the breaker is assumed to ignite the TR, hence, the frequency of a TR fire F(tf), for that fraction of a year when the hoist would be operating T(fr), is:

F(tf) = [f(bf) + f(tf)] * T(fr)

F(tf) = [7.6E-03 + 8.7E-03]*0.021 = 3.4E-4

- Power Cable Fire F(pc)

A fire in the power cables routed from the control cabinets to the hoist area would cause a LOP to the hoist motor. The brakes could then be set automatically. Assume 0.5 of the cables are power and 0.5 of the cables are control or instrumentation cables. A failure in the power cables is equivalent to LOP to the hoist. This is included in the IE frequency for LOP accident LPU.

Frequency of cable fires f(cf): 12/920 years = 0.013/year

The frequency of a fire induced IE (requiring automatic braking) is

F(pc) = 0.5 x f(cf) x T(fr)

F(pc) = 0.5 x 0.013/year x 0.021 = 1.4E-4/year

4.2.2.3 Summary of Accident Analysis

The IE frequencies calculated for this PRA are shown on Table 4.2-6. Each of these initiators is combined with the appropriate mitigation systems to obtain the frequency of each damage state. The results of this quantification are shown on Table 4.4.2-7. Additional explanation of the quantification of the damage states is found in Section 4.5.

4.2.3 REFERENCES

1. "Final Environmental Impact Statement - Waste Isolation Pilot Plant," Volume 1, U.S. Department of Energy, October 1980.

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3. Letter from D. L. Nearing to J. M. Iacovino, 1/23/89, DA:89:5013 (Response to NS-RMOI-HM-89-010, 1/16/89).

4. Letter from D. L. Nearing to B. G. Holmes, 1/19/89, DA:89:5010 (Response to verbal request DSB to AM, 1/11/89).

5. Letter from D. L. Nearing to J. M. Iacovino, 1/27/89, DA:89:5015 (Response to NS-RMOI-HM-89-014, 1/20/89).

6. TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant; WIPP-DOE-069, Rev. 3, UC-70; January 1989.

7. "Probability of a Catastrophic Hoist Accident at the Waste Isolation Pilot Plant," WTSD-TME-063, July 1985.

8. A. D. Swain and H. E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," Sandia National Laboratories, NUREG/CR-1278, U.S. Nuclear Regulatory Commission, Washington, DC, 1983.

9. "Millstone Unit 3 Probabilistic Safety Study," Section 2, Volume 6, Chapter 2.5.2.2, Quantification of Fire Related Core Melt Frequency and Uncertainty in Each Zone, August 1983.

10. Shelagh J. Morandi and Harold L. Phillippi, "Waste Isolation Pilot Plant Fire Detection and Suppression Systems Notebook," Westinghouse Electric Corporation Risk Management and Operations Improvement, January 1989.

11. "Special Analysis: Heavy Truck Fires, 1982-1986," National Fire Protection Association Fire Analysis and Research Division/JHR, Table 1, Semi-Trailer Truck Fires by Ignition Factor Annual Average of 1982-86 Vehicle Fires Reported to U.S. Fire Departments.

12. Neill Darmstadter, Engineer, American Trucking Association Safety Department, Telephone Conversations on 2/22/89 and 2/24/89, Estimate of the number of semitrucks on the highway.

13. Letter from J. M. Iacovino to Norm Siepel, 2/22/89 confirming information received during telephone conversations on 2/7/89 and 2/9/89 regarding waste hoist systems, (NS-RMOI-HM-89-050).

14. Westinghouse Nuclear Power Plant Fire Event Data Base, Westinghouse Electric Corporation (Proprietary).

15. Letter from D. L. Nearing to John Iacovino, 2/28/89, DA:89:5030, (Response to NS-RMOI-HM-89-052, 2/27/89).

Table 4.2-1

FEIS ACCIDENT SCENARIOS FOR CONTACT-HANDLING AREAS

Area	Accident	Possible Scenario	Damage to Waste Package(s)
Receiving	C1	Vehicle collision with waste package	No serious damage (package classified as Type B)
Unloading	C2	Drop of whole package from crane	Drop less than 30 feet; same as C1
	C3	Drum drop on forklift (or down the dock)	Six drums drop; lid broken off one drum
Pallet storage	C4	Drum puncture by forklift	Hole in side of two drums; lid broken off third drum
	C5	Drop from forklift	Crack in one drum
	C6	Drum failure from excess internal pressure	Drum fails, releasing half the contents
	C7	External fire	Contents of two drums (or one box) released because of internal pressure and contents of one additional drum (or box) burned
	C8	Fire caused by internal combustion in drum	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one additional drum burned
Overpack and repair	C9	Drum drop on way to repair	Crack in one drum; size of crack five times that of C3 since drum is defective initially
	C10	Drum failure on way to repair	Drum splits open, releasing 100% of contents

*This table is Table 9-48, Section 9.5.1, Volume 1 of 2 of WIPP FEIS, October 1980 and is presented here for reference purposes only.

Table 4.2-1
(Continued)

FEIS ACCIDENT SCENARIOS FOR CONTACT-HANDLING AREAS

Area	Accident	Possible Scenario	Damage to Waste Package(s)
	C11	External fire	Surface contamination vaporizes from 24 drums; contents of two drums released because of internal pressure and contents of one additional drum burned
	C12	Fire caused by internal combustion in drum (or box)	Surface contamination from eight drums vaporizes; contents of one drum released because of internal pressure and contents of one additional drum burned
Cage loading	C13	Hoist drops down mine shaft	48 drums crack open, releasing 100% of contents
	C14	Fire in hoist caused by internal combustion in drum	Surface contamination vaporizes from eight drums (or two boxes); contents of one drum (or one box) released because of internal pressure and contents of one additional drum (or one box) burned
Underground disposal	C15	Pallet hit by transporter	Lid of one drum knocked off and cracks appear in sides of three other drums; area of cracks is 2.75 in.^{2}
	C16	Drum punctured by forklift	Hole in side of one drum (or box); hole is 12 in.^{2} in area
	C17	Drum drop from forklift	Same as C5
	C18	Rock fall from mine-shaft walls	Holes in sides of 12 drums; holes are 12 in.^{2} area

Table 4.2-1
(Continued)

FEIS ACCIDENT SCENARIOS FOR CONTACT-HANDLING AREAS

Area	Accident	Possible Scenario	Damage to Waste Package(s)
	C19	External fire during handling	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one drum burned
	C20	Fire caused by internal combustion in drum (or box)	Surface contamination vaporizes from eight drums; contents of one drum released because of internal pressure and contents of one drum burned
	C21	Drum puncture by backfilling equipment	Same as C4
Disposal room	C22	Fire caused by internal combustion in drum	Contents of two drums released because of internal pressure and contents of one drum burned

Table 4.2-2

FSAR ACCIDENT SCENARIOS INVOLVING CH TRU WASTE

Area	Scenario ID	Estimated Frequency	Damage to Waste Package(s)
Radiological Control Area -	C0	INF	Forklift knocks TRUPACT-II from trailer
Outside of WHB			
Off-loading/Loading	C1	MF	Vehicle collision in off-loading area
Inventory/Preparation	C2	MF	Drum drops from forklift
	C3	MF	Drum punctured by forklift
Underground Storage	C4	MF	Transporter hits pallet
	C5	MF	Drums drop from forklift
	C6	MF	Other equipment punctures drums
Inventory/Preparation	C7	LIM (NC)	Spontaneous ignition within a drum
Hoist Loading Area	C8	LIM (NC)	A loaded hoist cage drops down waste handling shaft
Underground Storage	C9	LIM (NC)	Diesel fire in storage array underground
	C10	LIM	Spontaneous ignition within a drum

MF – Moderate Frequency
INF – Infrequent
LIM – Limiting
NC – Not Credible

*This table is Table 1A.4-1 of WIPP FSAR, 1988 and is presented here for reference purposes only.

Table 4.2-3

POTENTIAL CH RELEASE ACCIDENT SCENARIOS

Accident ID	Scenario Description	FEIS Area	FSAR ID	Possible Scenario ID	Consequences	Category	Number of Drums Affected
Q1	Drum drops from forklift	CH Bay	C3 C5	C2	*7 drums drop, lid breaks off 1 drum	A1	3
Q2	Drum punc-tured by forklift	CH Bay	C4	C3	2 drums punc-tured, lid falls off 1 other drum	A1	3
Q3	External fire aboveground	CH Bay Decon Room	C7 C11	-- --	Contents of 1 drum will burn; 2 other drums will burst	A2	3
Q4	Transporter hits pallet in hoist	U/G	C15	C4	*Same as Q1	U1B	3
Q5	Drum drops from fork-lift	U/G	C17	C5	*Same as Q1	U1B	3
Q6	Other equipment punctures drum	U/G	C21	C6	Same as Q2	U1B	3
Q7	External fire	U/G	C19	C9	90 drums burn all combusti-ble material within	U2	90
Q8	Hoist hits headframe due to LOP; drums fall down shaft or into the WHB	Hoist Shaft	--	--	28 drums re-lease 100% of contents	LPU	28

*Even though some of the accident scenarios would result in damage to fewer than three drums (see Q1, Q4, Q5), for conservatism these accidents are included in the release category R3D (i.e., damage to three drums).

Table 4.2-4

MITIGATION SYSTEM SUMMARY TABLE FOR RISK QUANTIFICATION

WB1 – Success of WHB filtration through HEPA filters

UF1 – Success of underground filtration through EFB HEPA filters

UF2 – Successful radioactive containment underground in the event of an underground fire

MAG – Successful suppression of fire using manual methods (aboveground)

MUG – Successful suppression of fire using manual methods (underground)

FW – Successful suppression of fire using fire water system (includes failure of the sprinkler head)

CUG – Successful suppression of fire using dry chemical system

Table 4.2-5

IDENTIFICATION OF ACCIDENT SEQUENCES BY CONSEQUENCE CATEGORY

Sequence Number	Release/Consequence Category	Initiator	Sequence
1	FR3	A1	WB1
2	R3D	A1	WB1
3	FR3	A2	MAG * FW * WB1
4	R3D	A2	MAG * FW * WB1
5	FR3	U1B	UF1
6	R3D	U1B	UF1
7	FR90	U2	UF2
8	R90	U2	UF2
9	FR28	LPU	HB * UF1
10	R28	LPU	HB * UF1

Notes:
1) The bar on top of a mitigative system symbol represents the failure of that system.
2) All release categories beginning with F represent filtered releases, i.e., the appropriate HVAC filtration system was available. All release categories beginning with R represent unfiltered releases; the appropriate HVAC system was not available.

Table 4.2-6

INITIATING EVENT FREQUENCIES
(PER YEAR)

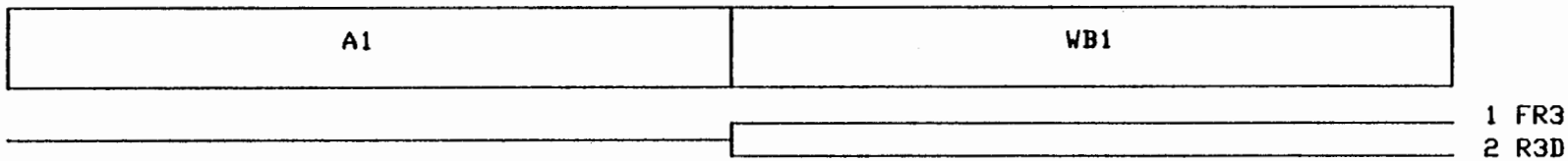
A1	–	Breach of Drum Aboveground	7.5E-02
A2	–	Fire Aboveground	3.0E-03
U1B	–	Breach of Drum Underground	1.2E-01
U2	–	Underground Fire	9.0E-05
LPU	–	Loss of Electric Power	2.8E-02

Table 4.2-7

SUMMARY OF DAMAGE STATE FREQUENCIES BY RELEASE CATEGORY

Release Category	Description of Accident Release	Damage State Frequency (/yr)
R3D	Three Drums Damaged - 100% of contents of each of two drums with average curie loading spilled; 25% of the contents of the third drum with maximum curie loading burned.	5.5E-05
R28	Twenty-eight Drums Damaged - 100% of contents of all drums is spilled. Two have a maximum curie loading. Twenty-six have an average curie loading.	6.9E-13
R90	Ninety Drums Damaged - 100% of combustible contents (25% of total contents) burned. Three have a maximum curie loading. Eighty-seven have an average curie loading. Maximum curie loading = 1000 PE-Ci Average curie loading = 12.9 PE-Ci	4.0E-07

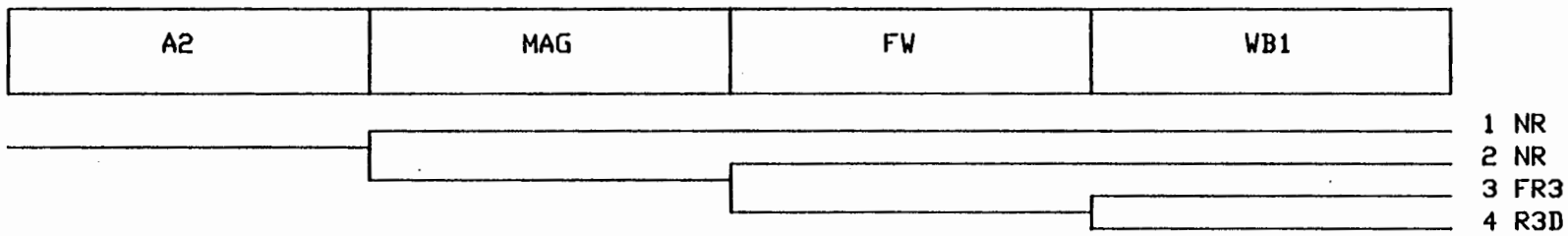
PE-Ci is Plutonium - Equvalent curies, discussed in Section 4.3.3.



EVENT	EVENT NAME	CATEGORY	DESCRIPTION
A1	ABOVE GROUND BREACH OF DRUMS	FR3	FILTERED RELEASE, 3 DRUMS
WB1	WHB HVAC FILTRATION	R3D	UNFILTERED RELEASE, 3 DRUMS

A1 - ABOVE GROUND BREACH OF DRUMS

FIGURE 4.2-1. A1 - Aboveground Breach of Drums Event Tree

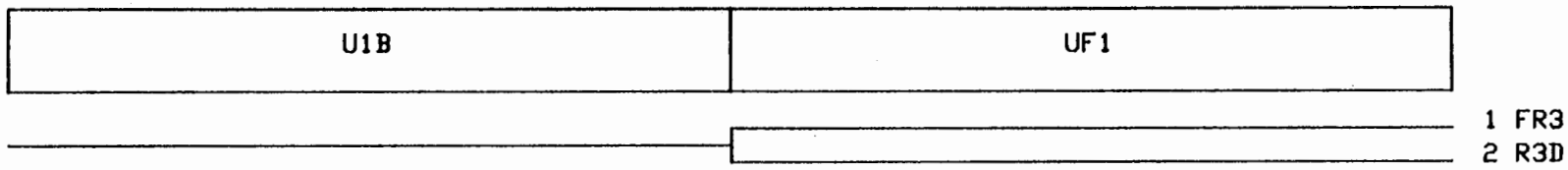


EVENT	EVENT NAME
A2	FIRE ABOVE GROUND
MAG	FIRE SUPPRESSION - MANUAL A/G
FW	FIRE SUPPRESSION - WATER
WB1	WHB HVAC FILTRATION

CATEGORY	DESCRIPTION
NR	NO RELEASE
FR3	FILTERED RELEASE, 3 DRUMS
R3D	UNFILTERED RELEASE, 3 DRUMS

A2-FIRE ABOVE GROUND

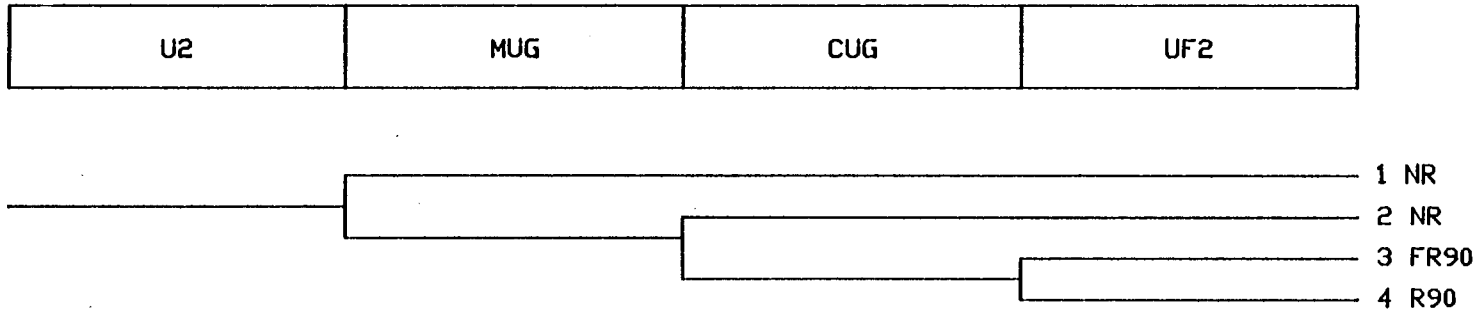
FIGURE 4.2-2. A2 - Fire Aboveground Event Tree



EVENT	EVENT NAME	CATEGORY	DESCRIPTION
U1B	U/G DRUM FAILURE STORAGE ROOMS	FR3	FILTERED RELEASE, 3 DRUMS
UF1	U/G FILTRATION SYS	R3D	RELEASE, 3 DRUMS

U1B -U/G DRUM FAILURE STORAGE ROOM

FIGURE 4.2-3. U1B - Underground Drum Failure Storage Room Event Tree

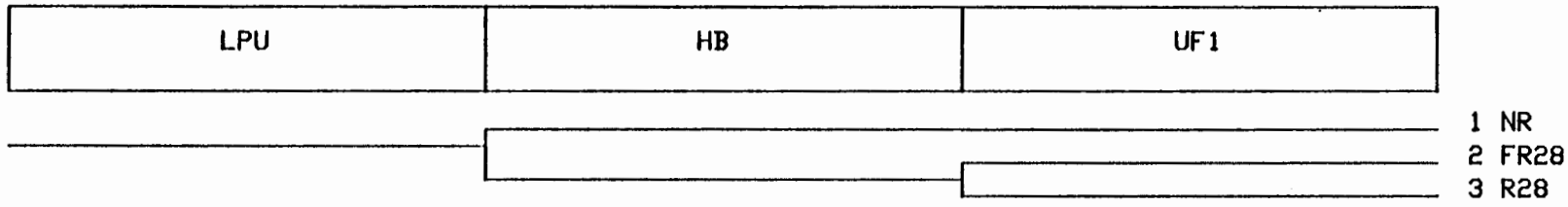


EVENT	EVENT NAME
U2	U/G FIRE WASTE STORAGE ROOMS
MUG	FIRE SUPRESSION, MANUAL U/G
CUG	FIRE SUPRESSION - DRY CHEMICAL
UF2	U/G FILTRATION SYS

CATEGORY	DESCRIPTION
NR	NO RELEASE
FR90	FILTERED RELEASE, 90 DRUMS
R90	RELEASE, 90 DRUMS DAMAGED

U2 - U/G FIRE

FIGURE 4.2-4. U2 - Underground Fire Event Tree



EVENT	EVENT NAME	CATEGORY	DESCRIPTION
LPU	LOSS OF POWER (HOIST FAILURE)	NR	NO RELEASE
HB	HOIST BRAKE SYSTEM	FR28	FILTERED RELEASE, 28 DRUMS
UF1	UNDERGROUND FILTRATION SYSTEM	R28	UNFILTERED RELEASE, 28 DRUMS

LOSS OF POWER EVENT TREE

FIGURE 4.2-5. Loss of Power Event Tree

4.3 CONSEQUENCE ANALYSIS

This section evaluates the off-site radiological consequences of the six release categories established in Section 4.2.0 - Accident Sequence Modeling. These categories are:

Three drums fire/breach - unfiltered (R3D)
Three drums fire/breach - filtered (FR3)
28 drums involved in hoist accident - unfiltered (R28)
28 drums involved in hoist accident - filtered (FR28)
90 drums on fire - unfiltered (R90)
90 drums on fire - filtered (FR90)

The consequence analysis is performed with the Sandia National Laboratories code--MACCS. This code calculates radiological impacts from airborne releases of radioactive material. No specific liquid pathway analysis or environmental analysis has been performed. The results are presented in terms of frequency of cancer fatalities and committed effective doses to the accessible population within 50 miles of the WIPP facility.

The release categories evaluated represent the range of postulated radioactivity releases for the event sequences modeled for the WIPP facility. The results reported here are conditional on the occurrence of an accident sequence. In Section 4.5, the frequency of occurrence of the accident sequences are combined with the consequences calculated here to produce an overall risk. This risk is presented in terms of postulated cancer fatalities to the accessible population surrounding the WIPP facility, due to CH waste drum receipt and emplacement operations.

4.3.1 CONSEQUENCE CODE SELECTION

Historical Background

The Reactor Safety Study (WASH 1150) presented the first comprehensive assessment of the consequences and risks to society from nuclear power plant accidents.

Consequence modeling has received widespread attention and application throughout the world since the Reactor Safety Study, and a significant number of consequence models have been developed.

During the last ten years, the need for improved, computationally efficient consequence models became clear. This is because consequence models were used to evaluate severe accident risks, emergency response plans, criteria for reactor siting, safety goals, and the benefits of alternative design features. Modular architecture, enhanced site-specific modeling capabilities, more realistic models of actions that mitigate radiation exposures, user specification of all model parameters, the capability to determine model sensitivities, and the ability to estimate the uncertainties associated with code predictions were widely recognized as desirable improvements.

There are many codes available to determine the atmospheric dispersion of radiological particles and the resultant dose as a consequence of accidents. These codes should produce desired results in a usable form, produce accurate results and have been judged against an adequate QA plan such that they will withstand licensing scrutiny.

Four atmospheric dispersion codes were evaluated for use in the PRA. These are: AIRDOS-EPA, MESORAD, MATHEW/ADPIC, and MACCS.

AIRDOS-EPA[1]

The AIRDOS-EPA code was developed at Oak Ridge National Laboratories for use by the Environmental Protection Agency (EPA). It employs a modified Gaussian plume model for air dispersion and follows the calculation through various exposure pathways to estimate dose to man.

A strength of AIRDOS-EPA is its relatively long history of use. Most of the limitations associated with AIRDOS-EPA are due to the constraints of the Gaussian plume model. These include the assumptions of constant wind speed, no wind shear, flat topography, and no chemical or physical interactions during plume travel.

[1]The AIRDOS-EPA, MESORAD and MATHEW/ADPIC code descriptions are primarily extracted from Riggle, et al. (Reference 6).

MESORAD

The MESORAD Code was developed at Pacific Northwest Laboratory for the NRC in responding to emergency situations and accidental releases. It uses the Gaussian puff model for calculating atmospheric dispersion and also calculates external and inhalation dose. Food-chain transport is not included as an exposure pathway. Since it is designed for emergency response applications, the time frame is on the scale of hours rather than days.

MATHEW/ADPIC

The MATHEW and ADPIC codes were developed by the Lawrence Livermore National Laboratory. MATHEW produces a mass-adjusted, three dimensional wind field which is used as input for ADPIC. ADPIC calculates time-dependent air concentrations by the particle-in-cell model. Dose calculations are not performed by these codes. Even though MATHEW/ADPIC has a sophisticated method of dealing with complex terrain, there are practical limitations to the accuracy of the method.

MACCS

The MACCS was developed by Sandia National Laboratories for the NRC. MACCS also calculates the off-site consequences of an atmospheric release of radioactive material.

The MACCS code employs a Gaussian plume dispersion model and can account for radioactive decay, wind speed changes, dry deposition, wet deposition, and building wake effects. MACCS is well suited for probabilistic calculations, since it can incorporate National Weather Service weather sampling files and U.S. Census population distribution data to determine the probabilistic distribution of a radioactive release. MACCS can model exposure of the human population from initial cloud and ground contamination, initial and resuspension inhalation, and ingestion of contaminated food and water. For the WIPP analysis, MACCS produced a whole body committed effective dose to an individual, based on a 24-hour exposure to a radiological release and it produced a committed effective dose to specific organ groups to the entire population in a 50-mile radius of the WIPP facility for 70 years based on 70-year inhalation exposure.

The goal of the MACCS development effort was to produce a portable code with a modular architecture and data base that facilitated performance of many site-specific calculations, estimation of sensitivities and uncertainties, and incorporation of new or alternative models.

Code Selection

All four of the above consequence analysis codes were available for use in the PRA. After reviewing the benefits and limitations of each of the codes, the MACCS code was chosen for application to the PRA consequence analysis. It is seen to have the best capability to model the probabilistic distribution of consequences. MACCS is able to account for actual weather variability, whereas the other codes apply weather averaging schemes. MACCS utilizes actual census population data in a radial grid around the point of release, and it facilitates sensitivity and uncertainty analyses. For dose calculations, MACCS provides WIPP with a proven analysis technique that is different from any previously used for the WIPP.

Therefore, it is felt that MACCS is the most appropriate consequence analysis code for this application.

Model Overview

It is now desirable to present more information on the actual models MACCS uses for consequence analysis.

MACCS models the off-site consequences of an accident that releases a plume of radioactive materials to the atmosphere. Should such an accidental release occur, the radioactive aerosols in the plume, while dispersing in the atmosphere, would be transported by the prevailing wind. The environment would be contaminated by radioactive materials deposited from the plume and the population would be exposed to radiation. MACCS estimates the range and probability of the health effects induced by the radiation exposures.

There are two fundamental aspects of the organization of MACCS that are basic to its understanding: the time scale after the accident is divided into various "phases," and the region surrounding the release point is divided into a polar-coordinate grid.

The time scale after the accident is divided into three phases: emergency phase, intermediate phase, and long-term phase.

The emergency phase begins immediately after the accident and could last up to seven days following the accident. Within the code, this period is modeled by the EARLY module of MACCS. In this period, the exposure to population of both radioactive clouds and ground contamination is modeled.

The intermediate phase can be used to represent a period in which evaluations are performed and decisions are made regarding the type of protective measure actions that need to be taken. Within the code, this period is modeled by the CHRONC module of MACCS. In this period, the radioactive clouds are assumed to be gone and the only exposure pathways are those from ground contamination.

The long-term phase determines a lifetime dose subsequent to the intermediate phase. Within the code, this period is modeled by the CHRONC module of MACCS. As with the intermediate phase, the only exposure pathways considered here are those resulting from ground contamination.

The spatial grid used to represent the region is centered on the WIPP Facility itself. The user specifies the number of radial divisions (sectors) as well as their endpoint distances. Sixteen sectors were defined extending out to a distance of 50 miles for this analysis. The angular divisions used to define the spatial grid correspond to the sixteen directions of the compass. All of the calculations of MACCS are stored on the basis of this polar-coordinate spatial grid.

Atmospheric Dispersion and Transport

MACCS allows a release of radioactive materials to the atmosphere to be divided into successive plume segments, which can have different compositions, release time, duration, release height, and energies (amounts of sensible heat). Plume segment lengths are determined by the product of the segment's release duration and the average wind speed during release. The initial vertical and horizontal dimensions of each plume segment are user specified. If release occurs into a building wake, then wake dimensions

can be used to set the initial crosswind dimensions of the plume. If not, a point source can be specified.

After release, wind speed determines the rates at which plume segments are transported in the downwind direction, and wind direction at the time of release determines the direction of travel. As is done in many consequence codes, MACCS neglects wind trajectories. The 16 population distribution sectors are assumed to constitute a representative set of downwind exposed populations. The exposure probability of each of the 16 population distribution sectors is assumed to be given by the frequency with which wind blows from the site into the sector (i.e., site wind rose frequencies by sector).

During transport, dispersion of the plume in the vertical and horizontal (crosswind) directions is estimated by using an empirical straight line Gaussian plume model. Thus, dispersion rates depend on wind speed and on atmospheric stability.

In MACCS, aerosols are removed from the plume by radioactive decay, if applicable, by washout, which varies with rainfall rate, and by diffusion to, impaction on, and gravitational settling onto surfaces. The combined removal rate from diffusion, impaction, and settling is modeled using an empirical, dry deposition velocity.

Exposure Pathways

In the WIPP application, five exposure pathways were modeled: exposure to the passing plume (cloudshine), exposure to materials deposited on the ground (groundshine), exposure to materials deposited on skin (skin deposition), inhalation of materials directly from the passing plume (cloud inhalation), inhalation of materials resuspended from the ground by natural and mechanical processes (resuspension inhalation). Long-term doses are caused by groundshine and inhalation of resuspended materials.

Dosimetry

The MACCS dosimetry model consists of three interacting processes: projection of individual exposures to radioactive contamination for each of the five exposure pathways modeled over a given time period specified by the user, mitigation of these exposures by protective measures, and calculation of the actual exposures incurred after mitigation by protective measures. For each exposure pathway, MACCS models the total radiological

consequences for the pathway diminished by the actions taken to mitigate that pathway dose. The total dose to an organ is obtained by summing the doses delivered by each of the individual pathways.

Health Effects

Health effects are calculated from dosage to specific organs. These doses are calculated using dose conversion factors (DCFs). If the postulated event warrants, early injuries and fatalities (those that occur within one year of the accident) are estimated using a nonlinear dose-response model.

MACCS calculates radiation-induced cancers using a linear-quadratic, zero-threshold, dose-response model. However, the quadratic portion of the model is usually not important, when long-term individual exposures are limited by some exposure criterion. Accordingly, MACCS cancer fatality predictions are usually linear with dose.

MACCS Quality Assurance and Verification

The MACCS code has been used for analyses by Westinghouse for several years. Version 1.4 has undergone rigorous nuclear-grade QA and has been put under configuration control. This version of MACCS was used to conduct the consequence analysis for the PRA.

4.3.2 MACCS CODE INPUT AND ASSUMPTIONS

MACCS calculations require extensive data input. Population and meteorological data is so extensive as to require input in magnetic tape format.

The radioactive inventories and atmospheric source terms are discussed separately in Section 4.3.3.

All releases were conservatively modeled as ambient temperature releases (buoyancy effects were considered but not applied since their potential influence is small).

The release heights used for the various release scenarios are: Underground Ventilation Fan Stack - 7.3 meters, WHB Filtered Stack - 14.9 meters and a ground level release - 0.0 meters.

Wake effects created as a result of wind flowing over and around stacks and buildings on the WIPP site are taken into account.

Meteorological data characteristics utilized were from a National Weather Service file prepared for El Paso, Texas. Although El Paso is physically separated from the WIPP site by mountainous terrain, it was the closest and most representative of 28 MACCS magnetic tape weather sample sites nationwide. However, the duration and persistence of wind at the WIPP site used in the analysis are derived from wind roses prepared for the WIPP site. This data was extracted directly from the FEIS, Appendix H, Figure H-15(a) and is repeated here as Figure 4.3-1.

The meteorological data contains one pair of hourly wind speed, atmospheric stability, and rainfall recordings. Although one year of hourly readings contain 8760 weather sequences, MACCS calculations examine only a representative subset of these sequences (typically about 150 sequences). Representative subsets are selected by sampling of the weather sequences after sorting them into weather bins defined by wind speed, atmospheric stability, and intensity and distance of the occurrence of rain.

The population distribution for a 50 mile radius around the WIPP facility was constructed from 1980 census data. The population within a 50-mile radius of WIPP has not grown significantly since the 1980 census. The off-site population surrounding WIPP was modeled using a partial grid identical to that portrayed in the WIPP FEIS, Appendix H. The population data within ten miles was obtained directly from the FEIS and is shown in Figure 4.3-2. The total accessible population within 50 miles of the WIPP site is approximately 100,000 people.

No evacuation or sheltering of the accessible population surrounding the WIPP site were considered in the MACCS model. No long-term protective measures based on protective action guides were considered.

No liquid pathway or consumption of contaminated food or water were modeled.

MACCS does not calculate radiological impacts based on accidental release of radioactive liquids. No impacts of contaminated food or water were modeled because no interdiction or protective action measures have been specified.

4.3.3 ATMOSPHERIC SOURCE TERMS

The PRA derives contact-handled TRU waste inventories and dispersion behavior from the WIPP FEIS and the FSAR. These inventories and source terms served as a basis for the analysis presented here.

The two types of CH TRU waste containers that will be handled are the DOT-17C drum (55-gallon steel drum) and the Standard Waste Box, a waste container specially designed to fit in the TRUPACT-II and holding the capacity of several 55-gallon drums.

Because the number of boxes expected at the WIPP is much smaller than the number of drums, the number of accidents involving boxes is expected to be much smaller than the number involving drums. Also, the relative radionuclide abundance per liter is greater for drums. For these reasons, the accident scenarios involving drums were analyzed and were assumed to bound accident scenarios involving waste boxes.

In all cases developed, the inventory available for release is composed of a mix of drums with the maximum postulated curie content (1000 PE-Ci) and an average curie content (12.9 PE-Ci). Table 4.3-1 shows these drum inventories both in terms of PE-Ci and Curies.

The PE-Ci is intended to eliminate the dependency of radiological analyses on the specific radionuclide composition of a TRU waste stream. A unique radionuclide composition and/or waste disposal distribution is associated with each TRU waste generator and storage facility. By normalizing all radionuclides to a common radiotoxic hazard index, radiological analyses can be conducted for the WIPP that are independent of these variations. Plutonium-239, as a common component of defense TRU wastes, was selected as the radionuclide to which the radiotoxic hazard of other TRU radionuclides could be indexed. Since TRU radionuclides primarily represent inhalation hazards, a valid relationship can be established that normalizes the inhalation hazard of a TRU radionuclide to that of Pu-239.

To obtain this correlation, the 50-year CEDE or DCF for a unit intake of each radionuclide is used. These DCFs have been determined by the method described in International Commission on Radiological Protection (ICRP) Publications 26 and 30 (ICRP-26, 1977; ICRP-30, 1979).

The average curie content and maximum curie content of drums vary widely because of differences in derivation. The average curie content for drums is a true mean derived from a large number of drums with low curie contents and a few drums with high curie contents. The maximum curie content drums were assumed to contain the WAC upper limit for conservatism.

The mix of maximum and average curie content drums represents an attempt to keep the analysis conservative. The one in thirty maximum to average drum ratio is the best estimate ratio and is used in the R90 release category analysis. The number of maximum curie content drums was reduced to two and one for the R28 and R3D release category analyses, respectively, to analyze a bounding case for maximum drums in each of those analyses. These maximum to average drum ratios were chosen consistent with the FEIS assumptions.

The PRA accident sequences analyzed differ slightly from those in the FSAR and the FEIS. The specific accident sequences are described in Section 4.2 of the PRA. What follows is a description of how the initial accident inventory is reduced and becomes available as an atmospheric source term. This atmospheric source term is composed of the CH TRU radionuclides that leave the WIPP site and are dispersed to the accessible population by the wind following an unmitigated accident sequence.

<u>Three drum surface fire/breach</u>

R3D (unfiltered)
FR3 (filtered)

The FEIS Accident C7 (Surface fire) was utilized as a starting point in addition to the FSAR estimate of drum loading. A description from the FEIS Accident C7 (Surface fire) follows.

The lack of flammable materials in the building makes the following assumption reasonable: if a fire occurs in the surface facility, not more than the contents of one drum will burn and not more than two adjacent drums will pressurize and burst because of the

heat. As a plausible way for a fire to start, it is postulated that a small puddle of combustible liquid or flammable gas spilled under a pallet of waste drums somehow ignites, even though it is very difficult to ignite diesel fuel. Although such a fire would be small, the adjacent drums are assumed to fail and spill half their contents. The contents spilled from the adjacent drums do not burn, and only 1 percent of the spilled material is in powder form.

It takes one hour to put out the fire and to repack or cover the exposed waste. Since only 25 percent of the drum content is combustible and 1 percent of the activity in the combustible contents is released in respirable form, the burning releases a total of 0.25 percent of one drum in respirable form. In addition, it is assumed that 0.014 percent of the spilled powdered waste from each of the adjacent drums is released and respirable per hour. The drum that is burned is assumed to contain the maximum curie content and the drums that are spilled are assumed to contain average curie contents.

The formulation of the atmospheric source term from the accident inventory is then:

2 Average drums x 1.0 (fraction spilled) x 0.00014 (fraction respirable) +
1 maximum drum x 0.25 (fraction burned) x 0.01 (fraction respirable)

<u>28 drum hoist accident</u>

R28 (unfiltered)
FR28 (filtered)

The calculation was made for release of 100 percent of the contents of 28 drums, with two drums containing the maximum postulated curie content and the remaining 26 drums containing an average curie content.

The assumptions are derived from FEIS Accident C10 (Surface container failure) and Accident C13 (U/G container failure, hoist drop). The PRA accident differs from the hoist drop postulated in the FEIS. In the PRA analysis the hoist hydraulic brakes fail and the hoist "falls" up (the hoist counter weight is heavier than the loaded hoist cage) crashing into the headframe. All 28 drums on the cage fall to the WHB floor or down the shaft. All released radioactive material is pulled down the shaft by the U/G ventilation system.

It is assumed that 100 percent of the contents of the drums are spilled. Based on FEIS Accident C10, the amount of radioactivity that is released and becomes airborne is one percent of the radioactive material with a particle size of less than ten microns, which in turn is one percent of the total waste dispersed.

The formulation of the atmospheric source term from the accident inventory is then:

26 average drums x 1.0 (fraction spilled)
x 0.01 (fraction smaller than 10 microns) x 0.01 (fraction dispersed)
+ 2 maximum drums x 1.0 (fraction spilled)
x 0.01 (fraction greater than 10 microns) x 0.01 (fraction dispersed)

<u>90 drum underground fire</u>

R90 (unfiltered)
FR90 (filtered)

The FEIS Accident C22 (Underground fire) was utilized in addition to the FSAR estimate of drum loading. Vehicles used in the U/G disposal area are diesel powered and contain sufficient fuel for one shift of operation (about 60 gallons). Because of the high flash point of diesel fuel, the probability of causing a fire with such a vehicle is quite low; such fires, however, have occurred in the past, and a fire is considered credible for this analysis. Even though CH waste is received in metal drums and boxes, only a portion of the waste is combustible, and there is a small probability that the two types of waste packages could be involved in a fire. Since the drums contain a higher total amount of radioactivity than the boxes, they are used in the calculation of the amount of radioactivity released in this accident. The following assumptions are made:

1. The combustible material is 60 gallons of diesel fuel contained in the full tank of a diesel-powered vehicle operating in the vicinity of a stored array of CH waste drums.

2. After an accident in which an engine fire is not extinguished, the engulfing fire causes the fuel tank to rupture, the diesel fuel spills out and pools around the base of the drums.

3. The diesel fuel ignites from a spark or other ignition source.

4. The heat of the diesel fire then causes the ignition of the waste in the drums. For consistency with the WIPP FEIS, 25 percent of the waste is assumed to be combustible. The waste is assumed to burn for about 13 hours (without any fire suppression), on the basis of tests with fuel of similar composition. It is assumed that 100 percent of the combustible material (25 percent of the waste) is consumed in the fire.

5. Five percent of the burned waste is given off as particulates (Stearn, 1968), with 20 percent of the particulates being smaller than eight microns in diameter. In summary, one percent of the burned waste is respirable (0.2 x 0.05).

6. Calculations made by the method described by Davies (1966) indicate that 50 percent of the particulates will be depleted from the release by fallout in the drifts and will not reach the environment.

It is assumed that all of the combustible contents of 90 drums are consumed in the postulated fire (87 drums containing the average curie content and three drums containing the maximum curie content).

The formulation of the atmospheric source term from the accident inventory is then:

87 average drums x 0.25 (fraction burned) x 0.01 (fraction respirable)
x 0.5 (fraction not falling out in the drifts)
+ 3 maximum drums x 0.25 (fraction burned) x 0.01 (fraction respirable)
x 0.5 (fraction not falling out in the drafts)

This concludes the development of the atmospheric source term input to MACCS. A summary of these atmospheric source terms is provided in Table 4.3-2. These were calculated by taking the accident inventories shown in Table 4.3-1 and applying the reduction factors discussed for each release category above.

4.3.4 CONSEQUENCE ANALYSIS RESULTS

The MACCS code was used to determine the radiological impact of six accident release categories. These categories are:

Three drum fire/breach unfiltered release	Case R3D
Three drum fire/breach filtered release	Case FR3
28 drum hoist accident unfiltered release	Case R28
28 drum hoist accident filtered release	Case FR28
90 drum underground fire unfiltered release	Case R90
90 drum underground fire filtered release	Case FR90

MACCS, as explained earlier, is a probabilistic consequence code. The results are presented in terms of complementary cumulative distribution functions (CCDFs). Unlike a deterministic (worst case) analysis that produces only a single answer at a time, CCDFs present the full range of radiological impacts. Consider the hypothetical CCDF in Figure 4.3-3. Under the best of weather conditions, Point 1, the lowest radiological impact could occur. If an accident with a release occurs, this will be its guaranteed lowest impact (Probability = 1.0).

There are other weather conditions that are less likely to occur. These could yield a greater accident impact. Such a condition could be achieved by stagnant weather while the radioactive plume is over a population center. Point 2 gives the greatest impact yet has 1/10,000 of the probability of the lowest impact situation.

CCDFs, then, more fully illuminate the impact of an accident. They give a range to the magnitude of the accident as well as the associated probabilities. MACCS can also calculate the mean of all potential impacts. These consequences are based on a 70-year exposure period following the accident.

There are three release cases in which the EFB or WHB HEPA filters function as intended: FR3, FR28 and FR90. The impact of successful filtration is to reduce the radiological impact by a factor of 100,000 to a million. As a result, the radiological impacts are reduced to minimal levels. The corresponding contribution to total plant risk is negligible. For this reason, the calculated consequences for the three filtered release cases will not be presented. An estimate of the magnitude of the filtered release results may be readily obtained through a factor of 100,000 reduction in the consequences calculated for the unfiltered release cases described in the balance of this section.

The unfiltered releases are made up of the three drum surface fire/breach (R3D), 28 drum hoist accident (R28) and 90 drum U/G fire (R90). A series of CCDFs have been created for each of these accidents. They are shown respectively in Figures 4.3-4 through 4.3-6, Figures 4.3-8 through 4.3-10 and Figures 4.3-12 through 4.3-14. Each series of CCDFs gives the impact on the total population within 50 miles of WIPP over a 70-year period in terms of total cancer fatalities, committed effective dose to red bone marrow, and committed effective dose to the lungs. The dose to red bone marrow was utilized in calculating total cancer fatalities.

From each of the calculations deriving CCDF curves, a mean value of the consequence can be calculated. These mean consequence values of total cancer fatalities for a population of 100,000 are used in the calculation of plant risk in Section 6.0 (Tables 6-8 and 6-9). The mean value of total cancer fatalities for a population of 100,000 within a 50-mile radius of the WIPP for the R3D consequence category (Figure 4.3-4) is 4.8E-03. The mean value for the R28 consequence category (Figure 4.3-8) is 4.4E-04. The mean value of total cancer fatalities for the R90 consequence category (Figure 4.3-12) is 9.3E-03.

Consider Figure 4.3-13, Impact on Red Bone Marrow, for the 90 drum release case. The maximum committed effective dose is 3900 rem for the total 100,000 population over a 70-year period, and this maximum dose is associated with the lowest probability of occurrence of 0.0001. The minimum value for this case is approximately 0.2 rem for the entire 100,000 population. Note that these postulated impacts are based on the low frequency 90 drum release occurring.

MACCS also calculated the maximum and average individual whole body doses. However, these doses are based on the whole body dose received in the acute period (24 hours) following an accident. These are different than the CCDF calculations that are the sum of exposure to organs over 70 years to the total population group following an accident.

The maximum and average total acute doses for an individual are presented in Tables 4.3-3 and 4.3-4. Table 4.3-5 shows the radiological impact of the largest accident (R90) as a function of distance from the WIPP site.

A sensitivity analysis for individuals was also performed for each case to indicate the reduction of dose as a function of distance from the WIPP site. The results for all three sensitivity cases are shown in Figures 4.3-7, 4.3-11, and 4.3-15.

A point of reference for the impact of the 90 drum unfiltered release case is the impact of natural background radiation on the maximum exposed individual in the vicinity of WIPP. The natural background radiation has been measured to be 0.065 rem/yr[3]. The 70-year committed effective dose from natural background radiation is approximately 70 years x 0.065 rem/year = 4.6 rem. This value can be compared to the 90 drum unfiltered release case with the following assumptions.

1. The maximally exposed individual is irradiated from only one WIPP accident during his lifetime.

2. The 70-year committed effective dose from an acute 24-hour release exposure is approximately equal (within a factor of two) to the total committed effective dose to the maximally exposed individual.

One can also look at the probability of an individual dying from cancer from the worst accident. This occurs in the 90 drum release case. The nearest accessible population is about 0.5 miles from the postulated accident release point. Figure 4.3-15 shows the probability of a latent cancer fatality from the acute (24 hour) exposure to be less than 0.03 for the peak dose. This probability of cancer death drops off steeply with distance from the site (a factor of 100 with 10 miles). Note that this probability of a cancer fatality is based on the accident occurring.

The DOE has established guidelines for exposure to accidental off-site releases of radioactive materials in LA-10294-MS, "A Guide to Radiological Accident Considerations for Siting and Design of DOE Nonreactor Nuclear Facilities."

[3]DOE/WIPP 89-005, Annual Site Environmental Report, p. 5-21.
This comparison calculates both doses over an equal time frame. A comparison reveals that the committed effective dose from natural background radiation is 240 times the maximum dose from the largest CH waste drum accident at WIPP.

> The following siting guidelines apply to off-site individuals receiving maximum dose from exposure to internally-deposited radioactive materials or to radiation from external sources.
>
> The maximum calculated dose shall not exceed 25 rem to the whole body, 300 rem to the thyroid, 300 rem to the bone surface, or 75 rem to the lung or any other organ. Where multiple organs receive doses from the same exposure, the summed risk from all organ doses shall not exceed 25 rem effective dose equivalent when using the ICRP Report No. 26 weighting factors.
>
> These siting guidelines apply to nonreactor nuclear facilities.
>
> The use of doses as set forth in these guidelines is not intended to imply that these doses constitute limits for emergency doses to the public under accident conditions. Rather, these values and reference values can be used in the evaluation of facility design and site evaluation with respect to potential accidents of exceedingly low probability of occurrence and low risk of public exposure to radiation.

The direction from LA-10294-MS additionally states that comparisons to the guidelines shall be based on a 50-year committed effective dose equivalent to an off-site individual receiving maximum exposure. MACCS 1.4 calculates the 70-year whole body committed effective dose based on an acute 24-hour exposure to a single individual, or it can calculate the 70 year committed effective dose to organ groups based on inhalation for a base population group. Use of this code provides the WIPP with a proven analysis technique that is different from any previously used at the WIPP. This result is presented in Table 4.3-3. This table shows that the individual receiving maximum exposure from the largest postulated release is well within the DOE guidelines for exposure to whole body and bone surface (0.019 rem versus 25 rem and 300 rem, respectively).

These radiological impacts will be shown to be even less significant when combined with the frequency of a particular release accident occurring. This process takes place in Section 4.5. The estimated frequencies of the various accident sequences derived in Section 4.2.0 are combined, with consequences derived in this section to provide overall estimates of risk to the public.

Conclusion

The consequence analysis performed with the MACCS code shows that if an accident occurs involving CH TRU waste, the associated committed effective doses are well within the DOE Order 6430.1 guidelines.

4.3.5 REFERENCES

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Table 4.3-1

RADIONUCLIDE COMPOSITION OF A MAXIMUM AND AVERAGE CH TRU DRUM

Maximum drums = 1000 PE-Ci

	PE-Ci	Curies
Pu-238	777.0	855.0
Pu-239	66.0	66.0
Pu-240	14.8	14.8
Pu-241	10.0	520.0
Am-241	132.0	132.0

Average Drum = 12.9 PE-Ci

	PE-Ci	Curies
Pu-238	10.0	11.0
Pu-239	0.85	0.85
Pu-240	0.19	0.19
Pu-241	0.13	6.8
Am-241	1.7	1.7

Notes: Only the five largest constituents (by quantity) Pu-238, Pu-239, Pu-240, Pu-241, and Am-241 are presented here and modeled with MACCS consequence code.

The distribution of nuclides in the maximum and average drums was assumed to be the same.

PE-Ci or Plutonium Equivalent Curies is a radioactive hazard index factor that relates the radiotoxicity of TRU radionuclides to that of Plutonium-239. (For additional information, see discussion of PE-Ci derivation in Section 4.3.3.)

Table 4.3-2

RELEASE CATEGORIES - ATMOSPHERIC SOURCE TERM

INPUT TO MACCS CODE (CURIES)

Number Drums:	3 Drums		28 Drums		90 Drums	
Releases:	unfiltered*	filtered	unfiltered*	filtered	unfiltered*	filtered
Case ID:	R3D	FR3	R28	FR28	R90	FR90
Radionuclide						
Pu-238	2.14E + 00	2.14E-05	2.00E-01	2.00E-06	4.40E + 00	4.40E-05
Pu-239	1.65E-01	1.65E-06	1.54E-02	1.54E-07	3.40E-01	3.40E-06
Pu-240	6.20E-02	6.20E-07	5.45E-03	5.45E-08	7.60E-02	7.60E-07
Pu-241	1.30E + 00	1.30E-05	1.22E-01	1.22E-06	2.69E + 00	2.69E-05
Am-241	3.30E-01	3.30E-06	3.08E-02	3.08E-07	6.80E-01	6.80E-06
Totals	3.99E + 00	3.99E-05	3.74E-01	3.74E-06	8.19E-00	8.19E-05

*This table assumes a decontamination factor of 100,000 for the HEPA filters. Thus, there is a five order of magnitude difference between the unfiltered and filtered cases. Only the unfiltered case results are presented in the results section.

Table 4.3-3

MAXIMUM INDIVIDUAL DOSES AS A RESULT OF POSTULATED ACCIDENTS AT WIPP*

Assuming an accident occurs, the maximum committed effective dose to an individual could be:

Case	Whole Body Dose (rem)
3 drum surface fire/breach (R3D)	0.012
28 drum hoisting accident (R28)	0.0009
90 drum underground storage fire (R90)	0.019

*70-year committed effective dose received by an individual as a result of standing under the plume centerline 0.5 miles from the release point. The individual is assumed to remain in this location for 24 hours following the postulated accident, and these results do not consider a long-term resuspended inhalation or ingestion dose contribution.

Table 4.3-4
AVERAGE INDIVIDUAL DOSES AS A RESULT
OF POSTULATED ACCIDENTS AT WIPP*

Assuming an accident occurs, the average committed effective dose to an individual could be:

Case	Whole Body Dose (rem)
3 drum surface fire/breach (R3D)	0.0024
28 drum hoisting accident (R28)	0.0002
90 drum underground storage fire (R90)	0.0039

*70-year committed effective dose received by an individual as a result of standing under the plume centerline 0.5 miles from the release point. The individual is assumed to remain in this location for 24 hours following the postulated accident, and these results do not consider a long-term resuspended inhalation or ingestion dose contribution.

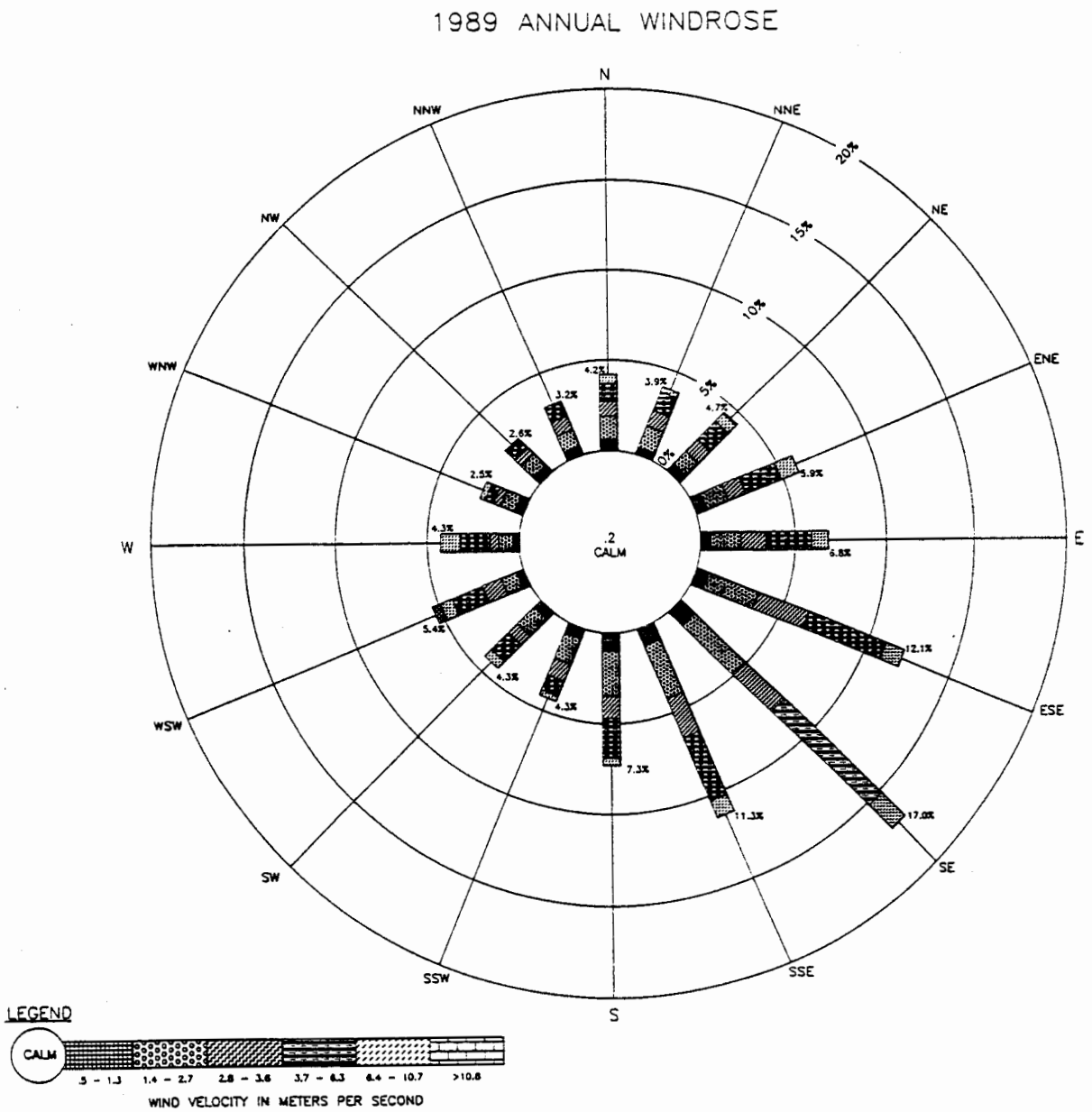
Table 4.3-5

AVERAGE INDIVIDUAL COMMITTED EFFECTIVE DOSE
FROM THE LARGEST RELEASE ACCIDENT

(Underground Fire Involving 90 drums)

Distance from WIPP Site (miles)	Average Individual Dose* (mrem)
0.5	3.9
1.0	1.1
2.0	0.4
3.0	0.2
4.0	0.09
5.0	0.06
7.5	0.03
10	0.02
12	0.01
14	0.008
16	0.006
18	0.005
20	0.004
30	0.002
40	0.0008
50	0.0005

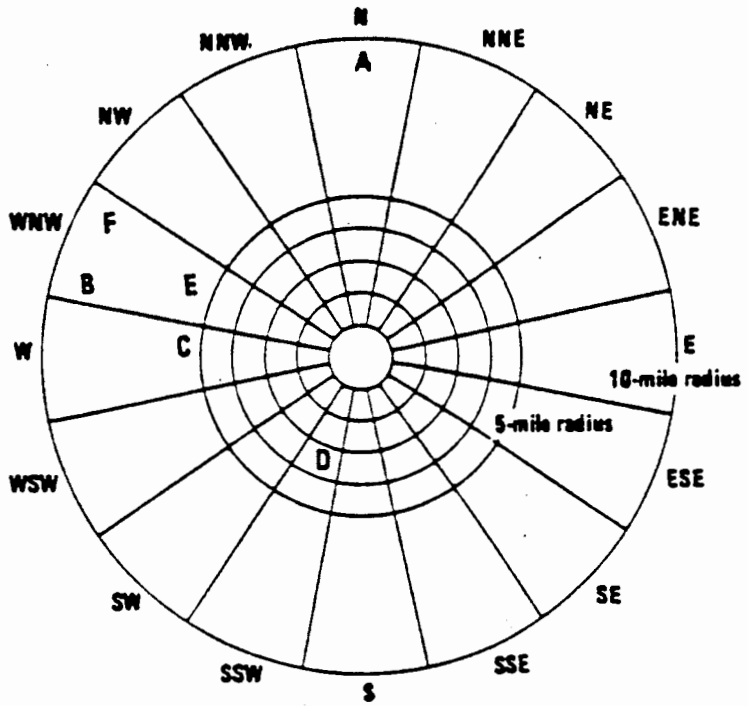
*70-year committed effective dose received by an individual as a result of standing under the plume centerline 0.5 miles from the release point. The individual is assumed to remain in this location for 24 hours following the postulated accident, and these results do not consider a long-term resuspended inhalation or ingestion dose contribution.



GG626

FIGURE 4.3-1. Direction and Persistence of Wind at the WIPP Site*

*Based on wind rose data June 1977 through May 1979



A. Kerr-McGee plant and mine: 151 employees (maximum) day shift

B. International Minerals and Chemical corporation: 450 employees (maximum), day shift

C. Duval Corporation (Nash Draw Mine): 46 employees (maximum), day shift

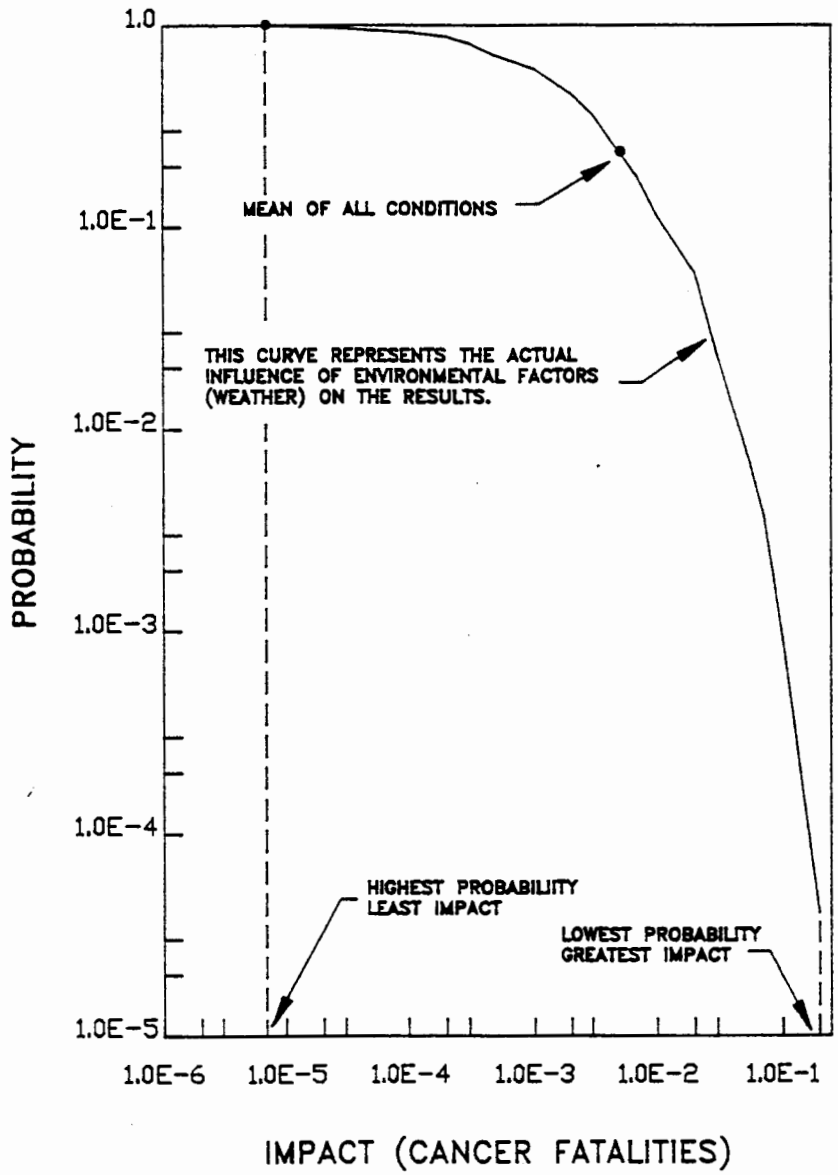
D. Mills Ranch: six permanent residents (six seasonal part-time employees)

E. Smith (Crawford) Ranch: seven permanent residents (18 seasonal part-time)

F. Pue's Store: three permanent residents

FIGURE 4.3-2. Population Within a 10-Mile Radius of the WIPP Site*

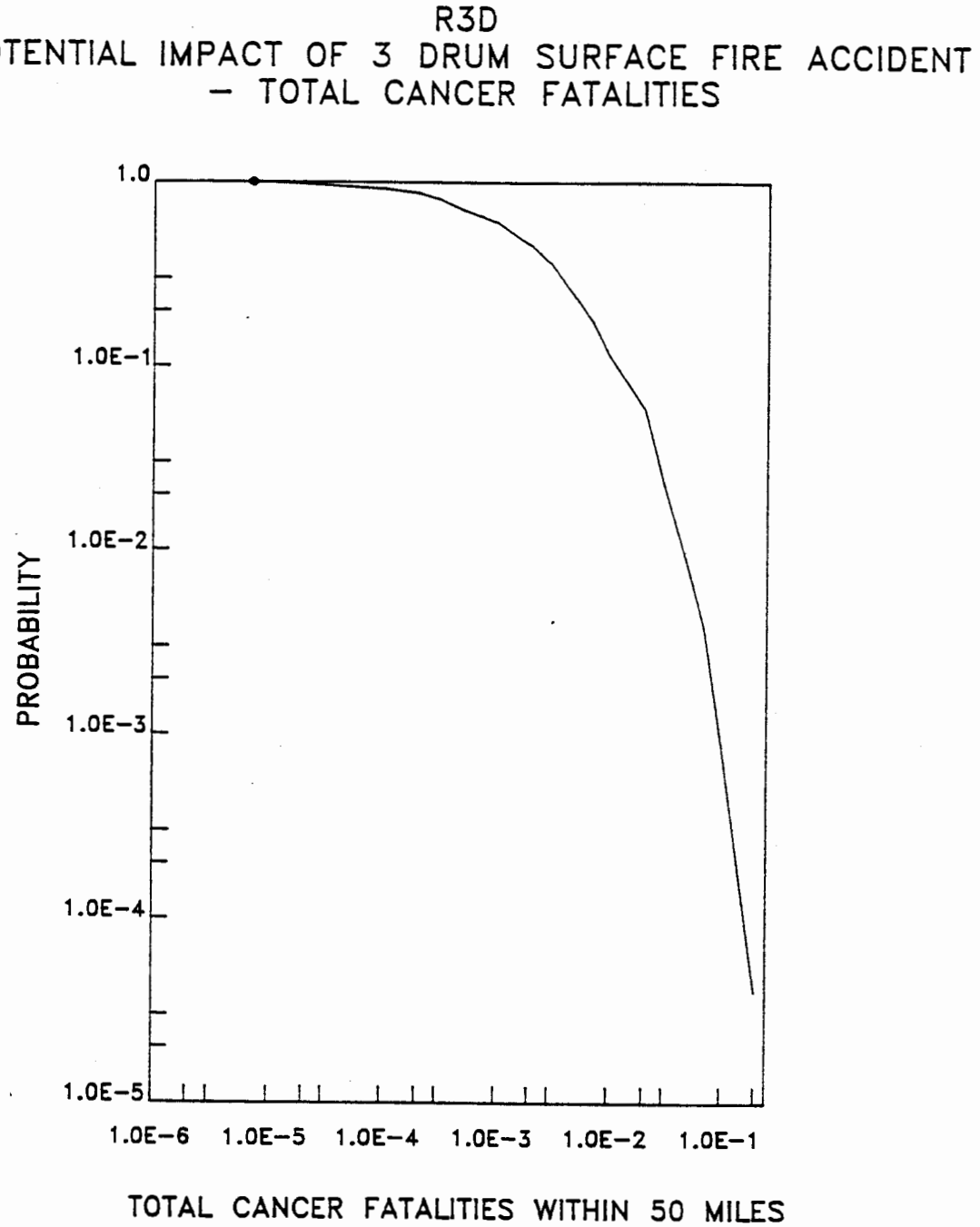
*Population information for 10 to 50 miles from the WIPP site was obtained from 1980 U.S. Census Data.



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMB\HMB42

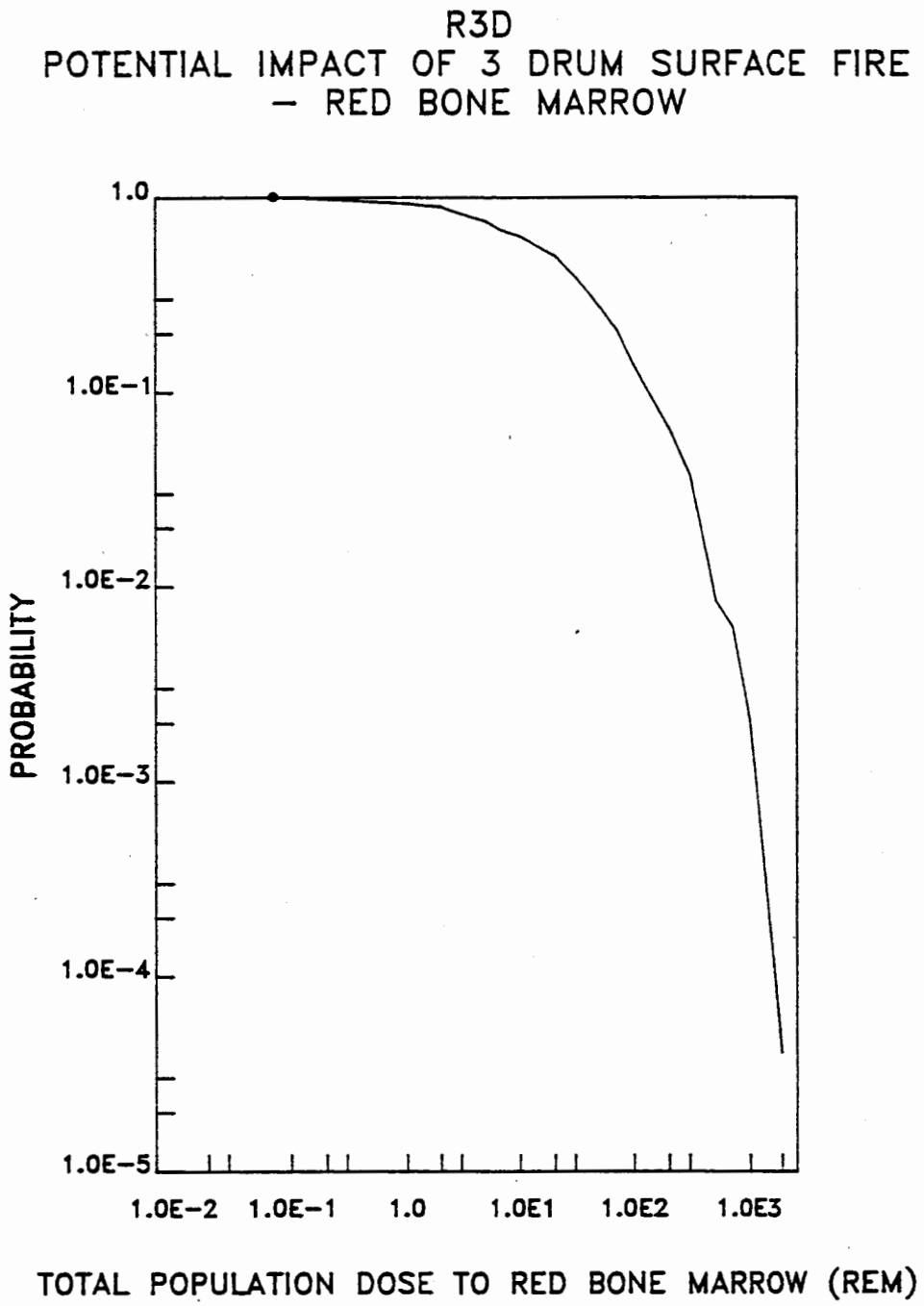
FIGURE 4.3-3. Hypothetical MACCS CCDF



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA83

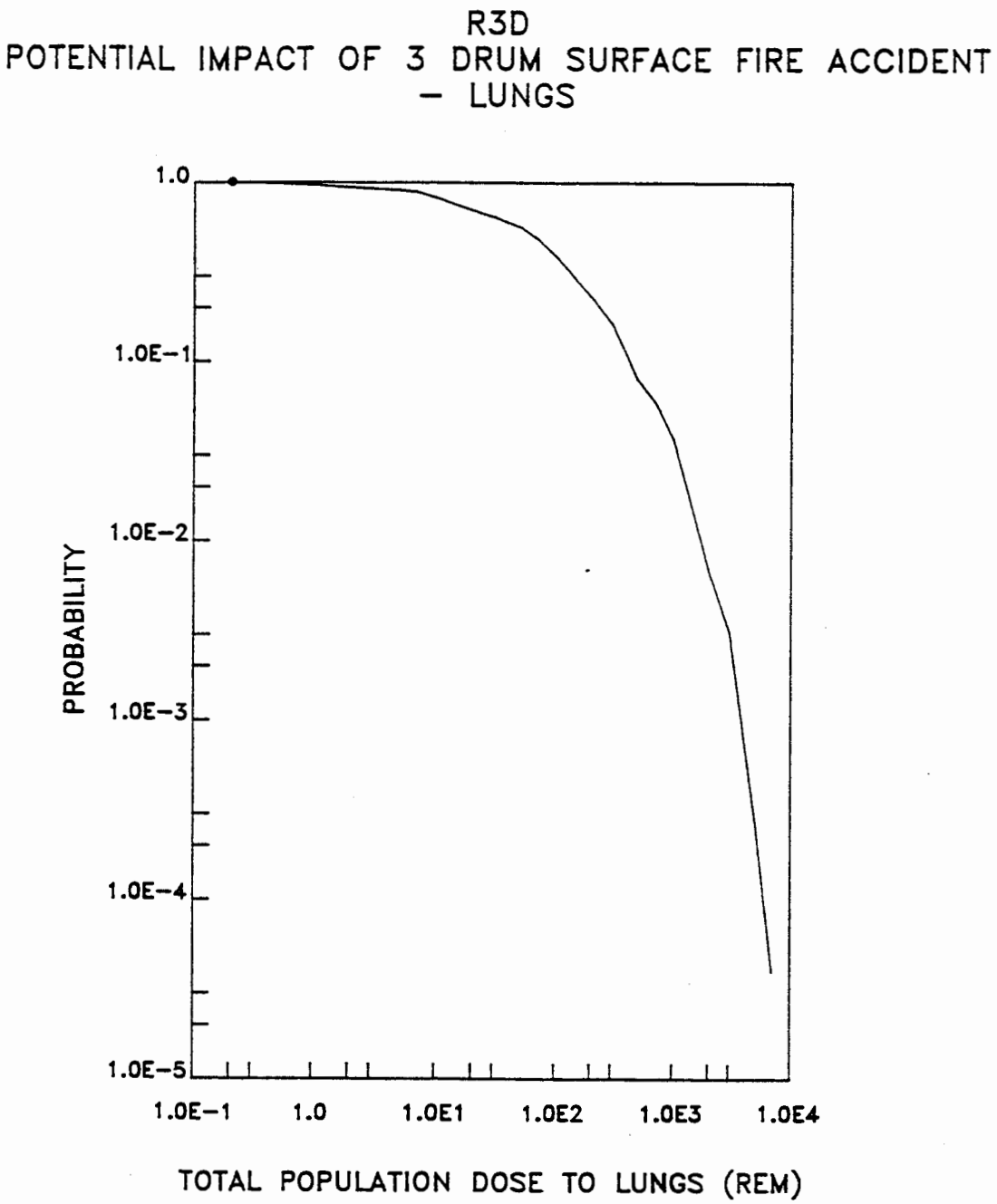
FIGURE 4.3-4. Potential Impact of Three Drum Surface Fire/Breach - Total Cancer Fatalities (R3D)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA84

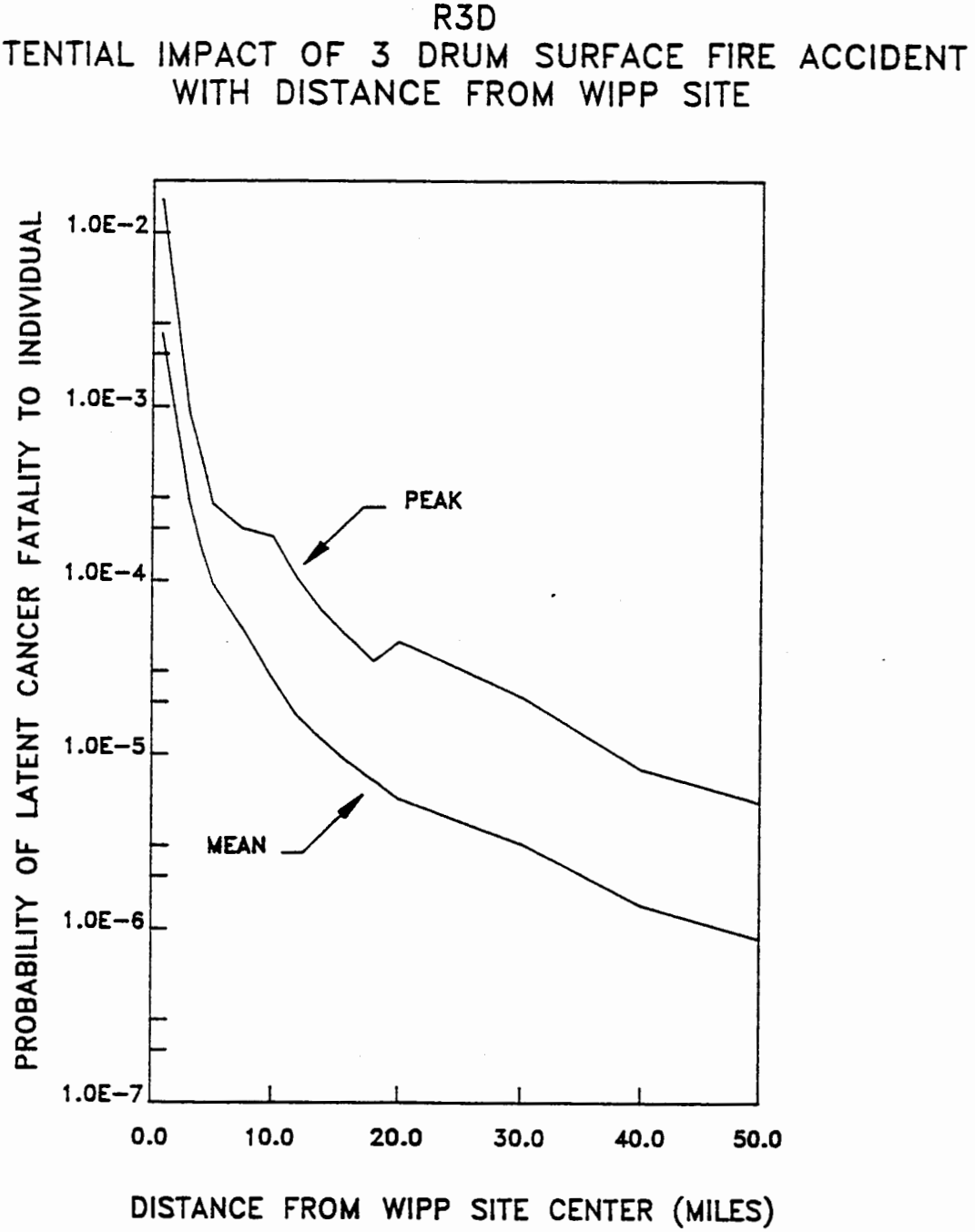
FIGURE 4.3-5. Potential Impact of Three Drum Surface Fire/Breach - Red Bone Marrow (R3D)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA85

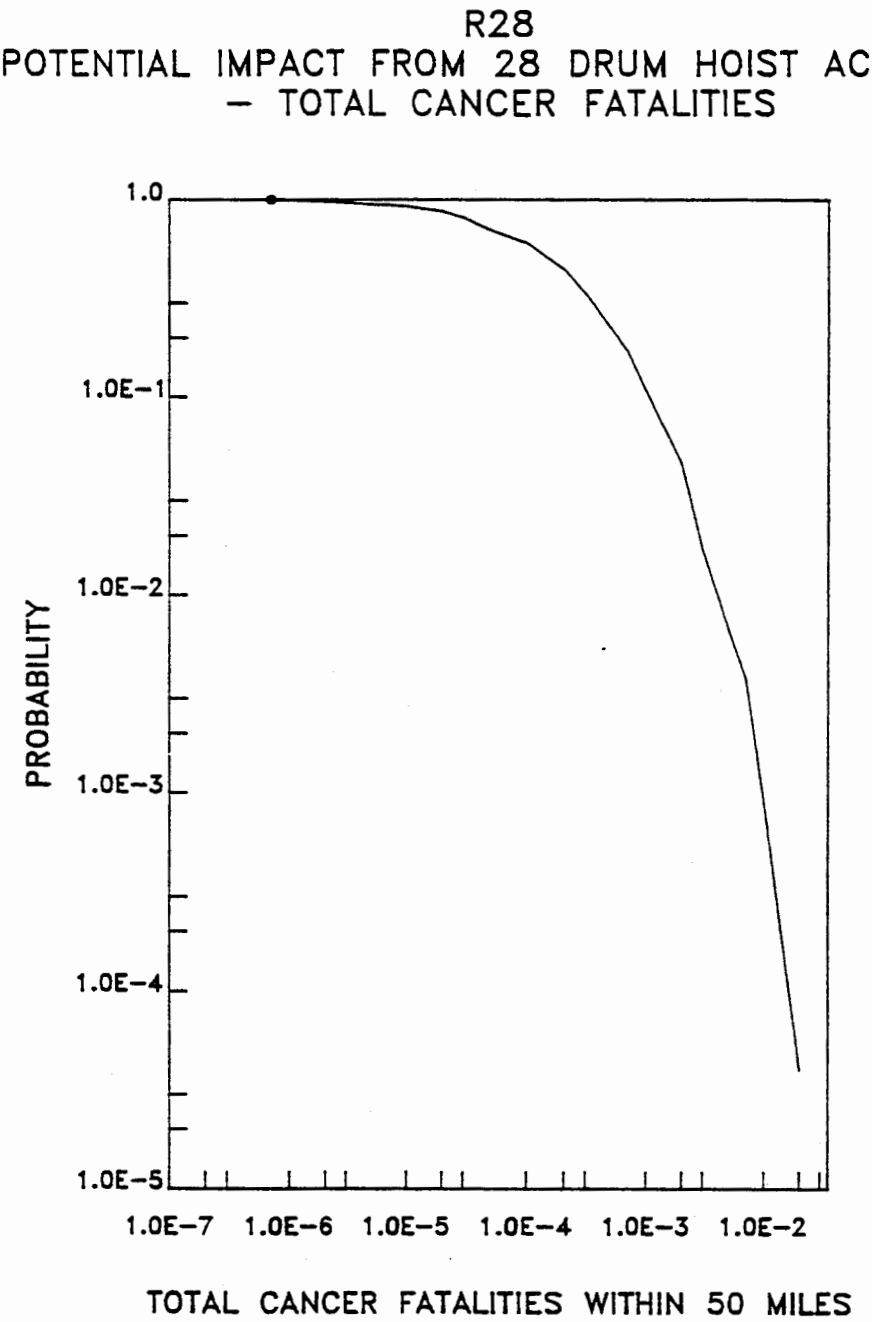
FIGURE 4.3-6. Potential Impact of Three Drum Surface Fire/Breach - Lungs (R3D)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C\HMA\HMA86

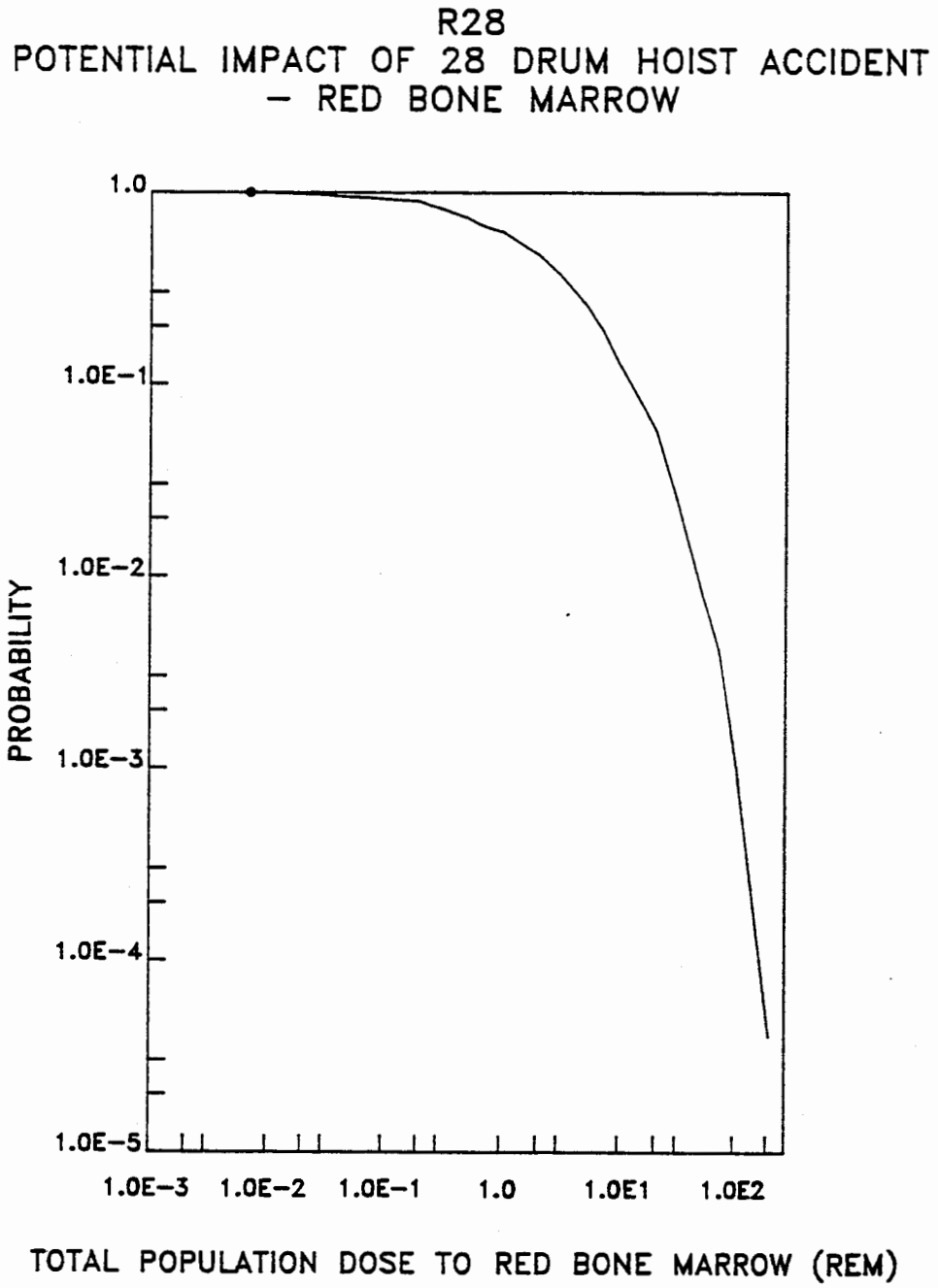
FIGURE 4.3-7. Potential Impact of Three Drum Surface Fire/Breach Accident with Distance from the WIPP Site (R3D)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING
AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA87

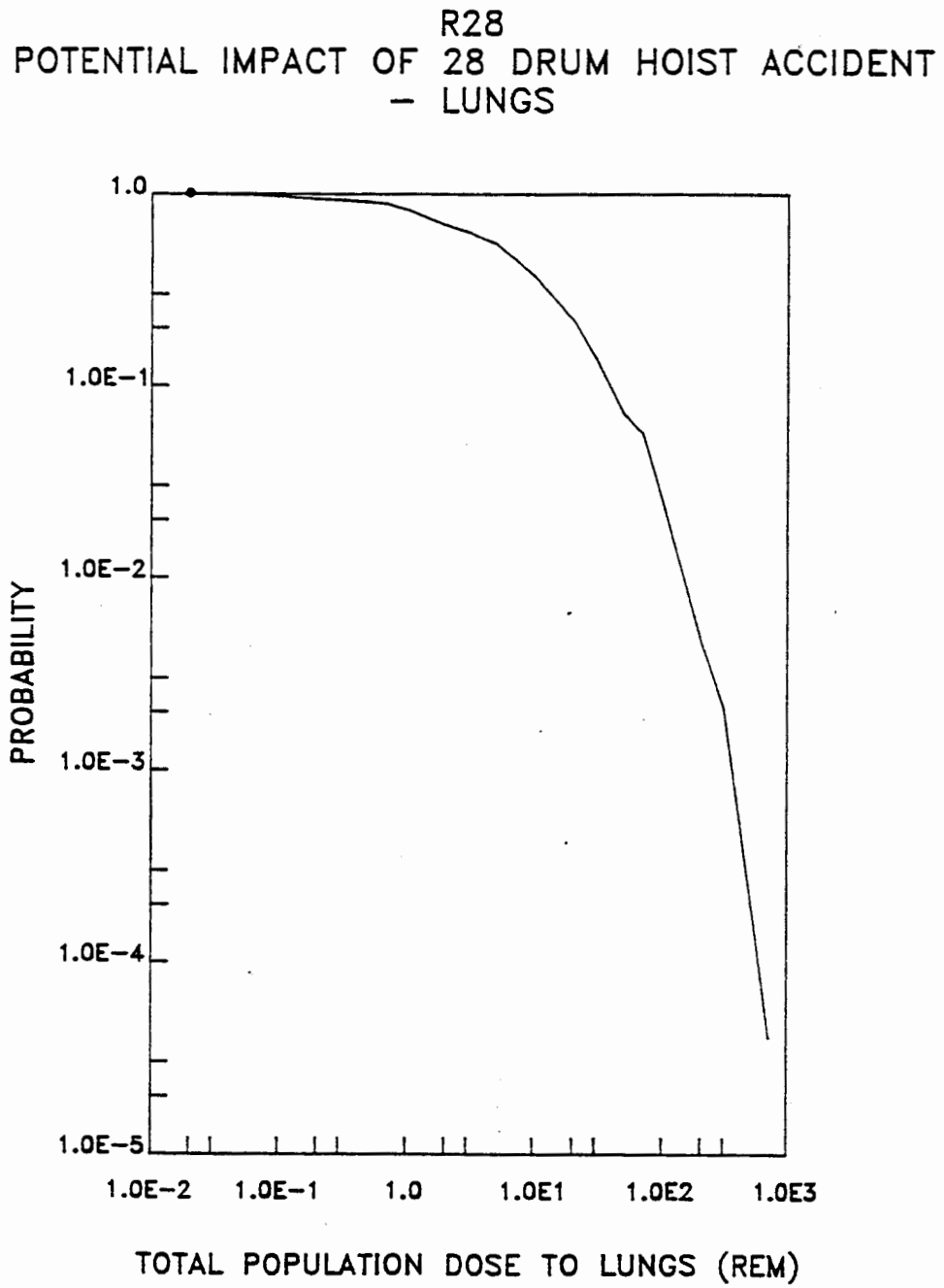
FIGURE 4.3-8. Potential Impact from 28 Drum Hoist Accident – Total Cancer Fatalities (R28)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA88

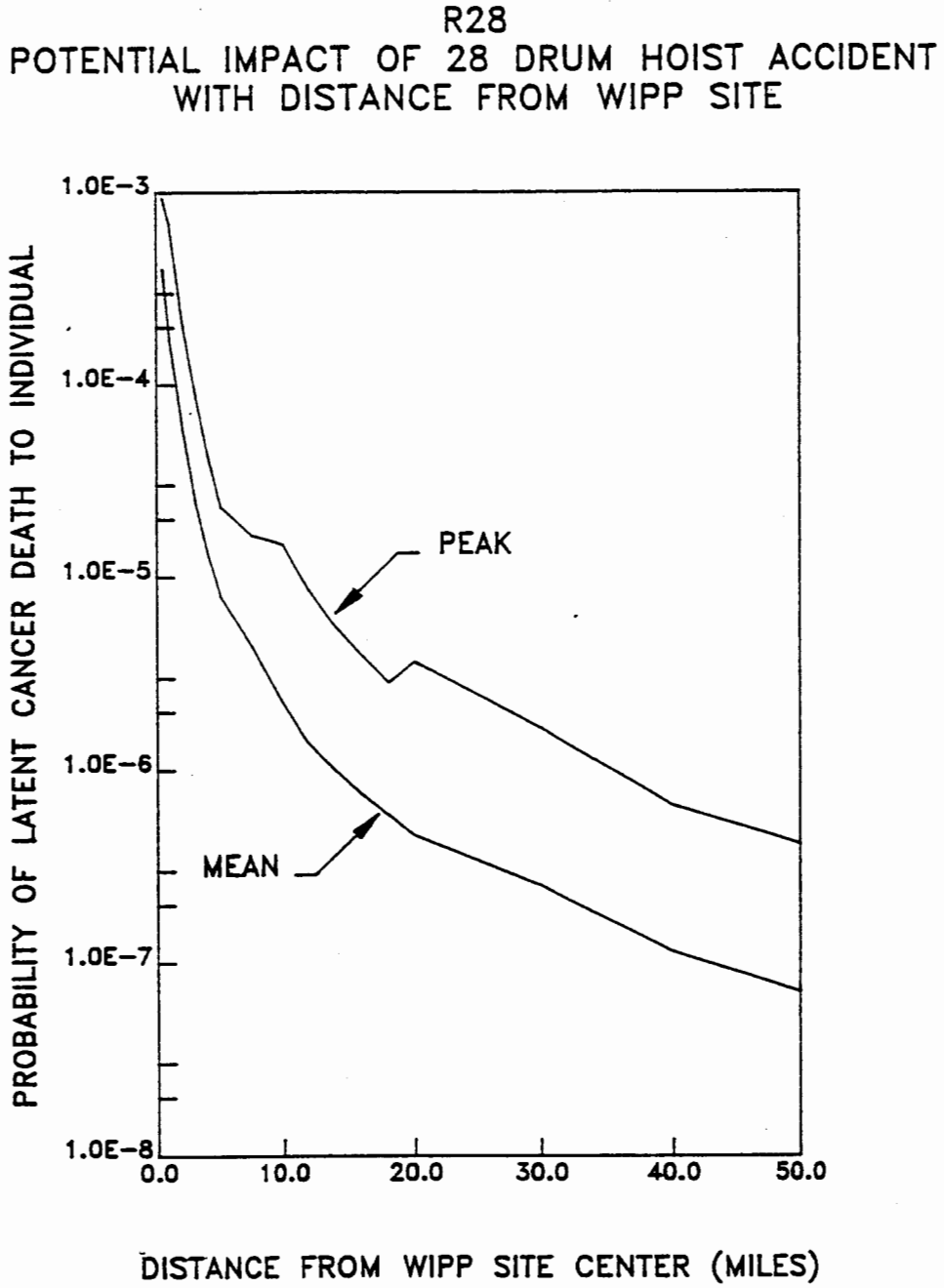
FIGURE 4.3-9. Potential Impact from 28 Drum Hoist Accident - Red Bone Marrow (R28)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA89

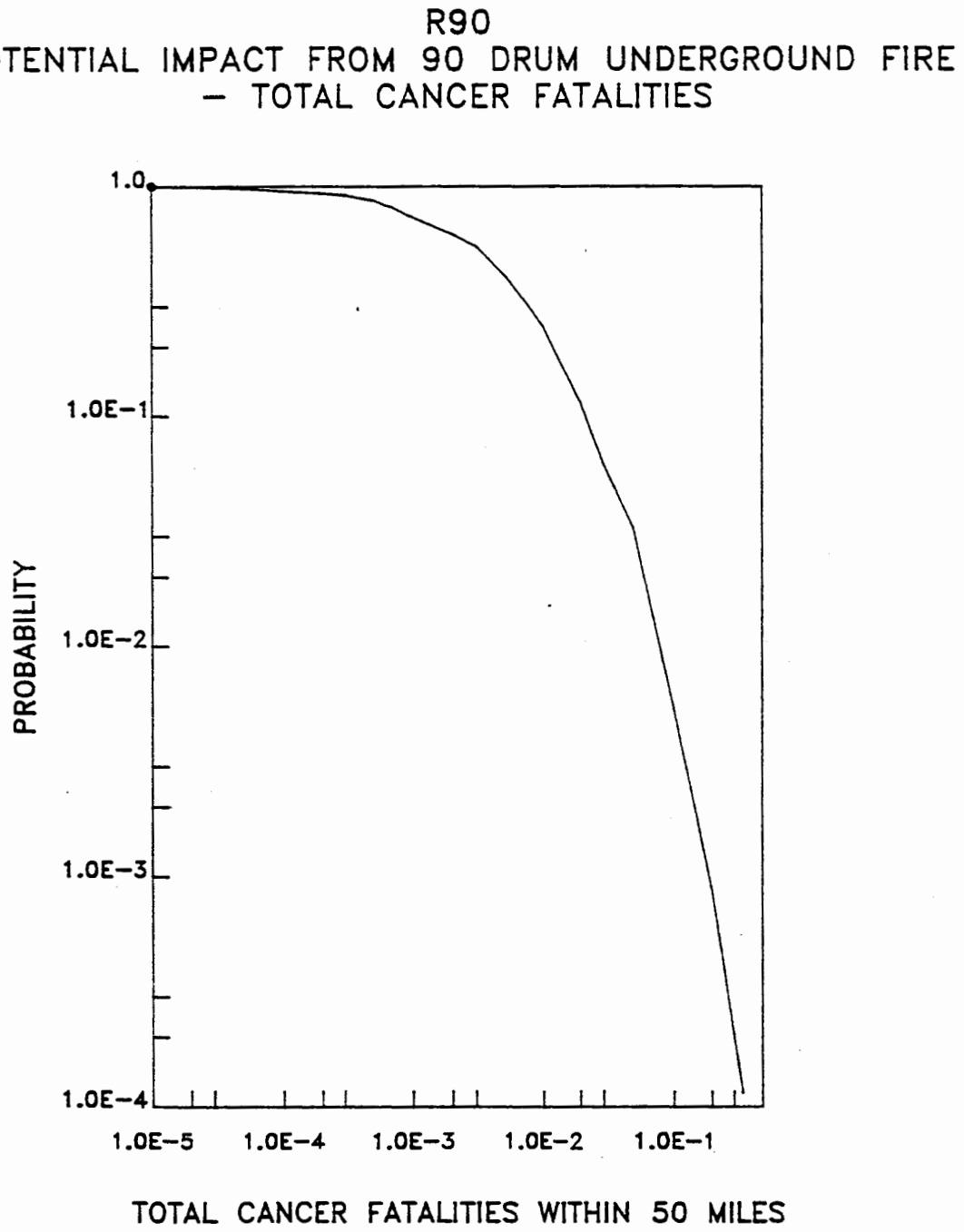
FIGURE 4.3-10. Potential Impact from 28 Drum Hoist Accident - Lungs (R28)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA90

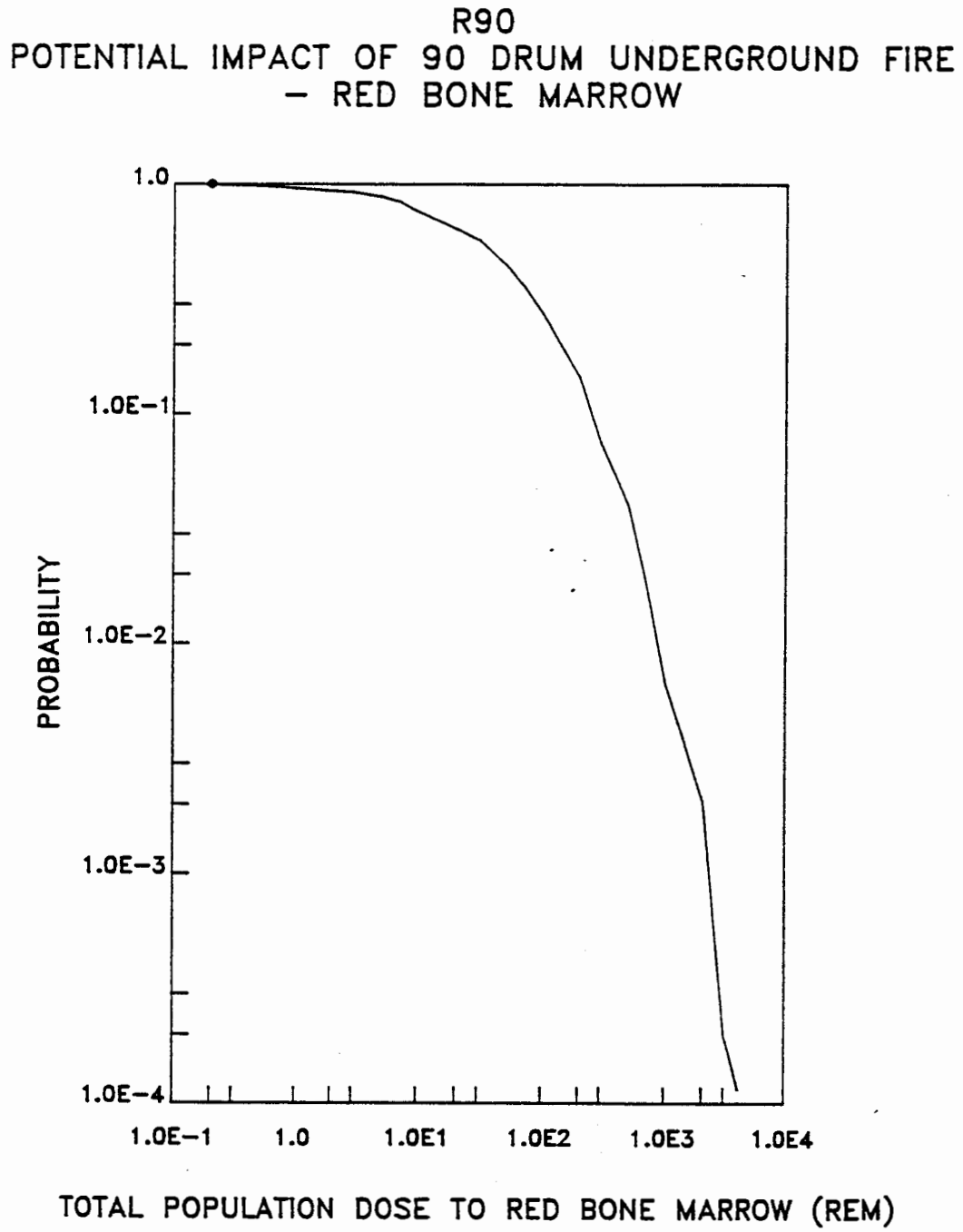
FIGURE 4.3-11. Potential Impact from 28 Drum Hoist Accident with Distance from the WIPP Site (R28)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA91

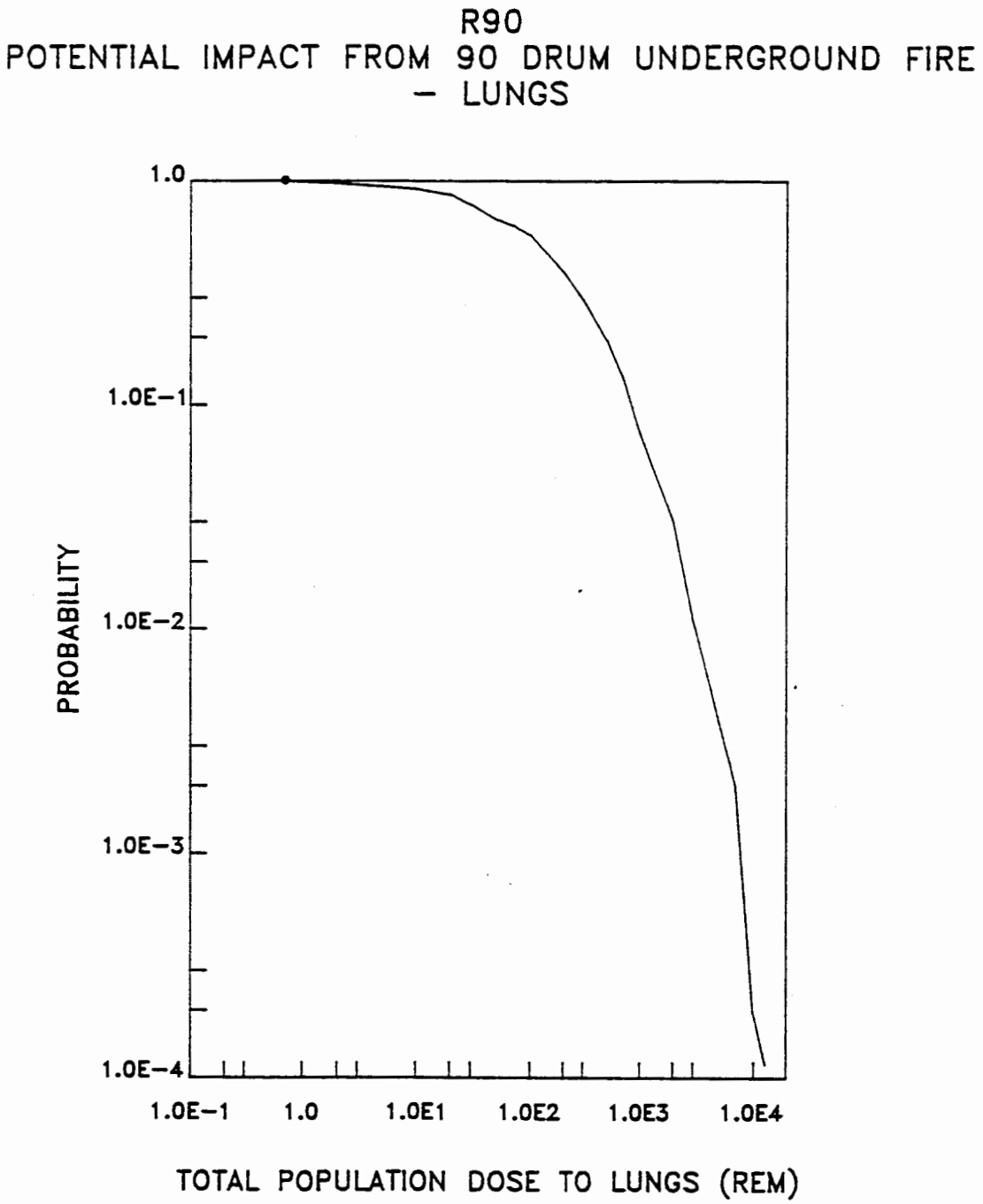
FIGURE 4.3-12. Potential Impact from 90 Drum Underground Fire - Total Cancer Fatalities (R90)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C\HMA\HMA92

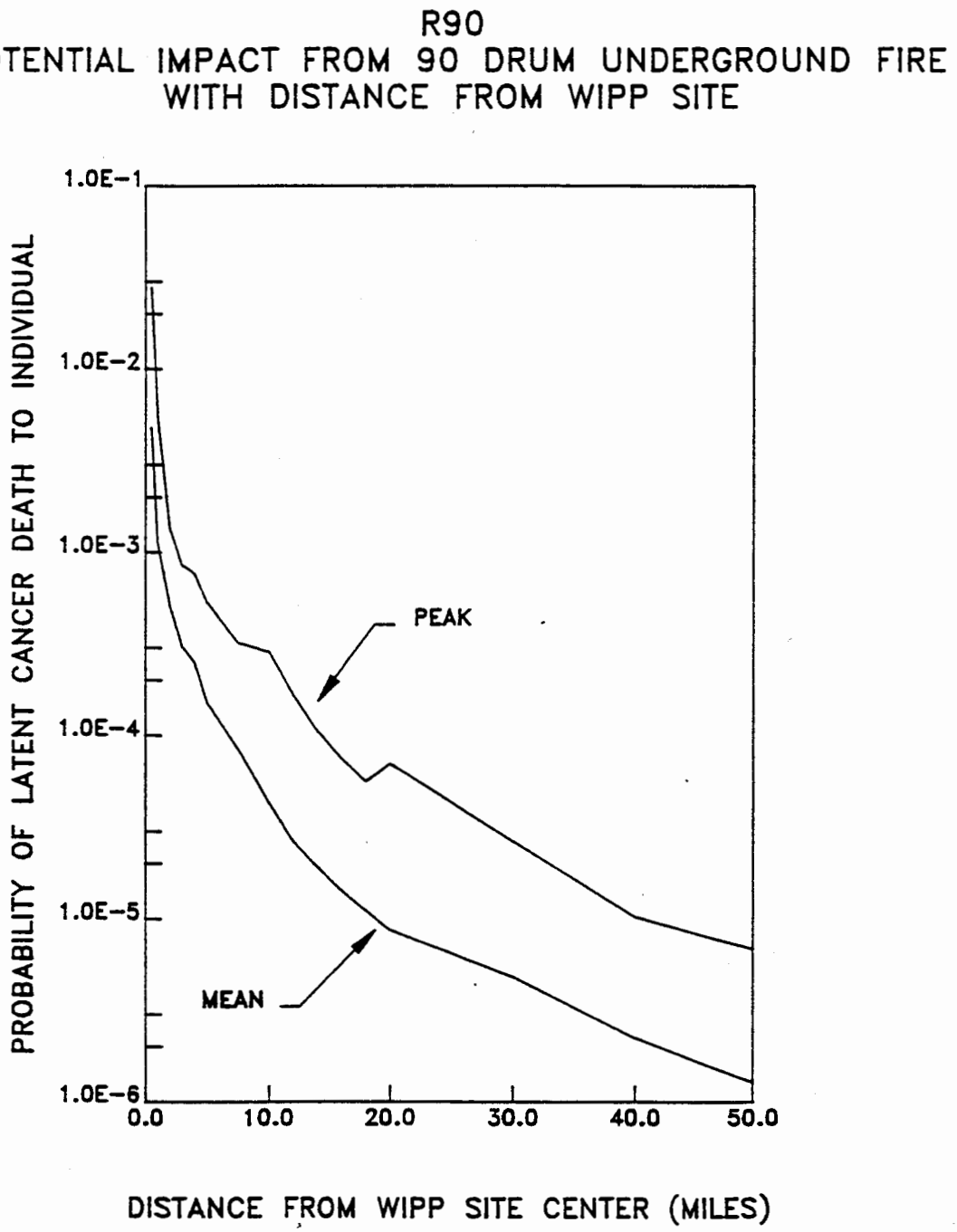
FIGURE 4.3-13. Potential Impact from 90 Drum Underground Fire - Red Bone Marrow (R90)



(NOTE: RESULT SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA93

FIGURE 4.3-14. Potential Impact from 90 Drum Underground Fire - Lungs (R90)



(NOTE: RESULTS SHOWN ARE BASED ON ACCIDENT OCCURRING AND RELEASE NOT FILTERED)

TJM C:\HMA\HMA94

FIGURE 4.3-15. Potential Impact from 90 Drum Underground Fire with Distance from the WIPP Site (R90)

4.4 SYSTEMS ANALYSIS

Detailed system modeling was performed in the PRA. The systems analyzed included:

- Waste Hoist System
- Salt Handling Hoist System
- HVAC Systems
- Electrical Power Systems
- Compressed Air Systems
- Fire Detection and Suppression Systems
- Central Monitoring System
- Radiation Monitoring Systems
- Other WIPP Support Systems

The focus of this study is fire induced risks. In order to make this report more compact only the Fire Detection and Suppression Systems is included here. Refer to Volume II of the WIPP Integrated Risk Assessment (DOE/WIPP 89-0/0-010) for these other systems analysis.

4.4.1 FIRE DETECTION AND SUPPRESSION SYSTEMS ANALYSIS SUMMARY

The purpose of this part of the study was to use quantitative fault tree methodology to analyze the failure of the FDSS. The FDSS would be used to avoid a fire at the WIPP site. As part of this study, WIPP site drawings of the FDSS were interpreted, followed by a site walkdown of these systems to verify the drawings and to evaluate component fitness. The systems were found to be as shown on the drawings, and findings from the walkdown are included in this report. The fault trees created for the FDSS are presented in Appendix E.

The report is organized into sections that include a description of the FDSS and their tests and maintenance, the analysis process, and the results of this study. A summary of key findings is also included.

The WIPP site incorporates both fire detection and fire suppression systems. Fire detection is accomplished by the use of fire detection devices which include thermal rate of rise, ionization, and photoelectric type smoke detectors. The detection of fire or smoke activates local alarms and remote alarms. Activation of the detectors may also provide suppression system actuation. Detection of fire may also be accomplished by manual

means. Manual pull alarms which are annunciated in the CMR may also provide localized detection of fire.

Fire suppression systems at the WIPP include water, Halon, dry chemical systems, and manual methods. The water system supplies water on demand to the sprinkler system, the manual hose reels, and/or fire hydrants. The sprinklers are activated by a rise in temperature to a fixed point. Halon systems (CMR, CR, and vault) may be discharged manually or by activation of the cross-zoned photoelectric and ionization detectors. The dry chemical systems (UFS, diesel-driven vehicles) may be discharged manually or by activation of rate of rise detectors. Manual fire suppression methods include the use of portable extinguishers, manual hose reels, hydrants, and/or the fire trucks.

As part of the analysis process, the fault tree guidelines in Section 4.1 of this study were followed in modeling the water, Halon, and dry chemical systems, and the use of manual methods in fire detection and suppression.

Success criteria for the fault trees were defined as follows:

Fire Water	- One of two fire water pumps - Valves in fire water loops open - Sprinklers open
Dry Chemical System	- Activation of rate of rise detectors - Valves and nozzles open and clear
Manual Methods	- Successful detection and locating of fire - Extinguishers/hose reels/fire trucks available and functional

These systems were modeled with fault trees, failure rates or probabilities were assigned, and the fault trees were quantified for the failure of the systems. The results of the quantification are presented below.

Water system unavailability in the CH Bay of the WHB was computed to be 1.1E-2/event. This implies that one out of every 92 times that the system is challenged, it may not work successfully. The dominant contributors to unavailability were found to be the plugging of

sprinklers and the simultaneous failure of both the electric and the diesel-driven fire pumps to run.

The dry chemical system unavailability for both the UFS and for the diesel-driven vehicles was computed to be 2.7E-2/event. This implies that one out of every 36 times that the system is challenged, it may not work successfully. The dominant contributor to unavailability was found to be the failure of the dry chemical supply, which encompasses the dry chemical bottles, the release mechanism, and the release valves.

Two analyses were performed for manual means of fire suppression - one for aboveground methods and one for U/G methods.

The aboveground methods were found to have an unavailability of 3.3E-2/event. This implies that one out of every 30 times that these methods are challenged, they may not work successfully.

The dominant contributors were found to be failure to locate or to detect a fire, and the personnel clearing the area without suppressing the fire.

The U/G methods were found to have an unavailability of 3.4E-2/event. This implies that one out of every 30 times that these methods are challenged, they may not work successfully.

The dominant contributors were found to be failure to locate or to detect a fire, and the personnel clearing the area without suppressing the fire.

An examination of the results shows that the results are subject to the failure rates applied to the fault tree. The failure rates for the systems analyzed were based on documented failure data for both system components and HEs.

4.4.1.1 System Description

This section describes the systems and components that comprise the FDSS. Fire detection methods will be discussed first, followed by fire suppression methods.

WIPP Fire Detection and Suppression Systems

Fire and Smoke Monitoring, Detection, and Alarm

The fire and smoke monitoring, detection, and alarm devices are activated by different stages of fire. Ionization detectors alarm at the presence of invisible particles of combustion gases during the incipient stage of fire. Fixed temperature/rate of rise detectors react to a fixed temperature or a rapid rise in ambient temperature (in excess of 15F/min) and provide alarm services, as well as release service, for certain systems discussed below.

Each fire detection or fire extinguishing system that is connected to the fire alarm system annunciates in the CMR.

The failure of a single fire detection device or electrical circuit is annunciated by the circuit's supervisory alarm. This enables inspection and replacement or repair of the circuit fault or failed component. These signals are displayed and annunciated in the CMR.

Normal power for fire detection and alarm is provided from the on-site AC power source at 120 VAC, 60 Hz. Backup power to the normal WIPP site power source is supplied by two diesel-driven generators. Each fire alarm and detection system (fire panel) has at least a 24 hour battery backup.

Fire Suppression

WIPP has four methods to protect its aboveground and underground facilities against fire and explosion:

1) Fire water distribution
2) Halon 1301
3) Dry chemical
4) Manual fire fighting

- Fire Water Distribution System

The fire water distribution system consists of two 180,000 gallon water storage tanks, with the capacity to handle the maximum credible fire as defined in DOE 5480.7 and the FSAR. Fire water storage is reserved and is capable of providing 1,500 gpm for two hours. The flow rate is based on the calculated water estimated for fire control.

Fire water is supplied to the WIPP facility structures by a compound loop distribution system serving the entire plant. System pressure is provided by one of two 1500 GPM capacity pumps. The main fire water pump is a centrifugal pump with electric motor drive supplied from normal power. The backup fire water pump is driven by a diesel engine.

A small jockey pump is provided to maintain the desired static pressure on the water supply system and minimize unnecessary operation of the main pumps.

The pumps have flood suction from the storage tanks. They discharge water into a 10-inch fire loop equipped with sectional valves. The loop is connected to all fire hydrants, sprinklers, and hose stations. The fire loop is separate and independent of the domestic water distribution system.

Water for the fire water system is supplied from the water storage tanks and distributed from the water pumphouse. The water pumphouse is located adjacent to the two water storage tanks. The pumphouse contains two fire pumps (one electric and one diesel) and three electric domestic water pumps.

Fire water is normally supplied by one electric-driven pump. A backup diesel-driven fire pump is also provided in case of power failure or when maintenance is required on the electric pump. Fire water pressure is maintained by an electric-driven jockey pump. During a fire, the fire pump is started, and the dedicated fire water reserve, in addition to any domestic water, is used for fire suppression.

If a water line breaks, isolation of the break is available by sectionalizing valves.

Pipes located aboveground near the water storage tanks are protected from freezing with insulation. The pumphouse and other buildings are heated to protect indoor piping from freezing; and interconnecting piping, which comprises the fire water loops, is buried a minimum of four feet underground.

Water is applied on the site of the fire through the sprinkler system.

The water sprinkler system operations is when a rise in the ambient temperature causes the sprinkler to open, which causes the heads to open. The flow of water through an alarm-check valve initiates the local alarms and registers an alarm condition in the CMR. Once initiated, sprinkler system operation must be shutdown manually by shutting an external post indicator gate valve or outside screw and yoke valve.

Halon 1301 System

The CMR, CR, and vault are provided with redundant fire protection systems. This protection consists of a primary Halon 1301 total flooding system with a connected reserve supply and a backup sprinkler system. This system was not analyzed because it could not impact the release of radioactive material.

The Halon 1301 systems in the CMR, CR, and vault are actuated by a cross-zoned detection system. This system combines ionization type smoke detectors with photoelectric smoke detectors. Prealarm is provided by the early warning system, while discharge of the Halon 1301 system is accomplished when detectors from both zones are activated after a 30-second delay. The system closes HVAC dampers and doors and shuts down the HVAC system to confine the extinguishing agent.

Dry Chemical System

The U/G fuel storage rooms and vehicle fueling areas have separate fire detection systems using rate of rise detectors that activate the discharge of the dry chemical system and simultaneously close the nearest storage room fire door. The connected reserve is available to maintain suppression capability.

Fire dampers in U/G air ducts are closed by release solenoids. Fire doors in U/G fuel areas are closed by release solenoids or by fusible links.

Selected U/G diesel-driven vehicle is equipped with a dry chemical system that is actuated manually or by temperature-sensing detectors that are located throughout the

engine. Nozzles, for distribution of the dry chemical, are aimed at the engine. Portable extinguishers are also available on each vehicle.

Manual Fire Fighting Efforts

Portable extinguishers are provided for manual fire fighting operations involving Class A, B, or C fires. Wet standpipes supplying hose reels through manually operated hose valves are also available for manual control of fires aboveground.

Two fire trucks are available. One truck is located aboveground to fight aboveground fires, while a second smaller unit is located underground.

System Boundaries

The following boundaries were established in performing this analysis:

Fire Water Distribution System

- Water input to water tanks
- Electric and diesel-driven fire water pumps
- Fire water lines and valves
- Sprinklers

Dry Chemical System

- Dry chemical storage tanks
- Distribution devices - nozzle output
- Detection devices

Manual methods

- Portable extinguishers
- Hose reels
- Firetruck
- Hydrants

4.4.1.2 System Interfaces

Fire Water System Interfaces

The following inputs have been identified for the fire water system:

- Water for fire water distribution

- Electricity for electric-motor driven fire water pump

  - Primary: Substation 4, CB6
  - Secondary: Emergency power from DG thru substation 4, CBL

- Diesel fuel for the diesel-driven fire pump

- Heat (from a fire) that activates the sprinklers

- The following outputs have been identified for the fire water system:

- Water from the sprinklers

- Fire alarms locally and in the CMR prompted by detection of a fire

Dry Chemical System Interfaces

The following inputs have been identified for the dry chemical system:

- Electricity for the detectors

  - Primary: Plant Substation, Buses A or B, CBs 2 or 3
  - Secondary: Emergency power from DG
  - Tertiary: UPS

- Heat (from a fire) that activates the thermal detectors

- The following outputs have been identified for the dry chemical system:

- Dry chemical from the nozzles
- Fire alarm locally and in the CMR, prompted by detection of the fire

Manual Method Interfaces

The following input has been identified:

Human or CMR detection of fire

The following outputs have been identified:

Dry chemical from portable extinguishers and firetruck U/G

Water from manual hose reels or from firetruck (aboveground)

Alarm in CMR

4.4.1.3 Operating History

Although radiological waste has not been received at the WIPP, the fire protection system is operational but has never been challenged in an actual fire.

Because the WIPP is not yet operational and the FDSS have never been challenged, operating history is not applicable.

4.4.1.4 Test and Maintenance

Inspection and Testing Requirements

Each fire pump is subjected to factory hydrostatic and performance tests, as required by NFPA 20. Each fire pump is field tested to 150 percent of rated capacity and full capacity of rated head in accordance with NFPA 20. Weekly fire pump functional tests and annual fire pump performance tests are performed.

Sprinkler systems are inspected and tested monthly.

Halon 1301 system tests to verify operation of all release mechanisms and the attainment of specified agent concentrations in the area protected were performed after installation according to NFPA 12A. Inspection and testing is performed annually according to NFPA 12A. Tests do not include agent discharge. Containers are checked for pressure monthly and content semiannually.

The dry chemical systems are tested similarly to the Halon 1301 systems, except in accordance with NFPA 17. The dry chemical system detector malfunctions are annunciated in the CMR to allow replacement of faulty detectors.

Fire alarm, fire detection, and smoke detection systems are operationally tested in accordance with NFPA 72E to ensure complete system operation. In addition, a complete evacuation alarm system test is performed annually.

The design, installation, inspection, and testing of the fire protection systems are performed as required by the National Fire Protection Association Standards.

Portable fire extinguishers and manual hose reels are visually inspected monthly.

In addition to regular inspection and testing, preventative maintenance (PM) is performed on the FDSS. PM procedures are a part of the WIPP Safety Manual, WP 12-1.

4.4.1.5 WIPP Site Walkdown

A walkdown of the WIPP FDSS was conducted on January 9, 1989. During this walkdown the FDSS in the following 14 areas/systems were examined:

Water Pumphouse
Water Storage Tanks
Yard Fire Water Distribution
Waste Handling Building
Computer Room and Vault
Central Monitoring Room
Salt Hoist Building

Exhaust Filter Building
Underground Fuel Storage Areas
Underground Waste Storage Areas
Underground Diesel-Driven Vehicles
Warehouse
Guard and Security Building
B49 Annex

While conducting the system walkdown, the following items were considered:

Verification of the as-built systems versus the drawings used in the analysis
Inspection, test and maintenance frequency and duration
Fitness of system components
The systems were found overall to be in very good conditions

Item 1

WATER PUMPHOUSE BUILDING 456 CHECKLIST

1. Verify P&ID Versus As-Built

The system piping configuration was verified to correspond to the P&IDs as closely as visual inspection would allow.

2. Maintenance, Test, and Inspection

Frequency

- Electric pump: Weekly - manual
- Diesel-driven pump: Weekly - test
- Pressure sensors PSL02, PSL04: Functional test weekly with pumps. Calibrated annually.

Duration of test or maintenance

- Electric pump: Due to the redundant design and the manner in which the test was performed, testing was not found to affect availability. Unavailability due to maintenance may vary according to the work to be done.

- Diesel-driven pump: Due to the redundant design and the manner in which the test was performed, testing was not found to affect availability. Unavailability due to maintenance may vary according to the work to be done.

- Low water pressure sensors: Due to the redundant design and the manner in which the test was performed, testing was not found to affect availability. Unavailability due to maintenance may vary according to the work to be done.

Procedures

- Valve position verification: Manual valve positions verified by stem. Valves are chain-locked in the normal working position (car-sealed-open, [CSO], or car-seal-closed, [CSC]).

3. System Flushed

System was flushed after installation, as well as being chlorinated and hydrostatically tested.

4. Diesel Fuel Storage

Location: 200+ gallon tank near diesel-driven pump

Type of fire protection: Automatic sprinkler with dike to isolate spillage. Portable extinguishers are also available.

5. Fitness of Components

Although some water leaks were observed around valve packings and through some valves, the physical condition of the equipment appeared to be normal for systems of this type and usage.

6. Remarks

1/4 turn plug valves for sensors PSL 02/04 should be CSO.

The water pumphouse has its own sprinkler system, which is inspected monthly and functionally tested quarterly for flow.

Item 2

WATER STORAGE TANKS CHECKLIST

1. Verify P&ID Versus As-Built

The system piping configuration was verified to correspond to the P&IDs as closely as visual inspection would allow.

2. Maintenance, Test and Inspection

Frequency

- Water Gauges: Float and pressure gauges are calibrated annually and readings are taken daily.

Procedures

- Valve positions: Impairment procedures require notification of the fire engineer, tagging of valves, and restoration to normal operating positions following maintenance.

3. Wet System Protected Against Freezing, Lightning Hazards

Pipes were protected against freezing by insulation. Both tanks and pipes were grounded, and a lightning protection system was installed.

4. Overflow

Each tank is provided with an overflow weir.

5. Level

Each tank is equipped with a Differential Pressure (DP) cell for level indication. Level readings are available in the water pumphouse.

Item 3

FIRE WATER DISTRIBUTION CHECKLIST

1. Verify P&ID Versus As-Built

Location of valves for main distribution and inlet to building sprinkler headers were identified. Verification of exact sprinkler location and number was not performed.

2. Maintenance, Test, and Inspection

Frequency

- Manual valves exercised: once/year

Procedures

- Valve position verification during and after maintenance: Valve positions indicated by reading "open" or "closed."

3. Fitness of Components

The fire water piping and the main distribution system are mostly underground and observation was not possible. All equipment aboveground appeared to be well maintained and in good working order. Only one pressure gauge, located at the exhaust filter building, was found to be faulty, but this should not affect the availability of the fire water system.

4. Wet System Protected Against Freezing, Heat Effects

Pipes are buried a minimum of four feet underground.

Item 4

WASTE HANDLING BUILDING (WHB) FIRE DETECTION AND SUPPRESSION CHECKLIST

1. Verify P&ID Versus As-Built

Location of valves for main distribution and inlet to building sprinkler headers were identified. Verification of exact sprinkler location and number was not performed.

2. Maintenance, Test, and Inspection

Frequency

- Detection devices and circuits: Heat/Thermal detectors in the WHB are tested annually.

- Inspection of sprinklers for buildup of corrosion: Sprinklers are visually inspected monthly, along with water flow alarm tests.

- Inspection of manual hose reels and portable extinguishers: These inspections are performed monthly.

- Pressure and other sensors: These sensors are tested monthly.

Procedures

- Valve positions during and after maintenance: Administratively controlled under tag-out and recertification procedures.

3. Fire Water System Flushed

The fire water system was flushed after installation.

4. Fitness of Components

See Point 3 under Fire Water Distribution Checklist (Item 3).

5. Remarks

Detection devices and circuits: The remote handling part of the building has fixed heat rate-of-rise detectors at the 10 foot level, which may be ineffective.

Sprinkler heads: Sprinkler heads are located 6 inch -12 inch below the ceiling throughout the building. Hydrostatic testing is performed.

Manual hose reels and portable extinguishers: Manual hose reels have 75 feet of hose available, and portable extinguishers are available within 100 feet of travel throughout the building.

6. Alarm Check Valves

In-line for all sprinkler zones, and used to alarm those zones which have been activated.

7. Fire Truck

500 gallon tank, 750 gpm pumping capability (60-minute Self-Contained Breathing Apparatus [SCBAs]).

Items 5 and 6

CENTRAL MONITORING SYSTEM (CMR), COMPUTER ROOM,AND VAULT FIRE DETECTION AND SUPPRESSION CHECKLIST

1. Verify P&ID Versus As-Built

Location of valves for main distribution and inlet to building sprinkler headers were identified. Verification of exact sprinkler location and number was not performed.

2. Maintenance, Test, and Inspection

Frequency

- Detection devices and circuits: Cross-zoned photoelectric and ionization detectors are functionally tested every six months.

- Inspection of sprinkler heads and Halon discharge header for buildup and corrosion: These inspections are visually performed monthly.

- Inspection of portable fire extinguishers: These inspections are performed monthly.

- Inspection of Halon bottles: Halon bottles are visually inspected monthly and functionally tested for actuation every six months.

3. Fire Water System Flushed

The fire water system was flushed after installation.

4. Remarks

The CMR shows status and location of fire zones. The Halon system control panel is also in the CMR.

Item 7

CONSTRUCTION AND SALT HANDLING HOIST BUILDING
FIRE DETECTION AND SUPPRESSION CHECKLIST

1. Sprinkler Locations

Sprinklers are located throughout the building, 6 inch - 12 inch below the ceiling.

2. Sprinkler Type

Fusible link, fixed temperature water sprinklers are used.

3. Number and Location of Portable Fire Extinguishers

There are five portable fire extinguishers located throughout the building and one manual pull box located in the middle of the south wall.

4. Number and Location of Monitors

There are alarm check valves in the sprinkler system which are connected to the fire panels.

5. Inspection and Testing for all of the Above Components/Systems

Sprinklers are visually inspected monthly, and flow tested quarterly with an opened sprinkler head on one-inch line.

Portable fire extinguishers are inspected monthly.

Item 8

EXHAUST FILTER BUILDING 413 CHECKLIST

1. Verify P&IDs Versus As-Built

Location of valves for main distribution and inlet to building sprinkler headers were identified. Verification of exact sprinkler location and number was not performed.

2. Maintenance, Test, and Inspection

Maintenance and tests were performed as per WIPP Safety Manual, WP 12-1.

3. Fire Water System Flushed

The fire water system was flushed after installation.

4. Fitness of Components

See Item #3 and remarks below.

5. Wet System Protected Against Freezing, Lightning Hazards

The wet system was protected against environmental effects.

6. Remarks

The Exhaust Filter Building (EFB) has a sprinkler system, portable fire extinguishers, and manual hose reels. There are not detectors, but there are two manual pull boxes. However, they are located in the middle of the building, away from optimal personnel activation.

Item 9

UNDERGROUND FUEL STORAGE FIRE DETECTION AND SUPPRESSION CHECKLIST

1. Verify Drawings Versus As-Built and Actual Operations

Location and number of suppression systems were verified.

2. Maintenance, Test, and Inspection

Frequency

- Detection Devices: Semiannual functional test with actuators removed.

- Dry Chemical Storage Tanks and Distribution System: Pressure in tanks checked monthly.

- Portable extinguishers: inspected monthly

Procedures

- Procedures were performed as per the WIPP Safety Manual, WP 12-1.

Actuation Requirements

- Rate-of-rise temperature detector with 30-second delay, or by manual actuation.

3. Alarm Mechanisms

Rate-of-rise detectors which measure rated change of heat, which activates an alarm and suppression system.

4. Fitness of Components

With consideration for the environment, the components were observed to be well maintained except for one discharge nozzle at Station #2. At Station #2 one nozzle was located on/above the Purple K storage bottle frame. Discharge through this nozzle was impossible because of placement.

5. Remarks

At storage area #1 the location of hand-actuated alarms (pull) appeared to be adequate. At storage area #2, the alarms on one side were located adjacent to the refueling nozzle. If the fire occurred in this area, the operator would probably leave prior to pulling an alarm. Alarm actuation relocation should be evaluated.

Item 10

UNDERGROUND WASTE STORAGE FIRE DETECTION AND SUPPRESSION CHECKLIST

1. Verify Drawings Versus As-Built and Actual Operations

Only operator actuated and other suppression and detection equipment as noted under remarks were identified. At the time of the walkdown, new installations were being proposed. Documentation was not verified.

2. Maintenance, Test, and Inspection

Maintenance and tests were performed as per the WIPP Safety Manual, WP 12-1

3. Alarm Mechanisms

Manual

4. Remarks

Ionization detection had been used in some areas with false alarms. These detectors are to be replaced with thermal rate-of-rise detectors.

Two 300-pound portable dry chemical extinguishers were observed.

Item 11

DIESEL-DRIVEN EQUIPMENT FIRE SUPPRESSION

1. Verify As-Built and Operations Versus Drawings

No drawings available. Each vehicle has one hand-held extinguisher and one dry chemical system which means three actuations: two manual, and one on bi-metallic temperature sensing wire.

2. Amount of Fuel and Lube oil - Portable fuel tank

60 gallon maximum per vehicle, 300 gallon maximum in fuel tank.

3. Detection Devices/Actuation System (sensor placements)

   See #1 and Remarks.

4. Location of Nozzles

   At various points around motor. Most were not verifiable.

5. Dry Chemical Suppression System

   Yes

6. Fan Size and Speed

   Not available.

7. Kill Switch Location/Requirement

   Operator required to stop engine manually.

8. Actuation Switch Location/Requirement

   One automatic, two manual: one in cab, one at exit side.

9. Remarks

   The suppression equipment was reviewed by an independent company (WORMALD Fire Suppression). Deficiencies were observed and documented. These deficiencies should be addressed.

   At present, the engine does NOT stop when the system actuates. It was not determined if the fan speed and force is sufficient to "blow away" any dry chemical suppression release. This should be evaluated in a functional test.

Item 12

WAREHOUSE DETECTION AND SUPPRESSION CHECKLIST

1. Sprinkler Locations

Sprinklers are located throughout the building, 6 inch - 12 inch below the ceiling.

2. Sprinkler Type

Closed sprinklers are used.

3. Manual Hose Reels and Portable Fire Extinguishers

There are four manual hose reels and many portable extinguishers located throughout the building.

4. Maintenance, Test, and Inspection

Sprinkler systems are inspected monthly.

Manual hose reels and portable fire extinguishers are inspected monthly.

Item 13

GUARD AND SECURITY BUILDING CHECKLIST

1. Sprinkler Locations

Sprinklers are located throughout the building.

2. Sprinkler Type

Closed sprinklers are used.

3. Dry Chemical System

There is a dry chemical system in the kitchen to suppress grease fires. This system may be actuated upon detector activation, or manually.

4. Manual Hose Reels and Portable Fire Extinguishers

These are located throughout the building.

5. Maintenance, Test, and Inspection

Sprinkler systems are visually inspected monthly.

Dry chemical system tank pressures are checked monthly, and tested semiannually.

Manual hose reels and portable fire extinguishers are inspected monthly.

Item 14

B49 ANNEX CHECKLIST

1. Sprinklers

Closed sprinklers are located throughout the annex.

2. Halon

A Halon detection and suppression system is located in the trailer portion of the annex. The system may be activated automatically by the detectors or manually.

3. Portable Fire Extinguishers

Portable fire extinguishers are located throughout the annex.

4. Maintenance, Test, and Inspection

Sprinkler systems are visually inspected monthly.

Halon bottles are visually inspected monthly and functionally tested semiannually.

Portable fire extinguishers are inspected monthly.

5. Remarks

The B49 Annex is used by Sandia National Laboratories to monitor underground experiments. The B49 Annex is not monitored by the Central Monitoring System.

4.4.1.6 Success Criteria

Success criteria are defined for the water, Halon, and dry chemical systems and for manual methods as follows:

Fire Water System

Success of the fire water system depends upon supplying fire water to the site of fire upon demand as follows:

a) The fusible element in the sprinkler opens at a designed fixed temperature, allowing water flow.

b) Distribution of water through the fire water loop to the sprinkler succeeds, with one of two main fire pumps running.

c) The site of the fire is covered with water.

Detection of the fire, either through manual pull alarms or through rate-of-rise temperature detectors (or ionization or photoelectric detectors) is not considered to be critical to the success of the fire water system, since fire water system actuation is independent of detection, which alarms in the Central Monitoring Room.

Dry Chemical System

Success of the dry chemical system depends upon providing dry chemical discharge to the site of the fire upon demand as follows:

a) The temperature detectors alarm and actuate the release of the dry chemical to the nozzles. The dry chemical system may also be activated manually.

b) Distribution of dry chemical from the tank to the nozzles is successful.

c) The site of the fire is blanketed with dry chemical.

Success of the dry chemical system on the diesel-driven equipment depends upon:

a) Fire detection and subsequent actuation of the dry chemical system, or by manual actuation of the system.

b) Successful discharge of the dry chemical agent.

c) Blanketing of the fire area by the dry chemical agent.

Manual Methods

Success of manual methods depends upon providing either a discharge of dry chemical to the site of a fire using a portable extinguisher, or by providing a discharge of water to the site of a fire using a manual hose reel or a hose from the fire truck aboveground as follows:

a) Remote detection of the fire and fire location in the CMR prompts an alarm, and subsequent human detection and location of the fire succeeds. The fire may also be detected locally by human means.

b) Portable extinguishers, manual hose reels, or the fire truck are available at, or moved to, the fire location.

c) Upon manual actuation, dry chemical, or water is released upon the site of the fire.

4.4.1.7 System-Specific Modeling Assumptions

In modeling the FDSS, the following assumptions were made:

The fire water distribution, Halon, and dry chemical systems are sized adequately to suppress all fires at the WIPP site. Sizing of these systems was performed in accordance with applicable NFPA Standards during the design phase. Design changes to the facility are administratively controlled through a review of the fire loading to ensure that existing systems will meet new demands.

Water is always available in the water storage tanks. The water levels in the two tanks are checked daily and monitored by a low level alarm. The primary source of water to the tanks is water from the Double Eagle Water Co. 10-inch diameter pipeline, and the secondary source is water from trucks.

The primary means of fire suppression at the WIPP site utilize automatic systems (sprinklers, Halon, dry chemical) while the secondary means include manual methods. However, it is likely that manual fire suppression activities will be conducted by personnel discovering the fire. These activities may precede activation of the systems.

Sabotage of fire suppression equipment is not considered in this analysis.

In areas with more than one type of fire suppression system, it was assumed that each system is independent of the other.

All equipment/component inspection, testing, and maintenance is performed as documented in WIPP Safety Manual, WP 12-1.

The first responder team is adequately trained in the use of manual fire suppression methods, and will be at the site of the fire within seven minutes.

4.4.1.8 System Analysis

Fault Tree Construction

Fault trees for the fire water, and dry chemical systems, and for the manual fire fighting methods were constructed. The fault trees used to determine the probability of failing to detect and suppress a fire are presented in Appendix E as Fault Trees E-1, E-2, E-3, E-4, E-5, E-6.

Failure Rate Data Development

Failure rate data that is specific to the fire detection and suppression analysis is described as follows:

Calculation of Unavailability due to Maintenance for Electric and Diesel-driven Fire Pumps:

References:

OREDA-84, pp 91, 95 (Reference 4)

$Q = Q_{RM} + Q_{SM}$

where

Q_{RM} = Unavailability due to unscheduled repair
Q_{SM} = Unavailability due to scheduled maintenance

$$Q_{RM} = f_R \left(\frac{t_R}{T_T}\right)$$

where:

f_R = frequency (per test period) for which repair is expected to occur

t_R = mean component repair time

T_T = test period

and

$$Q_{SM} = f_M \left(\frac{t_M}{T_T}\right)$$

where:

f_M = frequency (per test period) with which scheduled maintenance occurs

t_M = mean component outage time for scheduled maintenance

T_T = test period

Electric fire water pump (45-G-601):

$$Q_{RM} = f_R \left(\frac{t_R}{T_T}\right)$$

$$T_T = 5.49E+4 \text{ hr}$$

$$f_R = \left(\frac{210 \text{ failures}}{10^6 \text{ hours}}\right)(0.0549 \times 10^6 \text{ hours}) = 11.529$$

$$t_R = \frac{51 \text{ man-hrs}}{2 \text{ men working per repair}}$$

$$= 25.5$$

$$Q_{RM} = (11.529)\left(\frac{25.5}{5.49E+4}\right)$$

Q_{RM} = 5.4E-03

(Reference 4: OREDA 84, p 95)

$$Q_{SM} = f_M \left(\frac{t_M}{T_T}\right)$$

T_T = One year = 8760 hrs

f_M = 12 maintenance activities scheduled per year

t_M = Two hrs per maintenance activity

$$Q_{SM} = 12 \left(\frac{2}{8760}\right)$$

$$= 2.7E\text{-}3$$

Reference: WIPP Safety Manual
(Reference 5)

$Q = Q_{RM} + Q_{SM}$
$= 5.4E\text{-}3 + 2.7E\text{-}3$
$= 8.1E\text{-}3$

Unavailability of the electric fire water pump due to maintenance is 8.1E-3.

Diesel-driven fire water pump (45-G-602):

$$Q_{RM} = f_R \left(\frac{t_R}{T_T}\right)$$

T_T = 3.826E + 5 hrs

f_R = frequency per test period

$$= \frac{840 \text{ failures}}{10^6 \text{ hours}} (.3826 \times 10^6 \text{ hours})$$

= 321.384

$$t_R = \frac{81 \text{ man-hours}}{2 \text{ men working per repair}}$$

= 40.5 hours

$$Q_{RM} = (321.384)\left(\frac{40.5}{3.826E+06}\right)$$

= 3.4E-2

Reference: OREDA 84, p 91 (Reference 4).

$$Q_{SM} = f_M \left(\frac{t_M}{T_T}\right)$$

T_T = One year = 8760 hours

f_M = 12 maintenance activities scheduled per year

t_M = Two hours per maintenance activity

$$Q_{SM} = 12 \left(\frac{2}{8760}\right)$$

= 2.7E-03

Source: WIPP Safety Manual
(Reference 5).

$$Q = Q_{RM} + Q_{SM}$$
$$= 3.4E\text{-}2 + 2.7E\text{-}3$$
$$= 3.7E\text{-}2$$

Unavailability due to maintenance for the diesel-driven fire water pump is 3.7E-02.

Calculation of Failure Rate of CSO/CSC Valve:
Reference: NUREG/CR-2728 (Reference)

Failure rate of CSO/CSC valve = (CSO/CSC factor) (Failure rate of manual valve)

where:

CSO/CSC factor	=	Factor of 1.0E-2 that a locked/sealed valve will change position.
Failure rate of manual valve	=	5.0E-07/hr
Failure rate of	=	(1E-2) (5.0E-7/hr)
CSO/CSC valve	=	5.0E-9/hr

This is shown as item 511 in the master data file.

Calculations for Power Supply Fails

This is shown as item 534 in the master data file.

Calculation for the Unavailability of Fire Water

This was calculated as part of the fire water systems FTA to be 4.0E-03.

This is shown as item 535 in the master data file.

Calculation for the Fusible Element in the Sprinkler Head Not Opening

Reference: Loss Prevention in the Process Industries, p. 1007.

(Reference 7)

$$\text{Range to mean} = \frac{(M - L)}{(\ln M - \ln L)}$$

where M = maximum value

L = minimum value

$$\text{Mean} = \frac{(3.0E\text{-}5) - (3.0E\text{-}6)}{(\ln 3.0E\text{-}5) - (\ln 3.0E\text{-}6)}$$

$$= 1.2E\text{-}5$$

This is shown as item 516 of the master data file.

Calculation For Operator Error Under Stress of Fire

Item 170 in the master data file is "Fails Abnormal Operating Procedure." In the event of a fire, a performance shaping (or stress) factor may be applied.

Failure rate = 1.1E-2 (Item 170 of master data file)

Performance Shaping Factor = 10

Failure Rate = (1.1E-2)(10)
= 1.1E-1

This is shown as item 549 in the master data file.

Quantification Results

Through quantification of the fault trees, the dominant contributors to the failure of detecting and suppressing a fire may be derived. These dominant contributors, or cut-sets, determine what single failure or combination of failures may lead to failure to detect and suppress a fire. Discussion of the dominant contributors are summarized in the

following paragraphs. The quantification results for the fire detection and suppression fault trees are presented in Tables 4.4-1 through 4.4-15. An index of the tables precedes the results.

Each of the FDSS (fire water, the two dry chemical systems, and manual methods aboveground and underground) has three tables derived from quantification of their respective fault trees. On some tables a -not- precedes the description of some event. This notes that the equipment functions as required or designed, and is part of the failure sequence. The first table 4.4-1 links the basic and system events (from the fault tree) to the master data file, and lists the mission times for time-dependent events.

The second table 4.4-2 shows the cut-sets, both single and multiple order, listed from most to least likely to occur. The number to the left of the cut-set description is the probability that the event will occur. If the cut-set is a single order, the probability of failure is repeated at the right. If the cut-set is multiple order, the failure probability of each component of the cut-set is presented at the right, with the product of the individual failures offered at the left. For example, if the cut-set would be composed of three individual failures, X, Y, and Z, with failure rates of .1, .02, and .003, respectively, the cut-set would read as follows:

6.00E-6	X	1.00E-1
	Y	2.00E-2
	Z	3.00E-3

Thus, the cut-set would require a failure of X, Y, and Z, with a combined probability of 6.00E-6.

The third type of table 4.4-3 shows the individual component contribution to the accident sequences.

To read these tables, only the identifier as found on the fault tree is used to identify each event. Refer to the appropriate fault tree and the fault tree guidelines for a description as to how the identifiers were determined. Briefly, each identifier represents an individual component or failure, and is normally an abbreviation of the actual failure. For example, item 1 of Table 4.4-3, "FSHWATERPL" represents the plugging of a sprinkler head.

The column labeled # CS represents the number of cut-sets in which the basic event appears. Thus, FSHWATERPL appears in one cut-set.

CONT. TO Q represents the contribution to overall failure based on the number of cut-sets in which the event appears and the value of each cut-set. The final heading, "FAILURE PROBABILITY" represents the failure rate assigned to the individual component or event.

The second column, importance ranking, represents a general ranking based on the overall contribution of the event to system failure or accident frequency. This number represents the percent contribution to total system failure of all the cut-sets the basic event appears in. But this only applies to one cut-set at a time.

An individual component may not appear in these tables if it did not contribute significantly to the failure probability, because of an arbitrary cutoff assigned to each fault tree.

Fire Water System

Unavailability of the fire water system is 1.1E-2. This implies that one out of every 92 times that the fire water system is challenged, it may not work successfully. Failure of the fire water system is dominated by one first order cut-set and one second-order cut-set:

- The sprinkler head plugged

- The simultaneous failure of the electric and the diesel-driven pumps to run

Dry Chemical System

Unavailability of the UFS dry chemical system is 2.7E-2. This implies that one out of every 36 times that the system is challenged, it may not work successfully. Failure of the UFS area dry chemical system is dominated by two single order cut-sets:

- Failure of the dry chemical supply, which encompasses the dry chemical bottles, the start mechanism, and the release valve

- Failure of the thermal detector

Manual Methods

Unavailability of manual methods aboveground to suppress a fire is 3.3E-02. This implies that one out of every 30 times that these methods are challenged, they may not work successfully. Failure of aboveground manual methods is driven by two single-order cut-sets:

- Failure to detect or to locate fire
- Operator clears area

Unavailability of manual methods underground is 3.4E-2. This implies that one out of every 30 times that these methods are challenged, they may not work successfully. Failure of underground manual methods is driven by two single order cut-sets:

- Failure to detect or to locate the fire
- Operator clears area

The system walkdowns conducted as part of the PRA did identify changes to enhance system performance. Performance enhancements are presented below.

<u>Fire Detection and Suppression Systems</u> (FDSS)

Based on the results of the study and the site walkdown of the systems, the following recommendations are made:

- The availability of the Halon system may be enhanced by increasing the frequency of testing.

- A determination should be made whether continued operation of the engine after fire suppression system actuation can endanger effective fire suppression.

- Manual pull alarms should be relocated near egresses in the EFB and UFS #2.

- Valves PSL02 and PSL03 for pressure sensors for the firewater pumps should be secured in their normal operating positions (CSO).

- One discharge nozzle for the dry chemical system at UFS #2 should be directed away from the frame that holds the battery of dry chemical bottles.

4.4.1.9 References

1. "Final Environmental Impact Statement - Waste Isolation Pilot Plant (WIPP)," U.S. Department of Energy, Volumes 1 and 2, October 1980.

2. "WIPP FSAR," Draft, DOE/WIPP, Volumes 1, 2, 3, October 1988.

3. M. A. Quincy, "Fire Protection Handbook," National Fire Protection Association, Quincy, MA, Fifteenth Edition, 1981.

4. "OREDA, Offshore Reliability Data Handbook," OREDA Participants, Pennwell Publishing Company, First Edition, 1984.

5. "WIPP Safety Manual" WP 12-1.

6. "WIPP Master Preventative Maintenance Schedule."

7. F. P. Lees, "Loss Prevention in the Process Industries," Vol. 1 and 2, Butterworths, Boston, 1980.

8. A. D. Swain and H. E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications." Sandia National Labs, NUREG/CR-1278, August 1983.

9. Health and Safety Executive of the United Kingdom, "Canvey - An Investigation of Potential Hazards from Operations in the Canvey Island/Thurrock Area." 1978.

10. "Interim Reliability Evaluation Program (IREP) Procedures Guide," NUREG/CR-2728.

Table 4.4-1

FIRE WATER SYSTEM MAPPING OF FAULT TREE TO MASTER DATA FILE

```
'FIRE WATER FAULT TREE'
 50
'FXVPIV-1CC'   01   511   84.00000   0.0 'MAN. VALVE, CSO, CHECKED WEEKLY'
'FXVPIV-4CC'   01   511   84.00000   0.0 'MAN. VALVE, CSO, CHECKED WEEKLY'
'FTKH201ARU'   01   501   2.000000   0.0 '2 HR MISSION TIME'
'FTKH201BRU'   01   501   2.000000   0.0 '2 HR MISSION TIME'
'FTKH201ALK'   01   504   2.000000   0.0 '2 HR MISSION TIME'
'FTLH201AFA'   01   502   24.00000   0.0 'CHECKED DAILY'
'FTKH201AHE'   01   205   0.000000   0.0
'FTKH201BLK'   01   504   2.000000   0.0 '2 HR MISSION TIME'
'FTLH201BFA'   01   502   24.00000   0.0 'CHECKED DAILY'
'FTDPSL02FA'   01   503   84.00000   0.0 'TESTED WEEKLY WITH PUMPS'
'FPM601ELFS'   01   520   0.000000   0.0
'SUB-E4     '  01   050   0.000000   0.0
'FCB251-6CO'   01   364   8.000000   0.0
'FPM601ELFA'   01   521   2.000000   0.0 '2 HR MISSION TIME'
'FXV01MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV02MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV03MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV06MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FPM601ELMT'   01   524   0.000000   0.0
'FXV12MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FCV08CHKCC'   01   057   84.00000   0.0 'TESTED WEEKLY'
'FTDPSL04FA'   01   503   84.00000   0.0 'TESTED WEEKLY WITH PUMPS'
'FPM602DGFS'   01   522   0.000000   0.0
'FTK602DGRU'   01   501   84.00000   0.0 'TESTED WEEKLY'
'FTK602DGLK'   01   504   84.00000   0.0 'CHECKED WEEKLY'
'FPM602DPFA'   01   523   2.000000   0.0 'MISSION TIME 2 HR'
'FXV07MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FPM602DGMT'   01   525   0.000000   0.0
'FXV14MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FCV10CHKCC'   01   057   84.00000   0.0 'TESTED WEEKLY'
'FXV20MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV15MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV16MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV19MANCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXV602DGCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVPIV17CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVPIV16CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVPIV12CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVPIV-9CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVPIV19CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVNORTHCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FCVNORTHCC'   01   057   84.00000   0.0 'CHECKED WEEKLY'
'FXVPIV26CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FXVSOUTHCC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FCVSOUTHCC'   01   057   84.00000   0.0 'CHECKED WEEKLY'
'FXVPIV19CC'   01   511   84.00000   0.0 'MAN. VALVE FAILS CLSD, CSO, TESTED WEEKLY'
'FSHFUSELCC'   01   516   0.000000   0.0
'FSHINSTLHE'   01   165   0.000000   0.0
'FSHVERIFHE'   01   165   0.000000   0.0
'FSHWATERPL'   01   515   1095.000   0.0 'FUNCTIONALLY TESTED QUARTERLY'
```

Table 4.4-2

FIRE WATER SYSTEM FAULT TREE QUANTIFICATION RESULTS

FIRE WATER TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-08
GATE G0001 IS: FAILURE TO SUPPLY FIRE WATER TO CH BAY OF WHB ON DEMAND

NUMBER	CUTSET PROB.		BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
1.	6.57E-03		SPRINKLER HEAD PLUGGED	6.57E-03	FSHWATERPL
2.	9.60E-04		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
3.	5.87E-04		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
4.	4.68E-04		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT
5.	4.02E-04		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
6.	2.47E-04		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
7.	2.46E-04		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
8.	2.25E-04		SPRINKLER HEAD NOT INSTALLED CORRECTLY	1.50E-02	FSHINSTLHE
			SPRINKLER HEAD INSTALLATION NOT VERIFIED CORRECTLY	1.50E-02	FSHVERIFHE
9.	1.68E-04		CHECK VALVE FOR SOUTH SPRINKLER RISER CLOSED	1.68E-04	FCVSOUTHCC
10.	1.68E-04		CHECK VALVE FOR NORTH SPRINKLER RISER CLOSED	1.68E-04	FCVNORTHCC
11.	1.51E-04		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
12.	1.33E-04		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
13.	1.00E-04		OPERATOR FAILS TO RESTORE TANK FOLLOWING LEAK	1.00E-04	FTKH201AHE
14.	6.59E-05		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
15.	6.47E-05		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT
16.	5.56E-05		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
17.	3.42E-05		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
18.	3.21E-05		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT

Table 4.4-2 (Continued)

FIRE WATER SYSTEM FAULT TREE QUANTIFICATION RESULTS

FIRE WATER TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-08 (page 2)
GATE G0001 IS: FAILURE TO SUPPLY FIRE WATER TO CH BAY OF WHB ON DEMAND

NUMBER	CUTSET PROB.		BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
19.	3.18E-05		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
20.	2.76E-05		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
21.	1.95E-05		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
22.	1.70E-05		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
23.	1.44E-05		BUS 25S4 CIRCUIT BREAKER CB6 FAILS OPEN	2.40E-04	FCB251-6CO
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
24.	1.20E-05		FUSIBLE LINK IN SPRINKLER HEAD FAILS (WILL NOT OPEN)	1.20E-05	FSHFUSELCC
25.	1.01E-05		CHECK VALVE FW-456-V-8 CLOSED	1.68E-04	FCV08CHKCC
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
26.	8.81E-06		BUS 25S4 CIRCUIT BREAKER CB6 FAILS OPEN	2.40E-04	FCB251-6CO
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
27.	6.17E-06	-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			CHECK VALVE FW-456-V-8 CLOSED	1.68E-04	FCV08CHKCC
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
28.	4.40E-06		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
29.	2.69E-06		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
30.	2.18E-06		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
31.	1.99E-06		BUS 25S4 CIRCUIT BREAKER CB6 FAILS OPEN	2.40E-04	FCB251-6CO
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
32.	1.39E-06		CHECK VALVE FW-456-V-8 CLOSED	1.68E-04	FCV08CHKCC
			DIESEL-DRIVEN PUMP FAILS TO START (MECHANICAL)	8.30E-03	FPM602DGFS
33.	1.31E-06		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
34.	1.13E-06		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
35.	9.89E-07		BUS 25S4 CIRCUIT BREAKER CB6 FAILS OPEN	2.40E-04	FCB251-6CO
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA

Table 4.4-2 (Continued)

FIRE WATER SYSTEM FAULT TREE QUANTIFICATION RESULTS

FIRE WATER TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-08 (page 3)
GATE G0001 IS: FAILURE TO SUPPLY FIRE WATER TO CH BAY OF WHB ON DEMAND

NUMBER	CUTSET PROB.		BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
36.	6.92E-07		CHECK VALVE FW-456-V-8 CLOSED	1.68E-04	FCV08CHKCC
			PSL04 FAILS (LOGIC)	4.12E-03	FTDPSL04FA
37.	6.92E-07		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
38.	4.20E-07		PIV-19 CLOSED NORMALLY CSO, INDICATOR	4.20E-07	FXVPIV19CC
39.	4.20E-07		GATE VALVE FOR SOUTH SPRINKLER RISER CLOSED; CSO, INDICATOR	4.20E-07	FXVSOUTHCC
40.	4.20E-07		PIV-26 CLOSED NORMALLY CSO, INDICATOR	4.20E-07	FXVPIV26CC
41.	4.20E-07		GATE VALVE FOR NORTH SPRINKLER RISER CLOSED; CSO, INDICATOR	4.20E-07	FXVNORTHCC
42.	4.03E-07		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			DIESEL FUEL TANK FOR PUMP LEAKS	2.52E-05	FTK602DGLK
43.	1.97E-07		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
			DIESEL FUEL TANK FOR PUMP LEAKS	2.52E-05	FTK602DGLK
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT
44.	1.69E-07		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			DIESEL FUEL TANK FOR PUMP LEAKS	2.52E-05	FTK602DGLK
45.	1.04E-07		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			DIESEL FUEL TANK FOR PUMP LEAKS	2.52E-05	FTK602DGLK
46.	8.90E-08		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
47.	6.97E-08		FAULTY WATER GAUGE IN STORAGE TANK 25-D-001A	2.64E-04	FTLH201AFA
			FAULTY WATER GAUGE IN STORAGE TANK 25-D-001B	2.64E-04	FTLH201BFA
48.	4.03E-08		BUS 25S4 CIRCUIT BREAKER CB6 FAILS OPEN	2.40E-04	FCB251-6CO
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
49.	4.03E-08		ELECTRIC PUMP FAILS TO RUN	1.60E-02	FPM601ELFA
			DIESEL FUEL TANK FOR PUMP RUPTURES	2.52E-06	FTK602DGRU
50.	2.82E-08		CHECK VALVE FW-456-V-8 CLOSED	1.68E-04	FCV08CHKCC
			CHECK VALVE FW-456-V-10 CLOSED	1.68E-04	FCV10CHKCC
51.	2.52E-08		VALVE FW-456-V-12 CLOSED	4.20E-07	FXV12MANCC
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
52.	2.52E-08		VALVE FW-456-V-6 CLOSED	4.20E-07	FXV06MANCC
			DIESEL-DRIVEN PUMP FAILS TO RUN	6.00E-02	FPM602DPFA
53.	1.97E-08		ELECTRIC PUMP IN MAINTENANCE	8.10E-03	FPM601ELMT
			DIESEL FUEL TANK FOR PUMP RUPTURES	2.52E-06	FTK602DGRU
		-NOT-	DIESEL-DRIVEN PUMP IN MAINTENANCE	9.63E-01	FPM602DGMT
54.	1.69E-08		ELECTRIC PUMP FAILS TO START (MECHANICAL)	6.70E-03	FPM601ELFS
			DIESEL FUEL TANK FOR PUMP RUPTURES	2.52E-06	FTK602DGRU
55.	1.54E-08	-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			VALVE FW-456-V-12 CLOSED	4.20E-07	FXV12MANCC
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT

Table 4.4-2 (Continued)

FIRE WATER SYSTEM FAULT TREE QUANTIFICATION RESULTS

FIRE WATER TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-08 (page 4)
GATE G0001 IS: FAILURE TO SUPPLY FIRE WATER TO CH BAY OF WHB ON DEMAND

NUMBER	CUTSET PROB.		BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
56.	1.54E-08		VALVE FW-456-V-6 CLOSED	4.20E-07	FXV06MANCC
		-NOT-	ELECTRIC PUMP IN MAINTENANCE	9.92E-01	FPM601ELMT
			DIESEL-DRIVEN PUMP IN MAINTENANCE	3.70E-02	FPM602DGMT
57.	1.34E-08		LOSS OF NORMAL & EMERG. POWER ON SUBSTATION 4	5.30E-04	SUB-E4
			DIESEL FUEL TANK FOR PUMP LEAKS	2.52E-05	FTK602DGLK
58.	1.04E-08		PSL02 FAILS (LOGIC)	4.12E-03	FTDPSL02FA
			DIESEL FUEL TANK FOR PUMP RUPTURES	2.52E-06	FTK602DGRU

REDUCED SUM OF PROBABILITY OF FAILURE = 1.081E-02

Table 4.4-3

FIRE WATER SYSTEM RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

FIRE WATER FAULT TREE VERSION 1.5A

SYSTEM UNAVAILABILITY (Q) = 1.08E-02
NUMBER OF BASIC EVENTS = 49
NUMBER OF CUTSETS = 87

	BASIC EVENT	IMPORTANCE	# CS	CONT. TO Q	FAILURE PROBABILITY
1	FSHWATERPL	60.78	1	6.570E-03	6.570E-03
2	FPM602DPFA	19.72	9	2.132E-03	6.000E-02
3	FPM601ELFA	16.17	10	1.748E-03	1.600E-02
4	FPM602DGMT	9.42	8	1.018E-03	3.700E-02
5	FPM601ELFS	6.78	10	7.324E-04	6.700E-03
6	FPM601ELMT	5.24	9	5.663E-04	8.100E-03
7	FTDPSL02FA	4.16	10	4.500E-04	4.120E-03
8	FPM602DGFS	2.73	9	2.953E-04	8.300E-03
9	FSHINSTLHE	2.08	1	2.250E-04	1.500E-02
10	FSHVERIFHE	2.08	1	2.250E-04	1.500E-02
11	FCVNORTHCC	1.55	1	1.680E-04	1.680E-04
12	FCVSOUTHCC	1.55	1	1.680E-04	1.680E-04
13	FTDPSL04FA	1.35	9	1.465E-04	4.120E-03
14	FTKH201AHE	.93	1	1.000E-04	1.000E-04
15	SUB-E4	.54	10	5.798E-05	5.300E-04
16	FCB251-6CO	.24	10	2.624E-05	2.400E-04
17	FCV08CHKCC	.17	7	1.838E-05	1.680E-04
18	FSHFUSELCC	.11	1	1.200E-05	1.200E-05
19	FCV10CHKCC	.06	7	5.979E-06	1.680E-04
20	FTK602DGLK	.01	7	8.967E-07	2.520E-05
21	FXVNORTHCC	.00	1	4.200E-07	4.200E-07
22	FXVPIV26CC	.00	1	4.200E-07	4.200E-07
23	FXVSOUTHCC	.00	1	4.200E-07	4.200E-07
24	FXVPIV19CC	.00	1	4.200E-07	4.200E-07
25	FTK602DGRU	.00	7	8.967E-08	2.520E-06
26	FTLH201AFA	.00	2	6.986E-08	2.640E-04
27	FTLH201BFA	.00	2	6.986E-08	2.640E-04
28	FXV06MANCC	.00	4	4.582E-08	4.200E-07
29	FXV12MANCC	.00	4	4.582E-08	4.200E-07
30	FXV602DGCC	.00	6	1.486E-08	4.200E-07
31	FXV07MANCC	.00	6	1.486E-08	4.200E-07
32	FXV14MANCC	.00	6	1.486E-08	4.200E-07
33	FTKH201ALK	.00	1	1.580E-10	6.000E-07
34	FTKH201BLK	.00	1	1.580E-10	6.000E-07

Table 4.4-3 (Continued)

FIRE WATER SYSTEM RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

BASIC EVENTS THAT DO NOT APPEAR IN THE CUTSETS

BASIC EVENT		FAILURE PROBABILITY
35	FXVPIV-1CC	4.200E-07
36	FXVPIV-4CC	4.200E-07
37	FTKH201ARU	6.000E-08
38	FTKH201BRU	6.000E-08
39	FXV01MANCC	4.200E-07
40	FXV02MANCC	4.200E-07
41	FXV03MANCC	4.200E-07
42	FXV20MANCC	4.200E-07
43	FXV15MANCC	4.200E-07
44	FXV16MANCC	4.200E-07
45	FXV19MANCC	4.200E-07
46	FXVPIV17CC	4.200E-07
47	FXVPIV16CC	4.200E-07
48	FXVPIV12CC	4.200E-07
49	FXVPIV-9CC	4.200E-07

BASIC EVENTS WITH PROBABILITIES 0.0 OR 1.0

BASIC EVENT	FAILURE PROBABILITY
NONE	

Table 4.4-4

DRY CHEMICAL SYSTEM; UNDERGROUND FUEL STORAGE AREA – MAPPING OF FAULT TREE TO MASTER DATE FILE

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'DRY CHEMICAL SYSTEM FAULT TREE - UNDERGROUND FUEL STORAGE AREA'
 9
'FLPUGSTNLP'   01   174   0.000000   0.0
'FLPBATUGLP'   01   111   0.500000   0.0 'UPS/DETECTORS TESTED SEMI-ANNUALLY'
'FLPEMERGLP'   01   173   0.000000   0.0
'FDITEMPRDE'   01   547   2190.000   0.0 'DETECTORS TESTED SEMI-ANNUALLY'
'FDITEMPRMP'   01   165   0.000000   0.0
'FDITEMPRFA'   01   548   2190.000   0.0 'DETECTORS TESTED SEMI-ANNUALLY'
'FDCDCHEMFA'   01   546   2190.000   0.0 'DRY CHEM SYS TESTED SEMI-ANNUALLY'
'FNZDCHEMFA'   01   543   365.0000   0.0 'NOZZLES CHECKED MONTHLY'
'FACOPERRHE'   01   530   0.000000   0.0
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Table 4.4-5
DRY CHEMICAL SYSTEM; UNDERGROUND FUEL STORAGE AREA – FAULT TREE QUANTIFICATION RESULTS

DRY CHEMICAL SYSTEM - UNDERGROUND FUEL STORAGE AREA

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-10
GATE G0001 IS: FAILURE TO DETECT AND SUPPRESS FIRE USING DRY CHEM.

NUMBER	CUTSET PROB.	BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
1.	1.75E-02	FAILURE OF DRY CHEMICAL SUPPLY (PURPLE K)	1.75E-02	FDCDCHEMFA
2.	9.86E-03	FAULTY DEVICE - RATE-OF-RISE TEMPERATURE DETECTOR	9.86E-03	FDITEMPRFA
3.	9.85E-05	FAILURE TO DISTRIBUTE DRY CHEMICAL (PURPLE K)	9.85E-05	FNZDCHEMFA
4.	4.92E-06	ERRONEOUS OUTPUTS/ FALSE ALARMS	3.28E-04	FDITEMPRDE
		OPERATOR FAILS TO RESTORE FOLLOWING MAINTENANCE	1.50E-02	FDITEMPRMP

REDUCED SUM OF PROBABILITY OF FAILURE = 2.729E-02

Table 4.4-6

DRY CHEMICAL SYSTEM; UNDERGROUND FUEL STORAGE AREA – RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

CHEM.CUT - DRY CHEM. SYSTEM FOR UNDERGROUND FUEL STORAGE AREA VERSION 1.5A

SYSTEM UNAVAILABILITY (Q) = 2.73E-02
NUMBER OF BASIC EVENTS = 9
NUMBER OF CUTSETS = 4

	BASIC EVENT	IMPORTANCE	# CS	CONT. TO Q	FAILURE PROBABILITY
1	FDCDCHEMFA	64.13	1	1.750E-02	1.750E-02
2	FDITEMPRFA	36.13	1	9.860E-03	9.860E-03
3	FNZDCHEMFA	.36	1	9.850E-05	9.850E-05
4	FDITEMPRDE	.02	1	4.920E-06	3.280E-04
5	FDITEMPRMP	.02	1	4.920E-06	1.500E-02

BASIC EVENTS THAT DO NOT APPEAR IN THE CUTSETS

	BASIC EVENT	FAILURE PROBABILITY
6	FLPUGSTNLP	2.420E-04
7	FLPEMERGLP	8.560E-02
8	FLPBATUGLP	5.000E-07
9	FACOPERRHE	7.500E-03

BASIC EVENTS WITH PROBABILITIES 0.0 OR 1.0

BASIC EVENT	FAILURE PROBABILITY

NONE

1

CONFIGURATION CONTROL

CODE NAME : COMP2
VERSION NO. : 1.50
DATE OF CONFIGURATION : DECEMBER 15,1987
DATE OF ISSUANCE : DECEMBER 15,1987
DATE : MARCH 21, 1989
TIME : 15:45:34: 7
CONFIGURATION NO. : 4494672983931

Table 4.4-7

DRY CHEMICAL SYSTEM; DIESEL-DRIVEN VEHICLES –
MAPPING OF FAULT TREE TO MASTER DATA FILE

```
'DRY CHEMICAL SYSTEM FAULT TREE'
 6
'FDITEMPRDE'   01   547   2190.000   0.0 'DETECTORS TESTED SEMI-ANNUALLY'
'FDITEMPRMP'   01   165   0.000000   0.0
'FDITEMPRFA'   01   548   2190.000   0.0 'DETECTORS TESTED SEMI-ANNUALLY'
'FDCDCHEMFA'   01   546   2190.000   0.0 'DRY CHEM SYS TESTED SEMI-ANNUALLY'
'FNZDCHEMFA'   01   543   365.0000   0.0 'NOZZLES CHECKED MONTHLY'
'FACOPERRHE'   01   530   0.000000   0.0
```

Table 4.4-8
DRY CHEMICAL SYSTEM; DIESEL-DRIVEN VEHICLES – FAULT TREE QUANTIFICATION RESULTS

DRY CHEMICAL SYSTEM FAULT TREE - DIESEL-DRIVEN VEHICLES

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-10
GATE G0001 IS: FAILURE TO DETECT AND SUPPRESS FIRE USING DRY CHEM.

NUMBER	CUTSET PROB.	BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
1.	1.75E-02	FAILURE OF DRY CHEMICAL SUPPLY	1.75E-02	FDCDCHEMFA
2.	9.86E-03	FAULTY DEVICE - RATE-OF-RISE TEMPERATURE DETECTOR	9.86E-03	FDITEMPRFA
3.	9.85E-05	FAILURE TO DISTRIBUTE DRY CHEMICAL (NOZZLE FAILS)	9.85E-05	FNZDCHEMFA
4.	4.92E-06	ERRONEOUS OUTPUTS/ FALSE ALARMS	3.28E-04	FDITEMPRDE
		OPERATOR FAILS TO RESTORE FOLLOWING MAINTENANCE	1.50E-02	FDITEMPRMP

REDUCED SUM OF PROBABILITY OF FAILURE = 2.729E-02

Table 4.4-9

DRY CHEMICAL SYSTEM; DIESEL-DRIVEN VEHICLES –
RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

CUG.CUT - DRY CHEM. SYSTEM FOR DIESEL-DRIVEN VEHICLES VERSION 1.5A

SYSTEM UNAVAILABILITY (Q) = 2.73E-02
NUMBER OF BASIC EVENTS = 6
NUMBER OF CUTSETS = 4

	BASIC EVENT	IMPORTANCE	# CS	CONT. TO Q	FAILURE PROBABILITY
1	FDCDCHEMFA	64.13	1	1.750E-02	1.750E-02
2	FDITEMPRFA	36.13	1	9.860E-03	9.860E-03
3	FNZDCHEMFA	.36	1	9.850E-05	9.850E-05
4	FDITEMPRDE	.02	1	4.920E-06	3.280E-04
5	FDITEMPRMP	.02	1	4.920E-06	1.500E-02

BASIC EVENTS THAT DO NOT APPEAR IN THE CUTSETS

	BASIC EVENT	FAILURE PROBABILITY
6	FACOPERRHE	7.500E-03

BASIC EVENTS WITH PROBABILITIES 0.0 OR 1.0

BASIC EVENT	FAILURE PROBABILITY

NONE

1

CONFIGURATION CONTROL

CODE NAME : COMP2
VERSION NO. : 1.50
DATE OF CONFIGURATION : DECEMBER 15,1987
DATE OF ISSUANCE : DECEMBER 15,1987
DATE : MARCH 21, 1989
TIME : 15: 1:50:67
CONFIGURATION NO. : 4494672989584

Table 4.4-10

MANUAL METHODS ABOVEGROUND –

MAPPING OF FAULT TREE TO MASTER DATA FILE

```
'MANUAL METHODS FAULT TREE - ABOVE GROUND'
 12
'FAAFINDDHE'   01   530   0.000000   0.0
'FDIALERTFA'   01   165   0.000000   0.0
'FFXERRORHE'   01   549   0.000000   0.0
'FFXCHGEDDE'   01   165   0.000000   0.0
'FFXBADFXFA'   01   546   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FNZMHRNGFA'   01   543   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FPPH2ONANI'   01   535   0.000000   0.0
'FFXFAILSFA'   01   546   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FPMFPUMPFA'   01   526   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FHECLEARHE'   01   170   0.000000   0.0
'FHRERRORHE'   01   549   0.000000   0.0
'FHETRUCKHE'   01   549   0.000000   0.0
```

Table 4.4-11
MANUAL METHODS ABOVEGROUND – FAULT TREE QUANTIFICATION RESULTS

MANUAL METHODS ABOVE GROUND FAULT TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-10
GATE G0001 IS: FAILURE TO DETECT AND SUPPRESS FIRE -MANUAL METHODS

NUMBER	CUTSET PROB.	BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
1.	1.50E-02	FIRE NOT DETECTED BY PEOPLE	1.50E-02	FDIALERT
2.	1.10E-02	OPERATOR CLEARS AREA WITHOUT EMPLOYING MANUAL METHODS	1.10E-02	FHECLEAR
3.	7.50E-03	FIRE DETECTED, OPERATOR CAN'T LOCATE ALARM	7.50E-03	FAAFIND
4.	1.08E-05	OPERATOR ERROR IM EMPLOYING FIRE EXTINGUISHER	1.10E-01	FFXERROR
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERROR
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
5.	3.89E-06	OPERATOR ERROR IM EMPLOYING FIRE EXTINGUISHER	1.10E-01	FFXERROR
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERRORHE
		OPERATOR ERROR IN USING TRUCK	1.10E-01	FHETRUCKHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILS
6.	1.48E-06	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDDE
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERRORHE
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
7.	1.28E-06	OPERATOR ERROR IM EMPLOYING FIRE EXTINGUISHER	1.10E-01	FFXERRORHE
		WATER NOT AVAILABLE TO STANDPIPE	4.00E-03	FPPH2ONANI
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
8.	5.30E-07	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDD
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERRORHE
		OPERATOR ERROR IN USING TRUCK	1.10E-01	FHETRUCKHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
9.	2.88E-07	FAULTY DEVICE (PORTABLE EXTINGUSIHER)	2.92E-03	FFXBADFXF
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERRORHE
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
10.	1.75E-07	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDDE
		WATER NOT AVAILABLE TO STANDPIPE	4.00E-03	FPPH2ONANI
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
11.	1.03E-07	FAULTY DEVICE (PORTABLE EXTINGUSIHER)	2.92E-03	FFXBADFXF
		OPERATOR ERROR IN EMPLOYING MANUAL HOSE REEL	1.10E-01	FHRERRORHE
		OPERATOR ERROR IN USING TRUCK	1.10E-01	FHETRUCKHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF
12.	3.41E-08	FAULTY DEVICE (PORTABLE EXTINGUSIHER)	2.92E-03	FFXBADFXFA
		WATER NOT AVAILABLE TO STANDPIPE	4.00E-03	FPPH2ONANI
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSF

Table 4.4-11 (Continued)

MANUAL METHODS ABOVEGROUND –

FAULT TREE QUANTIFICATION RESULTS

MANUAL METHODS ABOVE GROUND FAULT TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-10 (page 2)
GATE G0001 IS: FAILURE TO DETECT AND SUPPRESS FIRE -MANUAL METHODS

NUMBER	CUTSET PROB.	BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
13.	9.71E-09	OPERATOR ERROR IM EMPLOYING FIRE EXTINGUISHER	1.10E-01	FFXERRORHE
		HOSE NOZZLE CLOGGED, HOSE RUPTURES	9.85E-05	FNZMHRNGFA
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
14.	3.48E-09	OPERATOR ERROR IM EMPLOYING FIRE EXTINGUISHER	1.10E-01	FFXERRORHE
		HOSE NOZZLE CLOGGED, HOSE RUPTURES	9.85E-05	FNZMHRNGFA
		OPERATOR ERROR IN USING TRUCK	1.10E-01	FHETRUCKHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
15.	1.32E-09	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDDE
		HOSE NOZZLE CLOGGED, HOSE RUPTURES	9.85E-05	FNZMHRNGFA
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
16.	4.75E-10	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDDE
		HOSE NOZZLE CLOGGED, HOSE RUPTURES	9.85E-05	FNZMHRNGFA
		OPERATOR ERROR IN USING TRUCK	1.10E-01	FHETRUCKHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
17.	2.58E-10	FAULTY DEVICE (PORTABLE EXTINGUSIHER)	2.92E-03	FFXBADFXFA
		HOSE NOZZLE CLOGGED, HOSE RUPTURES	9.85E-05	FNZMHRNGFA
		FIRE TRUCK PUMP NOT FUNCTIONAL	3.07E-01	FPMFPUMPFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA

REDUCED SUM OF PROBABILITY OF FAILURE = 3.316E-02

Table 4.4-12

MANUAL METHODS ABOVEGROUND – RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

MANUAL METHODS ABOVE GROUND FAULT TREE VERSION 1.5A

SYSTEM UNAVAILABILITY (Q) = 3.32E-02
NUMBER OF BASIC EVENTS = 12
NUMBER OF CUTSETS = 17

	BASIC EVENT	IMPORTANCE	# CS	CONT. TO Q	FAILURE PROBABILITY
1	FDIALERTFA	45.24	1	1.500E-02	1.500E-02
2	FHECLEARHE	33.17	1	1.100E-02	1.100E-02
3	FAAFINDDHE	22.62	1	7.500E-03	7.500E-03
4	FFXFAILSFA	.06	14	1.860E-05	2.920E-03
5	FHRERRORHE	.05	6	1.709E-05	1.100E-01
6	FFXERRORHE	.05	5	1.598E-05	1.100E-01
7	FPMFPUMPFA	.04	6	1.258E-05	3.070E-01
8	FHETRUCKHE	.01	5	4.527E-06	1.100E-01
9	FFXCHGEDDE	.01	5	2.187E-06	1.500E-02
10	FPPH2ONANI	.00	3	1.489E-06	4.000E-03
11	FFXBADFXFA	.00	4	4.254E-07	2.920E-03
12	FNZMHRNGFA	.00	5	1.524E-08	9.850E-05

BASIC EVENTS THAT DO NOT APPEAR IN THE CUTSETS

BASIC EVENT	FAILURE PROBABILITY

NONE

BASIC EVENTS WITH PROBABILITIES 0.0 OR 1.0

BASIC EVENT	FAILURE PROBABILITY

NONE

1

CONFIGURATION CONTROL

CODE NAME : COMP2
VERSION NO. : 1.50
DATE OF CONFIGURATION : DECEMBER 15,1987
DATE OF ISSUANCE : DECEMBER 15,1987
DATE : MARCH 21, 1989
TIME : 15: 3:28:55
CONFIGURATION NO. : 4494672989750

Table 4.4-13

MANUAL METHODS UNDERGROUND – MAPPING OF FAULT TREE TO MASTER DATA FILE

```
'MANUAL METHODS FAULT TREE - UNDERGROUND'
 8
'FAAFINDDHE'   01   530   0.000000   0.0
'FDIALERTFA'   01   165   0.000000   0.0
'FFXERRORHE'   01   549   0.000000   0.0
'FFXCHGEDDE'   01   165   0.000000   0.0
'FFXBADFXFA'   01   546   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FHRERRORHE'   01   170   0.000000   0.0
'FFXFAILSFA'   01   546   365.0000   0.0 'MONTHLY MAINT. PER MASTER PM SCHED.'
'FHECLEARHE'   01   170   0.000000   0.0
```

Table 4.4-14
MANUAL METHODS UNDERGROUND – FAULT TREE QUANTIFICATION RESULTS

MANUAL METHODS UNDERGROUND FAULT TREE

CUT SETS FOR GATE G0001 WITH CUTOFF PROBABILITY OF 1.00E-10
GATE G0001 IS: FAILURE TO DETECT AND SUPPRESS FIRE -MANUAL METHODS

NUMBER	CUTSET PROB.	BASIC EVENT NAME	EVENT PROB.	IDENTIFIER
1.	1.50E-02	FIRE NOT DETECTED BY PEOPLE	1.50E-02	FDIALERTFA
2.	1.10E-02	OPERATOR CLEARS AREA WITHOUT EMPLOYING MANUAL METHODS	1.10E-02	FHECLEARHE
3.	7.50E-03	FIRE DETECTED, OPERATOR CAN'T LOCATE ALARM	7.50E-03	FAAFINDDHE
4.	3.21E-04	OPERATOR ERROR	1.10E-01	FFXERRORHE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
5.	4.38E-05	FIRE EXTINGUISHER NOT CHARGED	1.50E-02	FFXCHGEDDE
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA
6.	8.53E-06	FAULTY DEVICE (PORTABLE EXTINGUSIHER)	2.92E-03	FFXBADFXFA
		FIRETRUCK EXTINGUSHERS NOT FUNCTIONAL	2.92E-03	FFXFAILSFA

REDUCED SUM OF PROBABILITY OF FAILURE = 3.350E-02

Table 4.4-15

MANUAL METHODS UNDERGROUND – RELATIVE IMPORTANCE OF INDIVIDUAL COMPONENTS/FAILURE MODES

MANUAL METHODS UNDERGROUND FAULT TREE VERSION 1.5A

SYSTEM UNAVAILABILITY (Q) = 3.35E-02
NUMBER OF BASIC EVENTS = 7
NUMBER OF CUTSETS = 6

	BASIC EVENT	IMPORTANCE	# CS	CONT. TO Q	FAILURE PROBABILITY
1	FDIALERTFA	44.77	1	1.500E-02	1.500E-02
2	FHECLEARHE	32.83	1	1.100E-02	1.100E-02
3	FAAFINDDHE	22.39	1	7.500E-03	7.500E-03
4	FFXFAILSFA	1.11	3	3.733E-04	2.920E-03
5	FFXERRORHE	.96	1	3.210E-04	1.100E-01
6	FFXCHGEDDE	.13	1	4.380E-05	1.500E-02
7	FFXBADFXFA	.03	1	8.530E-06	2.920E-03

BASIC EVENTS THAT DO NOT APPEAR IN THE CUTSETS

BASIC EVENT	FAILURE PROBABILITY

NONE

BASIC EVENTS WITH PROBABILITIES 0.0 OR 1.0

BASIC EVENT	FAILURE PROBABILITY

NONE

1

CONFIGURATION CONTROL

CODE NAME : COMP2
VERSION NO. : 1.50
DATE OF CONFIGURATION : DECEMBER 15,1987
DATE OF ISSUANCE : DECEMBER 15,1987
DATE : MARCH 22, 1989
TIME : 8:44:42:35
CONFIGURATION NO. : 4494672993144

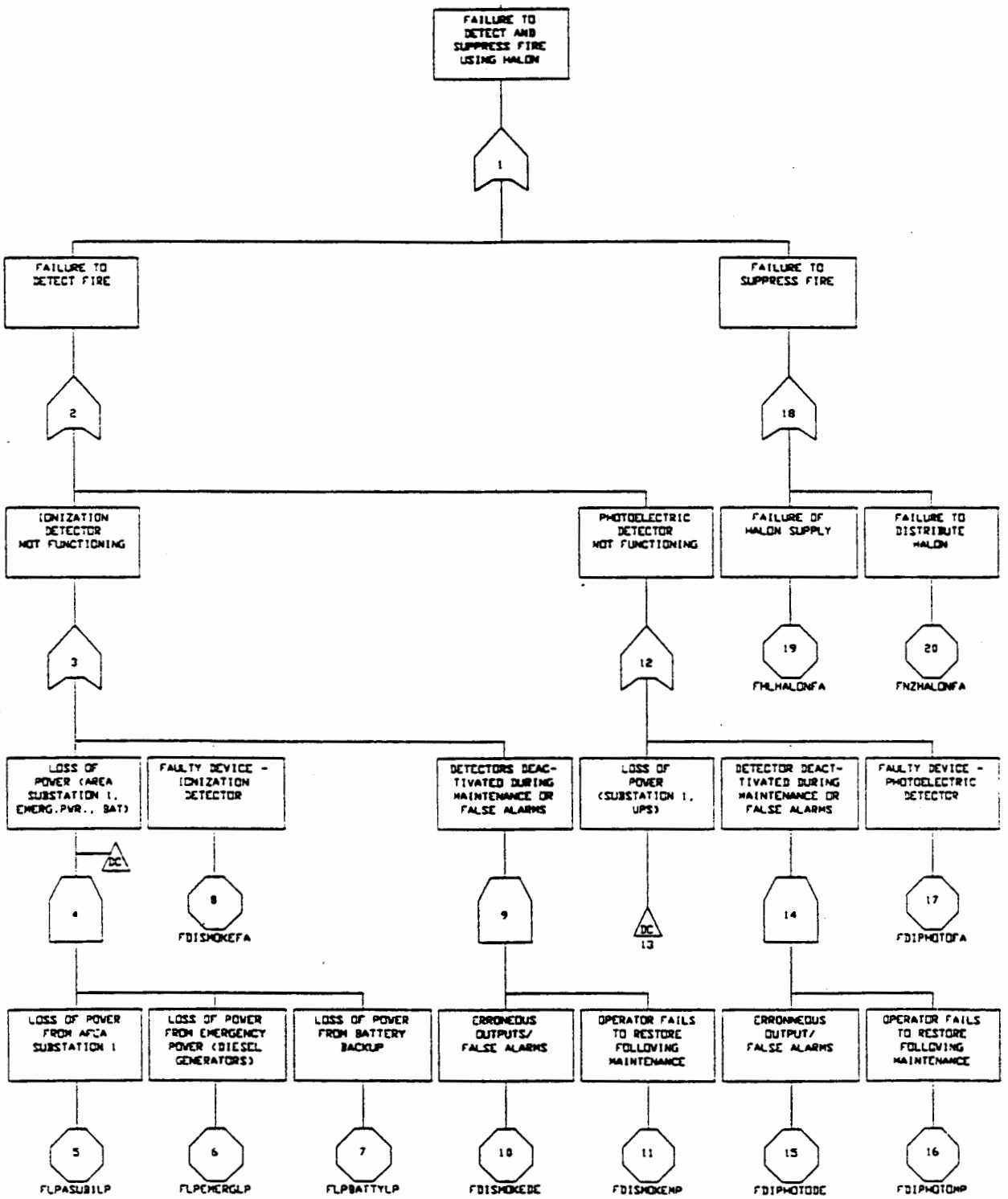

FIGURE 4.4-1. Typical Fault Tree

4.5 WIPP CH WASTE RISK QUANTIFICATION AND RESULTS

This section compiles the system failure probabilities quantified in Appendix C, the accident sequences defined in Section 4.2 and the Consequence Analysis of Section 4.3. The net result represents the total WIPP plant risk (R), that is defined as the probability (P) of an accident multiplied by its consequences (C), (R = P x C). The dominant accident sequences and their contributors are also discussed in detail.

4.5.1 FAULT TREE LINKING AND THE WLINK© CODE SYSTEM

A fault tree is a quantified logic diagram showing the various paths of failures and combinations of failures that can lead to an undesired event (top event) for the system being studied. The FTA determines the probability of occurrence of each path, as well as the logical sum of these probabilities, which is the probability of failure of the system as a whole. The analysis also identifies the dominant failure paths and ranks the importances of the individual failures. The fault tree may lead to the discovery of complex failure conditions of significant probability that may not be recognized otherwise.

In constructing the fault tree logic diagram, the effects of failures progress from the bottom of the structure (terminal nodes) upward through logic gates to the top undesired event (root node). Standard symbols depict the events and logic gates to the top undesired event (root node). Standard symbols depict the events and logic gates. Fault trees may consist of a few gates and events or several hundred or more, depending on the design of the system and the level of detail of the analysis. This collection of events, gates, values and labels are the features necessary to describe a fault tree.

When a fault tree is quantified (e.g., by using the GRAFTER Code System), the topgate probability and minimal cut-sets (combinations of basic event failures that will result in the top event) can be obtained. Then, one can combine fault trees using AND or OR logic to represent larger systems or accident sequences. The WLINK© code system performs such combinations of fault trees (fault tree linking) by combining the cut-sets of the individual fault tree by using the Boolean Algebra rules.

Fault tree linking is one of two methods approved by the NRC for conservatively modeling complex nuclear power plant systems with interdependent support systems. The NRC presents and discusses the two approved methods in NUREG-2300, "PRA Procedures

Guide." Additional information can be obtained from this document, but an overview of fault tree linking is presented here.

In fault tree linking, an accident sequence is represented by a fault tree whose top event is an AND gate with inputs representing the top gates of the system fault trees for each system depicted in the accident sequence. System dependencies are explicitly treated in the fault tree logic. The resultant fault tree can then be analyzed by a number of available fault tree reduction techniques. The result of this step is a set of accident sequence minimal cut-sets whose frequency estimates dominate the frequency of the accident sequence. The cut-sets are then used to develop a probability expression for determining the sequence or release category frequency. This frequency can be characterized as a distribution or as an estimate.

The fault tree linking method involves constructing accident sequence fault trees, solving these fault trees for dominant cut-sets, generating a probability expression from the accident sequence dominant cut-sets, and combining the probability equations for each accident sequence into an equation for the entire set of release categories.

The main purpose for using fault tree linking for the quantification of accident sequences and release categories is to eliminate the double counting of failures that can occur for support systems if each accident sequence and release category is quantified separately and then the results combined. Fault tree linking allows each failure or combination of failures in front line or support systems to be counted only once in the final results.

Each accident sequence is developed as a fault tree with the IE frequency linked with the front line systems so that the IE frequency will show up in each of the minimum cut-sets. References to support systems are nested, where appropriate, in the front line system fault trees, and an independent fault tree is constructed to represent each support system.

The fault tree linking software then runs through iterations to incorporate the nested levels of support systems. Boolean algebra is then applied to the fault tree to yield all possible combinations of failures that could result in a particular accident sequence. The cut-sets for a particular accident sequence are then ranked in decreasing order of frequency; a cutoff may be applied in order to limit the total number of cut-sets for complex systems. The frequencies of the dominant cut-sets are summed to yield the overall accident sequence frequency.

Accident sequences with similar results can be grouped into release categories and the release categories evaluated with fault tree linking. The linking quantification yields the dominant cut-sets and total release frequency for the release category. In addition, all accident sequences or release categories can be combined and quantified with fault tree linking to determine the dominant cut-sets and the overall release frequency for the entire plant or facility.

The WCS is a menu-driven system of computer codes used to perform fault tree linking for system reliability and accident sequences analysis. The code system functions in an interactive manner using an IBM AT or PS/2 microcomputer (and some compatible computers).

WCS actually consists of four executable codes, each performing a different function. Each of these codes can be run separately, if needed. These codes are 1) WLINK©; 2) COMPLNK; 3) SCE; and 4) LISTER.

WLINK© Code performs fault tree linking by combining minimal cut-sets of previously quantified fault trees. This is done by using Boolean Logic rules.

COMPLNK Code uses the output of the WLINK© Code to calculate component importances.

SCE Code uses the output of the WLINK© Code to perform cut-set editing, basic event probability changes, and sensitivity analysis of the results.

The LISTER code prepares tables such as basic event descriptions and sources, a list of basic events with multiple probability values, and a list of accident sequences.

WCS is compatible with the GRAFTER Code System, which is used for FTA. The cut-set output of the GRAFTER Code System can be used as input to the WCS.

The technical approach and methodology employed for the PRA is based on a thorough fault tree linking process that includes the development of event tree models to formulate the radionuclide release accident sequences (see Section 2.1 - accident sequences consist of IEs combined with combinations of failures of recovery/mitigation systems that

ultimately result in an accident). Each sequence identifies which system fault trees and operator actions are combined to calculate the frequency of an accident involving release of radionuclides (i.e., damage state frequencies). Each of these fault trees is quantified independently (Section 4.4) to yield cut-sets (combinations of events that result in the undesired event) and to assess the probability of system failure. The quantitative results of the fault trees involved in the accident sequences are coupled together using Revision 2.1 of WCS. WCS uses fault tree linking methods to calculate and link the results of several fault trees and formulate the basis for the accident sequences. The accident sequences are quantified via the fault tree linking phase of the PRA to obtain the radionuclide release frequency (i.e., damage state frequency) and the specific accident sequence cut-sets.

In this section, plant risk results are calculated and presented. The input for this analysis is obtained from the previous sections of the report. WCS uses the fault tree linking method to calculate the release category frequencies and identify fault sequences (cut-sets) in terms of component failures, operator errors, and other failures. These fault sequences and their summed damage state frequencies are grouped by release category and by IE.

The WIPP plant risk is shown in Section 4.5.4, where the plant damage state frequencies are combined with the results of the consequence analysis in Section 4.3. A summary of results and the conclusions to be drawn from the study are contained in Section 4.5.4.

4.5.2 INPUT SUMMARY FOR PLANT DAMAGE STATE QUANTIFICATION

This section summarizes the input used to calculate the plant damage state frequencies.

4.5.2.1 Initiating Event Frequencies

The IE frequencies calculated in Section 4.2.2 of this report were used in the quantification of plant damage frequency. These IEs appear as basic events in the fault sequences for plant damage frequency calculations. Each of these basic events are labeled as IEs by IEV-XXX, where XXX refers to one of the five IE categories.

The input frequencies for the IEs are presented in Table 4.5-1. This data is taken from Section 4.2.2 and is used in the quantification of the damage state frequencies for the accident sequences listed in Table 4.5-2.

4.5.2.2 Accident Sequences

For each IE, an event tree was developed and accident sequences that lead to plant damage were identified (see Section 4.2.2). These accident sequences are used in the plant damage analysis to obtain plant damage state frequencies. The accident sequences are taken from Section 4.2.2, and are repeated in Table 4.5-2 for convenience.

The accident sequences are treated as cut-sets by WLINK©. For analysis purposes, the following nomenclature is used to write the accident sequences as basic event cut-sets:

> IEs are labeled as IEV-XXX, where XXX is the IE specific symbol. Note that IEV-XXX is a scaler quantity (e.g., frequency), not a fault tree.
>
> The fault trees are labeled as SYS-YYY, where YYY is the name of the fault tree cut-set file for a system or operator action. These cut-set files are created by the GRAFTER Code System (Revision 1.5), and are labeled by the file name YYY.WLK.

4.5.2.3 Fault Trees Used in the Accident Sequences

The list of fault trees used in the accident sequences is provided in Table 4.5-3. These are the frontline systems that explicitly appear in the accident sequences listed in Table 4.5-2.

The support systems are modeled as subtrees within the frontline systems. These fault trees were quantified by the GRAFTER Code System. Electrical power support system fault trees are quantified specifically to account for possible LOP during an accident or as an accident initiator. The instrument air fault tree models the potential for a loss of air during an accident.

4.5.3 CALCULATION OF PLANT DAMAGE STATE FREQUENCIES

The plant damage state frequencies (i.e., frequency of radionuclide release) are calculated using the WCS. The accident sequences are linked using the fault tree linking method. The resulting plant damage state frequencies and the dominant cut-sets (fault sequences) are reported as the final plant damage state frequencies.

Plant damage state frequency results are presented in the following manner:

Damage state frequencies for each release category and IE

IE importances

Dominant fault sequences

4.5.3.1 Damage State Frequency Quantification and Results

In this section, the damage state frequency results for each release category and each IE are given. The calculation of these damage state frequencies was performed with the WCS, and the results for each damage state and IE are summarized in Table 4.5-5. The importance column shown in the table relates the contribution of the damage state frequency for that accident sequence to the overall damage state frequency. Results for each release category are shown in Table 4.5-6.

Table 4.5-7 contains a description of the dominant accident sequences for all IEs. Five accident sequences are considered credible events (that is, their frequency of occurrence exceeds 1.0E-6/yr). The frequencies calculated for these dominant sequences have some inherent conservatisms that ensure the results of this assessment offer a conservative, upper bound prediction of accident frequencies suitable for a safety analysis. Comments are provided below that include the identification of conservatisms inherent in the analysis reinforcing the validity of this analysis from a safety perspective.

Cut-set Sequence 1 involves a breach of waste drums aboveground coincident with a circuit breaker (CB) failure. For most failure modes, complete recovery could be made by the operator during the course of the accident.

Cut-set Sequences 2, 3, 4, and 5 involve a breach of waste drums aboveground coincident with failures of HEPA filters in the WHB HVAC System. Partial recovery actions are available to the operator through the termination of HVAC flow during the course of the accident.

4.5.4 CALCULATION OF PLANT RISK

The calculation of plant risk is derived by combining the frequency of accident sequences (damage state frequency) developed in Section 4.5.3 above with the off-site consequences for each release category developed in Section 4.3. This calculation has been performed for each IE and the results combined to determine the risk from all accident sequences.

Table 4.5-8 shows the combination of damage state frequency (DSF) and cancer fatality cases (consequence) for each IE. The combination of these two factors yields the yearly risk of cancer fatalities in the vicinity of the WIPP due to each accident initiator. The combination of risks from each initiator yields the overall plant risk, 0.00000027 cancer fatalities for the population of 100,000 people in the vicinity of the WIPP per year.

Table 4.5-9 groups the accident initiators by release category. The release category R3D is composed of initiators, A1, A2, and U1B. The release categories R28 and R90 are each composed of a single initiator, LPU and U2, respectively. The DSF for each release category is then the sum of the DSFs of the accident sequences of which it is composed. These release category frequencies are then combined with cancer fatality cases (consequences) to yield the yearly risk of cancer fatalities in the vicinity of WIPP due to each release category. The combination of risks from each release category again yields the overall plant risk, 0.00000027 cancer fatalities for the population of 100,000 people in the vicinity of the WIPP per year.

4.5.4.1 Results

This analysis examines CH waste drum receipt, emplacement and disposal. There are approximately 100,000 people within a 50-mile radius of the WIPP site, according to 1980 census figures. The population within a 50-mile radius has not grown significantly since the 1980 census. The PRA has estimated that the total number of cancer fatalities within a 50-mile radius and attributable to WIPP facility operations for the above conditions is minimal: 0.00000027 fatalities per year.

This minimal risk is best understood by comparing the 0.00000027 yearly rate against the normal yearly rate of cancer deaths in New Mexico, which is 141 cancer deaths per 100,000 people.[1] Risk acceptability is a very complicated issue; however, many industry experts feel that one of the best ways to judge the acceptability of risk is through comparison. A comparison of the yearly risk posed from the WIPP and other voluntary and involuntary risks per 100,000 people is found on Table 4.5-10.

While the risk posed to the public by the worst potential release that can be identified from CH waste drums is miniscule, the effects of such a release on the public's confidence and on the nation's nuclear future could be devastating. For that reason, this PRA presents detailed and meticulous fault tree analyses of the important systems at the WIPP facility so as to identify significant paths or accident scenarios that could conceivably lead to rupture of drums. This analysis has included equipment failures, HEs, and other failures which could contribute to a radioactive release.

The result of these detailed analyses is that the total frequency of drum rupture events is less than 0.23/year, and the total frequency of airborne release events from the site is less than 0.000055/year. This frequency and the associated consequences are miniscule. Nevertheless, in the course of the analysis, the PRA identifies certain improvements to hardware, procedures, and training that could reduce risk still further. These improvements are presented in Appendix XXVIII.

4.5.4.2 Conclusion

The results of this study indicate that CH waste drum handling and emplacement operations at the WIPP present an acceptable low level of risk to the public that is orders

[1]National Data Book and Guide to Sources, Statistical Abstract of the United States 1989, 109th edition, G. W. Blackburn, P. G. Oden, editors, Superintendent of Documents, U.S. Government Printing Office.

of magnitude below other voluntary and involuntary risks to which the public may be exposed.

Table 4.5-1

WIPP INITIATING EVENT FREQUENCIES

Initiating Event (IEV)	Definition	Frequency (/yr)
IEV-A1	Breach of Waste Drums Aboveground	7.5E-02
IEV-A2	Fire Aboveground	3.0E-03
IEV-U1B	Breach of Waste Drum Underground	1.2E-01
IEV-U2	Fire Underground	9.0E-05
IEV-LPU	Loss of Power - Underground Release	2.8E-02

Table 4.5-2

LIST OF ACCIDENT SEQUENCES

1. IEV-A1 * SYS-WB1

   Breach of Waste Drums Aboveground and Coincident Failure of the WHB HVAC Filtration System

2. IEV-A2 * SYS-MAG * SYS-FW * SYS-WB1

   Fire Aboveground, Coincident Failure of Manual Fire Suppression, Coincident Failure of Fire Water, and Coincident Failure of the WHB HVAC Filtration System

3. IEV-U1B * SYS-UF1

   Breach of Waste Drum Underground and Coincident Failure of EFB HVAC (Underground Filtration) System

4. IEV-U2 * SYS-UF2

   Fire Underground (which includes Failure of Manual Fire Suppression and Failure of Dry Chemical Suppression), and Coincident Failure of EFB HVAC (Underground Filtration) System

5. IEV-LPU * SYS-HB * SYS-UF1

   Loss of Electric Power - Underground Release, Coincident Failure of the Waste Hoist Braking System, and Coincident Failure of EFB HVAC (Underground Filtration) System

Table 4.5-3

FAULT TREES USED IN ACCIDENT SEQUENCES

Identifier	Description
SYS-WB1	Failure of WHB HVAC Filtration System
SYS-UF1	Failure of EFB HVAC (Underground Filtration) System
SYS-UF2	Failure of EFB HVAC System for Underground Fire
SYS-HB	Failure of the Waste Hoist Braking System
SYS-MAG	Failure of Fire Suppression - Manual Methods Aboveground
*SYS-MUG	Failure of Fire Suppression - Manual Methods Underground
*SYS-CUG	Failure of Fire Suppression - Dry Chemical Underground Vehicle
SYS-FW	Failure of Fire Suppression - Fire Water (Including Sprinkler Heads) Aboveground

*Quantified in Section 4.4.1 and results used in Section 4.2.2.2 - these were not part of the linking process.

Table 4.5-4

SUPPORT SYSTEM FAULT TREES USED IN ANALYSIS

Identifier	Description
SUB-AIR	Failure of Compressed Air
SUB-E1	Loss of Power on Substation 1
SUB-E2	Loss of Power on Substation 2
SUB-E3A	Loss of Power on Substation 3, Bus A
SUB-E3B	Loss of Power on Substation 3, Bus B
SUB-E4	Loss of Power on Substation 4
SUB-ESB	Loss of Power on Support Building Substation
SUB-EU1	Loss of Power on Underground Substation 1
SUB-CMU	Loss of Radiation Detection on Underground CAMs
SUB-CMA	Loss of Radiation Detection on Station A CAMs
*SUB-CM1	Loss of Radiation Detection on WHB Station C CAMs
*SUB-CMB	Loss of Radiation Detection on Station B CAMs

*Quantified - these were not part of the linking process.

Table 4.5-5

SUMMARY OF DAMAGE STATE FREQUENCIES BY INITIATING EVENT

Overall Damage State Frequency (DSF) = 5.49E-5
Number of Cut-sets = 1085

Initiating Event	Damage State	Contribution Importance	Cut-sets	To DSF	Initiating Event Frequency (/yr)
IEV-A1	R3D	97.63	878	5.4E-5	7.5E-2
IEV-U1B	R3D	1.65	47	9.1E-7	1.2E-1
IEV-U2	R90	0.72	308	4.0E-7	9.0E-5
IEV-A2	R3D	0	210	3.0E-10	3.0E-3
IEV-LPU	R28	0	773	6.9E-13	2.8E-2

Table 4.5-6

SUMMARY OF DAMAGE STATE FREQUENCIES BY RELEASE CATEGORY

Release Category	Description of Accident Release	Damage State Frequency (/yr)
R3D	3 Drums Damaged 100% of contents of each of two drums with average curie loading spilled; 25% of the contents of the third drum with a maximum curie loading burned.	5.5E-5
R28	28 Drums Damaged 100% of contents of all drums is spilled. Two have a maximum curie loading. Twenty-six have an average curie loading.	6.9E-13
R90	90 Drums Damaged 100% of combustible contents (25% of total contents) burned. Three have a maximum curie loading. Eighty-seven have an average curie loading. Maximum curie loading = 1000 PE-Ci* Average curie loading = 12.9 PE-Ci*	4.0E-7

*PE-Ci is Plutonium-Equivalent curies

Table 4.5-7

ACCIDENT SEQUENCES FOR ALL INITIATING EVENTS ANALYZED

Accident Sequence Number	Cut-Set Probability	Basic Event Name	Event Probability	Event Identifier
1.	1.80E-5	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Sub 2 Circuit Breaker 1 Fails Open	2.40E-4	ECB1SUB2CO
2.	4.60E-6	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		CHA Train B HEPA Filter 41-B-815 Ruptures Due to Local Faults	6.13E-5	HFI41815RU
3.	4.60E-6	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		CHA Train A HEPA Filter 41-B-814 Ruptures Due to Local Faults	6.13E-5	HFI41814RU
4.	4.60E-6	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		RCA Train B HEPA Filter 41-B-979 Ruptures Due to Local Faults	6.13E-5	HFI41979RU
5.	4.60E-6	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		RCA Train A HEPA Filter 41-B-834 Ruptures Due to Local Faults	6.13E-5	HFI41834RU
6.	6.00E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Sub 2 Transformer 15/2 Fails	8.00E-6	ETR2SUB2FA
7.	2.59E-7	Breach of Waste Drum Underground	1.20E-1	IEV-U1B
		Failure of Exhaust Filter Switch Latch Relay L-R on Filter Signal	2.16E-6	HRLEXHFIFA
8.	2.59E-7	Breach of Waste Drum Underground	1.20E-1	IEV-U1B
		Failure of Relay R7 to Stop Fans and Close Dampers on L-R Signal	2.16E-6	HRER7---FA
9.	1.98E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Operator Fails to Realign Key Switch to Bus A	1.10E-2	ESWASUB2HE
		Plant Sub Circuit Breaker 6 Fails Open	2.40E-4	ECB6SUBPCO
10.	1.98E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Operator Fails to Realign Key Switch to Bus A	1.10E-2	ESWASUB2HE
		Sub 2 Switch 15/2B Fails Open	2.40E-4	ESW2BSB2CO

Table 4.5-7 (Continued)

ACCIDENT SEQUENCES FOR ALL INITIATING EVENTS ANALYZED

Accident Sequence Number	Cut-Set Probability	Basic Event Name	Event Probability	Event Identifier
11.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Solenoid Oper. Valve FCV-332/333 Fails Open	2.40E-4	ASV33233CC
12.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Solenoid Oper. Valve FCV-289 Fails Local and Blocks Air	2.40E-4	ASV289--CC
13.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Solenoid-Oper. Valve FVC-284 Fails Open to Muffler	2.40E-4	ASV284--CC
14.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Solenoid Oper. Valve FCV-278/281 Fails Open	2.40E-4	ASV27881CC
15.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Bus 41M3 Circuit Breaker CB1 Fails Open	2.40E-4	ACB413-1CO
16.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Bus 25S1 Circuit Breaker CB5 Fails Open	2.40E-4	ACB251-5CO
17.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Bus 41M5 Circuit Breaker CB20 Fails Open	2.40E-4	ACB41520CO
18.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Bus 41M5 Circuit Breaker CB1 Fails Open	2.40E-4	ACB415-1CO

Table 4.5-7 (Continued)

ACCIDENT SEQUENCES FOR ALL INITIATING EVENTS ANALYZED

Accident Sequence Number	Cut-Set Probability	Basic Event Name	Event Probability	Event Identifier
19.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
		Bus 25S2 Circuit Breaker CB1 Fails Open	2.40E-4	ACB252-1CO
20.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Solenoid Oper. Valve FCV-332/333 Fails Open	2.40E-4	ASV33233CC
21.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Solenoid Oper. Valve FCV-289 Fails Local and Blocks Air	2.40E-4	ASV289--CC
22.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Solenoid-Oper. Valve FVC-284 Fails Open to Muffler	2.40E-4	ASV284--CC
23.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Solenoid Oper. Valve FCV-278/281 Fails Open	2.40E-4	ASV27881CC
24.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Bus 41M3 Circuit Breaker CB1 Fails Open	2.40E-4	ACB413-1CO
25.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Bus 25S1 Circuit Breaker CB5 Fails Open	2.40E-4	ACB251-5CO
26.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Bus 41M5 Circuit Breaker CB20 Fails Open	2.40E-4	ACB41520CO

Table 4.5-7 (Continued)

ACCIDENT SEQUENCES FOR ALL INITIATING EVENTS ANALYZED

Accident Sequence Number	Cut-Set Probability	Basic Event Name	Event Probability	Event Identifier
27.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Bus 41M5 Circuit Breaker CB1 Fails Open	2.40E-4	ACB415-1CO
28.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
		Bus 25S2 Circuit Breaker CB1 Fails Open	2.40E-4	ACB252-1CO
29.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 41M6 Circuit Breaker CB1 Fails Open	2.40E-4	HCB416-1CO
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
30.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 41M6 Circuit Breaker CB1 Fails Open	2.40E-4	HCB416-1CO
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
31.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 45S1 Circuit Breaker CB3 Fails Open	2.40E-4	HCB451-3CO
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
32.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 45S1 Circuit Breaker CB3 Fails Open	2.40E-4	HCB451-3CO
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK
33.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 45S1 Circuit Breaker CB1 Fails Open	2.40E-4	ACB451-1CO
		Emergency Door Seal B Leaks	1.09E-2	HDSB----LK
34.	1.96E-7	Breach of Waste Drums Aboveground	7.50E-2	IEV-A1
		Bus 45S1 Circuit Breaker CB1 Fails Open	2.40E-4	ACB451-1CO
		Emergency Door Seal A Leaks	1.09E-2	HDSA----LK

Table 4.5-7 (Continued)

ACCIDENT SEQUENCES FOR ALL INITIATING EVENTS ANALYZED

Accident Sequence Number	Cut-Set Probability	Basic Event Name	Event Probability	Event Identifier
35.	1.06E-7	Breach of Waste Drum Underground	1.20E-1	IEV-U1B
		Air Vacuum Pump Fails to Continue to Run	2.40E-4	RVP121--FR
		Blockage Failure of the Station A Probe Nozzle A-1	3.68E-3	RSNA1---PL
36.	1.06E-7	Breach of Waste Drum Underground	1.20E-1	IEV-U1B
		Air Vacuum Pump Fails to Continue to Run	2.40E-4	RVP117--FR
		Blockage Failure of the Station A Probe Nozzle A-1	3.68E-3	RSNA1---PL

TOTAL PROBABILITY OF FAILURE = 5.49E-5

Table 4.5-8
PLANT RISK BY INITIATOR

Initiator	Frequency (events/yr)	Total Cancer* Fatality Cases Within 50 Miles	Risk of Cancer Fatality (per year)
A1 (R3D)	5.4E-5	4.8E-3	2.6E-7
A2 (R3D)	3.0E-10	4.8E-3	1.4E-12
U1B (R3D)	9.1E-7	4.8E-3	4.3E-9
U2 (R90)	4.0E-7	9.3E-3	3.7E-9
LPU (R28)	6.9E-13	4.4E-4	3.0E-16
	Frequency x	Consequence =	Risk
		TOTAL	0.00000027

A1 – Breach of Drum Aboveground
A2 – Fire Aboveground
U1B – Breach of Drum Underground
U2 – Underground Fire
LPU – Loss of Electric Power to Waste Hoist

*Mean consequence value of cancer fatality cases for population of 100,000 based on 70-year committed effective dose.

Table 4.5-9
PLANT RISK BY RELEASE CATEGORY

Release Category	Frequency (events/yr)	Total Cancer* Fatality Cases Within 50 Miles	Risk of Cancer Fatality (per year)
R3D	5.5E-5	4.8E-3	2.6E-7
R28	6.9E-13	4.4E-4	3.0E-16
R90	4.0E-7	9.3E-3	3.7E-9
	Frequency x	Consequence =	Risk
		TOTAL	0.00000027

*Mean consequence value of cancer fatality cases for population of 100,000 based on a 70-year committed effective dose.

Table 4.5-10
RISK FACTOR COMPARISONS
Fatalities Per Year
(per 100,000 people exposed to or engaged in activities)

Cause of Fatality	Per 100,000 People/Per Year
Cigarette Smoking	360.0 (US)
Diseases of the Heart	193.4 (NM)
Cancer - All Causes	140.7 (NM)
Accidents - All Causes	55.0 (NM)
Pneumonia and Flu	23.3 (NM)
Alcohol, Light Drinker	2.0 (US)
Electrocution	0.53 (US)
*WIPP CH Accidents - Cancer	0.00000027

(NM) New Mexico
(US) United States

*Population within 50-mile radius of the WIPP site.

Source for United States statistics: "Risk Assessment and Comparison," Chapter 14), Carcinogen Risk Assessment, Edited by C. C. Travis, Plenum Press, 1988.

Source for New Mexico statistics: National Data Book and Guide to Sources, Statistical Abstract of the United States I989, 109th edition, G. W. Blackburn, P. G. Oden, editors, Superintendent of Documents, U.S. Government Printing Office.

Table 4.5-11

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

Table 4.5-11 contains the list of basic events and their descriptions. If a basic event appears in multiple fault trees, the description was read and listed from the first fault tree it appears in.

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

1	AAM01---CO	SAFETY RELIEF	VALVE PSV-01	OPENS SPURIOUSLY	
2	AAM25---CO	SAFETY RELIEF	VALVE PSV-25	OPENS SPURIOUSLY	
3	AAM31---CO	SAFETY RELIEF	VALVE PSV-31	OPENS SPURIOUSLY	
4	AAM39---CO	SAFETY RELIEF	VALVE PSV-39	OPENS SPURIOUSLY	
5	AAM44---CO	SAFETY RELIEF	VALVE PSV-44	OPENS SPURIOUSLY	
6	ACB251-5CO	BUS 25S1	CIRCUIT BREAKER	CB5	FAILS OPEN
7	ACB252-1CO	BUS 25S2	CIRCUIT BREAKER	CB1	FAILS OPEN
8	ACB413-1CO	BUS 41M3	CIRCUIT BREAKER	CB1	FAILS OPEN
9	ACB413-5CO	BUS 41M3	CIRCUIT BREAKER	CB5	FAILS OPEN
10	ACB413-9CO	BUS 41M3	CIRCUIT BREAKER	CB9	FAILS OPEN
11	ACB415-1CO	BUS 41M5	CIRCUIT BREAKER	CB1	FAILS OPEN
12	ACB41520CO	BUS 41M5	CIRCUIT BREAKER	CB20	FAILS OPEN
13	ACB451-1CO	BUS 45S1	CIRCUIT BREAKER	CB1	FAILS OPEN
14	ACM021A-FA	FAILURES OF AIR	COMPRESSOR	41-G-021A	
15	ACM021ABCM	FAILURE OF BOTH	COMPRESSORS 1 &	2 DUE TO COMMON	CAUSE
16	ACM021B-FA	FAILURES OF AIR	COMPRESSOR	41-G-021B	
17	AFA014--FA	FAILURE OF COOL.	FAN CONTROL IN	AIR COOLED HEAT	EXCHANGER
18	AFI01---PL	PLUGGING OF THE	COMPRESSOR 1 AIR	INTAKE FILTER	
19	AFI02---PL	PLUGGING OF THE	COMPRESSOR 2 AIR	INTAKE FILTER	
20	AFI04---PL	BLOCKAGE IN	AIR DRYER	PRE-FILTER 04	
21	AFI05---PL	BLOCKAGE IN	AIR DRYER	PRE-FILTER 05	
22	AFI42---PL	BLOCKAGE IN	AFTERFILTER 42		
23	AFI43---PL	BLOCKAGE IN	AFTERFILTER 43		
24	AFL109--PL	STRAINER BETWEEN	FCV-109 AND	FCV-110 CLOGS	
25	AFL115--PL	STRAINER BETWEEN	FCV-115 AND	FCV-116 CLOGS	
26	AFL17---PL	STRAINER NEAR	T1-17 CLOGS		
27	AHX014--LK	TUBES FAIL IN	AIR COOLED HEAT	EXCHANGER	41-E-014
28	AHXAFC1-LK	TUBES LEAK IN	COMPRESSOR 1	AFTERCOOLER	
29	AHXAFC2-LK	TUBES LEAK IN	COMPRESSOR 2	AFTERCOOLER	
30	APM041A-FA	FAILURES OF	MOTOR DRIVEN	PUMP 41-G-041-A	
31	APM041B-FA	FAILURES OF	MOTOR DRIVEN	PUMP 41-G-041-B	
32	APVZ015-RU	RUPTURE OF AIR	DRYER TOWER DUE	TO PRESSURE	CYCLING
33	ARE28489FA	INTERLOCK	BETWEEN FCV-284	& FCV-289 FAILS	
34	ARECOMP-FA	FAILURE OF	COMPRESSOR	AUTOSTART	INTERLOCK
35	ARR290--CC	PRESSURE CONTROL	VALVE FCV-290	FAILS CLOSED	
36	ASV110--CC	SOLENOID OPER.	VALVE FCV-110	FAILS TO OPEN	
37	ASV116--CC	SOLENOID OPER.	VALVE FCV-116	FAILS TO OPEN	
38	ASV27881CC	SOLENOID OPER.	VALVE FCV-278/	281 FAILS OPEN	
39	ASV284--CC	SOLENOID-OPER.	VALVE FVC-284	FAILS OPEN TO	MUFFLER
40	ASV289--CC	SOLENOID OPER.	VALVE FCV-289	FAILS LOCAL AND	BLOCKS AIR
41	ASV33233CC	SOLENOID OPER.	VALVE FCV-332/	333 FAILS OPEN	
42	AWHBDIV---	FLOW DIVERSION	AT THE PLANT AIR	& SUPPORT BLDG	INTERFACE
43	AXV101--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-101
44	AXV102--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-102
45	AXV103--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-103
46	AXV104--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-104
47	AXV105--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-105
48	AXV106--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-106
49	AXV108--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-108
50	AXV109--HE	OPERATOR	ERRONEOUSLY	CLOSES MANAUAL	VALVE FCV-109
51	AXV112C-HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-112
52	AXV112O-HE	OPERATOR	ERRONEOUSLY	FULLY OPENS MAN.	VALVE FCV-112
53	AXV114--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-114
54	AXV115--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-115
55	AXV118C-HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-118
56	AXV118O-HE	OPERATOR	ERRONEOUSLY	FULLY OPENS MAN.	VALVE FCV-118
57	AXV121--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-121
58	AXV122--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-122
59	AXV234--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-234
60	AXV266--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-266

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

1	AAM01---CO	SAFETY RELIEF	VALVE PSV-01	OPENS SPURIOUSLY	
2	AAM25---CO	SAFETY RELIEF	VALVE PSV-25	OPENS SPURIOUSLY	
3	AAM31---CO	SAFETY RELIEF	VALVE PSV-31	OPENS SPURIOUSLY	
4	AAM39---CO	SAFETY RELIEF	VALVE PSV-39	OPENS SPURIOUSLY	
5	AAM44---CO	SAFETY RELIEF	VALVE PSV-44	OPENS SPURIOUSLY	
6	ACB251-5CO	BUS 25S1	CIRCUIT BREAKER	CB5	FAILS OPEN
7	ACB252-1CO	BUS 25S2	CIRCUIT BREAKER	CB1	FAILS OPEN
8	ACB413-1CO	BUS 41M3	CIRCUIT BREAKER	CB1	FAILS OPEN
9	ACB413-5CO	BUS 41M3	CIRCUIT BREAKER	CB5	FAILS OPEN
10	ACB413-9CO	BUS 41M3	CIRCUIT BREAKER	CB9	FAILS OPEN
11	ACB415-1CO	BUS 41M5	CIRCUIT BREAKER	CB1	FAILS OPEN
12	ACB41520CO	BUS 41M5	CIRCUIT BREAKER	CB20	FAILS OPEN
13	ACB451-1CO	BUS 45S1	CIRCUIT BREAKER	CB1	FAILS OPEN
14	ACM021A-FA	FAILURES OF AIR	COMPRESSOR	41-G-021A	
15	ACM021ABCM	FAILURE OF BOTH	COMPRESSORS 1 &	2 DUE TO COMMON	CAUSE
16	ACM021B-FA	FAILURES OF AIR	COMPRESSOR	41-G-021B	
17	AFA014--FA	FAILURE OF COOL.	FAN CONTROL IN	AIR COOLED HEAT	EXCHANGER
18	AFI01---PL	PLUGGING OF THE	COMPRESSOR 1 AIR	INTAKE FILTER	
19	AFI02---PL	PLUGGING OF THE	COMPRESSOR 2 AIR	INTAKE FILTER	
20	AFI04---PL	BLOCKAGE IN	AIR DRYER	PRE-FILTER 04	
21	AFI05---PL	BLOCKAGE IN	AIR DRYER	PRE-FILTER 05	
22	AFI42---PL	BLOCKAGE IN	AFTERFILTER 42		
23	AFI43---PL	BLOCKAGE IN	AFTERFILTER 43		
24	AFL109--PL	STRAINER BETWEEN	FCV-109 AND	FCV-110 CLOGS	
25	AFL115--PL	STRAINER BETWEEN	FCV-115 AND	FCV-116 CLOGS	
26	AFL17---PL	STRAINER NEAR	T1-17 CLOGS		
27	AHX014--LK	TUBES FAIL IN	AIR COOLED HEAT	EXCHANGER	41-E-014
28	AHXAFC1-LK	TUBES LEAK IN	COMPRESSOR 1	AFTERCOOLER	
29	AHXAFC2-LK	TUBES LEAK IN	COMPRESSOR 2	AFTERCOOLER	
30	APM041A-FA	FAILURES OF	MOTOR DRIVEN	PUMP 41-G-041-A	
31	APM041B-FA	FAILURES OF	MOTOR DRIVEN	PUMP 41-G-041-B	
32	APVZ015-RU	RUPTURE OF AIR	DRYER TOWER DUE	TO PRESSURE	CYCLING
33	ARE28489FA	INTERLOCK	BETWEEN FCV-284	& FCV-289 FAILS	
34	ARECOMP-FA	FAILURE OF	COMPRESSOR	AUTOSTART	INTERLOCK
35	ARR290--CC	PRESSURE CONTROL	VALVE FCV-290	FAILS CLOSED	
36	ASV110--CC	SOLENOID OPER.	VALVE FCV-110	FAILS TO OPEN	
37	ASV116--CC	SOLENOID OPER.	VALVE FCV-116	FAILS TO OPEN	
38	ASV27881CC	SOLENOID OPER.	VALVE FCV-278/	281 FAILS OPEN	
39	ASV284--CC	SOLENOID-OPER.	VALVE FVC-284	FAILS OPEN TO	MUFFLER
40	ASV289--CC	SOLENOID OPER.	VALVE FCV-289	FAILS LOCAL AND	BLOCKS AIR
41	ASV33233CC	SOLENOID OPER.	VALVE FCV-332/	333 FAILS OPEN	
42	AWHBDIV---	FLOW DIVERSION	AT THE PLANT AIR	& SUPPORT BLDG	INTERFACE
43	AXV101--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-101
44	AXV102--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-102
45	AXV103--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-103
46	AXV104--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-104
47	AXV105--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-105
48	AXV106--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-106
49	AXV108--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-108
50	AXV109--HE	OPERATOR	ERRONEOUSLY	CLOSES MANAUAL	VALVE FCV-109
51	AXV112C-HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-112
52	AXV112O-HE	OPERATOR	ERRONEOUSLY	FULLY OPENS MAN.	VALVE FCV-112
53	AXV114--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-114
54	AXV115--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-115
55	AXV118C-HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-118
56	AXV118O-HE	OPERATOR	ERRONEOUSLY	FULLY OPENS MAN.	VALVE FCV-118
57	AXV121--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-121
58	AXV122--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-122
59	AXV234--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-234
60	AXV266--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-266

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

61	AXV268--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-268
62	AXV269--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-269
63	AXV270--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-270
64	AXV271--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-271
65	AXV275--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-275
66	AXV276--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-276
67	AXV277--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-277
68	AXV279--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-279
69	AXV280--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-280
70	AXV292--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-292
71	AXV293--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-293
72	AXV294--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-294
73	AXV295--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-295
74	AXV298--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-298
75	AXV302--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-302
76	AXV307--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-307
77	AXV311--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-311
78	AXV316--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-316
79	AXV317--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-317
80	AXV318--HE	OPERATOR	ERRONEOUSLY	CLOSES MANUAL	VALVE FCV-318
81	ECB10SB3CO	SUB 3	CIRCUIT BKR 10	FAILS OPEN	
82	ECB11SB3CO	CIRCUIT BREAKER	11	FAILS OPEN	
83	ECB1SS1-CO	U/G SWITCH STA 1	CIRCUIT BKR 1	FAILS OPEN	
84	ECB1SS2-CO	U/G SWITCHING	STA 2 CIRCUIT	BKR 1 FAILS OPEN	
85	ECB1SUB1CO	SUB 1 CIRCUIT	BREAKER 1	FAILS OPEN	
86	ECB1SUB2CO	SUB 2 CIRCUIT	BREAKER 1 FAILS	OPEN	
87	ECB1SUB4CO	SUB 4 CIRCUIT	BREAKER 1 FAILS	OPEN	
88	ECB1SUBSCO	SUB S CIRCUIT	BREAKER 1	FAILS OPEN	
89	ECB1SUBUCO	UTILITY SUB	CIRCUIT BREAKER	1 FAILS OPEN	
90	ECB2SUBPCO	PLANT SUB A	CIRCUIT BREAKER	2 FAILS OPEN	
91	ECB2SUBUCO	UTILITY SUB	CIRCUIT BREAKER	2 FAILS OPEN	
92	ECB3SUBPCO	PLANT SUB	CIRCUIT BREAKER	3 FAILS OPEN	
93	ECB4SUBPCO	PLANT SUB	CIRCUIT BKR 4	FAILS OPEN	
94	ECB5SUBPCO	PLANT SUB	CIRCUIT BREAKER	5 FAILS OPEN	
95	ECB6SUBPCO	PLANT SUB	CIRCUIT BREAKER	6 FAILS OPEN	
96	ECB7SUB3CO	CIRCUIT BREAKER	7	FAILS OPEN	
97	ECB7SUBPCO	PLANT SUB	CIRCUIT BKR 7	FAILS OPEN	
98	ECB8SUB3CO	SUB 3	CIRCUIT BKR 8	FAILS OPEN	
99	ECB9SUB3CO	CIRCUIT BREAKER	9 BETWEEN SUB 3	BUSES A AND B	FAILS OPEN
100	ECB9SUBPCO	PLANT SUB TIE	BREAKER CB 9	FAILS OPEN	
101	ECB9SUBPHE	OPERATOR FAILS	TO CLOSE PLANT	SUB TIE BKR 9	
102	ECB9SUBPOO	PLANT SUB TIE	BKR 9 FAILS	TO CLOSE	
103	ECBG1SB3CO	CIRCUIT BREAKER	G1	FAILS OPEN	
104	ECBG1SB3HE	OPERATOR FAILS	TO CLOSE	CIRCUIT BREAKER	G1
105	ECBG2SB3CO	CIRCUIT BREAKER	G2	FAILS OPEN	
106	ECBG2SB3HE	OPERATOR FAILS	TO CLOSE	CIRCUIT BREAKER	G2
107	ECBMUG1-CO	U/G SUB 1 MAIN	600A CIRCUIT	BREAKER FAILS	OPEN
108	ECBTSUB1OO	CIRCUIT BREAKER	IN 480 V TIE	LINE FAILS TO	CLOSE
109	ECBTSUBSOO	CIRCUIT BREAKER	IN 480V TIE LINE	FAILS TO CLOSE	
110	EDG-----CM	NO EMERG. POWER	FROM D-G 1 & 2	DUE TO	COMMON CAUSE
111	EDG1----FR	D-G NO. 1	FAILS TO RUN	FOR DEMAND	PERIOD
112	EDG1----FS	D-G NO. 1	FAILS TO START		
113	EDG1----MT	D-G NO. 1	IS IN	MAINTENANCE	
114	EDG1SUB3HE	OPERATOR FAILS	TO INITIATE	D-G NO. 1 START	
115	EDG2----FR	D-G NO. 2	FAILS TO RUN	FOR DEMAND	PERIOD
116	EDG2----FS	D-G NO. 2	FAILS TO START		
117	EDG2----MT	D-G NO. 2	IS IN	MAINTENANCE	
118	EDG2SUB3HE	OPERATOR FAILS	TO INITIATE	D-G NO. 2 START	
119	EFU1SUBSCO	SUB S FUSE 15/1	OPENS	PREMATURELY	
120	EFU3ASB3CO	SUB 3 FUSE 15/3A	OPENS	PREMATURELY	

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

121	EFU3BSB3CO	SUB 3 BUS B	FUSE	15/3B	FAILS OPEN
122	EFU4SUB4CO	SUB 4 FUSE 15/4	OPENS	PREMATURELY	
123	EFUASUB3CO	SUB 3 FUSE A	OPENS	PREMATURELY	
124	EFUBSUB3CO	SUB 3 FUSE B	OPENS	PREMATURELY	
125	ELOOP-----	LOSS OF UTILITY	POWER		
126	ESW1ASBSOO	SUB S SWITCH	15/1A FAILS TO	CLOSE	
127	ESW1ASS1CO	U/G SWITCH STA 1	SWITCH SW1A	FAILS OPEN	
128	ESW1BSBSCO	SUB S SWITCH	15/1B FAILS OPEN		
129	ESW1BSS1HE	OPERATOR FAILS	TO CLOSE U/G	SWITCH STATION 1	KEY SWITCH 1B
130	ESW1BSS1OO	U/G SWITCH STA 1	SWITCH 1B	FAILS TO CLOSE	
131	ESW1SUB1CO	SWITCH 15/1	FAILS OPEN		
132	ESW1WSL-CO	WASTE SHAFT LINE	SWITCH 31P-15/1	FAILS OPEN	
133	ESW2ASB2OO	SUB 2 SWITCH	15/2A FAILS TO	CLOSE	
134	ESW2ASS2HE	OPERATOR FAILS	TO REALIGN KEY	SWITCH 2A TO EXH	SHAFT LINE
135	ESW2ASS2OO	U/G SWITCH STA 2	SWITCH 15/2A	FAILS TO CLOSE	
136	ESW2BSB2CO	SUB 2 SWITCH	15/2B FAILS OPEN		
137	ESW2BSS2HE	OPERATOR FAILS	TO REALIGN KEY	SWITCH 15/2B TO	WASTE SHAFT LINE
138	ESW2BSS2OO	U/G SWITCH STA 2	SWITCH 15/2B	FAILS TO CLOSE	
139	ESW3ASB3CO	SUB 3 SWITCH	15/3A FAILS OPEN		
140	ESW3BSB3CO	SUB 3 SWITCH	15/3B FAILS OPEN		
141	ESW4ASB4CO	SUB 4 SWITCH	15/4A FAILS OPEN		
142	ESW4BSB4OO	SUB 4 SWITCH	15/4B FAILS TO	CLOSE	
143	ESW5ESL-CO	EXHAUST SHAFT	LINE SWITCH	25P-SW15/5	FAILS OPEN
144	ESWASUB2HE	OPERATOR FAILS	TO REALIGN	KEY SWITCH	TO BUS A
145	ESWASUBSHE	OPERATOR FAILS	TO REALIGN	SUB TO BUS A	
146	ESWBSUB4HE	OPERATOR FAILS	TO REALIGN	KEY SWITCH	TO BUS B
147	ETR1SUB1FA	SUB 1	TRANSFORMER 15/1	FAILS	
148	ETR1SUBSFA	SUB S	TRANSFORMER 15/1	FAILS	
149	ETR1UG1-FA	U/G SUB 1	TRANSFORMER 15/1	FAILS	
150	ETR2SUB2FA	SUB 2	TRANSFORMER	15/2 FAILS	
151	ETR3ASB3FA	SUB 3 TRANSFORMR	15/3A FAILS		
152	ETR3BSB3FA	SUB 3 BUS B	TRANSFORMER	15/3B	FAILS
153	ETR4SUB4FA	SUB 4	TRANSFORMER 15/4	FAILS	
154	ETRASUB3FA	SUB 3	TRANSFORMER A	FAILS IN	STEP-UP SERVICE
155	ETRBSUB3FA	SUB 3	TRANSFORMER B	FAILS IN	STEP-UP SERVICE
156	ETRSUBU-FA	UTILITY SUB	TRANSFORMER	OA/FA	FAILS
157	FAAFINDDHE	FIRE DETECTED,	OPERATOR CAN'T	LOCATE ALARM	
158	FACOPERRHE	OPERATOR FAILS	TO MANUALLY	ACTUATE DRY	CHEM. SYSTEM
159	FCB251-6CO	BUS 25S4	CIRCUIT BREAKER	CB6	FAILS OPEN
160	FCV08CHKCC	CHECK VALVE	FW-456-V-8	CLOSED	
161	FCV10CHKCC	CHECK VALVE	FW-456-V-10	CLOSED	
162	FCVNORTHCC	CHECK VALVE FOR	NORTH SPRINKLER	RISER CLOSED	
163	FCVSOUTHCC	CHECK VALVE FOR	SOUTH SPRINKLER	RISER CLOSED	
164	FDCDCHEMFA	FAILURE OF DRY	CHEMICAL SUPPLY		
165	FDIALERTFA	FIRE NOT	DETECTED BY	PEOPLE	
166	FDITEMPRDE	ERRONEOUS	OUTPUTS/	FALSE ALARMS	
167	FDITEMPRFA	FAULTY DEVICE -	RATE-OF-RISE	TEMPERATURE	DETECTOR
168	FDITEMPRMP	OPERATOR FAILS	TO RESTORE	FOLLOWING	MAINTENANCE
169	FFXBADFXFA	FAULTY DEVICE	(PORTABLE	EXTINGUSIHER)	
170	FFXCHGEDDE	FIRE	EXTINGUISHER	NOT CHARGED	
171	FFXERRORHE	OPERATOR ERROR			
172	FFXFAILSFA	FIRETRUCK	EXTINGUSHERS	NOT FUNCTIONAL	
173	FHECLEARHE	OPERATOR CLEARS	AREA WITHOUT	EMPLOYING	MANUAL METHODS
174	FHETRUCKHE	OPERATOR ERROR	IN USING TRUCK		
175	FHRERRORHE	OPERATOR ERROR	IN EMPLOYING	MANUAL HOSE	REEL
176	FNZDCHEMFA	FAILURE TO	DISTRIBUTE	DRY CHEMICAL	(NOZZLE FAILS)
177	FNZMHRNGFA	HOSE NOZZLE	CLOGGED,	HOSE RUPTURES	
178	FPM601ELFA	ELECTRIC PUMP	FAILS TO RUN		
179	FPM601ELFS	ELECTRIC PUMP	FAILS TO START	(MECHANICAL)	
180	FPM601ELMT	ELECTRIC PUMP	IN MAINTENANCE		

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

181	FPM602DGFS	DIESEL-DRIVEN	PUMP FAILS TO	START	(MECHANICAL)
182	FPM602DGMT	DIESEL-DRIVEN	PUMP IN	MAINTENANCE	
183	FPM602DPFA	DIESEL-DRIVEN	PUMP FAILS	TO RUN	
184	FPMFPUMPFA	FIRE TRUCK	PUMP NOT	FUNCTIONAL	
185	FPPH2ONANI	WATER NOT	AVAILABLE TO	STANDPIPE	
186	FSHFUSELCC	FUSIBLE LINK	IN SPRINKLER	HEAD FAILS	(WILL NOT OPEN)
187	FSHINSTLHE	SPRINKLER HEAD	NOT INSTALLED	CORRECTLY	
188	FSHVERIFHE	SPRINKLER HEAD	INSTALLATION	NOT VERIFIED	CORRECTLY
189	FSHWATERPL	SPRINKLER HEAD	PLUGGED		
190	FTDPSL02FA	PSL02 FAILS	(LOGIC)		
191	FTDPSL04FA	PSL04 FAILS	(LOGIC)		
192	FTK602DGLK	DIESEL FUEL	TANK FOR PUMP	LEAKS	
193	FTK602DGRU	DIESEL FUEL	TANK FOR PUMP	RUPTURES	
194	FTKH201AHE	OPERATOR FAILS	TO RESTORE	TANK FOLLOWING	LEAK
195	FTKH201ALK	WATER STORAGE	TANK 25-D-001A	LEAKS	
196	FTKH201ARU	WATER STORAGE	TANK 25-D-001A	RUPTURES	
197	FTKH201BLK	WATER STORAGE	TANK 25-D-001B	LEAKS	
198	FTKH201BRU	WATER STORAGE	TANK 25-D-001B	RUPTURES	
199	FTLH201AFA	FAULTY WATER	GAUGE IN STORAGE	TANK 25-D-001A	
200	FTLH201BFA	FAULTY WATER	GAUGE IN STORAGE	TANK 25-D-001B	
201	FXV01MANCC	VALVE	FW-456-V-1	CLOSED	
202	FXV02MANCC	VALVE	FW-456-V-2	CLOSED	
203	FXV03MANCC	VALVE	FW-456-V-3	CLOSED	
204	FXV06MANCC	VALVE	FW-456-V-6	CLOSED	
205	FXV07MANCC	VALVE	FW-456-V-7	CLOSED	
206	FXV12MANCC	VALVE	FW-456-V-12	CLOSED	
207	FXV14MANCC	VALVE	FW-456-V-14	CLOSED	
208	FXV15MANCC	VALVE	FW-456-V-15	CLOSED	
209	FXV16MANCC	VALVE	FW-456-V-16	CLOSED	
210	FXV19MANCC	VALVE	FW-456-V-19	CLOSED	
211	FXV20MANCC	VALVE	FW-456-V-20	CLOSED	
212	FXV602DGCC	VALVE FROM	DIESEL FUEL	TANK CLOSED	
213	FXVNORTHCC	GATE VALVE FOR	NORTH SPRINKLER	RISER CLOSED;	CSO, INDICATOR
214	FXVPIV-1CC	PIV-1 CLOSED;	NORMALLY CSO,	INDICATOR	
215	FXVPIV-4CC	PIV-4 CLOSED;	NORMALLY CSO,	INDICATOR	
216	FXVPIV-9CC	PIV-9 CLOSED;	NORMALLY CSO,	INDICATOR	
217	FXVPIV12CC	PIV-12 CLOSED;	NORMALLY CSO,	INDICATOR	
218	FXVPIV16CC	PIV-16 CLOSED;	NORMALLY CSO,	INDICATOR	
219	FXVPIV17CC	PIV-17 CLOSED;	NORMALLY CSO,	INDICATOR	
220	FXVPIV19CC	PIV-19 CLOSED	NORMALLY CSO,	INDICATOR	
221	FXVPIV26CC	PIV-26 CLOSED	NORMALLY CSO,	INDICATOR	
222	FXVSOUTHCC	GATE VALVE FOR	SOUTH SPRINKLER	RISER CLOSED;	CSO, INDICATOR
223	H---138BHE	AIRLOCK DOOR 138	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
224	HACHD14-FA	PNEUMATIC	ACTUATOR	HD-14 FAILS DUE	TO LOCAL FAULTS
225	HACHD40-FA	PNEUMATIC	ACTUATOR HD-40	FAILS DUE TO	LOCAL FAULTS
226	HACXD41-FA	PNEUMATIC	DAMPER ACTUATOR	FAILS DUE TO	LOCAL FAULTS
227	HACXD42-FA	PNEUMATIC	DAMPER ACTUATOR	FAILS DUE TO	LOCAL FAULTS
228	HAL101----	A MEASURABLE	RELEASE OCCURS	THROUGH TRUCK	AIRLOCK 101
229	HAL102----	A MEAURABLE	RELEASE OCCURS	THROUGH TRUCK	AIRLOCK 102
230	HALFSL10FA	LOCAL FAILURE OF	LOW FLOW ALARM	FSL-10, -11, OR	-12 (52K CFM)
231	HCB--816CO	COMPONENT	41-B-816	CIRCUIT BREAKER	FAILS OPEN
232	HCB--817CO	COMPONENT	41-B-817	CIRCUIT BREAKER	FAILS OPEN
233	HCB100-3CO	COMPONENT	CIRCUIT BREAKER	03AB	FAILS OPEN
234	HCB100-5CO	COMPONENT	CIRCUIT BREAKER	05ABCD	FAILS OPEN
235	HCB100-9CO	COMPONENT	CIRCUIT BREAKER	09,10,11,12	FAILS OPEN
236	HCB10013CO	COMPONENT	CIRCUIT BREAKER	8,9,10,11,12,13	FAILS OPEN
237	HCB252-3CO	BUS 25S2	CIRCUIT BREAKER	CB3	FAILS OPEN
238	HCB252-4CO	BUS 25S2	CIRCUIT BREAKER	CB4	FAILS OPEN
239	HCB252-5CO	BUS 25S2	CIRCUIT BREAKER	CB5	FAILS OPEN
240	HCB253A2CO	BUS 25S3A	CIRCUIT BREAKER	CB2	FAILS OPEN

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

241	HCB253B3CO	BUS 25S3B	CIRCUIT BREAKER	CB3	FAILS OPEN
242	HCB253B4CO	BUS 25S3B	CIRCUIT BREAKER	CB4	FAILS OPEN
243	HCB415-1CO	BUS 41M5	CIRCUIT BREAKER	CB1	FAILS OPEN
244	HCB416-1CO	BUS 41M6	CIRCUIT BREAKER	CB1	FAILS OPEN
245	HCB451-3CO	BUS 45S1	CIRCUIT BREAKER	CB3	FAILS OPEN
246	HDA3071ACO	FAN ISOL DAMPER	HD307-1A FAILS	OPEN DUE TO	LOCAL FAULTS
247	HDA3071BCO	FAN ISOL DAMPER	HD307-1B FAILS	OPEN DUE TO	LOCAL FAULTS
248	HDA3072ACO	FAN ISOL DAMPER	HD307-2A FAILS	OPEN DUE TO	LOCAL FAULTS
249	HDA3072BCO	FAN ISOL DAMPER	HD307-2B FAILS	OPEN DUE TO	LOCAL FAULTS
250	HDA4125AOC	BUTTERFLY DAMPER	41-B-25A FAILS	CLOSED DUE TO	LOCAL FAULTS
251	HDA4125BOC	BUTTERFLY DAMPER	41-25B FAILS	CLOSED DUE TO	LOCAL FAULTS
252	HDA4132AOC	BUTTERFLY DAMPER	41-B-32A FAILS	CLOSED DUE TO	LOCAL FAULTS
253	HDA4132BOC	BUTTERFLY DAMPER	41-B-32B FAILS	CLOSED DUE TO	LOCAL FAULTS
254	HDA5601ACO	BYPASS DAMPER	HD-056-01A FAILS	OPEN	
255	HDA5601BCO	BYPASS DAMPER	HD-056-01B FAILS	OPEN	
256	HDA5601CCC	HEPA BACK FLOW	DAMPER HD-056-	01C FAILS CLOSED	ON FILTER SIGNAL
257	HDA5601CFC	HEPA BACK FLOW	DAMPER HD-056-	01C TRNSFR CLOSD	DURING OPERATION
258	HDA5601DCC	HEPA BACK FLOW	DAMPER HD-056-	01D FAILS CLOSED	ON FILTER SIGNAL
259	HDA5601DFC	HEPA BACK FLOW	DAMPER HD-056-	01D TRNSFR CLOSD	DURING OPERATION
260	HDA5601ECC	HEPA BACK FLOW	DAMPER HD-056-	01E FAILS CLOSED	ON FILTER SIGNAL
261	HDA5601EFC	HEPA BACK FLOW	DAMPER HD-056-	01E TRNSFR CLOSD	DURING OPERATION
262	HDA5601FCC	HEPA BACK FLOW	DAMPER HD-056-	01F FAILS CLOSED	ON FILTER SIGNAL
263	HDA5601FFC	HEPA BACK FLOW	DAMPER HD-056-	01F TRNSFR CLOSD	DURING OPERATION
264	HDA5610ACC	FAN 41-B-860A	FAILS START DUE	TO DAMPER HD-056	-10A FAILS CLOSD
265	HDA5610AOC	FAN 41-B-860A	FAILS TO RUN DUE	TO DAMPER HD-056	-10A TRNSFR CLSD
266	HDA5611ACC	FAN 41-B-860B	FAILS START DUE	TO DAMPER HD-056	-11A FAILS CLOSD
267	HDA5611AOC	FAN 41-B-860B	FAILS TO RUN DUE	TO DAMPER HD-056	-11A TRNSFR CLSD
268	HDA5612ACC	FAN 41-B-860C	FAILS START DUE	TO DAMPER HD-056	-12A FAILS CLOSD
269	HDA5612AOC	FAN 41-B-860C	FAILS TO RUN DUE	TO DAMPER HD-056	-12A TRNSFR CLSD
270	HDAHD14-OC	PARALLEL BLADE	DAMPER HD-14	FAILS CLOSED DUE	TO LOCAL FAULTS
271	HDAHD40-OC	PARALLEL BLADE	DAMPER HD-40	FAILS CLOSED DUE	TO LOCAL FAULTS
272	HDATRAXAOC	MANUAL VOLUME	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
273	HDATRBXAOC	MANUAL VOLUME	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
274	HDBTRASAOC	BACKDRAFT	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
275	HDBTRAXAOC	BACKDRAFT	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
276	HDBTRBSAOC	BACKDRAFT	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
277	HDBTRBXAOC	BACKDRAFT	DAMPER	FAILS CLOSED DUE	TO LOCAL FAULTS
278	HDLZZ03AFA	DOOR STRIKE	(LATCH)	ZZ-03A	FAILS
279	HDLZZ03BFA	DOOR STRIKE	(LATCH)	ZZ-03B	FAILS
280	HDLZZ03CFA	DOOR STRIKE	(LATCH)	ZZ-03C	FAILS
281	HDLZZ03DFA	DOOR STRIKE	(LATCH)	ZZ-03D	FAILS
282	HDLZZ05AFA	DOOR STRIKE	(LATCH)	ZZ-05A	FAILS
283	HDLZZ05BFA	DOOR STRIKE	(LATCH)	ZZ-05B	FAILS
284	HDLZZ08BFA	DOOR STRIKE	(LATCH)	ZZ-08B	FAILS
285	HDLZZ09-FA	DOOR STRIKE	(LATCH)	ZZ-09	FAILS
286	HDLZZ09BFA	DOOR STRIKE	(LATCH)	ZZ-09B	FAILS
287	HDLZZ10-FA	DOOR STRIKE	(LATCH)	ZZ-10	FAILS
288	HDLZZ10BFA	DOOR STRIKE	(LATCH)	ZZ-10B	FAILS
289	HDLZZ11BFA	DOOR STRIKE	(LATCH)	ZZ-11B	FAILS
290	HDLZZ12BFA	DOOR STRIKE	(LATCH)	ZZ-12B	FAILS
291	HDLZZ13BFA	DOOR STRIKE	(LATCH)	ZZ-13B	FAILS
292	HDR101A-HE	AIRLOCK DOOR 101	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
293	HDR101B-HE	AIRLOCK DOOR 101	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
294	HDR104A-HE	AIRLOCK DOOR 104	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
295	HDR104B-HE	AIRLOCK DOOR 104	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
296	HDR113A-HE	AIRLOCK DOOR 113	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
297	HDR113B-HE	AIRLOCK DOOR 113	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
298	HDR114A-HE	AIRLOCK DOOR 114	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
299	HDR114B-HE	AIRLOCK DOOR 114	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
300	HDR130A-HE	AIRLOCK DOOR 130	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

301	HDR130B-HE	AIRLOCK DOOR 130	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
302	HDR131A-HE	AIRLOCK DOOR 131	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
303	HDR131B-HE	AIRLOCK DOOR 131	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
304	HDR138A-HE	AIRLOCK DOOR 138	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
305	HDR139A-HE	AIRLOCK DOOR 139	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
306	HDR139B-HE	AIRLOCK DOOR 139	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
307	HDR157A-HE	AIRLOCK DOOR 157	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
308	HDR157B-HE	AIRLOCK DOOR 157	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
309	HDR163A-HE	AIRLOCK DOOR 163	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
310	HDR163B-HE	AIRLOCK DOOR 163	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
311	HDR203A-HE	AIRLOCK DOOR 203	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
312	HDR203B-HE	AIRLOCK DOOR 203	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
313	HDR204A-HE	AIRLOCK DOOR 204	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
314	HDR204B-HE	AIRLOCK DOOR 204	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
315	HDR205A-HE	AIRLOCK DOOR 205	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
316	HDR205B-HE	AIRLOCK DOOR 205	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
317	HDR206A-HE	AIRLOCK DOOR 206	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
318	HDR206B-HE	AIRLOCK DOOR 206	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
319	HDR207A-HE	AIRLOCK DOOR 207	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
320	HDR207B-FA	AIRLOCK DOOR 207	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
321	HDR208A-HE	AIRLOCK DOOR 208	IS OPENED DUE TO	OPERATOR ERROR	WITH INDICAT LGT
322	HDR208B-HE	AIRLOCK DOOR 208	IS OPENED BY	OPERATOR W/FAIL	INDICATOR LIGHT
323	HDRA----HE	EMERGENCY DOOR	A	IS OPEN DUE TO	HUMAN ERROR
324	HDRB----HE	EMERGENCY DOOR	B	IS OPEN DUE TO	TO HUMAN ERROR
325	HDS101--LK	AIRLOCK DOOR	SEAL	101	LEAKS
326	HDS104--LK	AIRLOCK DOOR	SEAL	104	LEAKS
327	HDS113--LK	AIRLOCK DOOR	SEAL	113	LEAKS
328	HDS114--LK	AIRLOCK DOOR	SEAL	114	LEAKS
329	HDS130--LK	AIRLOCK DOOR	SEAL	130	LEAKS
330	HDS131--LK	AIRLOCK DOOR	SEAL	131	LEAKS
331	HDS138--LK	AIRLOCK DOOR	SEAL	138	LEAKS
332	HDS139--LK	AIRLOCK DOOR	SEAL	139	LEAKS
333	HDS157--LK	AIRLOCK DOOR	SEAL	157	LEAKS
334	HDS163--LK	AIRLOCK DOOR	SEAL	163	LEAKS
335	HDS203--LK	AIRLOCK DOOR	SEAL	203	LEAKS
336	HDS204--LK	AIRLOCK DOOR	SEAL	204	LEAKS
337	HDS205--LK	AIRLOCK DOOR	SEAL	205	LEAKS
338	HDS206--LK	AIRLOCK DOOR	SEAL	206	LEAKS
339	HDS207--LK	AIRLOCK DOOR	SEAL	207	LEAKS
340	HDS208--LK	AIRLOCK DOOR	SEAL	208	LEAKS
341	HDSA----LK	EMERGENCY DOOR	SEAL	A	LEAKS
342	HDSB----LK	EMERGENCY DOOR	SEAL	B	LEAKS
343	HDTXD41-OC	TORNADO DAMPER	XD-41	FAILS DUE TO	LOCAL FAULTS
344	HDTXD42-OC	TORNADO DAMPER	XD-42	FAILS DUE TO	LOCAL FAULTS
345	HFA41812FA	SUPPLY AHU	41-B-812 FAILS	DUE TO LOCAL	FAULTS
346	HFA41813FA	SUPPLY AHU	41-B-813 FAILS	DUE TO LOCAL	FAULTS
347	HFA41816FA	EXHAUST FAN	41-B-816 FAILS	DUE TO	LOCAL FAULTS
348	HFA41817FA	EXHAUST FAN	41-B-817 FAILS	DUE TO	LOCAL FAULTS
349	HFA700A-FA	FAN 41-B-700A	FAILS TO STOP	DUE TO LOCAL	FAULTS
350	HFA700B-FA	FAN 41-B-700B	FAILS TO STOP	DUE TO LOCAL	FAULTS
351	HFA860--SS	SPURIOUS ACTUA-	TION OF 1 OR 2	ADDITIONAL FANS	(CONTRL FAILURE)
352	HFA860A-FR	FAN 41-B-860A	FAILS TO RUN	DUE TO LOCAL	FAULTS
353	HFA860A-FS	FAN 41-B-860A	FAILS TO START	DUE TO LOCAL	FAULTS
354	HFA860B-FR	FAN 41-B-860B	FAILS TO RUN	DUE TO LOCAL	FAULTS
355	HFA860B-FS	FAN 41-B-860B	FAILS TO START	DUE TO LOCAL	FAULTS
356	HFA860C-FR	FAN 41-B-860C	FAILS TO RUN	DUE TO LOCAL	FAULTS
357	HFA860C-FS	FAN 41-B-860C	FAILS TO START	DUE TO LOCAL	FAULTS
358	HFCDZ26AFA	FLOW CONTROLLER	PDZ-26A FAILS	DUE TO LOCAL	FAULTS
359	HFCDZZ6BFA	FLOW CONTROLLER	PDZ-26B FAILS	DUE TO LOCAL	FAULTS
360	HFCFZ04-FA	FLOW CONTROLLER	FZ-04	FAILS DUE TO	LOCAL FAULTS

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

361	HFCFZ15-FA	FLOW CONTROLLER	FZ-15	FAILS DUE TO	LOCAL FAULTS
362	HFI41814PL	HEPA FILTER UNIT	41-B-814	CLOGS	
363	HFI41814RU	CHA TRAIN A HEPA	FILTER 41-B-814	RUPTURES DUE TO	LOCAL FAULTS
364	HFI41815PL	HEPA FILTER UNIT	41-B-815	CLOGS	
365	HFI41815RU	CHA TRAIN B HEPA	FILTER 41-B-815	RUPTURES DUE TO	LOCAL FAULTS
366	HFI41834RU	RCA TRAIN A HEPA	FILTER 41-B-834	RUPTURES DUE TO	LOCAL FAULTS
367	HFI41979RU	RCA TRAIN B HEPA	FILTER 41-B-979	RUPTURES DUE TO	LOCAL FAULTS
368	HFIARSMPFA	FILTER TRAINS	FROM THE AIR	SAMPLING SYS FL	PREVENT RELEASE
369	HFIHOTCLFA	FILTER TRAINS	IN HOT CELL AREA	FAIL TO PREVENT	THE RELEASE
370	HFIRHAREFA	FILTER TRAINS	IN RH AREA	FAIL TO PREVENT	THE RELEASE
371	HFISUBLDFA	FILTER TRAINS	FROM THE SUPPORT	BUILDG FAIL TO	PREVENT RELEASE
372	HFITRA--RU	HEPA FILTERS	RUPTURE DUE TO	DESIGN OR MFG	FLAW OR CLOGGING
373	HFITRASAPL	TRAIN A SUPPLY	AIR FLOW FILTER	UNIT CLOGS	
374	HFITRBSAPL	TRAIN B SUPPLY	AIR FLOW FILTER	UNIT CLOGS	
375	HILDR101FA	INDICATOR LIGHT	AT DOOR 101	FAILS DUE TO	LOCAL FAULTS
376	HILDR104FA	INDICATOR LIGHT	AT DOOR 104	FAILS DUE TO	LOCAL FAULTS
377	HILDR113FA	INDICATOR LIGHT	AT DOOR 113	FAILS DUE TO	LOCAL FAULTS
378	HILDR114FA	INDICATOR LIGHT	AT DOOR 114	FAILS DUE TO	LOCAL FAULTS
379	HILDR130FA	INDICATOR LIGHT	AT DOOR 130	FAILS DUE TO	LOCAL FAULTS
380	HILDR131FA	INDICATOR LIGHT	AT DOOR 131	FAILS DUE TO	LOCAL FAULTS
381	HILDR138FA	INDICATOR LIGHT	AT DOOR 138	FAILS DUE TO	LOCAL FAULTS
382	HILDR139FA	INDICATOR LIGHT	AT DOOR 139	FAILS DUE TO	LOCAL FAULTS
383	HILDR157FA	INDICATOR LIGHT	AT DOOR 157	FAILS DUE TO	LOCAL FAULTS
384	HILDR163FA	INDICATOR LIGHT	AT DOOR 163	FAILS DUE TO	LOCAL FAULTS
385	HILDR203FA	INDICATOR LIGHT	AT DOOR 203	FAILS DUE TO	LOCAL FAULTS
386	HILDR204FA	INDICATOR LIGHT	AT DOOR 204	FAILS DUE TO	LOCAL FAULTS
387	HILDR205FA	INDICATOR LIGHT	AT DOOR 205	FAILS DUE TO	LOCAL FAULTS
388	HILDR206FA	INDICATOR LIGHT	AT DOOR 206	FAILS DUE TO	LOCAL FAULTS
389	HILDR207FA	INDICATOR LIGHT	AT DOOR 207	FAILS DUE TO	LOCAL FAULTS
390	HILDR208FA	INDICATOR LIGHT	AT DOOR 208	FAILS DUE TO	LOCAL FAULTS
391	HRE03AB-FA	INTERLOCK	DEVICE	03AB	FAILS
392	HRE09-12FA	INTERLOCK	DEVICE	09,10,11,12	FAILS
393	HRE5ABCDFA	INTERLOCK	DEVICE	05ABCD	FAILS
394	HRE81216FA	41-B-812/816	SUPPLY/EXHAUST	FAN INTERLOCK	FAILS
395	HRE81317FA	41-B-813/817	SUPPLY/EXHAUST	FAN INTERLOCK	FAILS
396	HREI8-13FA	INTERLOCK	DEVICE	8,9,10,11,12,13	FAILS
397	HRER7---FA	FAILURE OF RELAY	R7 TO STOP FANS	& CLOSE DAMPERS	ON L-R SIGNAL
398	HRLEXHFIFA	FAILURE OF EXHST	FILTER SWITCH	LATCH RELAY L-R	ON FILTER SIGNAL
399	HSEISMONFA	SEISMIC MONITOR-	ING SYSTEM ERROR		
400	HSV14---FA	SOLENOID VALVE	SV-14	FAILS DUE TO	LOCAL FAULTS
401	HSV25---FA	SOLENOID VALVE	SV-25	FAILS DUE TO	LOCAL FAULTS
402	HSV32---FA	SOLENOID VALVE	SV-32	FAILS DUE TO	LOCAL FAULTS
403	HSV40---FA	SOLENOID VALVE	SV-40	FAILS DUE TO	LOCAL FAULTS
404	HSV41---FA	SOLENOID VALVE	SV-41	FAILS DUE TO	LOCAL FAULTS
405	HSV42---FA	SOLENOID VALVE	SV-42	FAILS DUE TO	LOCAL FAULTS
406	HSW33/14FA	SWITCH HS-33/	LP14 FAILS	DUE TO	LOCAL FAULTS
407	HSW38/13FA	SWITCH HS-38/	LP13 FAILS	DUE TO LOCAL	FAULTS
408	HSWHS14-FA	ACTUATION SYSTEM	SWITCH HS-14/	LP14 FAILS DUE	TO LOCAL FAULTS
409	HSWHS313FA	ACTUATION SYSTEM	SWITCH HS-03/	LP13 FAILS DUE	TO LOCAL FAULTS
410	HZS03A--FA	OPPOSITE DOOR	POSITION SWITCH	ZS-03A FAILS	(DOOR 113)
411	HZS03B--FA	OPPOSITE DOOR	POSITION SWITCH	ZS-03B FAILS	(DOOR 157)
412	HZS05A--FA	OUTSIDE DOOR	POSITION SWITCH	ZS-05A FAILS	(DOOR 114)
413	HZS05B--FA	INSIDE DOOR	POSITION SWITCH	ZS-05B FAILS	(DOOR 138)
414	HZS05C--FA	INSIDE DOOR	POSITION SWITCH	ZS-05C FAILS	(DOOR 139)
415	HZS05D--FA	INSIDE DOOR	POSITION SWITCH	ZS-05D FAILS	(DOOR 163)
416	HZS08A--FA	INSIDE DOOR	POSITION SWITCH	ZS-08A FAILS	(DOOR 203)
417	HZS09---FA	OPP PERS DOOR	POSITION SWITCH	ZS-09 FAILS	(DOOR 104)
418	HZS09A--FA	INSIDE DOOR	POSITION SWITCH	ZS-09A FAILS	(DOOR 204)
419	HZS10---FA	OPP PERS DOOR	POSITION SWITCH	ZS-10 FAILS	(DOOR 130)
420	HZS10A--FA	INSIDE DOOR	POSITION SWITCH	ZS-10A FAILS	(DOOR 205)

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

421	HZS11A--FA	INSIDE DOOR	POSITION SWITCH	ZS-11A FAILS	(DOOR 206)
422	HZS12A--FA	INSIDE DOOR	POSITION SWITCH	ZS-12A FAILS	(DOOR 207)
423	HZS13A--FA	OUTSIDE DOOR	POSITION SWITCH	ZS-13A FAILS	(DOOR 208)
424	HZSLS11AFA	OPP TRUCK DOOR	CLOSE LIMIT SW	ZS-11A FAILS	(DOOR 101)
425	HZSLS12AFA	OPP TRUCK DOOR	CLOSE LIMIT SW	ZS-12A FAILS	(DOOR 131)
426	RAVPIVAWFA	TRAIN A VACUUM	PUMP INLET	VALVE FAILS DUE	TO LOCAL FAULTS
427	RAVPIVBWFA	TRAIN B VACUUM	PUMP INLET	VALVE FAILS DUE	TO LOCAL FAULTS
428	RAVPOVAWFA	TRAIN A VACUUM	PUMP OUTLET	VALVE FAILS DUE	TO LOCAL FAULTS
429	RAVPOVBWFA	TRAIN B VACUUM	PUMP OUTLET	VALVE FAILS DUE	TO LOCAL FAULTS
430	RBA117--FA	LOSS OF BATTERY	POWER TO SKID	117-118	
431	RBA121--FA	LOSS OF BATTERY	POWER TO SKID	121-122	
432	RBASTA--FA	LOSS OF BATTERY	POWER TO STATION	A COMPONENTS	
433	RBASTB--FA	LOSS OF BATTERY	POWER TO STATION	B COMPONENTS	
434	RBASTC--FA	LOSS OF BATTERY	POWER TO EFFLUNT	MONITORING	SYSTEM
435	RCB-1178CO	CONTINUOUS AIR	MONITORS 117 & 8	CIRCUIT BREAKER	FAILS OPEN
436	RCB-1212CO	CONTINUOUS AIR	MONITORS 121 & 2	CIRCUIT BREAKER	FAILS OPEN
437	RCB-1556CO	CONTINUOUS AIR	MONITORS 155 & 6	CIRCUIT BREAKER	FAILS OPEN
438	RCB000-1CO	BUS 00P-MCC00/0	CIRCUIT BREAKER	CB1	FAILS OPEN
439	RCB000-2CO	BUS 00P-MCC00/0	CIRCUIT BREAKER	CB0	FAILS OPEN
440	RCB000-3CO	BUS 00-DP00/00	CIRCUIT BREAKER	CB0	FAILS OPEN
441	RCB111-1CO	BUS 11P-MCC11/1	CIRCUIT BREAKER	CB1	FAILS OPEN
442	RCB111-2CO	BUS 11P-MCC11/1	CIRCUIT BREAKER	CB0	FAILS OPEN
443	RCB111-3CO	BUS 11-DP11/11	CIRCUIT BREAKER	CB0	FAILS OPEN
444	RCB300-0CO	BUS 41-DP03/00	CIRCUIT BREAKER	CB0	FAILS OPEN
445	RCB31024CO	BUS 41-DP03/10	CIRCUIT BREAKER	CB24	FAILS OPEN
446	RCB40X-1CO	BUS 41P-MCC04/X	CIRCUIT BREAKER	CB1	FAILS OPEN
447	RCB40X-2CO	BUS 41P-MCC04/X	CIRCUIT BREAKER	CB2	FAILS OPEN
448	RCB417-0CO	BUS 41M7	CIRCUIT BREAKER	CB0	FAILS OPEN
449	RCB417-1CO	BUS 41M7	CIRCUIT BREAKER	CB1	FAILS OPEN
450	RCBSTA--CO	STATION A	RAD MONITOR	CIRCUIT BREAKER	FAILS OPEN
451	RCBSTB--CO	STATION B	RAD MONITOR	CIRCUIT BREAKER	FAILS OPEN
452	RFVV117-FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
453	RFVV121-FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
454	RFVVAA--FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
455	RFVVAB--FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
456	RFVVAW--FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
457	RFVVBA--FA	TRAIN B VACUUM	CONTROL VALVE	FAILS DUE	TO LOCAL FAULTS
458	RFVVBB--FA	TRAIN B VACUUM	CONTROL VALVE	FAILS DUE	TO LOCAL FAULTS
459	RFVVBW--FA	VACUUM CONTROL	VALVE	FAILS DUE	TO LOCAL FAULTS
460	RPSV117-FA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
461	RPSV121-FA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
462	RPSVAW--FA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
463	RPSVBW--FA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
464	RPSVTRAAFA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
465	RPSVTRABFA	AIR VACUUM PUMP	STARTER	FAILS DUE TO	LOCAL FAULTS
466	RPSVTRBAFA	TRAIN B VACUUM	PUMP STARTER	FAILS DUE TO	LOCAL FAULTS
467	RPSVTRBBFA	TRAIN B VACUUM	PUMP STARTER	FAILS DUE TO	LOCAL FAULTS
468	RRETRBA-FA	AUTOSTART	INTERLOCK	FAILS	
469	RRETRBB-FA	AUTOSTART	INTERLOCK	FAILS	
470	RRMA01W-FA	ALPHA CONTINUOUS	AIR MONITOR	DETECTOR A-01	FAILS
471	RRMA117-FA	ALPHA CONTINUOUS	AIR MONITOR	DETECTOR 117	FAILS
472	RRMA121-FA	ALPHA CONTINUOUS	AIR MONITOR	DETECTOR 121	FAILS
473	RRMAA---FA	ALPHA CONTINUOUS	AIR MONITOR	DETECTOR AT	STATION A FAILS
474	RRMAB---FA	ALPHA CONTINUOUS	AIR MONITOR	DETECTOR AT	STATION B FAILS
475	RRMGM01WFA	SAMPLING	GEIGER-MUELLER	TUBE GM-01	FAILS
476	RRMGM02WFA	BACKGROUND	GEIGER-MUELLER	TUBE GM-02	FAILS
477	RRMGM118FA	SAMPLING	GEIGER-MUELLER	TUBE GM-118S	FAILS
478	RRMGM122FA	SAMPLING	GEIGER-MUELLER	TUBE GM-122S	FAILS
479	RRMGM188FA	BACKGROUND	GEIGER-MUELLER	TUBE GM-118B	FAILS
480	RRMGM22BFA	BACKGROUND	GEIGER-MUELLER	TUBE GM-122B	FAILS

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

481	RRMGMBA-FA	BACKGROUND	GEIGER-MUELLER	TUBE AT STATION	A FAILS
482	RRMGMBB-FA	BACKGROUND	GEIGER-MUELLER	TUBE AT STATION	B FAILS
483	RRMGMSA-FA	SAMPLING	GEIGER-MUELLER	TUBE AT STATION	A FAILS
484	RRMGMSB-FA	SAMPLING	GEIGER-MUELLER	TUBE AT STATION	B FAILS
485	RSN1A---PL	SAMPLING NOZZLE	1A	IS PLUGGED	
486	RSN1B---PL	SAMPLING NOZZLE	1B	IS PLUGGED	
487	RSN1C---PL	SAMPLING NOZZLE	1C	IS PLUGGED	
488	RSN1D---PL	SAMPLING NOZZLE	1D	IS PLUGGED	
489	RSN1E---PL	SAMPLING NOZZLE	1E	IS PLUGGED	
490	RSN2A---PL	SAMPLING NOZZLE	2A	IS PLUGGED	
491	RSN2B---PL	SAMPLING NOZZLE	2B	IS PLUGGED	
492	RSN2C---PL	SAMPLING NOZZLE	2C	IS PLUGGED	
493	RSN2D---PL	SAMPLING NOZZLE	2D	IS PLUGGED	
494	RSN2E---PL	SAMPLING NOZZLE	2E	IS PLUGGED	
495	RSN3A---PL	SAMPLING NOZZLE	3A	IS PLUGGED	
496	RSN3B---PL	SAMPLING NOZZLE	3B	IS PLUGGED	
497	RSN3C---PL	SAMPLING NOZZLE	3C	IS PLUGGED	
498	RSN3D---PL	SAMPLING NOZZLE	3D	IS PLUGGED	
499	RSN3E---PL	SAMPLING NOZZLE	3E	IS PLUGGED	
500	RSN4A---PL	SAMPLING NOZZLE	4A	IS PLUGGED	
501	RSN4B---PL	SAMPLING NOZZLE	4B	IS PLUGGED	
502	RSN4C---PL	SAMPLING NOZZLE	4C	IS PLUGGED	
503	RSN4D---PL	SAMPLING NOZZLE	4D	IS PLUGGED	
504	RSN4E---PL	SAMPLING NOZZLE	4E	IS PLUGGED	
505	RSNA1---PL	BLOCKAGE FAILURE	OF THE STATION A	PROBE NOZZLE A-1	
506	RSNALL--CM	COMMON CAUSE	FAILURE OF	ISOKINETIC	SAMPLING RAKES
507	RSNB1---PL	BLOCKAGE FAILURE	OF THE STATION B	PROBE NOZZLE B-1	
508	RSNCM117PL	BLOCKAGE FAILURE	OF THE CAM-117	SAMPLING NOZZLE	
509	RSNCM118PL	BLOCKAGE FAILURE	OF THE CAM-118	SAMPLING NOZZLE	
510	RSNCM121PL	BLOCKAGE FAILURE	OF THE CAM-121	SAMPLING NOZZLE	
511	RSNCM122PL	BLOCKAGE FAILURE	OF THE CAM-122	SAMPLING NOZZLE	
512	RVAVC117FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
513	RVAVC121FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
514	RVAVCAA-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
515	RVAVCAB-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
516	RVAVCAW-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
517	RVAVCBA-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
518	RVAVCBB-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
519	RVAVCBW-FA	VACUUM CONTROL	VALVE ACTUATOR	FAILS DUE	TO LOCAL FAULTS
520	RVP117--FR	AIR VACUUM	PUMP	FAILS TO	CONTINUE TO RUN
521	RVP121--FR	AIR VACUUM	PUMP	FAILS TO	CONTINUE TO RUN
522	RVPAW---FR	AIR VACUUM	PUMP	FAILS TO	CONTINUE TO RUN
523	RVPBW---FR	AIR VACUUM	PUMP	FAILS TO	CONTINUE TO RUN
524	RVPTRAA-FR	TRAIN A AIR	VACUUM PUMP	FAILS TO	CONTINUE TO RUN
525	RVPTRAB-FR	TRAIN A AIR	VACUUM PUMP	FAILS TO	CONTINUE TO RUN
526	RVPTRBA-FA	TRAIN B AIR	VACUUM PUMP	FAILS TO	CONTINUE TO RUN
527	RVPTRBB-FA	TRAIN B AIR	VACUUM PUMP	FAILS TO	CONTINUE TO RUN
528	RXVVPIAAFA	AIR VACUUM PUMP	INLET VALVE	FAILS DUE	TO LOCAL FAULTS
529	RXVVPIABFA	AIR VACUUM PUMP	INLET VALVE	FAILS DUE	TO LOCAL FAULTS
530	RXVVPIBAFA	TRAIN B VACUUM	PUMP INLET VALVE	FAILS DUE	TO LOCAL FAULTS
531	RXVVPIBBFA	TRAIN B VACUUM	PUMP INLET VALVE	FAILS DUE	TO LOCAL FAULTS
532	RXVVPOAAFA	AIR VACUUM PUMP	OUTLET VALVE	FAILS DUE	TO LOCAL FAULTS
533	RXVVPOABFA	AIR VACUUM PUMP	OUTLET VALVE	FAILS DUE	TO LOCAL FAULTS
534	RXVVPOBAFA	TRAIN B VACUUM	PUMP OUTLET	VALVE FAILS DUE	TO LOCAL FAULT
535	RXVVPOBBFA	TRAIN B VACUUM	PUMP OUTLET	VALVE FAILS DUE	TO LOCAL FAULT
536	SUB-AIR	LOSS OF AIR	SUPPLY SYSTEM		
537	SUB-CMA	DETECTION FAILRE	BY STATION A	EFFLUENT MONITOR	ING SYSTEM
538	SUB-CMU	UNDERGROUND	CAMS FAIL TO	DETECT RADIATION	IN EXHAUST FLOW
539	SUB-E1	LOSS OF NORMAL &	EMERG. POWER ON	SUBSTATION 1	(25S1)
540	SUB-E2	LOSS OF NORMAL &	EMERGENCY POWER	ON SUBSTATION 2	(S5S2)

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

541	SUB-E3A	LOSS OF NORMAL &	DG POWER ON	UNDERGROUND	SUBSTATION 3A
542	SUB-E3B	NO POWER ON	SUB 3 BUS B		
543	SUB-E4	LOSS OF NORMAL &	EMERG. POWER ON	SUBSTATION 4	
544	SUB-ESB	LOSS OF NORMAL &	EMERG. POWER ON	SUPPORT BUILDING	SUBSTATION
545	SUB-EU1	LOSS OF NORMAL &	DG POWER ON	UNDERGROUND	SUBSTATION 1
546	WAV27.1-CC	HYDRAULIC RELIEF	VALVE 27.1 FAILS	TO OPEN	
547	WAV27.2-CC	HYDRAULIC RELIEF	VALVE 27.2 FAILS	TO OPEN	
548	WBCA1---FA	SPRING LOAD IN	BRAKE CALIPER A1	SEIZED	
549	WBCA2---FA	SPRING LOAD IN	BRAKE CALIPER A2	SEIZED	
550	WBCB1---FA	SPRING LOAD IN	BRAKE CALIPER B1	SEIZED	
551	WBCB2---FA	SPRING LOAD IN	BRAKE CALIPER B2	SEIZED	
552	WBCC1---FA	SPRING LOAD IN	BRAKE CALIPER C1	SEIZED	
553	WBCC2---FA	SPRING LOAD IN	BRAKE CALIPER C2	SEIZED	
554	WBCD1---FA	SPRING LOAD IN	BRAKE CALIPER D1	SEIZED	
555	WBCD2---FA	SPRING LOAD IN	BRAKE CALIPER D2	SEIZED	
556	WBCE1---FA	SPRING LOAD IN	BRAKE CALIPER E1	SEIZED	
557	WBCE2---FA	SPRING LOAD IN	BRAKE CALIPER E2	SEIZED	
558	WBCF1---FA	SPRING LOAD IN	BRAKE CALIPER F1	SEIZED	
559	WBCF2---FA	SPRING LOAD IN	BRAKE CALIPER F2	SEIZED	
560	WCV14.1-CC	BY-PASS CHECK	VALVE 14.1 FAILS	CLOSED	
561	WCV15.1-OC	BYPASS CHECK	VALVE 15.1	FAILS CLOSED	
562	WCV37.1-CC	CHECK VALVE	37.1 FAILS	CLOSED	
563	WCV37.2-CC	CHECK VALVE	37.2 FAILS	CLOSED	
564	WFL15.1-PL	FILTER 15.1	PLUGGED, DUE TO	LOCAL FAULTS	
565	WFV28.1-OC	FLOW CONTROL VLV	28.1 FAILS	CLOSED	
566	WFV28.2-OC	FLOW CONTROL VLV	28.2 FAILS	CLOSED	
567	WHV25---CM	SOLENOID OPERATD	HV 25.1.2.3 & .4	FAIL TO DE-ENERD	DUE TO C.C
568	WHV25.1-FA	SOLENOID OPERATD	HV 25.1 FAILS TO	DE-ENERGIZ DUE	TO LOCAL FAULTS
569	WHV25.1-OC	SOLENOID OPERATD	HV 25.1 FAILS,	RESULTING IN	TOTAL BLOCKAGE.
570	WHV25.2-FA	HV 25.2 FAILS TO	DE-ENERGIZE DUE	TO LOCAL FAULT	
571	WHV25.2-OC	SOLENOID OPERATD	HV 25.2 FAILS	RESULTING IN	TOTAL BLOCKAGE
572	WHV25.24CM	HYDRAULIC VALVES	25.2 & 25.4	TOTALLY BLOCKED	BY COMMON CAUSE
573	WHV25.3-FA	HV 25.3 FAILS TO	DE-ENERGIZE DUE	TO LOCAL FAULTS	
574	WHV25.3-OC	SOLENOID OPERATD	HV 25.3 FAILS,	RESULTING IN	TOTAL BLOCKAGE
575	WHV25.4-FA	SOLENOID OPERATD	HV 25.4 FAILS TO	DE-ENERGIZE DUE	TO LOCAL FAULTS
576	WHV25.4-OC	SOLENOID OPERATD	HV 25.4 FAILS	RESULTING IN	TOTAL BLOCKAGE
577	WHV45---FA	DIRECTIONAL VLV	45 FAILS DUE TO	LOCAL FAULTS,	BLOCKING FLOW
578	WHV51---FA	DIRECTIONAL VLV	51 FAILS DUE TO	LOCAL FAULTS,	BLOCKING FLOW
579	WHX13.1-PL	HEAT EXCHANGER	13.1 PLUGS,	BLOCKING FLOW	
580	WREFDEC-CC	FAILURE TO	DECELERATE RELAY	FAILS TO OPEN	
581	WRELOS--CC	LILLY OVERSPEED	RELAY FAILS TO	OPEN	
582	WRELOT--CC	OVERTRAVEL RELAY	FOR HOIST	LOWERING LOT	FAILS TO OPEN
583	WRELOT--SP	OVERTRAVEL RELAY	LOT SHORTS TO	POWER, DISABLE	OPENING
584	WREMXE--CC	RELAY MXE	FAILS TO OPEN	WHEN E-STOP	SITUATION EXISTS
585	WREMXE--SP	RELAY MXE SHORTS	TO POWER,	DISABLING OPENIG	OF LOOP CONTACTR
586	WREROT--CC	OVERTRAVEL RELAY	FOR HOIST	RAISING ROT	FAILS TO OPEN
587	WREROT--SP	OVERTRAVEL RELAY	ROT SHORTS TO	POWER, DISABLE	OPENING
588	WRETIMERCC	TIMER RELAY	FAILS TO OPEN		
589	WSV106--CM	BOTH EMERGENCY	DUMP VALVES	FAIL TO DE-ENERD	DUE TO C.C
590	WSV1061-CC	SOLENOID OPERATD	EMERGENCY DUMP	VLV 106.1 FAILS	TO DE-ENERGIZE
591	WSV1062-CC	SOLENOID OPERATD	EMERGENCY DUMP	VLV 106.2 FAILS	TO DE-ENERGIZE
592	WSV107120C	SOL.-OPERATED	RETURN VALVE	107.1/2 FAILS	CLOSED (OPT 8-1)
593	WTIBCNTLFA	BRAKE CONTROL	TIMER FAILS		
594	WTXLOT--FA	OVERTRAVEL	SENSORS LOTLS1,	LS2 & LS3 FAIL	
595	WTXROT--FA	OVERTRAVEL	SENSORS ROTLS1,	LS2 & LS3	FAIL
596	WXV101.1OC	MANUAL VALVE	101.1 FAILS	CLOSED	
597	WXV101.2OC	MANUAL VALVE	101.2 FAILS	CLOSED	
598	WXV102.1OC	MANUAL VALVE	102.1 FAILS	CLOSED	
599	WXV102.2OC	MANUAL VALVE	102.2 FAILS	CLOSED	
600	WXV103.1OC	MANUAL VALVE	103.1 FAILS	CLOSED	

Table 4.5-11 (Continued)

LIST OF FAULT TREE BASIC EVENTS FOR THE WIPP PRA

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WIPP ACCIDENT SEQUENCE LINKING - FTS
LIST OF BASIC EVENTS AND THEIR DESCRIPTIONS

601 WXV103.2OC     MANUAL VALVE     103.2 FAILS       CLOSED
602 WXV26.1-OC     MANUAL VALVE     26.1 FAILS        CLOSED
603 WXV26.12CM     MANUAL VALVES    26.1 & 26.2 FAIL  CLOSED DUE TO    COMMON CAUSES
604 WXV26.2-OC     MANUAL VALVE     26.2 FAILS        CLOSED
605 WXV56.3-OC     MANUAL VALVE     56.3 FAILS        CLOSED
606 WXV56.36CM     MANUAL VALVES    56.3 & 56.6       FAIL CLOSED DUE  TO COMMON CAUSE
607 WXV56.6-OC     MANUAL VALVE     56.6 FAILS        CLOSED

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                    CONFIGURATION  CONTROL
                    ---------------------

                 CODE NAME : LISTER
                 VERSION NO. :   2.10
                 DATE OF CONFIGURATION : MAY 18, 1989
                 DATE OF ISSUANCE : MAY 18, 1989
                 DATE : SEPTEMBER   8, 1989
                 TIME : 14:40:54:52
                 CONFIGURATION NO. : 5311582282782
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APPENDIX A
GENERAL HAZOPS GUIDELINES AND GROUND RULES

A.1 Fluid System Guidelines

To provide consistency in hazard evaluations, Westinghouse follows a set of guidelines for systems analyses. These guidelines were developed, consistent with methods now used in other analysis applications. It is not expected that each guideline will necessarily be used. Engineering judgment is the final arbitrator in taking exception to these guidelines and is noted by the analyst in the applicable documentation.

A.2 Random Fault Postulation/Consideration

There are 20 random fault postulations and/or considerations, as follows:

(1) Misposition of normally open manual, air, check, solenoid, and motor-operated valves before the hazard or to initiate the hazard, caused by human error and/or a spurious control signal, remains as a system fault, if credible.

(2) All potential flow diversion/mixing/spillage paths isolated from the main flow path by normally closed valves are considered, as appropriate. Valve misposition before the accident, caused by human error or a spurious control signal, is considered a system fault, if credible.

(3) Check valves failing open to flow in the reverse direction are included as credible potential events. Where appropriate, some normal leakage of check valves in the reverse direction is assumed (that is, normal leakage is not a fault).

(4) The system is assumed to be in the operating mode for this analysis. When the operator has a choice of two or more operating modes (each of which is a normal operating mode; not an emergency operating mode), each of the available modes is analyzed. This includes, where possible, operation with certain components or equipment bypassed.

Where seasonal (winter/summer) variations occur in process conditions, only the more limiting case will be evaluated. System reactions to failures are considered to

be part of the normal operating mode, although such conditions are not normal in the strictest sense. Examples of these failures are (1) electric power failure (main, emergency, and uninterruptible power source), (2) total instrument air failure, (3) hydraulic failure, and (4) all automated startup and shutdown sequences, including transition from operating to shut-in modes. Similarly, emergency and operation shutdowns are not counted as faults, but rather are assumed to be anticipated system states.

(5) Pressures and temperatures outside acceptable limits are system faults or hazards.

An overpressure event is considered to be one where the component design pressure is exceeded. Applicable codes may consider the hydrostatic test pressure to be an acceptable limit during a faulted condition, but all transients which exceed the design pressure are identified to optimize the usefulness of the hazard evaluation. Similarly, an overtemperature hazard is considered to be one where the component design temperature is exceeded even though there may be substantial operating margin prior to component failure.

Identified failure sequences that could cause temperatures within process piping or components to exceed design values specified in the P&IDs are reported as potential overtemperature hazards, but are not further categorized.

Finally, identified failure sequences that could cause temperatures within process piping to drop below design values, as specified in the P&IDs and in the support pipe specification and rating data sheets provided if applicable, are reported as potential undertemperature hazards, but are not further categorized. Similarly, potential hazards due to formation of a vacuum in vessels, or containers not rated for full vacuum are treated individually and reported as potential under pressure hazards.

(6) Passage of gaseous or liquid streams into system components not specifically designed to accommodate them (carry-over, blow-by, mixing, and backflow) are treated as faults of the system if a hazardous condition or gas line contamination results.

Faults initiating heat exchanger tube leakage may be hazardous because of overpressure or product contamination. For example, if hydrocarbons contaminate a heating and cooling system, there may be a potential for a gas release or fire hazard.

(7) The creation of an ignition/explosion source is treated as a hazard.

(8) Spillage of liquids into a discharge system collection is not considered a hazard because the liquids are ultimately directed to a slop oil tank or other appropriate collection device. However, the analysis considers any potential hazards to the discharge systems because of excessive liquid flow into the knockout drum, slop oil tank, and the like, with possible subsequent spillage.

(9) All lines of like service are assumed to be identical where they include identical types and numbers of devices and are tied to identical sources and outlets at each end. The plant operator or designer will advise Westinghouse if line configuration variations are to be taken into account.

(10) Devices which perform only an accounting function (data measurement, collection, processing) are not individually considered in the hazard analysis.

(11) The closure or blockage of components in series in a given piping segment or the opening or leakage of components in parallel is evaluated as a single event.

(12) The closure of isolation valves on the two paths of a redundant system by the operator is treated as two independent faults.

(13) The small-diameter startup valves in parallel with shutdown valves are not individually analyzed because the effect, if they fail open, is the same as that of the shutdown valve failing open, but possibly to a lesser degree.

(14) For two similar isolation valves in series which are both stroked to initiate a different operating mode, a potential always exists for a single-operator common mode failure which results in the inadvertent mispositioning of both valves. In circumstances where the operators are cognizant of the system design and the

potential for this type of human error during normal operation, the likelihood of such an error is greatly reduced.

Failure of the operator to return both valves to the normal operating position after system use is considered a single-operator failure. Similarly, neglecting to align both valves before system startup is a single failure. In either case, credit is taken for indicators of valve position as appropriate. This is particularly applicable to the relief valves from main pressure vessels because of the close proximity of the two isolation valves.

(15) Calculating the capacities of relief valves, if required, will be performed as per information supplied by the Operator, designer, any applicable government agency, and ASME Boiler Code.

(16) The hazards study need not include spurious line blockages or plugging unless there is an identifiable cause such as freezing, hydrates, sand, and the like. Blockages in level sensor lines and piping upstream of relief valves could still be caused by spurious valve closure if one exists.

(17) The potential for pump damage due to cavitation following the loss of suction flow is considered as a potential hazard initiator. Pump damage due to a blocked suction or discharge is also treated in this manner unless such damage can lead to a more serious hazard (such as overpressurization).

(18) Where the process uses two 50-percent capacity components or trains, both are expected to be operational under normal operating conditions. Therefore, hazards endemic to both components are explicitly evaluated.

(19) No common-cause hardware failures between components in redundant systems need be considered (for example, design defects common to identical safety valves).

(20) Credit has been taken, where appropriate, for the proper functioning of process sensors and transmitters. That is, failures of such devices to perform properly have been counted as faults or failures. This assumes these devices are routinely tested and maintained by the plant operators on an appropriate schedule.

APPENDIX B

WIPP CH WASTE FACILITY P&IDS USED IN HAZOPS AND QUANTIFICATION

Drawing No.	Title
Refer to Applicable Forklift O&M Manual	Battery Recharger in CH Area of Waste Handling Bldg.
41-H-012 (O&M Manual)	Waste Handling Building Electric-Driven Forklift
41-K-026-014	Waste Handling Bldg. 411 Access Control System Airlock Door Instr. Diagram
41-T-151A/B	CH Dock Bridge Crane
41-G-501-014	Waste Handling Bldg. 411 Equipment Arrangement Plan El. 100'-0"
41-G-501-014	Waste Handling Bldg. 411 Equipment Arrangement Plan El. 100'-0"
41-H-018 (O&M Manual)	Electric Driven Conveyance Loading Car
31-J-542-014	Waste Handling Bldg. 411Hoist Tower Power & Control Auxiliary Plans
31-J-542-014	Waste Handling Bldg. 411Hoist Tower Sections & Details
41-G-507-014	Hoist Motor Room
Refer to Applicable Forklift O&M Manual	U/G Battery Charging Equipment
53-F-130-01E 53-D-016	Underground Development Vehicle Fuel System
52-H-008 (O&M Manual)	U/G Diesel-Powered CH Transporter
74-UE-060 (O&M Manual)	U/G Getman Lube Truck
52-H-007B (O&M Manual) 52-H-005	U/G Diesel-Powered Forklift
74-H-010A (O&M Manual)	U/G Electric-Driven Forklift
74-U-039 (O&M Manual)	All other U/G Diesel-Driven Equipment
25-J-020-W	Operations Surface and Underground
54-W-005-W	U/G Maintenance Shop
54-W-005-W	U/G Office Area/Conex

Drawing No.	Title
25-J-020-W	Operations Surface and Underground Utility Subsection 252
25-J-020-W	Operations Surface and Underground Diesel Generators (Facility 255.1 & 255.2)
25-J-020-W	Operations Surface and Underground Facility Substations 254.1 & 254.2
25.-J-020-W	Operations Surface and Underground Facility Substation 254.3 for Exhaust Filter Bldg.
25-J-020-W	Operations Surface and Underground Facility Substation 254.5 for Salt Hoist
25-J-020-W	Operations Surface and Underground Facility Substation 451 for Support Building
38-J-027-W	Salt Handling Hoist House Building 384
41-J-656-021	Trupact Maintenance Facility 412
41-D-001-W	Air Compressor Building 463
45-G-101-010	Water Pumphouse Building 456
45-G-101-010	Water Pumphouse Building 456
41F-309-34B	U/G Ventilation Modifications Station A Instrument Shed P&IDs
41F-308-34B	U/G Ventilation Modifications Station B Instrument Shed P&IDs
9582	Nuclear Research Corporation U/G Sampling Station with UPS

Drawing Number	Title
1734E30	CMS Configuration WIPP
1735E-03	CMS LPU Electronics Cabinet Assy. WIPP
1735E33	CMS Power Connection Diagram WIPP
1735E79	CMS Schematic Block Diagram WIPP
1807E32	CMS Data Highway Interconnection WIPP

Drawing Number	Drawing Title or Description
25-C-042	Yard Piping Fire Water System Plan
25-F-005	Domestic & Fire Water Yard Distr. System P&ID
41-F-043	Fire Protection Floor Plan & Utility P&ID
41-F-088	Fire Protection Floor Plan
41-J-572	Fire Alarm & Security - Block Diagram
41-J-580	Fire Protection System Block Diagram
45-F-004	B-49 Annex Fire Sprinkler System
45-F-008	Water Pumphouse - Fire Water Pumping System - P&ID
45-F-082	Fire Protection Plan
45-F-089	Halon System - P&ID
45-H-108	Water Pumphouse - Fire Water Pumping System - Control Logic Diagram
45-H-130	Water Pumphouse Fire & Security Systems Control Logic Diagram
45-H-314	Fire Alarm System - Control Logic Diagram
45-J-009-W	Fire Alarm Block Diagram
53-F-120	U/G Dev. - Fire Protection System - Floor Plan
53-F-140	U/G Dev. - Vehicle Fuel Fire Protection - P&ID
53-H-006	U/G Area - Fire Detection & Alarm System - Instr. & Contr. Diagram
53-H-206	U/G Area - Fire Detection & Alarm System - Control Logic Diagram
A-054	Manual Fire Alarm Station - Wiring
A-055	Smoke Detectors - Wiring
A-056	Thermal Detectors - Wiring

Drawing Number	Title
41-F-040-014	Waste Handling Building 411 Compressed Air System Piping and Instrumentation Diagram
41-F-041-014	Waste Handling Building 411 Compressed Air Distribution System Piping and Instrumentation Diagram
41-F-044-019	Exhaust Filter Building 413 Compressed Air System Piping and Instrumentation Diagram
41-F-042-014	Support Building 451 Compressed Air System Sht. 1 of 2 Piping and Instrumentation Diagram
41-F-043-014	Support Building 451 Compressed Air System Sht. 2 of 2 Piping and Instrumentation Diagram

Drawing Number	Title
25-X-001-W	REFERENCE DRAWING ONLY FOR USE WITH ELECTRICAL LOAD LIST
25-J-001-009	YARD ELECTRICAL 13.8KV POWER DISTRIBUTION SYSTEM SINGLE LINE DIAGRAM
25-J-002-009	YARD ELECTRICAL MAIN SUB.13.KV SWGR. 25P-SWG15-1 SINGLE LINE DIAGRAM
25-J-003-009	YARD ELECTRICAL AREA SUBS.1, 2&4 480V SWGRS. SINGLE LINE DIAGRAM
25-J-004-009	YARD ELECTRICAL EMERGENCY POWER SYSTEM SINGLE LINE DIAGRAM
25-J-005-009	YARD ELECTRICAL AREA SUBSTATION NO.3 480V SWGR 25P-SWG04/3 SINGLE LINE DIAGRAM
25-J-006-34B	U/G VENTILATION & MODIFICATION SINGLE LINE DIAGRAM & AREA SUBSTATION NO. 7
31-J-511-W	WASTE HANDLING BUILDING 411 WASTE HOIST 31H001 & 480V MCC 31P-MCC04/1 - SINGLE LINE DIAGRAM
38-J-511-IFc-3	C&SH HOIST HOUSE SINGLE LINE DIAGRAM
41-J-406-34B	U/G VENTILATION MODIFICATION STA. "A"&.B" INSTRUMENT SHEDS SINGLE LINE DIAGRAM
41-J-510-W	EXHAUST FILTER BUILDING 413 480V MCC 41P-MCC04/7 SINGLE LINE DIAGRAM
41-J-512-W	WASTE HANDLING BUILDING 411 480V MCC 41P-MCC04/3 & DP 41P-DP04/3 SINGLE LINE DIAGRAM
41-J-513-W	WASTE HANDLING BLDG. 411 480V 41P-MCC04/5 SINGLE LINE DIAGRAM
41-J-514-014	WASTE HANDLING BUILDING 411 480V MCC 41P-MCC04/6 SINGLE LINE DIAGRAM
41-J-515-014	WASTE HANDLING BLDG. 411 480V SWGR25P-SWG04/1&2 AND 13.8KV SW 31P-SW15/1-SINGLE LINE DIAGRAM ,
45-J-510-W	SUPPORT BLDG. 451 480V SWGR 45P-SWG04/I,MCC 45P-MCC04/4 & 45P-DP04/1 SINGLE LINE DIAGRAM
45-J-511-W	SUPPORT BLDG.451 480V MCC 45P-MCC04/3 &DP 45P-DP04/2 SINGLE LINE DIAGRAM
45-J-512-W	WATER PUMP HOUSE 456 480V MCC 45P-MCC 04/2 SINGLE LINE DIAGRAM
53-J-511-01E	UNDERGROUND UTILITIES 480V DISTRIBUTION PANEL 53P-DP04/4,4/8,4/10 SINGLE LINE DIAGRAM
25-J-006-009	YARD ELECTRICAL INCOMING 24PSWG15/1 & MAIN SUB.13.8KV SWGR. 25PSWG15-1 SCHEMES 24SCB-25SCB9
25-J-520-009	YARD ELECTRICAL GROUNDING AND LIGHTNING PROTECTION PLAN

Drawing Number	Title
25-J-521-009	YARD ELECTRICAL PLANT AND UTILITY SUBSTATIONS PLAN, SECTION AND DETAILS
25-J-522-009	YARD ELECTRICAL AREA SUBSTATIONS NO. 1 & 2 PLANS & SECTIONS
25-J-523-009	YARD ELECTRICAL AREA SUBSTATION NO. 3 & 4 PLAN & SECTIONS
25-J-530-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN SHEET 1 OF 6
25-J-531-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN
25-J-532-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN SHEET 3 OF 6
25-J-533-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN
25-J-534-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN SHEET 5 OF 6
25-J-535-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING SECTIONS SHEET 1 OF 2
25-J-536-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING PLAN SHEET 6 OF 6
25-J-537-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING SECTION AND DETAIL
25-J-551-009	YARD ELECTRICAL CONDUIT AND CABLE ROUTING SECTIONS SHEET 2 OF 2
25-J-554-009	YARD ELECTRICAL YARD & SECURITY LIGHTING PLAN
31-J-541-014	WASTE HANDLING BUILDING 411 HOIST TOWER RECEPTACLES, COMMUNICATION & INSTRUMENTATION PLAN
31-J-542-014	WASTE HANDLING BUILDING 411 HOIST TOWER POWER & CONTROL AUXILIARY PLANS
31-J-543-014	WASTE HANDLING BUILDING 411 HOIST TOWER SECTIONS & DETAILS
31-J-544-014	WASTE HANDLING HOIST CONTROL CABLE BLOCK DIAGRAM
31-J-545-014	WASTE HANDLING BUILDING 411 HOIST SHAFT CABLE INSTALLATION
31-J-546-014	WASTE HANDLING BUILDING 411 HOIST SHAFT STATION CABLE INSTALLATION
41-J-401-34B	U/G VENTILATION MODIFICATION CABLE ROUTING PLOT PLANS
41-J-403-34B	EXHAUST FILTER BUILDING 413 POWER CONTROL AND GROUNDING PLANS
41-J-404-34B	EXHAUST FILTER BUILDING 413 UNDERGROUND EXHAUST FAN MODIFICATION SCHEMATIC DIAGRAM

Drawing Number	Title
41-J-520-019	EXHAUST FILTER BLDG. 413 POWER, CONTROL AND GROUNDING PLANS
41-J-521-014	WASTE HANDLING BLDG. 4II BELOW GROUND RACEWAY & GROUNDING PLAN
41-J-523-014	WASTE HANDLING BUILDING 411 BELOW GROUND RACEWAY PLANS & DETAILS
41-J-524-014	WASTE HANDLING BUILDING 411 480V MCC 41P-MCC04/1 & 41P-MCC04/2 MCC ARRANGEMENT
41-J-525-014	WASTE HANDLING BUILDING 411 480V MCC 41P-MCC04/3 & 41P-MCC04/5 MCC ARRANGEMENT
41-J-526-014	WASTE HANDLING BUILDING 411 480V MCC 41P-MCC04/6 MCC ARRANGEMENT
41-J-541-014	WASTE HANDLING BUILDING 411 POWER AND CONTROL PLAN EL. 100'- 0" SH.1 OF 2
41-J-542-014	WASTE HANDLING BUILDING 411 POWER & CONTROL PLAN EL. 100'- 0" SH.2 OF 2
41-J-543-014	WASTE HANDLING BUILDING 411 POWER AND CONTROL PLAN EL. 123'- 0"
41-J-544-014	WASTE HANDLING BUILDING 411 POWER AND CONTROL PLAN AT EL.122'- 1"
41-J-545-014	WATER CHILLER AREA 414 INSTRUMENTATION, GROUNDING, POWER & CONTROL PLAN
41-J-546-014	WASTE HANDLING BUILDING 411 HOIST CONTROL ROOM POWER AND CONTROL PLAN
41-J-548-014	WASTE HANDLING BUILDING 411 HOT CELL POWER AND CONTROL PLANS
41-J-551-014	WASTE HANDLING BUILDING 411 ELECTRICAL LIGHTING PLAN EL.100' - 0" SHEET 1 OF 2
41-J-552-014	WASTE HANDLING BUILDING 411 ELECTRICAL LIGHTING PLAN EL.100'- 0" SHEET 2 OF 2
41-J-553-014	WASTE HANDLING BUILDING 411 ELECTRICAL LIGHTING PLAN AT EL.123'- 0"
41-J-554-014	WASTE HANDLING BUILDING 411 ELECTRICAL LIGHTING PLAN EL.122'- 1"
41-J-555-014	WASTE HANDLING BUILDING 411 HOIST TOWER LIGHTING PLANS
41-J-558-014	WASTE HANDLING BLDG. 411 HOT CELL LIGHTING PLANS
41-J-559-014	WASTE HANDLING BUILDING 411 HOT CELL POWER AND CONTROL SECTION AND DETAILS
41-J-560-019	EXHAUST FILTER BLDG. 413 LIGHTING PANEL SCHEDULES 41P-LP04/11 & 41P-DP03/31 &31A

Drawing Number	Title
41-J-561-014	WASTE HANDLING BUILDING 411 PANEL SCHEDULES 41P-LP04/3, LP04/4, LP04/5
41-J-562-014	WASTE HANDLING BUILDING 411 PANEL SCHEDULES 41P-LP04/1, LP04/2, & 31P-LP04/1
41-J-563-014	WASTE HANDLING BUILDING 411 PANEL SCHEDULES 41P-DP03/10, 11
41-J-567-014	WASTE HANDLING BUILDING 411 PANEL SCHEDULES 41P-DP03/1, 03/2, 02/4, 03/5 & 31P-DP03/1
41-J-570-019	EXHAUST FILTER BLDG. 413 UNDERGROUND EXHAUST FANS SCHEMATIC DIAGRAM
41-J-571-014	WASTE HANDLING BUILDING 411 RH AREA SCHEMATIC DIAGRAM SH.1 OF 3
41 J.574.014	WASTE HANDLING BUILDING RH AREA SCHEMATIC DIAGRAM SH.2 OF 3
41-J-575-014	WASTE HANDLING BUILDING 411 RH AREA SCHEMATIC DIAGRAM SH.3 OF 3
41-J-576-014	WASTE HANDLING BLDG. 411 CHILLED WATER SYSTEM SCHEMATIC DIAGRAM
41-J-577-014	WASTE HANDLING BUILDING 411 MECHANICAL ROOM AREA SCHEMATEC DIAGRAM
41-J-578-014	WASTE HANDLING BUILDING 411 SUSPECT WASTE COLL. & AIR SAMPLING SYSTEM RH AREA-SCHEMATIC DIAGRAM
41-J-579-014	WASTE HANDLING BUILDING 411 RH AREA SCHEMATIC DIAGRAM
41-J-760-014	WASTE-HANDLING BUILDING 411 LOCAL PROCESSING UNIT LAYOUT PLAN SHT.1 OF 4
41-J-761-014	WASTE HANDLING BUILDING 411 LOCAL PROCESSING UNIT LAYOUT PLAN SHT.2 OF 4
41-J-762-014	WASTE-HANDLING BUILDING 411 LOCAL PROCESSING UNIT LAYOUT PLAN SHT.3 OF4
41-J-763-014	WASTE HANDLING BUILDING 411 LOCAL PROCESSING UNIT LAYOUT PLAN
45-J-522-014	SUPPORT BUILDING 451 ELECTRICAL EQUIPMENT ROOMS ARRANGEMENT PLANS
45-J-523-014	SUPPORT BUILDING 451 480V MCC 45P-MCC04/3 & 45P-MCC04/4 MCC ARRANGEMENT
45-J-540-014	SUPPORT BUILDING 451 POWER & CONTROL PLAN ELEV 100'- 0"
45-J-541-014	SUPPORT BLDG. 451 POWER AND CONTROL PLAN ELEV. 114'- 6"
45-J-542-014	SUPPORT BUILDING 451 POWER AND CONTROL ROOF PLAN

Drawing Number	Title
45-J-552-014	SUPPORT BUILDING 451 ENVIRONMENT MONITORING & LOCAL PROCESS UNIT, LAYOUT PLAN, EL. 100'- 0
45-J-560-014	SUPPORT BUILDING 451 DISTRIBUTION PANEL SCHEDULES 45P-DP03/11, /12, /13, /14 & /15
45-J-573-014	SUPPORT BUILDING 451 CMR AND INSTRUMENT SHOP SCHEMATIC DIAGRAM
53-J-520-OIE	UNDERGROUND UTILITIES POWER DISTRIBUTION & GROUNDING PLANS SH.1 OF 2
53-J-521-OIE	UNDERGROUND UTILITIES POWER DISTRIBUTION & GROUNDING PLANS SH.2 OF 2
71-J-674-017	SECURITY, UPS AND ENVIRONMENTAL MONITORING SYSTEM SEISMIC, METEOROLOGICAL AND AIR QUALITY CABLE BLOCK DIAGRAM
76-J-301-W	ELECTRICAL STANDARDS ABBREVIATIONS FOR DRAWINGS AND EQUIPMENT
76-J-303-W	ELECTRICAL STANDARDS ELECTRICAL SYMBOLS FOR SINGLE LINE DIAGRAMS
76-J-304-W	ELECTRICAL STANDARDS ELECTRICAL SYMBOLS FOR ELEMENTARY AND INTERCONNECTION DIAGRAMS
76-J-305-W	ELECTRICAL STANDARDS ELECTRICAL SYMBOLS FOR INSTALLATION DRAWINGS
76-J-306-014	ELECTRICAL STANDARDS GROUNDING DETAILS SHT.1 OF 2
76-J-307-014	ELECTRICAL STANDARDS GROUNDING DETAILS SHT.2 OF 2
76-J-308-014	ELECTRICAL STANDARDS MOTOR CONNECTION DETAILS
76-J-309-014	ELECTRICAL STANDARDS LIGHTING FIXTURE MOUNTING & CONNECTION DETAILS SHT.1 OF 2
76-J-312-014	ELECTRICAL STANDARDS ELECTRICAL OEVICES MOUNTING & CONNECTION DETAILS
76-J-314-014	ELECTRICAL STANDARDS U/G AND EMBEDDED RACEWAY INSTALLATION DETAILS
76-J-316-014	ELECTRICAL STANDARDS EXPOSED RACEWAY SYSTEMS INSTALLATION DETAILS SHT.1 OF 2
76-J-317-014	ELECTRICAL STANDARDS EXPOSED RACEWAY SYSTEM INSTALLATION DETAILS SHT.2 OF 2

Drawing Number	Title
41-F-022-014	WHB 411 CH Area HVAC Flow Diagram
41-F-026-019	U/G Exhaust System - Flow Diagram
41-F-030-014	Waste Handling-Hoist Room/Waste Shaft - HVAC System Flow Diagram
41-F-033-014	Waste Handling - Misc. HVAC - Flow Diagram
41-F-037-019	HVAC System - Flow Diagram
41-F-052-014	WHB 411 CH Area HVAC Sheet 1 of 2 P&ID
41-F-056-019	Underground Exhaust System - P&ID
41-F-059-014	WHB 411 CH Area HVAC Sheet 2 of 2 P&ID
41-F-060-014	Waste Handling-Hoist Room Waste Shaft HVAC - P&ID
41-F-063-014	WHB 411 - Misc, HVAC - P&ID
41-F-067-019	HVAC System - P&ID
41-F-308-34B	U/G Ventilation Mods Station B Instr Shed P&ID
41-F-309-34B	U/G Ventilation Mods Station A Instr Shed P&ID
41-F-310-34B	U/G Vent Mods Shrouded Probe Nozzle and Splitter
41-H-152-014	WHB 411 CH Area HVAC Control Logic Diagram Sheet 1 of 2
41-H-156-019	U/G Exhaust System - Control Logic Diagram
41-H-159-014	WHB 411 CH Area HVAC Control Logic Diagram Sheet 2 of 2
41-H-160-014	WHB Hoist Room Waste Shaft HVAC Control Logic Diagram
41-H-167-019	HVAC System - Control Logic Diagram
54-W-001-W	Underground Mine Ventilation System

Drawing Number	Title
54-W-002-W	U/G Ventilation Plan Normal Mode
54-W-004-W	U/G Ventilation Plan - Filtration Mode
54-W-008-W	Surface Exhaust Shaft & Exhaust Filter Building Arrangement for Underground Ventilation
54-W-010-W	Exhaust Filter Building & Exhaust Shaft Arrgt for U/G Vent Filtration Mode - October 1988
76-H-006-014	Control Systems Standard - Control Logic Symbols
76-H-006-019	Control Systems Standard - Control Logic Symbols

Drawing Number	Drawing Title or Description
95080333	Pneumatic Circuitry
95080335	Field Piping Diagram
95060584	Linkage Assembly

The following drawings for the Waste Isolation Pilot Plant are enclosed:

Drawing Number	Drawing Title or Description
95080294	Hyd Brake System - Sheet 1 (drawing has been marked to identify additional components used for design options)
237B6688	Sheet ID
237B6688	Brake Solenoids - Sheet IE
237B6688	Emergency Stop - Sheet IM
237B6688	Shaft Limit Switch Layout - Sheet OE

APPENDIX C
GUIDE TO FAULT TREE DEVELOPMENT

C.1 FAULT TREE GUIDELINES FOR WIPP CH INTEGRATED RISK ASSESSMENT

C.1.1 GENERAL ANALYSIS OBJECTIVES AND METHODOLOGY

The general objective of the PRA is to identify and quantify the failure of systems, subsystems, and components, which could lead to an off-site radiological release. If during the course of the above analysis, the analyst finds a failure or series of failures, which could lead to a hazard to on-site personnel, the analyst shall identify this hazard as a by-product of the plant walk-down and insight gained through the PRA analysis.

The approach used for this project employs a thorough fault tree linking process that includes the development of event tree models to formulate the radionuclide release accident sequences. Each sequence identifies which system fault trees and operator actions are to be linked. The accident sequences are quantified through the fault tree linking phase of the PRA to obtain the radionuclide release frequency and the specific accident sequence cut-sets.

The event trees model the plant response to specific initiating events and develop the subsequent accident sequences. During the course of the project, the accident scenario model is refined based on the analyst's understanding of plant response during accident conditions.

Fault tree modeling is primarily used for the quantitative analysis of both frontline safety systems and support systems. Fault tree modeling of support systems will be performed to the same level of detail as the safety systems. Support system fault trees are either directly incorporated into the fault tree models for the safety systems or logically combined with the safety systems during the fault tree linking process, which form the overall accident scenario model. A mixture of two treatments is typically the most efficient, and either treatment properly models the contribution of the support systems to the failure of the frontline safety systems. Based on the analyst's experience, we feel that this approach is the most effective way to accurately treat support system dependencies for the PRA.

C.1.2 GENERAL OVERVIEW OF FAULT TREE CONSTRUCTION AND ANALYSIS

Fault tree techniques are used as the basis for the quantitative analyses performed for each critical safety system. Copies of the fault trees used for each system analysis are included in Volume III of this report. This section describes the conceptual description of a fault tree, its uses, and its benefits. In addition, the Westinghouse Fault Tree Analysis (FTA) methodology and the primary symbols used in the fault tree construction are briefly described.

A fault tree is used to represent a reliability model of a physical system, just as a process and instrumentation diagram (P&ID) is used to represent a process model. The FTA is a method for systematically identifying, analyzing, prioritizing, and documenting potential safety or reliability problems.

The FTA is performed using system design information such as P&IDs and operating procedures established for test, maintenance, and plant operation. Fault tree construction is based on guidelines contained in the "Fault Tree Handbook," (NUREG-0492, March 1980). The top of the tree is established with a statement of the undesired event. The fault tree is logically developed using computer graphics and appropriate software from a "top" undesired event through progressively greater detail to the root cause of the system malfunction, such as individual component failure. The fault tree includes failures such as random component failures, common cause faults, human errors (HEs), test and maintenance to evaluate the safety hazards or unavailability of the system.

A fault tree is composed of logic gates that permit or inhibit the passage of lower fault events to the "top" undesired event of the tree. These gates show the relationships of the input fault events required for the occurrence of intermediate fault events that cause the "top" undesired event. A typical fault tree is depicted in Figure 4.4-1 and is composed of various logic and event symbols, which are described below.

Primary events are fault events that need no further development. Probabilities are assigned to these events and the model is quantified to determine the probability of undesired events.

An octagon or circle depicts a basic event that requires no further development and signifies that the appropriate limit of resolution has been reached. Unique identifiers will be assigned based on the guidance in the fault tree guidelines.

A diamond depicts a SYSTEM FAULT (Undeveloped Event), an event that is not further developed, either because the event is insignificant or because information relevant to the event is unavailable, or it represents an event common to other systems. Probabilities for these events are assigned using engineering judgement, databases, or specific calculations.

An INTERMEDIATE EVENT identifies a system malfunction that results from the combination of lower-level fault events passing through a logic gate and is represented by a rectangle. A description of the INTERMEDIATE EVENT is given within the rectangle.

Gates serve to permit or inhibit the passage of fault tree logic up the tree. There are four frequently used types of fault tree logic gates: the OR GATE, and AND GATE, the NOT GATE, and the COMBINATION GATE.

An OR GATE is used when any of the fault input events are present.

An AND GATE defines the situation whereby the output event exists only if all the fault events occur.

A COMBINATION GATE is used when the output event exists if any combination of x of the y fault events occur.

Gate types represented by triangles are introduced as transfer symbols for the duplication of fault tree logic and primary events are represented by a fault tree. These are more than just a convenient method of avoiding duplication. They are critical to ensure faults common to the contribution of an undesired event are properly represented. A figure of commonly used fault tree symbols are shown in Figure C-1.

A vertical line from the apex of the triangle denotes a TRANSFER IN symbol, and a horizontal line from the side denotes a TRANSFER OUT symbol. A TRANSFER IN symbol attached to a logic gate or an intermediate event must be linked to a TRANSFER OUT

symbol. The TRANSFER OUT symbol contains that portion of the fault tree logic being transferred to another event or logic gate represented by the TRANSFER IN symbol.

C.1.3 CONSTRUCTION OF WIPP FAULT TREES

Overview of Construction Guidelines

- Basis for Guidelines

  To ensure consistency in the system fault trees for the WIPP CH PRA, Westinghouse will follow a set of basic guidelines for their systems analyses. The guidelines have been developed with the intent of following the principal methods now used in PRAs, as described in the "PRA Procedures Guide" (NUREG/CR-2300, Revision 1), and also outlined in "Probabilistic Safety Analysis Procedures Guide" (NUREG/CR-2815, Jan. 1984). Engineering judgment will be the final arbiter in taking exception to these guidelines and shall be noted in tree documentation.

- Definition of Components

  The systems of the WIPP facility that were analyzed in the IRA using FTA include electrical, hydraulic, and pneumatic systems. A hydraulic or pneumatic system fault tree involves the major system components that are important or essential to the operation of the system. These components may include valves, pumps, heat exchangers, tanks, piping, compressors, fans, dampers, ducts, and filters. Similarly, the major components of an electrical system include power buses, circuit breakers, transfer switches, transformers, batteries, diesel generators, inverters, rectifiers, and power cables.

- System Failure Modes

  The top event of a system fault tree describes the failure of the system to perform a required function. For fluid systems, the failure of the system to supply water or transfer heat are typical top events that are developed in the tree based on a determination of the conditions that define the failure of the system.

The failure modes of a system are developed in a fault tree based on an investigation and understanding of the effects of various system component failures and the effects of support system and interfacing system failures. The failure of a fluid system is usually the result of one or more of the following:

1. Failure of one or more active components such as pumps, fans, active valves, or compressors.

2. Loss of main system function resulting from failure of a support system such as electric power or cooling water.

3. Diversion of fluid flow resulting from failure or improper operation of system components, or due to a misalignment error.

4. Loss of flow due to a rupture in the pressure boundary of the system.

The fault tree guidelines provide further guidance when considering these failure modes in the fault tree models.

The failure of an electric power system to supply control or motive power to essential components and systems of the plant is the most common type of electric power system failure, which is described at the top of the fault tree. The other type of system failure is one that results in unintentional energization of one or more components, or in failure to de-energize a component. The modes of failure of electric power systems are: 1) failure of one or more electrical components in the system, 2) improper operator actions, and 3) failure of systems that support electric power such as loss of cooling water to a diesel generator.

Construction and Documentation of Fault Trees

- Structure and Content of Fault Trees

Fault trees for the PRA include the failure or unavailability of components due to random causes, HE, common cause, and test and maintenance activities. The dependence that components have on shared subsystems or support systems are modeled in the system fault trees. Common cause failure (CCF) of components will

be analyzed according to the methodology described in Section C.2. The calculations contained within the system analysis are sufficiently detailed for later reproduction or sensitivity analysis.

- Fault Tree Development

System fault trees will be developed down to the level of major components failing to operate or function or to specific failure modes (as mandated by the needs of the analysis). Many components have two or more causes or modes of failure. For example, a pump failure may be the result of failure to start, failure to run, or failure of a circuit breaker (CB) to close and energize the pump motor. A component of this type is described as having multiple modes of failure because any one of the modes or causes of failure results in the failure of the component to function or operate. As a general guideline, multiple modes of failure will not be detailed in the fault trees because it is desirable that fault tree analyses not produce excessively long lists of minimal system cut-sets as input to the fault tree linking model. The list of cut-sets produced by quantification will be controlled by using single blocks in the fault tree that represent all of the multiple modes of failure of the major components. However, all modes of component failure will be properly accounted for in the process of quantification of the fault trees. The details of quantification are discussed elsewhere in these guidelines.

Fault tree development may include human error (HE) contributions involving incorrect positioning. This type of HE may include failure to restore a valve to its proper position following test or maintenance. HEs of this type occur prior to the accident or fault sequences. In addition to the disposition errors, there may be errors that occur as a result of human interaction with the system during the fault sequence. The latter errors are not included in the fault trees. In this analysis, human errors important to the accident sequences were included. HEs that may occur during the fault sequence were shown explicitly in the fault tree. If the HE resulted in the failure of a system, the error appeared at a higher level of the fault tree.

- Fault Event Identification Codes

Each system fault (diamond symbol) and basic component fault (round symbol) in a fault tree will be given a ten character fault event identification code.

The format of fault event identifiers in the system fault trees is XYYZZZZZWW, where:

- X is the system code from Table C-1. This associates the identifier with a system-specific analysis and is useful for the fault tree linking process.

- YY is the component type identification code from Table C-2. This uniquely identifies the component type with which the identifier is associated. If a fault tree node is not associated with a specific component, these spaces shall be filled with the independent identifier, as described below.

- ZZZZZ is the component identifier. This identifier shall clearly and uniquely identify the component involved and shall be consistent with the component numbering that is used in the system analysis to describe the components. As far as possible, component identification codes shall be the same as the component identification acronyms that appear on the plant drawings and documents. The identifier shall be as descriptive as possible so that the event identifier can be associated with the component/failure mode when separated from its text block. If the system and component identification code is less than five characters long, it should be left justified and a dash (-) shall be used to fill in the blanks to the right.

- WW is the failure mode identification code from Table C-3. This identifier denotes the failure mode of the component or process identified by this node in the fault tree. If this component or process does not fail by a regular mode, these spaces shall be filled with dashes (-) or an extension of the independent identifier, ZZZZZ.

C.1.4 GENERAL ASSUMPTIONS AND CLARIFICATIONS FOR FAULT TREE CONSTRUCTION

Modeling of Random Faults in Liquid and Air Systems

It was assumed that all piping complies with the maximum expected pressure that could be supplied by any single component failure. In the fault tree analysis it was assumed that all piping, valve, and pump faults were designed to handle the maximum pressure that may occur during a blockage event.

Valves which fail to a "safe" position were not modeled. When opening/closing time is critical for the accident condition, it was evaluated on a case-by-case basis.

Control circuit faults of components, after successful initial operation, will be considered only in those cases where the component is expected to receive an additional signal during the course of the accident to readjust or change its operating state.

Tank failures related to plugging or blockage of the fluid path due to failure or dispositioning of valves in the line from the tank shall be included in the fault trees.

The failure of heat exchangers or coolers to transfer heat may be the result of plugging of the primary side or leakage from the primary to secondary side. Plugging need not be included as a component fault if 1) the heat exchanger performance in this regard is checked periodically during normal operation, and 2) the accelerated plugging or fouling due to chemical crystallization (see paragraph two of this section) is found to have a very low probability of occurrence or is not applicable. Leakage from tubes need not be considered if the heat exchanger is inspected and tested for leaks periodically when taken out of service.

Check valves failing to close the flow in the forward direction and failing to open the flow in the reverse direction will be included as credible faults only when the valve is located in a pipe not used in normal operation. The failure of those check valves and normally open manual valves located in a pipe used in normal operation will not be modeled in the fault trees.

It is assumed that the system is structurally designed for thermal stresses/shocks and any necessary bounding analyses would be performed as part of the design. Therefore, these failure modes and structural failures in general are not explicitly analyzed.

Ambient temperatures in this region are not expected to be at or below the freezing point of water, precluding the need for development of equipment failures or system faults initiated by freezing.

The cause and effects of sabotage are outside the scope of this analysis.

Considerations for Test and Maintenance Unavailability

Unavailability of components due to test or maintenance and HEs associated with failing to restore components to their operable state, following test or maintenance, are considered along with random hardware faults.

A component can be tested or maintained during system operation if it can be flow isolate from the system by a manual valve or power-operated valve in series with the component.

The preferred method of treating test and maintenance unavailability in the fault trees shall include the unavailability with the multiple faults of the component.

First, it must be determined whether the component is tested or maintained during normal plant operation and whether the testing or maintenance makes the component unavailable or incapable of performing its required safety function. Test and maintenance unavailability is not modeled if the component is not tested during normal operation. In response to the second concern, a component may be available or unavailable depending on the type of maintenance. It shall be verified that the major scheduled and unscheduled maintenance activities with the longest outages make the component unavailable because these activities have the greatest affect on the quantification of unavailability. Testing may or may not make a component unavailable. An example of a major plant component, which remains available during a test, is a backup DG.

Test and Maintenance unavailability shall be included in the fault tree at the component level. Each component unavailability shall be calculated from the component's mean outage times and frequency for scheduled and unscheduled maintenance. Test and

maintenance unavailability can be included in the fault tree at the train level under special circumstances, which shall be documented in the system analysis. One example may be where a train of two or more components is tested or maintained as a unit such that there is one outage time for testing or maintenance that is applicable to the entire train.

It is possible that the fault tree quantification may count the simultaneous test and maintenance unavailability of two or more redundant components in separate trains. If procedures prohibit this type of simultaneous outage, the quantification results would be conservative. However, this double counting would not be immediately apparent since test and maintenance would be hidden in the random component failure modes. The analyst will, however, examine all dominant cut-sets to identify any such double counting or other significant contributors and revise the modeling, as necessary.

Only those components that are tested during normal operation of the plant, or those that are rotated in and out of service during normal operation, will be considered maintainable.

The test mode of a pump and its associated valves and other components that prevent a system from meeting its design safety function will be considered as a credible failure mode, unless automatically realigned within acceptable time limits.

Stroke testing is assumed for all valves following a maintenance operation.

One assumption that was made in conducting this evaluation was that sensors and related components are regularly tested and calibrated. No attempt was made in this study to evaluate the possible consequences of faulty signals due to the miscalibration of sensors.

Proper maintenance is a critical factor in safe system operation. It must be recognized that poor maintenance and maintenance practices have the potential for being a critical contributor to problems. Explicit identification of specific failures, which may occur during equipment maintenance, is beyond the scope of this study. General problems that may occur during maintenance are identified.

Inclusion of Operator Action and Human Error

Operator errors that result in failure to align valves or failure to operate other components in response to the accident will be included only for those components that are specifically identified in procedures requiring operator manipulation.

Operator recovery of failed systems may be modeled, if credible, from diagnostic, time frame, and accessibility viewpoints. "Verify" statements in procedures that instruct the operator to verify the functioning of automatic safety system's are treated as recovery operations, and thus are not included in the FTA . Local indicators and alarms, such as those in a location not continually manned, shall not normally be considered.

The failure of test personnel to return valves or pump trains to their normal position after a test will be considered a credible event if the following conditions are met: 1) the component does not receive an emergency signal, which automatically positions the component; and 2) the valve position or pump status is not alarmed or annunciated at the control board.

The failure of maintenance personnel to return valves or pump trains to their normal position after valve or pump maintenance will be considered as credible events if: 1) proper positioning can not be detected using required post-maintenance tests, 2) the incorrect position is not immediately detected at the control board by alarm or annunciation, or 3) the component does not receive emergency signal. Credit is not taken for control indication.

Consideration of Common Cause Faults

The CCF must be considered for active components such as pumps, fans, and valves; which are of the same design and operate in a redundant application in the same type of service or environment. Check valves and strainers (in open or once-through systems) may also be subject to the CCF.

The CCF of two or more similar components that are not of the same design or manufacture shall be considered, if the components can be subjected to a common abnormal environment during an accident sequence that is outside of the design basis of the components. Quantification of common cause is detailed in Section 4.2.

Modeling of Random Faults in Electrical Systems

- Considerations for Random Faults

- Local faults of wiring or cables shall be considered for inclusion in electrical system fault trees. The failure modes judged to be most appropriate for the plant are open-circuit failures and short-to-ground faults. Short-to-power wiring faults are not typically included.

  Bus faults include mechanical faults that affect electrical performance of the bus and electrical faults within the bus enclosure. CB faults are not included with the bus faults. The failure of HVAC or room cooling is assumed to have a negligible effect on the overall probability of failure of electrical buses and need not be included in the fault tree development.

  Control circuit, control power, and actuation system faults shall be included as CB faults in the modeling of breakers that change state in order to transfer power to an electrical bus.

  Control circuit faults are included for DGs in the basic faults "failure to start" and "failure to run."

- Considerations for Test and Maintenance Unavailability

  Components such as breakers and protective relays are not tested during normal power operation if the electrical system operates and supplies loads. Normally, the required operational tests of these systems will be performed during plant shutdowns. The backup power DGs and associated control circuitry are individually tested during power operation in accordance with plant operating procedures. No test unavailability is postulated for the backup electrical systems that interface with the DGs.

  Since the electrical power buses are constantly being monitored during plant operations, unscheduled maintenance on any component related to a backup

power bus is permissible depending on plant procedure requirements, with an upper limit of 24 hours.

- Inclusion of Operator Action and Human Error

  Operator errors such as failing to actuate power switches or failing to operate other power components in response to the accident should be considered. The fault tree should include any operator errors that involve components which are specifically identified in procedures as requiring manipulation.

- Consideration of Common Cause Faults

CCF of DGs cables, CBs, buses, and TRs will be considered. See Section 4.2 for additional information on quantification of common cause.

C.1.5 CALCULATION OF BASIC COMPONENT UNAVAILABILITY

The unavailability of a basic component is the sum of the unavailabilities or failure probabilities of the individual modes of failure of the component.

Each system analysis shall contain a tabulation of the unavailabilities of components that are modeled in the system fault tree. The general formula for calculating total component unavailability is:

$$q - q(s) + q(o) + q(d) + q(e) + q(t) + q(m) + q(he)$$

Where:

q(s)	=	Component standby failure probability
q(o)	=	Component operating failure probability
q(d)	=	Component demand failure probability
q(e)	=	Failure probability of support systems
q(t)	=	Test outage unavailability
q(m)	=	Maintenance outage unavailability
q(he)	=	Component unavailability due to human error
Q	=	Total component unavailability

Not all of the failure modes will be applicable to each component. For example, a component may be in continuous operation during both normal plant operation and the accident sequences, which result in no standby failure of the component. Entries for test and maintenance may also not be applicable to certain components. Care shall be taken in listing the test and maintenance unavailability under the correct component. For example, a valve may be closed in order to support the maintenance of another component, but the test and maintenance unavailability should be computed only once for the major component that is being maintained. As a general rule, a valve or other component, which is used to support the maintenance of another component, shall not be given a test and maintenance unavailability if it leads to an incorrect or double counting of the effect of test and maintenance in the quantification of the system unavailability.

In some cases the basic failure data selected for a component may encompass more than one mode of failure. For example, failure of a pump to start encompasses a standby failure probability and a demand failure probability. The standby failure probability can be visualized as a probability that the pump is in a failed state or fails while idle. The demand failure probability involves the observation that the pump may fail each time that a demand is placed on it. For the sake of consistency, it is suggested that the probability of failure to start be listed as a demand failure probability. Other modes of pump failure such as failure of a valve in a seal or oil cooling subsystem for the pump may be included under pump standby failures, if appropriate or included with the operating failure probability. Care should be taken to ensure that there is no double counting of standby and demand faults in the unavailability quantification.

Calculation of Hardware Failure Unavailability

When evaluating component failure contribution, one must consider whether the component is operating or in a standby mode. If the component is part of a standby system, the average unavailability is estimated using either a time-based failure rate or a demand failure probability for component failure in the standby mode.

A time-based-failure rate is applicable when the failure mechanism causing the failure mode is related to the time the component is in standby between checks of its operability. The time between tests is thus an important part of the unavailability calculations of these components. A demand failure probability is appropriate for component failure modes that

do not depend on the test period length, but rather are related to the number of times that the component is "demanded" to operate. The length of the test period is irrelevant for a component whose failure mode is truly demand dependent. The component average unavailability using a time-based failure rate is given by the expression:

$$q_c = 1/2\ g_s\ T_T \quad (1)$$

Where:

q_c = Component average unavailability

g_s = Standby failure rate (failures per hour)

T_T = Length of the test period (hours)

An estimate obtained using this expression is adequate assuming an exponential failure distribution and the product of $g_s T_T \leq$ 0-1-

The demand failure probability is given directly by the data base and thus:

$$q_c = q_d \ (2)$$

Where:

q_c = Component average unavailability and q_d is the demand failure probability

A more appropriate model for calculation of the unavailability of components in standby, assuming that such components have both time-dependent and demand failure contributions, is given by:

$$q_c = q_d + 1/2 g_s\ T_T \ (3)$$

with the parameters q_c, q_d, g_s and T_T defined as above. Data is usually not available, however, to estimate both the time-dependent and demand-related port ion of component standby unavailabilities.

When a component test period is relatively small (e.g., on the order of three months or less) either equation (1) or equation (2) may be used to estimate the unavailability of standby components without introducing excessive error into the fault tree quantification results.

The calculation model to compute the unavailability or failure probability of nonrepairable components in an operating system is given by the equation:

$$q_c = g_o T_M \quad (4)$$

Where:

q_c = Component average unavailability

g_o = Operating failure rate (failures per hour)

T_M = Total defined mission time

Again, the expression is adequate assuming an exponential failure distribution and the product of g_o TM $\leq$ 0.1

In standby safety-related systems, components once actuated may fail to perform for the desired mission time (e.g., a pump fails to start and run for a desired time). The unavailability calculation model for such components is

$$q_c = q_d + g_o T_M \quad (5)$$

or

$$q_c = 1/2\, g_s T_T + g_o T_M \quad (6)$$

with each parameter for both of the above equations, as previously defined. The selection of which equation to use for the quantification being performed is dependent on the type of data given by the selected data bank being used. Usually, equation (5) will be used to quantify the standby and operating failure probability of the component.

In some operating systems, component failures, once detected, may be repairable. The approximation equation for such components is given by:

$$q_c = g_o t \quad (7)$$

Where:

t = Average total time in hours the component is out of service after it has failed

q_c = Component average unavailability

g_o = Component operating failure ability

Calculation of Maintenance Outage Unavailability

As stated previously, component outages may occur when components are removed from service for test, preventive maintenance, and/or repair. These are generally classified as:

- Scheduled outages resulting from periodic tests and scheduled preventive maintenance
- Unscheduled outages resulting from a need to repair a failed component

Scheduled preventive maintenance may be performed on major equipment during normal plant operation. When scheduled preventive maintenance removes a component from service, then a scheduled maintenance outage contribution to component unavailability occurs.

An unscheduled outage occurs when a component fails and is in need of repair to continue system operation. For standby components, this usually happens during a periodic test when a component is discovered to be in a failed state.

Repair often ensues when a component is found to be degraded but operable (i.e., leaky pump and valve seals, excessive back leakage through check valves, etc.), as well as when a catastrophic failure occurs. Thus the frequency with which unscheduled repair

occurs shall be as least as large as the component's failure rate which, in many reported data banks, includes only catastrophic failures.

The unscheduled repair (maintenance) outage contribution to component unavailability due to failures detected during test is given by the equation:

$$q_{RM} = f_R\ (t_R/T_T) \quad (8)$$

Where:

q_{RM} = Component unavailability due to unscheduled repair

f_R = Frequency (per test period) with which repair is expected to occur

t_R = Mean component repair time (hours)

T_T = Test period

The scheduled preventive maintenance outage contribution to component unavailability for point value computation is estimated by:

$$q_{SM} = f_M\ (t_M/T_T) \quad (9)$$

Where:

q_{SM} = Component unavailability due to scheduled maintenance

f_M = Frequency (per test period) with which scheduled maintenance occurs

t_M = Mean component outage time for scheduled maintenance

T_T = Test period

In both of the above equations (8 and 9), since q_{RM} and q_{SM} are probability values, all of the parameters on the right-hand side of the equations must be compatible and cancel out so that "q" values obtained are dimensionless. For instance, for monthly testing, if the test

period (T_T) is expressed in hours per month, the repair duration (t_R) is in hours, and f_R is the reciprocal of the number of months between repair acts, then q_{RM} is dimensionless.

The mean component repair time (t_R) and the outage time for scheduled maintenance (t_M) should be determined from the WIPP plant experience. The system analysis shall contain a summary of the calculation of these mean values and an explanation or justification shall be given if data from sources other than the WIPP experience is used.

The frequency per test period with which repair is expected to occur (f_R) shall also be determined from WIPP plant experience.

Calculation of Test Outage Unavailability

Most testing of safeguards equipment during normal plant operation will not prevent such equipment from carrying out its intended safety function if an accident happens while the equipment is undergoing testing in accordance with the plant's safety analysis report. If a test procedure results in a component being removed from active service for all or a portion of a test, then a test outage occurs. The unavailability of a component due to testing is given by the equation:

$$q_t = t_t/T_T \quad (10)$$

Where:

q_t - Average unavailability from the test outage

t_t - Average duration of test (hours)

T_T - Time interval between test in hours

Test outage unavailability will be treated on a case-by-case basis using plant-specific data to calculate test outage unavailability. The average duration of a test will be based on actual plant experience as estimated by:

$$t_T = \frac{1}{N} \sum_{i=1}^{N} t_i \qquad (11)$$

Where:

t_i = Individual test duration time

N = Total number of tests in the sample

For reliable estimates, N should be larger than 10. The interval between tests (T_T) shall be determined from the plant's procedures.

C.2 TREATMENT OF COMMON CAUSE IN FAULT TREE MODELS

Purpose

The purpose of this notebook is to describe the methodology for the treatment of common cause failures (CCFs) in fault tree models and provide sufficient background information to conduct a consistent and technically accurate availability/risk analysis. These types of dependent failures are typically analyzed as part of a systems (fault tree) analysis and often represent the dominant contributors to system failure. The Multiple Greek Letter (MGL) method is recommended for the PRA.

C.2.1 INTRODUCTION AND BACKGROUND

The term "common cause failure" (CCF) is widely employed to describe events involving hardware failures or unavailabilities, which are the result of the sa me (single) cause. Equipment redundancy, which has been utilized to avoid system and functional level failures, is potentially susceptible to this kind of event. Because dependent failures are extremely important in system unavailability quantifications, adequate treatment of CCFs must be given to avoid a possible underestimation of system unavailability.

For this study, component-related CCFs will be explicitly quantified using the MGL Method applied to each system, for each distinct set of mission success requirements arising from distinct accident initiators.

This notebook provides a procedure for the calculation of CCFs using the MGL method and the recommended factors to use in the calculation.

Background

The treatment of common cause in fault tree models and the specific use of the MGL method for this study is consistent with Westinghouse and industry practice. The following describes the MGL method and its relation to the beta-factor method.

The MGL method is an extension of the beta-factor method. In the MGI method, other parameters in addition to the beta-factor are introduced to distinguish among common cause events affecting larger numbers of components in a higher order redundant system.

The beta-factor method assumes that Q, the total (constant) failure probability rate for each component, may be expanded into independent and dependent failure contributions:

$$Q - Q_r + Q_{cc}$$

Where:

Q_r = Failure probability for independent failures

Q_{cc} = Unit failure probability for dependent failures

For convenience, a parameter, b, is defined as the fraction of the total failure probability of a component attributable to dependent failures:

$$b = \frac{Q_{cc}}{Q_r + Q_{cc}} = \frac{Q_{cc}}{Q}$$

so that $Q_{cc} = bQ$

The MGL parameters are an extension of the beta factor and consist of a set of failure fractions (or extended beta-factors) used to quantify the conditional probabilities of all the possible ways a CCF of a component can be shared with other components in the same group, given component failure has occurred. For a system of "m" redundant components and for each given failure mode, "m" different parameters are defined.

For the MGL Method, different beta-factors are used to describe dual and multiple component dependencies:

$b = b_2 =$ Failure of exactly two components due to common cause

$b_3 =$ Failure of exactly three components due to common cause

$b_4 =$ Failure of exactly four components due to common cause

In general:

$b_i =$ Fraction of total failures of a given train/component that will result in the dependent failure of another i-1 specific trains/components

These fractions are easy to use as a multiplier for a total failure probability or unavailability. This fraction is used only for similar, applicable component populations, to properly represent the magnitude of the common cause effects. The beta-factors are defined and used as the conditional probability of a common cause initiated failure of a component, given that a "similar" component has failed.

C.2.2 APPLICATION AND DATA BASE

This section identifies the approach for the application of the MGL Methodology to FTA for both two and multiple component dependencies.

Two Component Dependencies

For a system (or cut-set) containing two parallel and identical components and with a success criteria of either of the two components functioning, the unavailability of the system due to independent (random) failures is simply:

$$Q\text{-}Q_a{*}Q_b$$

Where:

$Q_a =$ Total failure probability of component "a"

Q_b = Total failure probability of component "b"

To account for component failure dependencies, the CCF contribution can be simply calculated as:

$$Q_{cc} = b^* Q$$

Multiple Component Dependencies

The treatment of multiple component dependencies is similar to that for the treatment of dual components in that both independent and dependent failures must be considered. To properly account for component failure dependencies, the CCF contribution can be simply calculated as:

Q_{cc} = SUM [Common Cause Failure Contribution of Each Combination of Two Components (applying b) * Random Failure Contribution of Remaining Components] +

SUM [Common Cause Failure Contribution of Each Combination of Three Components (applying b_3) * Random Failure Contribution of Remaining Components] + etc.

Higher order beta-factors were defined earlier to accommodate for the dependency potential between multiple parallel trains/components. In general, to apply these beta-factors for higher order systems, the equations in Table C-4 may be useful. These are derived from combinations of component dependent failures and independent failures.

The dependency data used for the treatment of common cause in fault tree models for the PRA is consistent with Westinghouse and industry practice and is included in Table C-4.

C.2.3 REFERENCES

1. Pickard, Lowe and Garrick, "Procedures for Treating Common Cause Failures in Safety and Reliability Studies, Procedural Framework and Examples," EPRI NP-5613, Volume 1, February 1988 (also under NUREG/CR-4780).

2. Pickard, Lowe and Garrick, K. N. Fleming, et al., "Classification and Analysis of Reactor Operating Experience Involving Dependent Failures," EPRI NP-3967, Sponsored by Electric Power Research Institute, June 1985.

3. A Study of Common Cause Failures, Phase 1: A Classification System," EPRI NP-3383, Los Alamos Technical Associates, Inc., January 1984.

4. A Study of Common Cause Failures, Phase 2: A Comprehensive Classification System for Component Fault Analysis," EPRI NP-3837, Los Alamos Technical Associates, Inc., June 1985.

Table C-1

SYSTEM IDENTIFICATION CODES

Code Letter	System
W	Waste Hoist
C	C&SH Hoist
H	HVAC
E	Electrical
F	Fire Detection and Suppression
R	Radiation Detection
A	Compressed Air
M	Central Monitoring System

Table C-2

COMPONENT IDENTIFICATION CODES

Code Letters	Component Identification
	Mechanical Components
AC	Actuator
BC	Brake Caliper
BD	Disc Brakes
BL	Blower
BV	Ball Valve
CL	Cylinder, Piston
CM	Air Compressor
DA	Damper
XJ	Expansion Joint
FL	Strainer
GB	Glass Bottle
GK	Gasket
HX	Heat Exchanger
LI	Lilly Controller
NZ	Nozzle
OR	Orifice
PP	Pipe
CP	Pipe Cap
PV	Pressure Vessel
PM	Motor-Driven Pump
RF	Refrigeration Unit/Air Cooler
TK	Tank
TG	Tubing
VP	Vacuum Pump
VA	Valve Actuator
CV	Valve, Check
EV	Valve, Explosive Operated
HV	Valve, Hydraulic Operated
XV	Valve, Manual
MV	Valve, Motor Operated
FV	Valve, Flow Control
RR	Valve, Pressure Control (reducing regulator)
AV	Valve, Relief Pneumatic or Hydraulic Operated
AS	Valve, Relief Solenoid Operated
AM	Valve, Relief Mechanical Operated
SV	Valve, Solenoid Operated
KV	Valve, Stop Check
VV	Valve, Vacuum Relief
VT	Vent
WL	Well
	Electrical Components
AA	Audible Alarm
AX	Auxiliary Switch

Table C-2

COMPONENT IDENTIFICATION CODE

Code Letters	Component Identification
BY	Battery
BC	Battery Charger
BS	Bus
CA	Cable
CB	Circuit Breaker
CL	Clutch
CS	Control Switch
CO	Coil
DI	Detector
DE	Diode or Rectifier
FS	Flow Switch
FU	Fuse
GE	Generator
GS	Ground Switch
HG	Heating Element
HT	Heat Tracing Heating Element
IM	Input Module
IV	Inverter
ES	Level Switch
LT	Light Bulb
LA	Lightning Arrester
LS	Limit Switch
LO	Lockout Relay or Switch
SW	Manual Switch (Push Button)
SR	Manual Switch (Rotary)
MO	Motor
MG	Motor-Generator
MS	Motor Starter
PT	Potentiometer
PI	Power Interface Module
PS	Pump Starter
RC	Recorder
RE	Relay
RL	Relay (Latching Type)
CN	Relay or Switch Contact
RS	Reset Switch
RT	Resistor, Temperature Device
AD	Signal Comparator
SE	Sensor
SW	Switch
SP	Switch, Pressure
SQ	Switch, Torque
ST	Switch, Temperature
TM	Terminal Board
SB	Test Push-button Switch
OL	Thermal Overload Element

Table C-2

COMPONENT IDENTIFICATION CODE

Code Letters	Component Identification
TI	Timer
CT	Transformer, Current
OT	Transformer, Potential
TR	Transformer, Power
TF	Transmitter, Flow
TL	Transmitter, Level
TP	Transmitter, Pressure
TD	Transmitter, Differential Pressure
TT	Transmitter, Temperature
WR	Wire
VR	Protective Relay, Undervoltage
PR	Protective Relay, Overcurrent
FR	Protective Relay, Underfrequency
RM	Radiation Monitor
SD	Solid State Device
TX	Proximity Sensor
ZS	Position Switch
	General
AC	Accumulator
AL	Alarm
AS	Air Supply System
CA	Actuation Circuit
CC	Control Circuit
CE	Calibration
CP	Control Power
CR	CRT - Cathode Ray Tube
DB	Backdraft Damper
DG	Diesel Generator
DL	Door Latch
DP	Differential Pressure Sensor
DR	Door
DS	Door Seal
DT	Tornado Damper
DY	Air Dryer
EG	General Instrumentation
FA	Fan
FC	Flow Controller
FI	Filter
IL	Indicator Light
IS	Instrumentation - Sensor
MC	Motor Control Center
MT	Maintenance
PC	Power Cable

Table C-2

COMPONENT IDENTIFICATION CODE

Code Letters	Component Identification
PR	Printer (Alarm Printer)
SM	Seismic Monitoring System
WF	Trap Float
WT	Water Trap
SN	Air Sampling Nozzle
SH	Sprinkler Head
HL	Halon System
DC	Dry Chemical System
FX	Fire Extinguisher
HR	Hose Reel

Table C-3

FAILURE MODE IDENTIFICATION CODES

Code Letters	Failure Mode
FS	Does Not Start (Fails to Start)
ST	Open Circuit
CC	Closed Fails Closed (Fails to Open)
MP	Mispositioned After Test
FA	Loss of Function (i.e., Does Not Operate)
MP	Mispositioned after Maintenance
HE	Erroneous Human Actions (Errors)
IN	Interference
DE	Degarded
OO	Open Fails Open (Does Not Close or Fails to Close)
LK	Leakage
MT	Maintenance
NI	No Input
OO	Open
PL	Plugged
SC	Short Circuit
RU	Rupture
SG	Short to Ground
TS	Test
CO	Closed Fails Open (Spurious Opening or Opens Prematurely)
OC	Open Fails Closed (Spurious Closing or Fails Closed)
FR	Fails to Run (Does Not Run, e.g., Pumps, Fans and Generators, Compressors)
SP	Short to Power
CM	Common Cause (Common Mode Failure)
LP	Loss of Power

Table C-4

EQUATIONS USEFUL FOR COMMON CAUSE CALCULATIONS USING THE MULTIPLE GREEK LETTER METHOD

FAILURE CRITERIA	SUCCESS CRITERIA	COMMON CAUSE CONTRIBUTION
2/2	1/2	$b*Q$
3/3	1/3	$3*b*Q^2 + b_3*Q$
2/3	2/3	$3*b*Q + b_3*Q$
4/4	1/4	$6*b*Q^3 + 4*b_3*Q^2 + b_4*Q$
3/4	2/4	$12*b*Q^2 + 4*b_3*Q + b_4*Q$
2/4	3/4	$6*b*Q + 4*b_3*Q + b_4*Q$

Where Q = total unavailability for the particular component and failure mode

Figure C-1

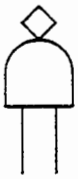
Commonly Used Fault Tree Symbols

THE BASIC EVENT. THE CIRCLE DESCRIBES A BASIC INITIATING FAULT EVENT THAT REQUIRES NO FURTHER DEVELOPMENT. THE CIRCLE THUS SIGNIFIES THAT THE APPROPRIATE LIMIT OF RESOLUTION HAS BEEN REACHED.

NOR GATE. A NOR GATE HAS A SINGLE OUTPUT HAVING TWO MANDATORY INPUTS. THE BOOLEAN EXPRESSION IS $\overline{A+B}$.

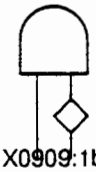
OR GATE. THE OR GATE IS USED TO SHOW THAT THE OUTPUT EVENT OCCURS IF AND ONLY IF ONE OR MORE OF THE INPUT EVENTS OCCUR. THERE MAY BE ANY NUMBER OF INPUTS TO AN OR GATE.

NOT GATE. A LOGIC NOT IS WHERE A SINGLE OUTPUT HAS A VALUE OF 1 MINUS THE INPUT VALUE.

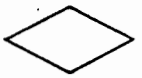


NAND GATE. A NAND GATE HAS A SINGLE OUTPUT HAVING TWO MANDATORY INPUTS. THE BOOLEAN EXPRESSION IS $\overline{A*B}$.

ONOT GATE. A LOGIC ONOT HAS A SINGLE OUTPUT WITH TWO INPUTS EVALUATED AS A OR NOT B.



ANOT GATE. A LOGIC ANOT HAS A SINGLE OUTPUT WITH TWO INPUTS EVALUATED AS A AND NOT B.



THE UNDEVELOPED OR SYSTEM EVENT. THE DIAMOND DESCRIBES A SPECIFIC FAULT EVENT THAT IS NOT FURTHER DEVELOPED, EITHER BECAUSE THE EVENT IS OF INSUFFICIENT CONSEQUENCE OR BECAUSE RELEVANT INFORMATION IS NOT AVAILABLE.

INTERMEDIATE EVENT. AN INTERMEDIATE EVENT IS A FAULT EVENT THAT OCCURS BECAUSE OF ONE OR MORE ANTECEDENT CAUSES ACTING THROUGH LOGIC GATES. IT IS SOMETIMES REFERRED TO AS A DESCRIPTION BOX.

COMBINATION GATE. A MODIFIED 'AND' HAVING A SINGLE OUTPUT AND FROM TWO TO EIGHT INPUTS. A USER-SPECIFIED COMBINATION OF INPUT EVENT FAILURES IS REQUIRED TO PRODUCE A FAILED OUTPUT STATE. TEXT WITHIN THE SMALL BOX TO THE RIGHT OF THE COMBINATION SYMBOL IS LIMITED TO THE EXACT COMBINATION REQUIRED FOR A FAULT TO OCCUR, IN THE FORM 'M OUT OF N' INPUT FAILURES PRODUCE THE OUTPUT FAILURE.

AND GATE. THE AND GATE IS USED TO SHOW THAT THE OUTPUT EVENT OCCURS IF AND ONLY IF ALL OF THE INPUT EVENTS OCCUR. THERE MAY BE ANY NUMBER OF INPUTS TO AN AND GATE.

TRANSFER SYMBOLS. TRIANGLES ARE SYMBOLS AND ARE USED AS A MATTER OF CONVENIENCE TO AVOID EXTENSIVE DUPLICATION IN THE FAULT TREE. A LINE FROM THE APEX OF THE TRIANGLE DENOTES A TRANSFER IN, AND A LINE FROM THE SIDE OF THE TRIANGLE DENOTES A TRANSFER OUT. A TRANSFER IN ATTACHED TO A GATE WILL LINK TO ITS CORRESPONDING TRANSFER OUT. THIS TRANSFER OUT, PERHAPS ON ANOTHER PAGE, WILL CONTAIN A FURTHER PORTION OF THE TREE DESCRIBING INPUT TO THE GATE.

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APPENDIX D
FAULT TREE DATA NOTEBOOK

This section presents the reliability data used in the fault tree modeling. All assumptions and references for the reliability data are also given. The reliability data base used in the GRAFTER (TM) Code System, SIMON, is printed in its entirety.

D.1 INTRODUCTION AND PURPOSE

The purpose of this section is to document the master data file (SIMON.DAT) used for all of the fault tree quantifications performed for the PRA. As part of this documentation in fulfillment of the QA requirements of this project, a clear basis and complete traceability is provided for all data derived from the various reference sources used for this project.

Table D-1 presents Vendor and Engineering Judgment used for unique WIPP-Specific Components in the Reliability Data Base.

D.2 CONVERSION OF DATA TO LOGNORMAL MEANS

An examination of the documentation for IEEE Std. 500-1984 revealed that the recommended failure rate for each component provided in the document is not consistently derived. IEEE-500 did not clearly identify the basis for the recommended values (i.e., mean, median, or otherwise). In some cases, the recommended failure rate is the lognormal median, and in other cases it is lower or higher than the lognormal median. In order to resolve this discrepancy, a standard method of checking and deriving failure rates from IEEE-500 was used for the PRA, so that where possible, a lognormal mean or a conservatively greater recommended value was used as the mean failure rate.

Where upper and lower confidence intervals are given for a component failure rate, a check is made to determine if the recommended value is the lognormal median for the data. The check is made as follows:

$$(\text{Lower Bound} * \text{Upper Bound})^{1/2} = \text{Lognormal Median}$$

In order to derive the lognormal mean from the median, the following calculations are used.

z = 1.645 (IPEM - Upper 95 percent Confidence Limit - Consistent with Lognormal Distribution)

$e^{z\theta}$ = (Upper Bound/Median) = Error Factor [IPEM]

$e(\mu + z\theta)$ = Upper Bound [IPEM]

Mean $(\lambda) = e(\mu + \theta^{2/2})$ [IPEM]
Where μ is the population mean and θ is the standard deviation.

IPEM - Individual Plant Evaluation Methodology for Pressurized Water Reactors, Revision 3, December 1986, page 2-287 and 2-288.

Once the lognormal mean is calculated, it is compared to the recommended value from IEEE-500, and the greater of the two is used. There is typically a minimal difference between the two values and the use of the larger value is more accurate (conservative) and not expected to impact the overall conclusions of the study.

The above calculations were performed using a LOTUS 1-2-3 worksheet on an IBM PC for ease in performing the calculations on a large number of data points from IEEE-500. The low, recommended, and high failure rates are input for each component, and the worksheet applies the above equations and logic to deduce the mean failure rate for use in the PRA.

If no high and low confidence intervals are given for the data, the lognormal mean and median cannot be calculated. In this case, it is assumed that the recommended value is the conservative best-estimate failure rate, since no other data can be used to modify the recommended value. This was not necessary for most data entries.

The above calculations were used to provide consistency in the derivation of data from IEEE-500. However, this technique could be applied to other data sources if the recommended value is not explicitly stated to be the mean failure rate for the component. Of all the data sources utilized for the PRA, only IEEE-500 was judged to be sufficiently unclear in the basis for the recommended values to necessitate the application of this procedure.

Table D-2 summarizes the calculations performed for the PRA. For entries where the lower bound was too low (or zero) or if the range (i.e., difference between upper and lower bounds) was too large, the statistical validity of the distribution was questioned and the IEEE-500 recommended value was used directly.

D.3 MASTER DATA FILE FOR WIPP INTEGRATED RISK ASSESSMENT

The purpose of this section is to present the master data file for the project, provide guidance in its interpretation and use, and identify the basis for this data.

Table D-3 presents the master data file with its many data entries. Each entry contains (from left to right) a reference number, probability value, variance (zero for this study - uncertainty analysis outside scope), units indicator (1 - failures per hour, 2 - failures per demand), reference source, component type, system applicability, and description of the component/failure mode. Each of these data entries is used by the SIMON input file, which acts as a pointer file to couple the appropriate failure within a fault tree with the appropriate data from this master data file. Time periods are contained in the SIMON input file if the data entry from the master data file is an hourly rate.

References for the data sources (e.g., IEEE, 1400, etc.) are provided. Where applicable, the specific page number within the data source is also identified. The probability values for each entry are taken directly from the source except for IEEE-500 data which may have been modified to account for the specific properties of the statistical distribution (see Section D.3).

Other sources such as "CALC" or "4.3" indicate that the data was derived from calculations described in the system notebook or in a specific section of the PRA.

D.4 REFERENCES

1. Ernest J. Henley, Kumamoto Hiromitsu, Reliability Engineering and Risk Assessment, Prentice Hall, Inc., 1981.

2. H. P. Bloch and F. K. Geitner, "Practical Machinery Management for Process Plants," Volumes 1 and 2, Gulf Publishing Company.

3. Frank P. Lees, Loss Prevention in the Process Industries, Vol. 1 and 2, Butterworth & Co. Ltd., 1980.

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6. Common Cause Fault Rates for Valves, (NUREG/CR-2770) Nuclear Regulatory Commission, February 1983.

7. A. D. Swain and H. E. Guttman, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications (NUREG/CR-1278), prepared for the Nuclear Regulatory Commission, August 1983.

8. IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear - Power Generating Stations, (IEEE Std. 500 - 1984), Institute of Electrical and Electronics Engineers, Inc. John Wiley & Sons, Inc., 1983.

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10. A. E. Green and A. J. Bourne, Reliability Technology, 1972.

11. Nonelectric Reliability Notebook, Rome Air Development Center, Griffiss Air Force Base, NY, RADC-TR-75-22, January 1985.

12. Reactor Safety Study, Appendix III, WASH-1400, October 1975.

13. "WIPP CH PRA - Fault Tree Data Compilation," CN-HM-89-009, March 1989.

TABLE D-1

VENDOR INFORMATION AND ENGINEERING JUDGMENT USED FOR WIPP-SPECIFIC COMPONENTS RELIABILITY DATA BASE

Component Number	System	Failure Mode	Failure Rate	(HR-Hour) (D-Demand)	Source
20	SH	Safety Dogs Fail	1.0E-04	D	WIPP Engineering
29	SH	Lilly Controller Fails	2.9E-04	D	TME-063
30	SH	Cable Break	8.8E-03	D	TME-063
34	SH	Hoistman Fails to Open Manual Dump Valve	1.3E-02	D	Westinghouse Engineering
39	SH	Percentage of time hoist is travelling up or down	1.7E-01	D	WIPP Engineering
78	WH	Fraction of time Hoisting CH TRU Waste	2.5E-01	D	WIPP Engineering
79	WH	Fraction of time Hoisting Personnel or Material	6.9E-01	D	WIPP Engineering
80	WH	Fraction of time Hoisting RH Waste	6.1E-02	D	WIPP Engineering
162	HVAC	Human Error	4.7E-04	D	Westinghouse Engineering
170	ELEC	Operator Fails to take Action	1.1E-02	D	Westinghouse Engineering
183	CA	Human Error Operating Manual Valve	1.1E-04	D	Westinghouse Engineering

CA - Compressed Air
SH - Salt Handling Hoist
WH - Waste Hoist
HVAC - Heating, Ventilation, and Air Conditioning Systems (Underground and Waste Handling)
ELEC - Electrical Systems

TME-063, Probability of a Catastrophic Hoist Accident at the Waste Isolation Pilot Plant, WIPP Engineering, July 1985.

TABLE D-2

CONVERSION OF SELECT IEEE-500 DATA TO LOGNORMAL MEANS

COMPONENT	SIMON NUMBER	IEEE PG	LB	REC	UB	MEDIAN CALC	MEAN CALC	PRA VALUE	SIGMA
ALARM KLAXON	123	53	1.10E-07	2.30E-07	7.60E-06	9.14E-07	2.09E-06	2.09E-06	1.287352
RELAY (COMP)	35	154	0.00E+00	1.36E-06	4.75E-06			1.36E-06	
RELAY (COMP)	38	154	0.00E+00	1.36E-06	4.75E-06			1.36E-06	
RELAY PROTECTIVE CTRL AUX	67	163	0.00E+00	1.36E-06	4.75E-06			1.36E-06	
RELAY SWITCHGEAR	114	184	0.00E+00	7.00E-06	1.00E-05			7.00E-06	
RELAY SWITCHGEAR	141	184	0.00E+00	7.00E-06	1.00E-05			7.00E-06	
RELAY SWITCHGEAR	155	184	0.00E+00	7.00E-06	1.00E-05			7.00E-06	
RELAY LATCHING	105	212	1.00E-08	1.80E-07	1.80E-04			1.80E-07	2.978154
RELAY LATCHING	154	212	1.00E-08	1.80E-07	1.80E-04			1.80E-07	2.978154
CIRCUIT BREAKER TYPE MOTOR STARTER	140	214.10	5.00E-08	6.70E-07	1.50E-06	2.74E-07	4.67E-07	6.70E-07	1.033798
SWITCH (COMP)	40	214.16	0.00E+00	1.00E-08	1.10E-07			1.00E-08	
POWER SWITCH (COMP)	118	214-38	1.00E-08	2.34E-06	3.62E-06	1.90E-07	9.46E-07	2.34E-06	1.790773
AC MOTOR HP 110 VAC	60	222	3.00E-07	3.12E-06	1.21E-05	1.91E-06	3.58E-06	3.58E-06	1.123726
SOLENOID OPERATED VALVE	88	449	2.60E-07	7.10E-07	2.08E-06	7.35E-07	8.98E-07	8.98E-07	0.632049
SOLENOID NORMALLY CLOSED	51	450	5.60E-07	2.05E-06	7.55E-06	2.06E-06	2.81E-06	2.81E-06	0.790638
PNEUMATIC PISTON ACTIVATOR	16	475	2.50E-07	7.50E-07	2.30E-06	7.58E-07	9.52E-07	9.52E-07	0.674529
PROCESS SWITCH TEMPERATURE	189	535	5.00E-08	2.20E-07	3.20E-07	1.26E-07	1.48E-07	2.20E-07	0.564224
PROCESS SWITCH FLOW/VELOCITY	190	578	8.00E-08	9.80E-07	1.81E-06	3.81E-07	5.96E-07	9.80E-07	0.948041
DISPLACEMENT SENSOR	61	605	7.60E-07	2.83E-06	8.25E-06	2.50E-06	3.26E-06	3.26E-06	0.724817
SEISMIC INSTRUMENTATION	136	614	8.10E-07	3.37E-06	1.30E-05	3.24E-06	4.63E-06	4.63E-06	0.843230
ELECTRIC ON-OFF INDICATOR	153	645	1.77E-06	5.90E-06	1.77E-05	5.60E-06	7.15E-06	7.15E-06	0.699873
POWER CABLES	147	747	7.10E-07	4.84E-06	1.75E-04	1.11E-05	4.52E-05	4.52E-05	1.673944
PNEUHATIC ACTUATOR	144	822	1.21E-06	2.01E-06	1.57E-05	4.37E-06	5.92E-06	5.92E-06	0.780006
AMPER ACTUATOR PNEUMATIC 25PSI	130	823	1.21E-06	1.73E-06	2.41E-06	1.71E-06	1.75E-06	1.75E-06	0.209424
NEUMATIC ACT 3"D 125PSI 8X14.5	9	825	9.50E-06	1.22E-05	1.57E-05	1.22E-05	1.24E-05	1.24E-05	0.153662
PNEUMATIC ACT. 3"D 125PSI 8X30	11	825	9.50E-06	1.22E-05	1.57E-05	1.22E-05	1.24E-05	1.24E-05	0.153662
STNDBY MOTOR DRIVEN POS DISPL PUMP	180	879	0.00E+00	1.60E-03	2.10E-02			1.60E-03	
CENTRIFUGAL PMP 20GPH 50FTHD 3HP	181	902		1.10E-05				1.10E-05	
VALVE (COMP)	129	1014	3.00E-08	1.39E-06	3.23E-03			1.39E-06	3.521822
MANUAL OPERATED VALVE	139	1016		2.30E-08				2.30E-08	
MOTOR OPERATED VALVES	86	1023		6.00E-08				6.00E-08	
PRESSURE RELIEF VALVE	178	1034		5.00E-06				5.00E-06	
FLOAT OPERATED VENT VALVE 3/4IN	185	1035		3.11E-06				3.11E-06	
BALL VALVE	52	1044		6.50E-07				6.50E-07	
CHECK VALVE	18	1066		6.00E-05				6.00E-05	
CHECK VALVE	77	1066		6.00E-05				6.00E-05	
GATE VALVE 1/2-2 IN 200LBS	36	1112	6.00E-07	2.10E-07	9.20E-07	7.43E-07	7.49E-07	7.49E-07	0.129922
GATE VALVE SOLENOID 4-11.99 IN	121	1124	1.79E-05	2.97E-05	4.61E-05	2.87E-05	2.99E-05	2.99E-05	0.287541
GLOBE VALVE SOLENOID 2-3.99 IN	71	1150	7.20E-07	2.89E-06	1.16E-05	2.89E-06	4.13E-06	4.13E-06	0.844835
GLOBE VALVE SOLENOID 2-3.99 IN	50	1150	7.20E-07	2.89E-06	1.16E-05	2.89E-06	4.13E-06	4.13E-06	0.844835
NEEDLE VALVE	54	1166		1.36E-06				1.36E-06	
NEEDLE VALVE 1/2-1.99 IN	12	1173	1.20E-07	4.90E-07	1.96E-06	4.85E-07	6.95E-07	6.95E-07	0.848979
DAMPER (COMP)	112	1226	1.21E-06	1.37E-06	2.68E-06	1.80E-06	1.85E-06	1.85E-06	0.241731
DAMPER	117	1227		1.21E-06				1.21E-06	
DAMPER SHUT-OFF 2 POS PARL BLADE	122	1227		1.21E-06				1.21E-06	
DAMPER AUTO BAKDRFT PARL SLADE	116	1229		1.21E-06				1.21E-06	
AIR COMP RECIP 125PSI 3000CFH 2STG	179	1245		1.93E-04				1.93E-04	
AIR COMPRESSOR AXIAL	187	1248		3.80E-05				3.80E-05	
FAN CENTRIFUGAL	115	1252		3.04E-06				3.04E-06	
EXHAUST FAN	107	1256		2.71E-06				2.71E-06	
HYDRAULIC SNUBBER	62	1292	1.90E-06	2.53E-06	3.16E-06	2.45E-06	2.48E-06	2.53E-06	0.154625
NOZZLE 4 INCH/SAFE IND	101	1329	5.26E-06	1.75E-05	1.75E-03	9.59E-05	4.56E-04	4.56E-04	1.765118
HEAT EXCH, STRT TUBE RADIA	175	1361	1.59E-06	3.18E-06	7.16E-06	3.37E-06	3.75E-06	3.75E-06	0.457378
HEAT EXCH STRT TLBE HORZ SHEL&TUBE	176	1363	2.08E-06	4.18E-06	7.31E-06	3.90E-06	4.19E-06	4.19E-06	0.382028
MECH RESTRIC STRAINER Y PAT 1.8 IN	177	1402	6.00E-07	1.43E-06	4.22E-06	1.59E-06	1.90E-06	1.90E-06	0.592906
HYDRAULIC FLUID FILTER	188	1410	5.92E-06	7.43E-06	9.98E-06	7.69E-06	7.78E-06	7.78E-06	0.158757
AIR FILTER (COMP)	113	1412	1.56E-06	2.55E-06	1.81E-06	1.68E-06	1.68E-06	2.55E-06	0.045177
FILTER, 1 IN.100PSI	3	1415		4.76E-06				4.76E-06	
FILTR A/C - PRE24X24X2" 2000CFM	186	1417	1.59E-06	1.69E-06	1.81E-06	1.70E-06	1.70E-06	1.70E-06	0.039329

TABLE D-3

PROJECT MASTER DATA FILE

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'DATA FILE FOR WIPP ANALYSIS FROM COMBO OF PREVIOUS ANALYSES - 9/13/89'
177  137
  3  4.8E-06  0.0E+00  1 'IEEE' 'FI' 'C&SH' 'AIR FILTER FAILS-ALL MODES,P 1415'
  6  1.0E-06  0.0E+00  1 'CALC' 'TK' 'C&SH' 'AIR STORAGE TANK RUPTURES'
  8  1.0E-03  0.0E+00  2 '1400' 'SV' 'C&SH' '2-WAY SOLENOID VALVE(24V) FAILS TO OPERATE,APPENDIX III'
  9  1.2E-05  0.0E+00  1 'IEEE' 'CL' 'C&SH' '8X30INCH STROKE CYLINDER(WEIGHT ENGINE)FAILS,ALL MODES,P825'
 10  1.0E-05  0.0E+00  2 '1400' 'SV' 'C&SH' '3-WAY SOLENOID VALVE(24V) FAILS TO OPERATE ON DEMAND,APPENDIX III'
 11  1.2E-05  0.0E+00  1 'IEEE' 'CL' 'C&SH' '8X14.5 INCH STROKE CYLINDER(PRESSURE ENGINE)FAILS ALL MODES,P825'
 12  7.0E-07  0.0E+00  1 'IEEE' 'XV' 'C&SH' 'NEEDLE VALVE FOR FLOW CONTROL FAILS,ALL MODES,P1173'
 16  9.5E-07  0.0E+00  1 'IEEE' 'SV' 'C&SH' 'SOLENOID-PILOT,AIR OPERATED VALVE(VH,MVX) FAILS TO OPERATE,P475'
 17  3.0E-04  0.0E+00  2 '1400' 'LS' 'C&SH' 'LIMIT SWITCH FAILS TO OPERATE,APPENDIX III'
 18  6.0E-05  0.0E+00  2 'IEEE' 'CV' 'C&SH' 'CHECK VALVE FAILS TO OPERATE,P1066'
 20  1.0E-04  0.0E+00  2 'CALC' 'DO' 'C&SH' 'SAFETY DOGS FAIL - PER AL VARGA, WIPP, MAY 1988'
 21  1.2E-07  0.0E+00  1 'CALC' 'CL' 'C&SH' 'BOTH BRAKE PISTONS JAM DUE TO COMMON CAUSE'
 22  3.8E-08  0.0E+00  1 'CALC' 'AV' 'C&SH' 'BOTH AIR VALVES LMV-2 AND LMV-3A FAIL DUE TO COMMON CAUSE - SEE TEXT'
 24  3.0E-04  0.0E+00  2 '1400' 'LS' 'C&SH' 'LOWER TRACK LIMIT SWITCH FAILS TO OPERATE,APPENDIX III'
 26  3.0E-06  0.0E+00  2 '1400' 'LS' 'C&SH' 'MAGNETIC PROXIMITY SWITCH FAILS TO OPERATE,APPENDIX III'
 28  1.0E-05  0.0E+00  2 '1400' 'RR' 'C&SH' 'PRESSURE CONTROL VALVE(PRV-1) FAILS,APPENDIX III'
 29  2.9E-04  0.0E+00  2 'CALC' 'LI' 'C&SH' 'LILLY CONTROLLER FAILS,TME-063 P30'
 30  8.8E-03  0.0E+00  2 'CALC' 'CA' 'C&SH' 'CABLE BREAK,TME-063 P26 (FAILURES / YR)'
 31  3.0E-06  0.0E+00  2 'CALC' 'CV' 'C&SH' 'BOTH CHECK VALVES CVR4 AND CVL4 FAIL CLOSED DUE TO COMMON CAUSE'
 32  1.0E-05  0.0E+00  2 '1400' 'RR' 'C&SH' 'PRESSURE CONTROL(RELIEF) VALVE PRV-1FAILS,APPENDIX III'
 33  1.0E-05  0.0E+00  1 '1400' 'MO' 'C&SH' 'ELECTRIC MOTOR FAILS TO RUN,APPENDIX III'
 34  1.3E-02  0.0E+00  2 'CALC' 'HE' 'C&SH' 'HOISTMAN FAILS TO OPEN MANUAL DUMP VALVE - IN REPORT, SECTION 4.4.8.2'
 35  1.4E-06  0.0E+00  2 'IEEE' 'RE' 'C&SH' 'CONTROL RELAY FOR WEIGHT ENGINE FAILS CLOSED ON DEMAND,P154'
 36  7.5E-07  0.0E+00  1 'IEEE' 'XV' 'C&SH' 'GATE VALVE(XVL5 OR XVR5) TRANSFERS CLOSES,P1112'
 37  9.0E-02  0.0E+00  2 'CALC' 'LP' 'C&SH' 'LOSS OF SITE POWER TO HOIST MOTOR'
 38  1.4E-06  0.0E+00  2 'IEEE' 'RE' 'C&SH' 'HOIST PROCESS CONTROLLER RELAY FAILS CLOSED ON DEMAND,P154'
 39  1.7E-01  0.0E+00  2 'CALC' 'SK' 'C&SH' 'PERCENTAGE OF TIME HOIST IS TRAVELLING WHILE IN OPERATION, WIPP ENGIN'
 40  1.0E-08  0.0E+00  2 'IEEE' 'SW' 'C&SH' 'MEMORY PROXIMITY LIMIT SWITCH FAILS TO CLOSE ON DEMAND,P 214-16 ADDEND'
 50  4.1E-06  0.0E+00  1 'IEEE' 'SV' 'WH  ' 'SOLENOID OPERATED VALVE FAILS TO OPERATE,Pg 1150'
 51  2.8E-06  0.0E+00  2 'IEEE' 'SV' 'WH  ' 'NEW DUMP VALVE PROPOSED FOR SYSTEM FAILS TO OPERATE,Pg 450'
 52  6.5E-07  0.0E+00  1 'IEEE' 'XV' 'WH  ' 'BALL VALVE FAILED CLOSED,Pg 1044'
 53  3.0E-04  0.0E+00  2 'IREP' 'AV' 'WH  ' 'RELIEF VALVE FAILS TO OPEN'
 54  1.4E-06  0.0E+00  1 'IEEE' 'FV' 'WH  ' 'FLOW CONTROL VALVE (NEEDLE VALVE) FAILED CLOSED,Pg 1166'
 55  6.5E-06  0.0E+00  1 'ROME' 'AS' 'WH  ' 'ELCETRO-HYDRAULIC RELIEF VALVE FAILURE,Pg 2-291  '
 56  3.0E-06  0.0E+00  1 'ROME' 'FI' 'WH  ' 'FILTER PLUGGED,Pg 2-276                          '
 57  2.0E-06  0.0E+00  1 'NREP' 'CV' 'WH  ' 'CHECK VALVE FAILS TO CLOSE,2.4.2                  '
 58  7.4E-06  0.0E+00  1 'ROME' 'AC' 'WH  ' 'ACCUMULATOR,Pg 2-21                               '
 59  8.5E-09  0.0E+00  1 'MS-3' 'HX' 'WH  ' 'HEAT EXCHANGER TUBE SIDE PLUGS,FPL AFWS #32       '
 60  3.6E-06  0.0E+00  1 'IEEE' 'MO' 'WH  ' 'MOTOR COMPONENT(FAN) OF HEAT EXCHANGER AND FAN,Pg 222'
 61  3.3E-06  0.0E+00  1 'IEEE' 'SE' 'WH  ' 'OVERTRAVEL SENSOR-DISPLACEMENT SENSOR,Pg 605     '
 62  2.5E-06  0.0E+00  1 'IEEE' 'BD' 'WH  ' 'DISC BRAKE UNIT FAILS,Pg 1292'
 64  1.7E-07  0.0E+00  1 '4.3 ' 'HV' 'WH  ' 'ALL 4 HV FAIL DUE TO C.C '
 66  6.5E-08  0.0E+00  1 '4.3 ' 'XV' 'WH  ' 'TWO XV FAIL CLOSED IN C.C'
 67  1.4E-06  0.0E+00  2 'IEEE' 'RE' 'WH  ' 'PROTECTIVE RELAY FAILS TO OPEN,Pg 163'
 68  1.7E-07  0.0E+00  1 '4.3 ' 'SE' 'WH  ' '3 OVERTRAVEL SENSORS FAILING - VALUE FROM PG 605 * 0.04'
 70  1.0E-05  0.0E+00  1 'NREP' 'TI' 'WH  ' 'CONTROL TIMER FAILS TO TRANSFER, 4.8.2'
 71  4.1E-06  0.0E+00  1 'IEEE' 'SV' 'WH  ' 'SOLENOID OPERATED VALVE STICKS,Pg 1150'
 74  4.1E-07  0.0E+00  1 '4.3 ' 'HV' 'WH  ' '2 HYDRAULIC VALVES FAIL,BLOCKING FLOW DUE TO C.C'
 76  1.0E-08  0.0E+00  1 '1400' 'RE' 'WH  ' 'RELAY COIL SHORTS TO POWER,APP III'
 77  6.0E-05  0.0E+00  2 'IEEE' 'CV' 'WH  ' 'CHECK VALVE FAILS TO OPEN ON DEMAND,Pg 1066'
 78  2.5E-01  0.0E+00  2 '4.3 ' 'ET' 'WH  ' 'FRACTION OF TIME HOISTING CH-TRU WASTE, WIPP'
 79  6.9E-01  0.0E+00  2 '4.3 ' 'ET' 'WH  ' 'FRACTION OF TIME HOISTING PERSONNEL OR MATERIALS, WIPP'
 80  6.1E-02  0.0E+00  2 '4.3 ' 'ET' 'WH  ' 'FRACTION OF TIME HOISTING RH WASTE, WIPP'
 81  5.0E-02  0.0E+00  2 'WIPP' 'ET' 'WH  ' 'ANNUAL FREQUENCY OF LOSS OF ELECTRIC POWER'
 82  1.0E-03  0.0E+00  2 'WIPP' 'ET' 'WH  ' 'ANNUAL FREQUENCY OF HOIST MALFUNCTION'
 83  1.0E-03  0.0E+00  2 'WIPP' 'ET' 'WH  ' 'ANNUAL FREQUENCY OF CONTROLLER OR ELECTRICAL MALFUNCTION'
 84  6.9E-04  0.0E+00  2 'WIPP' 'ET' 'WH  ' 'ANNUAL FREQ OF OTHER CAUSES FOR UNPOWERED SCENARIOS'
 85  2.4E-10  0.0E+00  2 'WIPP' 'ET' 'WH  ' 'ANNUAL FREQ OF ALL THREE PAIRS OF CABLE'
 86  6.0E-08  0.0E+00  1 'IEEE' 'SV' 'WH  ' 'VALVES 45, 51, & 108 PLUG, PG 1023'
 87  2.8E-07  0.0E+00  2 '4.3 ' 'SV' 'WH  ' 'BOTH EMERGENCY DUMP VLVS FAILS TO DE-ENERGIZE,C.C'
 88  9.0E-07  0.0E+00  1 'IEEE' 'SV' 'WH  ' 'SOL.-OPER. VALVE 107.1/2 OPEN-FAILS-CLOSED - PG 449'
 89  1.0E+00  0.0E+00  2 '----' 'LG' 'WH  ' 'LOGICAL 1.0'
 90  0.0E+00  0.0E+00  2 '----' 'LG' 'WH  ' 'LOGICAL 0.0'
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TABLE D-3 (continued)

PROJECT MASTER DATA FILE

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900  0.0E-00  0.0E+00  2 '----'  ' '  'HVAC' 'USED FOR UNDEVELOPED SYSTEM EVENTS NOT IN SCOPE OF PROJECT'
100  1.0E-02  0.0E+00  2 '----'  '  '  'HVAC' 'HIGH FAILURE USED WITH LINKING PROCESS'
101  4.6E-04  0.0E+00  1 'IEEE' 'SN' 'HVAC' 'RADIATION SAMPLING NOZZLE FAILS BY PLUGGING      ,P1329'
102  3.0E-03  0.0E+00  2 'IREP' 'DA' 'HVAC' 'ISOLATION DAMPER FAILS ON DEMAND                 ,P129'
103  4.6E-05  0.0E+00  1 'CALC' 'CM' 'HVAC' 'COMMON CAUSE FAILURE OF RADMON SAMPLING NOZZLE, 0.1*ENTRY 101'
104  1.4E-08  0.0E+00  1 'DPNT' 'FI' 'HVAC' 'HEPA FILTER IN WHB RUPTURES/CLOGS FAULTS          ,P 18 '
105  1.8E-07  0.0E+00  1 'IEEE' 'RE' 'HVAC' 'NORMAL/FILTER MODE SWITCHOVER LATCH RELAY          ,P 212'
106  5.5E-06  0.0E+00  1 'DPNT' 'AS' 'HVAC' 'AIR SUPPLY SYSTEM FAILS                            ,P 10 '
107  2.7E-06  0.0E+00  1 'IEEE' 'FA' 'HVAC' 'EXHAUST FAN FAILS DUE TO LOCAL FAULTS             ,P 1256'
108  1.4E-05  0.0E+00  1 'DPNT' 'RM' 'HVAC' 'GEIGER-MUELLER DETECTOR FAILS                     ,P  17'
109  1.6E-05  0.0E+00  1 'DPNT' 'RM' 'HVAC' 'ALPHA CONTINUOUS AIR MONITOR DETECTOR FAILS       ,P  17'
111  1.0E-06  0.0E+00  1 'IREP' 'BY' 'HVAC' 'CAM BATTERY BACKUP FAILS TO PROVIDE PROPER OUTPUT,P 128'
112  1.9E-06  0.0E+00  1 'IEEE' 'DT' 'HVAC' 'TORNADO DAMPER FAILS DUE TO LOCAL FAULTS          ,P 1226'
113  2.6E-06  0.0E+00  1 'IEEE' 'FI' 'HVAC' 'SUPPLY AIR FILTER UNIT CLOGS                      ,P 1412'
114  7.0E-06  0.0E+00  2 'IEEE' 'RE' 'HVAC' 'SUPPLY/EXHAUST FAN INTERLOCK FAILS                 ,P184'
115  3.0E-06  0.0E+00  1 'IEEE' 'FA' 'HVAC' 'SUPPLY AIR HANDLING UNIT FAN FAILS DUE TO LOCAL FAULTS,P1252'
116  1.2E-06  0.0E+00  1 'IEEE' 'DB' 'HVAC' 'BACKDRAFT DAMPER FAILS CLOSED DUE TO LOCAL FAULTS,P1229'
117  1.2E-06  0.0E+00  1 'IEEE' 'DA' 'HVAC' 'PARALLEL BLADE DAMPER FAILS CLOSED               ,P 1227'
118  2.3E-06  0.0E+00  1 'IEEE' 'SW' 'HVAC' 'SWITCH FAILS DUE TO LOCAL FAULTS       ,P214-38 ADDENDUM'
119  3.0E-08  0.0E+00  1 'NREP' 'WR' 'HVAC' 'WIRING SHORTS TO POWER, 4.13.3                      '
120  7.0E-08  0.0E+00  1 'DPNT' 'FI' 'HVAC' 'HEPA FILTER IN EFB RUPTURES/CLOGS  (X 5)          ,P 18  '
121  3.0E-05  0.0E+00  1 'IEEE' 'SV' 'HVAC' 'SOLENOID VALVE FAILS DUE TO LOCAL FAULTS          ,P 1124'
122  1.2E-06  0.0E+00  1 'IEEE' 'DA' 'HVAC' 'MANUAL VOLUME DAMPER FAILS CLOSED                 ,P 1227'
123  2.1E-06  0.0E+00  1 'IEEE' 'AA' 'HVAC' 'AUDIBLE ALARM FAILS TO OPERATE ON DEMAND (KLAXON TYPE),P 53'
124  3.0E-07  0.0E+00  1 'IREP' 'WR' 'HVAC' 'WIRING SHORTS OR FAILS                             ,P 128'
129  1.4E-06  0.0E+00  1 'IEEE' 'VV' 'HVAC' 'VACUUM CONTROL VALVE FAILS DUE TO LOCAL FAULTS,  P 1014'
130  1.8E-06  0.0E+00  1 'IEEE' 'AC' 'HVAC' 'PNEUMATIC ACTUATOR FAILS DUE TO LOCAL FAULTS,     P 823'
132  1.0E-05  0.0E+00  1 'DPNT' 'DR' 'HVAC' 'AIRLOCK PERSONNEL DOOR PERIPHERAL SEAL LEAKS      P 17 '
133  5.0E-05  0.0E+00  1 'DPNT' 'DR' 'HVAC' 'AIRLOCK TRUCK DOOR PERIPHERAL SEAL LEAKS (#132 X 5) P 17'
134  1.0E-05  0.0E+00  1 'DPNT' 'DR' 'HVAC' 'NON-AIRLOCK PERSONNEL DOOR PERIPHERAL SEAL LEAKS  P 17 '
136  4.6E-06  0.0E+00  1 'IEEE' 'SM' 'HVAC' 'SEISMIC MONITORING SYSTEM ERROR                    ,P 614'
138  3.0E-05  0.0E+00  1 'IREP' 'VP' 'HVAC' 'AIR VACUUM PUMP FAILS TO CONTINUE TO RUN           ,P 126'
139  2.3E-08  0.0E+00  1 'IEEE' 'SV' 'HVAC' 'AIR VACUUM PUMP INLET/OUTLET VALVE FAILS DUE TO LOCAL FAULTS,P1016'
140  6.7E-07  0.0E+00  1 'IEEE' 'PS' 'HVAC' 'AIR VACUUM PUMP STARTER FAILS DUE TO LOCAL FAULTS,P214-10 ADDENDUM'
141  7.0E-06  0.0E+00  2 'IEEE' 'RE' 'HVAC' 'PUMP AUTO-START INTERLOCK FAILS                    ,P 184'
143  9.6E-06  0.0E+00  1 'MILE' 'CR' 'HVAC' 'ALARM CRT FAILS                          ,P 5.1.4.1-1'
144  5.9E-06  0.0E+00  1 'IEEE' 'FC' 'HVAC' 'FLOW CONTROLLER FAILS DUE TO LOCAL FAULTS          ,P 822'
146  3.0E-06  0.0E+00  1 'IREP' 'IS' 'HVAC' 'LOCAL DAMPER STATUS SENSOR FAULTS,                  ,P 129'
147  4.5E-05  0.0E+00  1 'IEEE' 'PC' 'HVAC' 'FAILURE OF ELECTRICAL POWER CABLE,                  ,P 747'
152  9.3E-07  0.0E+00  1 'MILE' 'IL' 'HVAC' 'INDICATOR LIGHT FAILS, P 5.1.17-1'
153  7.2E-06  0.0E+00  1 'IEEE' 'ZS' 'HVAC' 'DOOR POSITION SWITCH FAILS, P 645'
154  1.8E-07  0.0E+00  1 'IEEE' 'DL' 'HVAC' 'DOOR LATCH FAILS DUE TO LOCAL FAULTS,P 212'
155  7.0E-06  0.0E+00  2 'IEEE' 'RE' 'HVAC' 'AIRLOCK DOOR INTERLOCK FAILS, P 184'
157  4.3E-03  0.0E+00  2 '4.5 ' 'AL' 'HVAC' 'CALC RATE FOR WHB TRUCK AIRLOCKS'
158  3.2E-03  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE OPENS DOOR WITH INDICATOR LIGHT'
159  1.0E-00  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE OPENS DOOR WITH FAILED INDICATOR LIGHT'
160  3.2E-03  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE OPENS EMERGENCY DOOR'
161  4.7E-03  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE SELECTS WRONG CONTROL OR TURNS CONTROL WRONG DIR'
162  4.7E-04  0.0E+00  2 '4.5 ' 'HE' 'HVAC' 'HE ERROR DIVIDED BY FACTOR OF 10, W ENGINEERING'
163  2.1E-01  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE DIAGNOSIS ERROR ON UNRELATED ALARM'
164  2.1E-04  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE FAILURE TO RESPOND TO CRITICAL ANNUNCIATOR'
165  1.5E-02  0.0E+00  2 'SWAN' 'HE' 'HVAC' 'HE FAILURE OF ADMINISTRATIVE CONTROL'
170  1.1E-02  0.0E+00  2 '4.6 ' 'HE' 'ELEC' 'OPERATOR FAILS TO TAKE ACTION'
171  8.0E-06  0.0E+00  2 '4.6 ' 'EP' 'ELEC' 'CALC VALUE FOR SUBSTATION 3B UNAVAILABILITY'
172  2.2E-06  0.0E+00  2 '4.6 ' 'EP' 'ELEC' 'CALC VALUE FOR SUBSTATION 1 UNAVAILABILITY'
173  1.3E-05  0.0E+00  2 '4.6 ' 'EP' 'ELEC' 'CALC VALUE FOR SUPPORT BUILDING SUBSTATION'
175  3.8E-06  0.0E+00  1 'IEEE' 'HX' 'CAIR' 'AIR-COOLED HEAT EXCHANGER FAILS, P 1361'
176  4.2E-06  0.0E+00  1 'IEEE' 'HX' 'CAIR' 'COMPRESSOR AFTERCOOLER HEAT EXCHANGER FAILS, P 1363'
177  1.9E-06  0.0E+00  1 'IEEE' 'FL' 'CAIR' 'STRAINER FOR COOLING WATER FAILS, P 1402'
178  5.0E-06  0.0E+00  1 'IEEE' 'AM' 'CAIR' 'PRESSURE RELIEF VALVE OPENS SPURIOUSLY, P 1034'
179  1.9E-04  0.0E+00  1 'IEEE' 'CM' 'CAIR' 'AIR COMPRESSOR FAILS TO RUN, P 1245'
180  1.6E-03  0.0E+00  2 'IEEE' 'CM' 'CAIR' 'AIR COMPRESSOR FAILS TO START, P 879 (MOTOR DRIVEN PO PUMP)'
181  1.1E-05  0.0E+00  1 'IEEE' 'PM' 'CAIR' 'MOTOR DRIVEN COOLING WATER PUMP FAILS TO RUN, P 902'
183  1.1E-04  0.0E+00  2 '4.7 ' 'HE' 'CAIR' 'HE ERRONEOUSLY OPENS/CLOSES MANUAL VALVE'
184  5.7E-06  0.0E+00  1 '4.7 ' 'CM' 'CAIR' 'COMMON CAUSE FAILURE OF M.-D. COMPRESSORS AFTERCOOLER HEAT EXCH.'
185  3.1E-06  0.0E+00  1 'IEEE' 'WF' 'CAIR' 'FLOAT OPERATED VENT VALVE MALFUNCTIONS, P 1035'
186  1.7E-06  0.0E+00  1 'IEEE' 'FI' 'CAIR' 'PLUGGING OF THE COMPRESSOR AIR INTAKE FILTER, P 1417'
187  3.8E-05  0.0E+00  1 'IEEE' 'CM' 'CAIR' 'SCREW TYPE COMPRESSOR FAILS TO RUN, P 1248'
188  7.8E-06  0.0E+00  1 'IEEE' 'FI' 'CAIR' 'COOLING OIL FILTER FAILS/CLOGS, P 1410'
189  2.2E-07  0.0E+00  1 'IEEE' 'ST' 'CAIR' 'OIL TEMPERATURE SWITCH FAILS, P 535'
190  9.8E-07  0.0E+00  1 'IEEE' 'FS' 'CAIR' 'OIL FLOW SWITCH FAILS, P 578'
191  8.9E-03  0.0E+00  1 '4.7 ' 'CM' 'CAIR' 'WIPP AIR COMPRESSOR OUTAGE ON HOURLY BASIS'
```

TABLE D-3 (continued) PROJECT MASTER DATA FILE

```
205  1.0E-04  0.0E+00  2 'IPE ' 'OP' 'ALL ' 'OPER. ERROR - PROBLEM SOLVING- 1500 MIN'
317  3.0E-03  0.0E+00  2 'IREP' 'CB' 'ALL ' 'FAILURE TO TRANSFER (4.1.1)'
320  1.0E-06  0.0E+00  1 'IREP' 'TR' 'ALL ' 'ALL MODES (4.5.1)'
328  1.0E-06  0.0E+00  1 'IREP' 'BY' 'ALL ' 'FAILS TO PROVIDE PROPER OUTPUT (4.9.1)'
329  1.0E-06  0.0E+00  1 'IREP' 'BC' 'ALL ' 'FAILURE TO OPERATE (4.10.1)'
357  4.0E-02  0.0E+00  2 'IREP' 'DG' 'ALL ' 'DOES NOT START (4.6.1)'
358  3.0E-03  0.0E+00  1 'IREP' 'DG' 'ALL ' 'DOES NOT RUN, GIVEN START (4.6.2)'
363  1.0E-04  0.0E+00  1 'IREP' 'IV' 'EPS ' 'FAILURE TO OPERATE (4.12.1)'
364  3.0E-05  0.0E+00  1 'IREP' 'CB' 'EPS ' 'SPURIOUS TRIP (4.1.2)'
466  3.0E-06  0.0E+00  1 'IREP' 'FU' 'EPS ' 'FUSE PREMATURE OPEN RATE (D.A.McC)'
467  1.1E-03  0.0E+00  2 '4.6 ' 'DG' 'EPS ' 'DG IN MAINTENANCE'
468  4.5E-03  0.0E+00  2 '4.6 ' 'DG' 'EPS ' 'DG COMMON CAUSE FAILURE'
469  3.0E-06  0.0E+00  1 'IREP' 'MG' 'EPS ' 'MOTOR GENERATOR SET FAILS TO OPERATE - 4.11'
470  3.0E-06  0.0E+00  1 'IREP' 'SS' 'EPS ' 'HIGH POWER SOLID STATE DEVICE FAILS - 4.14'
501  3.0E-08  0.0E+00  1 'I63 ' 'TK' 'FIRE' 'STORAGE TANK FAILS '
502  1.1E-05  0.0E+00  1 'A87 ' 'LI' 'FIRE' 'LEVEL INDICATOR FAILS (ANALOG)  '
503  4.9E-05  0.0E+00  1 'A49 ' 'SP' 'FIRE' 'PRESSURE SWITCH FAILS (SIGNAL+SENSOR) '
504  3.0E-07  0.0E+00  1 'L001' 'TK' 'FIRE' 'STORAGE TANK LEAKS'
510  5.0E-07  0.0E+00  1 'N   ' 'XV' 'ALL ' 'MANUAL VALVE FAILS OPEN/CLOSED '
511  5.0E-09  0.0E+00  1 '4.8 ' 'XV' 'FIRE' 'MANUAL VALVE, CSO/CSC, TRANSFERS OPEN/CLOSED'
515  6.0E-06  0.0E+00  1 'L005' 'SH' 'FIRE' 'SPRINKLER HEAD PLUGS'
516  1.2E-05  0.0E+00  2 'L007' 'SH' 'FIRE' 'SPRINKLER HEAD WILL NOT OPEN'
520  6.7E-03  0.0E+00  2 'A95 ' 'PM' 'FIRE' 'MOTOR DRIVEN FIRE PUMP FAILS TO START '
521  8.0E-03  0.0E+00  1 'A95 ' 'PM' 'FIRE' 'MOTOR DRIVEN FIRE PUMP FAILS TO RUN '
522  8.3E-03  0.0E+00  2 'A93 ' 'PM' 'FIRE' 'DIESEL DRIVEN FIRE PUMP FAILS TO START '
523  3.0E-02  0.0E+00  1 'A93 ' 'PM' 'FIRE' 'DIESEL DRIVEN FIRE PUMP FAILS TO RUN '
524  8.1E-03  0.0E+00  2 '4.8 ' 'PM' 'FIRE' 'MOTOR DRIVEN PUMP IN MAINTENANCE'
525  3.7E-02  0.0E+00  2 '4.8 ' 'PM' 'FIRE' 'DIESEL-DRIVEN PUMP IN MAINTENANCE'
526  8.4E-04  0.0E+00  1 'A91 ' 'PM' 'FIRE' 'DIESEL PUMP FAILS'
530  7.5E-03  0.0E+00  2 'SWAN' 'HE' 'ALL ' 'ANNUNCIATOR RESPONSE, SWAIN, TAB. 20-23, #1'
534  2.9E-04  0.0E+00  1 '4.8 ' 'EP' 'ELEC' 'POWER SUPPLY FAILS'
535  4.0E-03  0.0E+00  2 '4.8 ' 'WA' 'FIRE' 'FIRE WATER NOT AVAILABLE'
540  6.7E-06  0.0E+00  1 'A29 ' 'DI' 'FIRE' 'IONIZATION DETECTOR FAILS'
541  1.1E-05  0.0E+00  1 'A37 ' 'DI' 'FIRE' 'PHOTOELECTRIC DETECTOR FAILS'
542  8.7E-05  0.0E+00  1 'A103' 'HL' 'FIRE' 'HALON SYSTEM FAILURE'
543  2.7E-07  0.0E+00  1 'A99 ' 'NZ' 'FIRE' 'NOZZLE FAILS'
544  2.4E-07  0.0E+00  1 'A35 ' 'DI' 'FIRE' 'IONIZATION DETECTOR ERRATIC OUTPUT'
545  4.0E-07  0.0E+00  1 'A37 ' 'DI' 'FIRE' 'PHOTOELECTRIC DETECTOR ERRATIC OUTPUT'
546  8.0E-06  0.0E+00  1 'A101' 'DI' 'FIRE' 'DRY CHEMICAL SYSTEM FAILURE'
547  1.5E-07  0.0E+00  1 'A41 ' 'DI' 'FIRE' 'RATE-OF-RISE TEMP DETECTOR ERREATIC OUTPUT'
548  4.5E-06  0.0E+00  1 'A41 ' 'DI' 'FIRE' 'RATE-OF-RISE TEMP DETECTOR FAILURE'
549  1.1E-01  0.0E+00  2 'SWAN' 'HE' 'FIRE' 'OPERATOR ERROR'
'Component Identification'
'                        '
'     Mechanical Components'
'                         '
'AC   Actuator            '
'BC   Brake Caliper       '
'BD   Disc Brakes         '
'BV   Ball Valve          '
'CL   Cylinder, piston    '
'CM   Air Compressor      '
'DA   Damper              '
'FL   Filter or Strainer  '
'HX   Heat Exchanger      '
'LI   Lilly Controller    '
'NZ   Nozzle              '
'PM   Motor-Driven Pump   '
'TK   Tank                '
'VP   Vacuum Pump         '
'CV   Valve, Check        '
'HV   Valve, Hydraulic Operated'
'XV   Valve, Manual       '
'MV   Valve, Motor Operated'
'FV   Valve, Flow Control  '
'RR   Valve, Pressure Control (reducing regulator)'
'AV   Valve, Relief Pneumatic or Hydraulic Operated'
'AS   Valve, Relief Solenoid Operated'
'AM   Valve, Relief Mechanical Operated'
'SV   Valve, Solenoid Operated'
'VV   Valve, Vacuum Relief '
```

TABLE D-3 (continued)

PROJECT MASTER DATA FILE

```
'                          '
'     Electrical Components'
'                          '
'AA   Audible Alarm        '
'BY   Battery              '
'BC   Battery Charger      '
'CA   Cable                '
'CB   Circuit Breaker      '
'CL   Clutch               '
'DI   Detector             '
'FS   Flow Switch          '
'FU   Fuse                 '
'IV   Inverter             '
'LS   Limit Switch         '
'SW   Manual Switch (Pushbutton)'
'MO   Motor                '
'MG   Motor-Generator      '
'MS   Motor Starter        '
'PS   Pump Starter         '
'RE   Relay                '
'RL   Relay (Latching Type)'
'SE   Sensor               '
'SW   Switch               '
'SP   Switch, Pressure     '
'ST   Switch, Temperature  '
'TI   Timer                '
'TR   Transformer, Power   '
'WR   Wire                 '
'PR   Protective Relay, Overcurrent'
'RM   Radiation Monitor    '
'ZS   Position Switch      '
'                          '
'     General              '
'                          '
'AC   Accumulator          '
'AL   Alarm                '
'AS   Air Supply System    '
'CA   Actuation Circuit    '
'CR   CRT - Cathode Ray Tube'
'DB   Backdraft Damper     '
'DG   Diesel Generator     '
'DL   Door Latch           '
'DR   Door                 '
'DS   Door Seal            '
'DT   Tornado Damper       '
'FA   Fan                  '
'FC   Flow Controller      '
'FI   Filter               '
'IL   Indicator Light      '
'IS   Instrumentation - Sensor'
'MT   Maintanence          '
'PC   Power Cable          '
'PR   Printer (Alarm Printer)'
'SM   Seismic Monitoring System'
'WF   Trap Float           '
'SN   Air Sampling Nozzle  '
'HL   Halon System         '
'                          '
' '
```

TABLE D-3 (continued)

PROJECT MASTER DATA FILE

```
'DATA REFERENCES'
' '
'IEEE - IEEE-500,1984'
'ROME - NONELECTRIC RELIABILITY NOTEBOOK,ROME AIR DEVELOPMENT,RADC-TR-75-22'
'MS-3 - MILLSTONE 3 PRA'
'WIPP - WIPP WASTE HOIST BRAKE SYSTEM PSA, SEC 3'
'NREP - U.S. NUCLEAR REGULATORY COMMISSION,'
'       "NATIONAL RELIABIL. EVAL. PROGRAM (NREP) PROCEDURE GUIDE",'
'       NUREG/CR-2815, BNL-NUREG-51559, FINAL DRAFT'
'IREP - INTERIM VERSION OF ABOVE DOCUMENT'
'1400 - U.S. NUCLEAR REGULATORY COMMISSION,'
'       "REACTOR SAFETY STUDY, WASH-1400"'
'       NUREG-75/014, APPENDIX III, "FAILURE DATA", OCTOBER 1975'
'WNTD - WESTINGHOUSE, NUCLEAR TECHNOLOGY DIVISION,'
'       MILLSTONE III PRA DATA BASE              '
'DPNT - "COMPONENT FAILURE RATE DATA WITH POTENTIAL APPLICABILITY TO A'
'       NUCLEAR FUEL REPROCESSING PLANT," (DP-1633), PREPARED FOR U.S. DOE'
'       BY E.I. DU PONT DE NEMOURS & CO., JULY 1982'
'MILE - MIL-HDBK-217E, MILITARY HANDBOOK, RELIABILITY PREDICTION OF'
'       ELECTRONIC EQUIPMENT'
'IPE  - TENNESSEE VALLEY AUTHORITY, SEQUOYAH NUCLEAR PLANT, UNIT 1,'
'       INDIVIDUAL PLANT EVALUATION, ELECTRIC POWER SYSTEM NOTEBOOK,'
'       MARCH 1987, P. 7-9'
'4.3  - SEE DERIVATION IN WIPP IRA SECTION 4.3'
'4.5  - SEE DERIVATION IN WIPP IRA SECTION 4.5'
'4.6  - SEE DERIVATION IN WIPP IRA SECTION 4.6'
'4.7  - SEE DERIVATION IN WIPP IRA SECTION 4.7'
'4.8  - SEE DERIVATION IN WIPP IRA SECTION 4.8.8.2'
'CN   - WESTINGHOUSE CALCULATION NOTE'
' '
'FIRE ANALYSIS NOTES'
' '
'A       OREDA DATA BASE  '
'B       IEEE 500         '
'C       NPRDS            '
'E       ENGINEERING JUDGEMENT  '
'N       NUREG/CR-2728          '
'WEST    WESTINGHOUSE DATA BASE '
'S       HUMAN ERROR ANALYSIS, SWAIN  (TABLE NUMBERS ARE REFERENCED)  '
'L       LOSS PREVENTION IN THE PROCESS CONTROL INDUSTRY              '
'I       CANVEY ISLAND STUDY  '
'SITE    SITE INFORMATION     '
'M       CHEMICAL ENGINEERING PROGRESS  '
' '
'C&SH HOIST NOTES'
  'FOR ENTRY 29, TME CONTROLLER MALFUNCTION NUMBER USED.  THIS COMPARES FAVORABLY'
  'WITH IEEE CENTRIFUGAL SWITCH FAILURE - P599 - 0.5(-6)/HR * 4680 HR = 2.3(-3)/YR'
  'ANNUAL FAILURE PROBABILITY'
  'FOR ENTRY 30, 3.4(-7) BREAKS/CYCLE (TME) * 2.6(4) CYCLES/YR (REPORT TEXT)'
```

APPENDIX E
FIRE DETECTION AND SUPPRESSION SYSTEMS FAULT TREE

Figure E-1 Chemical Underground Near Fuel Station

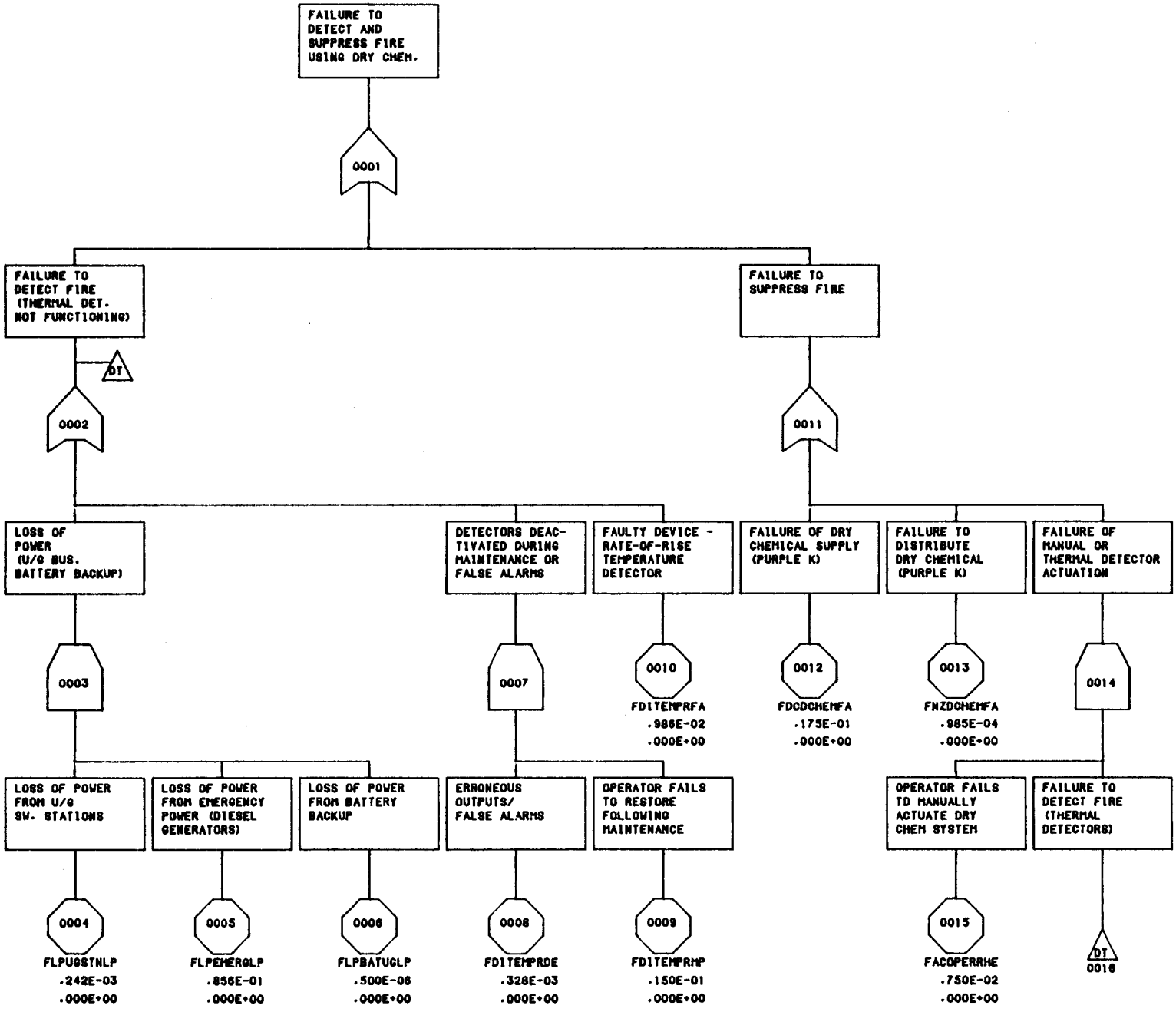
Figure E-2 Fire Water

Figure E-3 Halon

Figure E-4 Chemical Underground - Vehicles

Figure E-5 Manual Aboveground

Figure E-6 Manual Underground



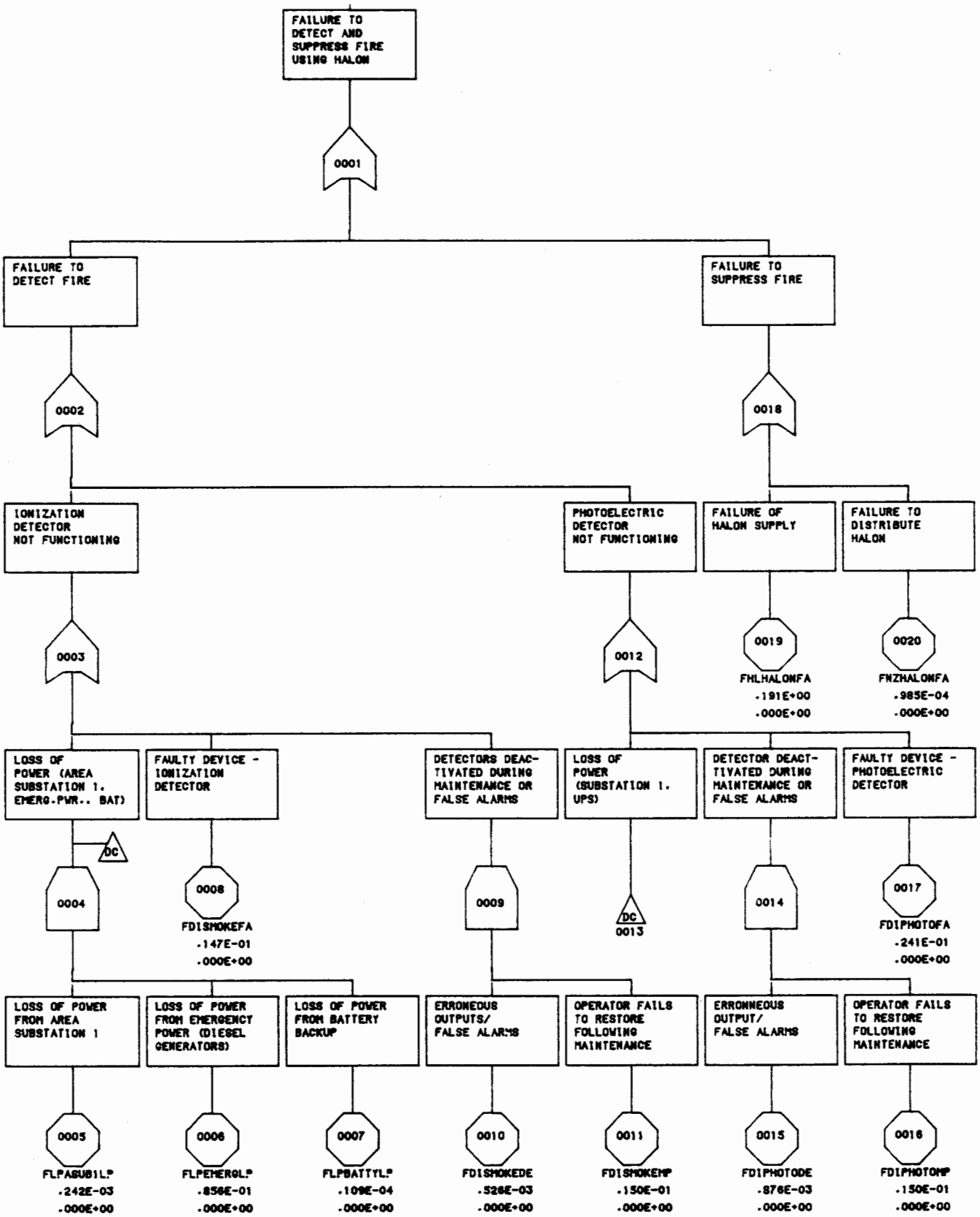
NOTES:
FILES USED TO MAKE PLOT
chem.DAT 3/21/89 14:24
chem.TXT 3/21/89 14:59

WESTINGHOUSE PROPRIETARY

Chemical Underground
Near Fuel Station

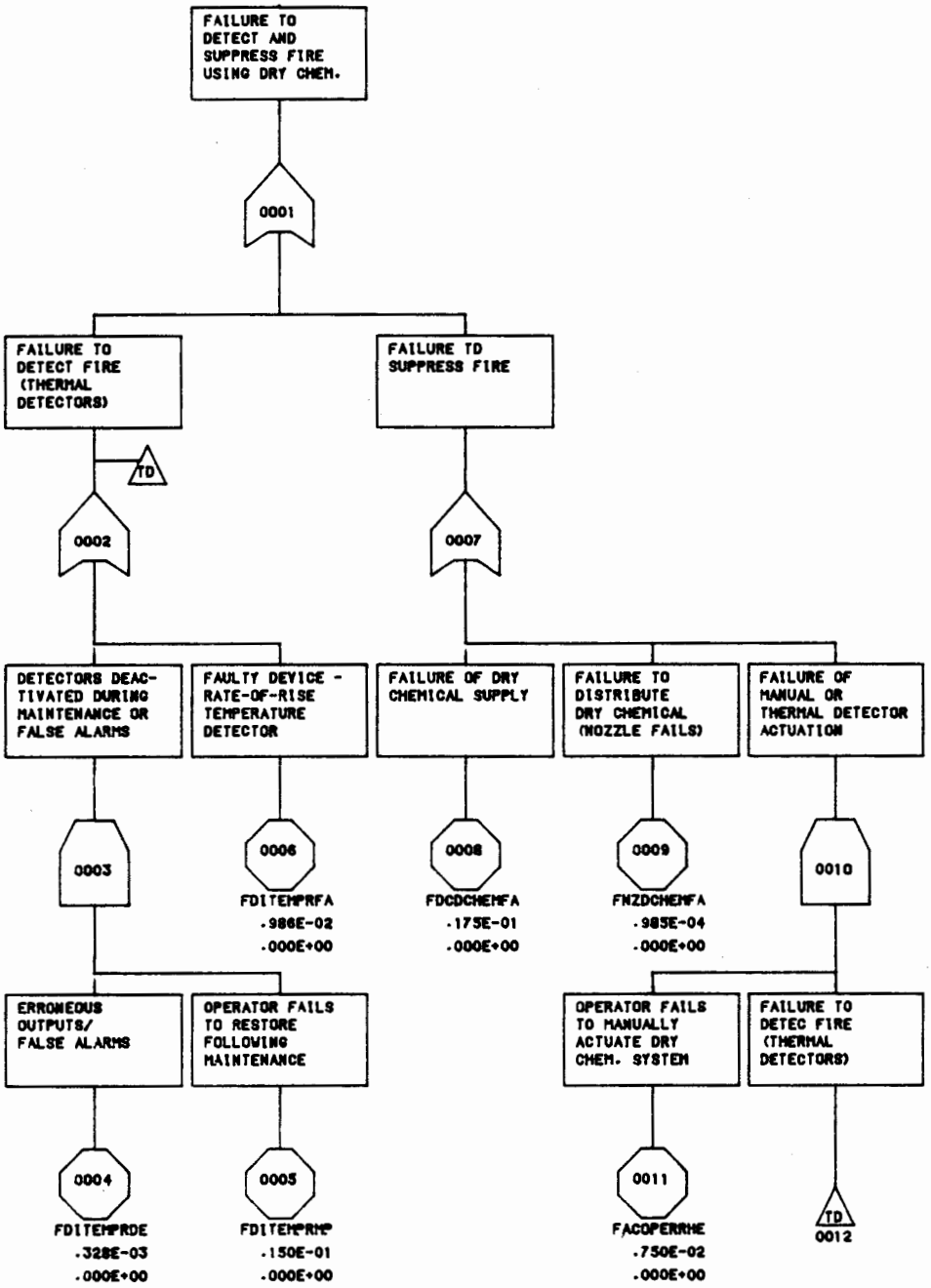
Figure E-1

13: 7:20 91- 5-20



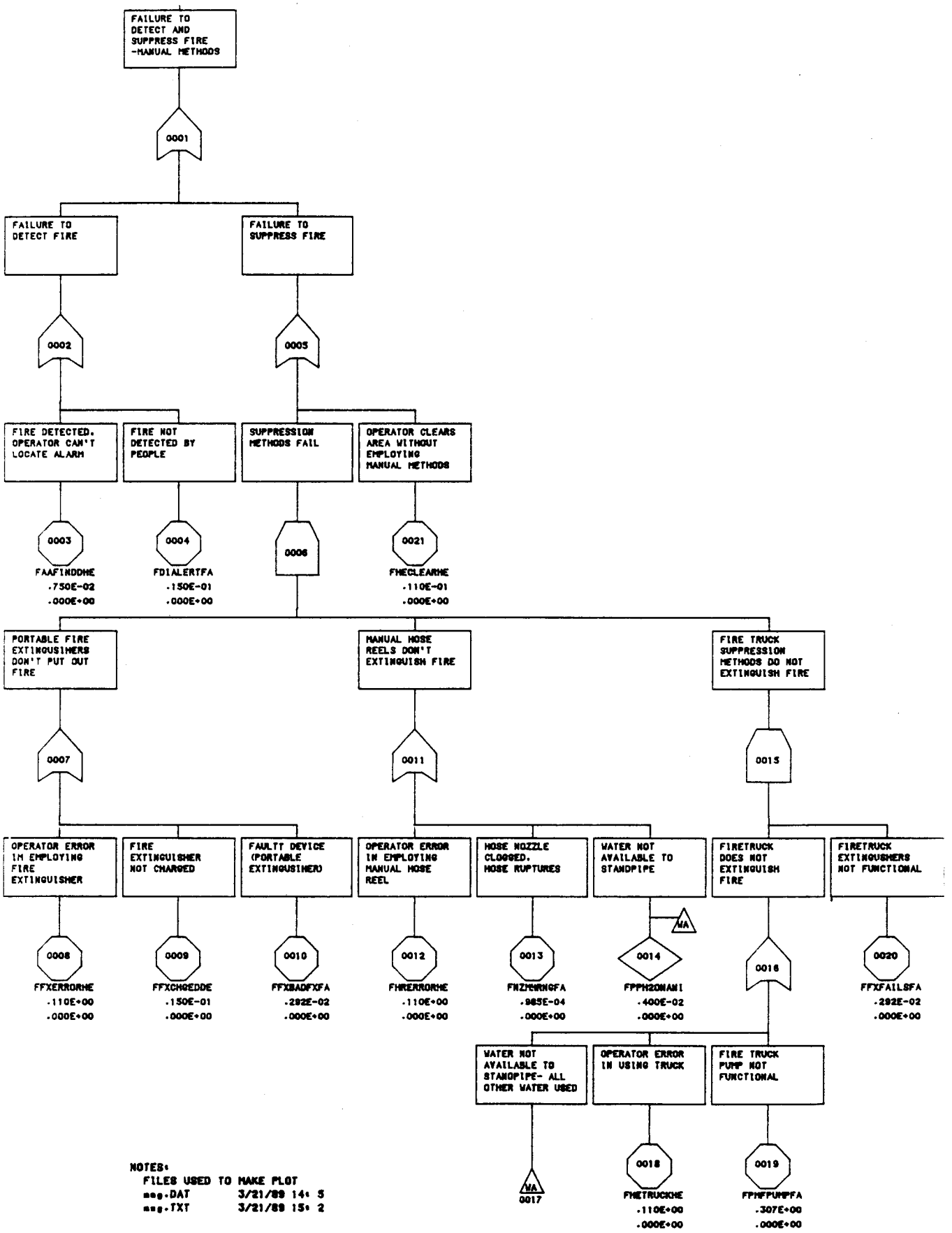
NOTES:
FILES USED TO MAKE PLOT
halon.DAT 3/21/89 14: 6
halon.TXT 3/21/89 14:57

WESTINGHOUSE PROPRIETARY	
Halon	
Figure E-3	13:10:46 91- 5-20



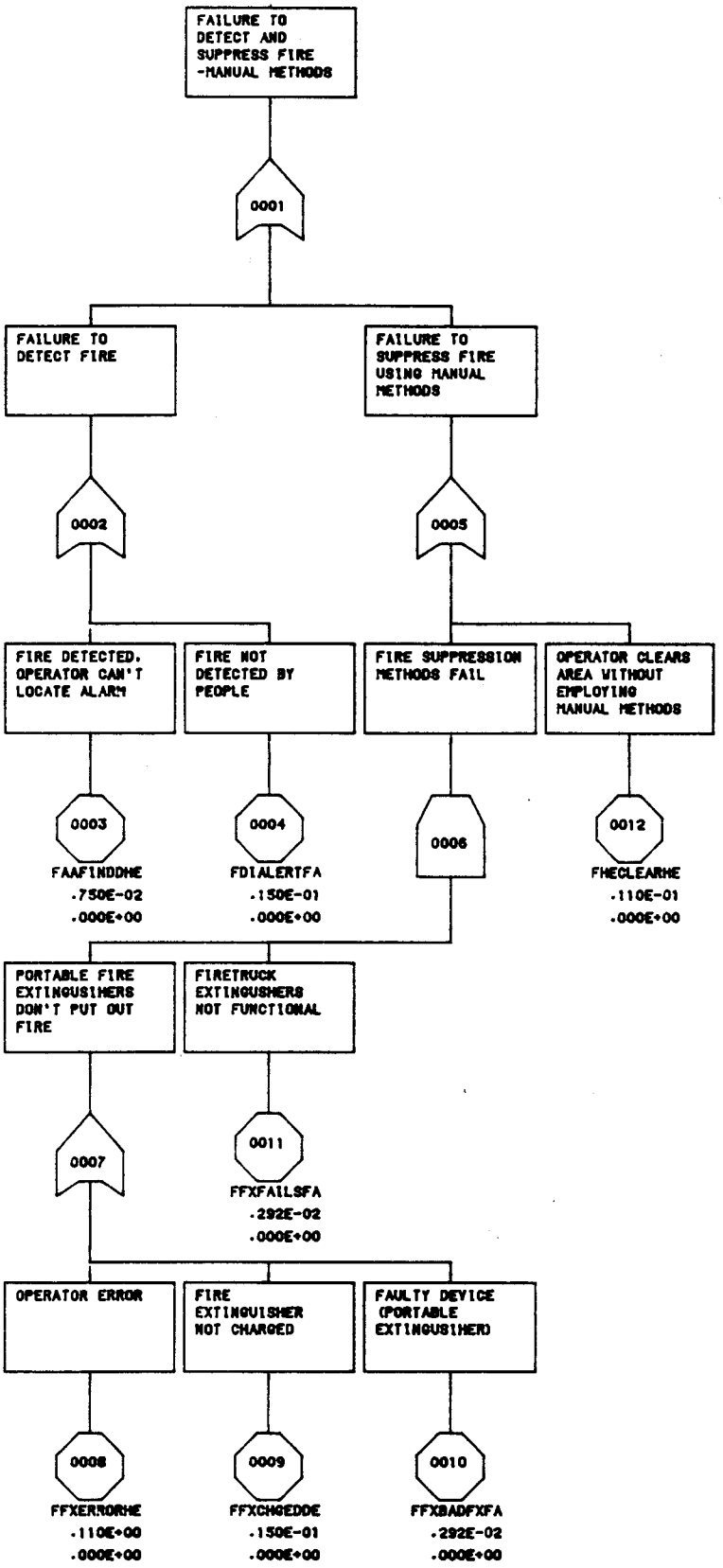
NOTES:
FILES USED TO MAKE PLOT
eug.DAT 2/ 3/89 16:16
eug.TXT 3/21/89 15: 1

WESTINGHOUSE PROPRIETARY	
Chemical Underground - Vehicles	
Figure E-4	13:11:30 91- 5-20



NOTES:
FILES USED TO MAKE PLOT
msg.DAT 3/21/89 14: 5
msg.TXT 3/21/89 15: 2

WESTINGHOUSE PROPRIETARY	
Manual Aboveground	
Figure E-5	13:12:22 91- 5-20



NOTES:
FILES USED TO MAKE PLOT
aug.DAT 3/21/89 14: 9
aug.TXT 3/22/89 8:44

WESTINGHOUSE PROPRIETARY	
Manual Underground	
Figure E-6	13:13:26 91- 5-20

APPENDIX F
HAZOPS STUDY TEAM BIOGRAPHIES

- Mickey Lovell, Westinghouse, WIPP
  Mr. Lovell is responsible for overall Fire Protection System Configuration Control, review and implementation of maintenance and modifications to Fire Protection Systems at WIPP. He has participated in operations readiness review of Fire Protection Systems, and has completed start-up testing of Fire Protection Systems for the Waste Handling Building, at WIPP. He has over ten years experience in the Nuclear Power Industry, performing Fire Protection Systems reviews, program administration and implementation.

- Ray Godfrey, Westinghouse, WIPP
  Mr. Godfrey spent ten years in Navy Nuclear Power Plant operations and maintenance. He has spent ten years in Air Force Electronic Navigation equipment operation and maintenance. His Westinghouse experience includes seven years research in reactor spent fuel characterization, storage and handling activities. He also has over five years at WIPP as a Facility Operations Shift Supervisor and currently working as an Operations Engineer.

- Sam Savorelli, Westinghouse, Nuclear and Advanced Technology Division (NATD)
  Mr. Savorelli has 21 years experience in Westinghouse in areas of flow-induced vibration, thermal & stress analysis, and flooding and fire PRA analysis. Recently, Mr. Savorelli has been working on flooding and fire PRA for the Donald C. Cook Nuclear Plant. He also has worked on evaluating fire initiating event frequencies for the Brunsbuttel Nuclear Plant (Germany) Fire Risk Assessment.

- Shelagh Morandini, Westinghouse, NATD
  Ms. Morandini is a senior engineer with the Risk Management and Operations Improvement group at NATD. She is experienced in fault tree methodology, fault tree linking, internal flooding analyses, internal fire analyses, data base development, FMEA's and risk calculations for both nuclear and non-nuclear projects. Ms. Morandini worked on the fault tree and event tree analysis of the Fire Detection and suppression system for the WIPP IRA.

- John Iacovino, Westinghouse, NATD
  (HAZOPS Team Leader)
  Mr. Iacovino was the Project Manager for the WIPP Integrated Risk Assessment. He has 20 years experience in safety analysis and risk assessment. Mr. Iacovino has extensive experience in applying HAZOPS and quantitative risk assessment techniques at DOE facilities as well as industrial sites especially refineries. Mr. Iacovino has recently completed the Brunsbuttel Nuclear Plant (Germany) Fire Risk Assessment and the Fort St. Vrain decommissioning accident analysis.