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GJPO-MWTP-31

Grand Junction Projects Office
Mixed-Waste Treatment Program

PO*WW*ER Mobile Treatment Unit Process Hazards Analysis

June 1996

U.S. Department of Energy
Grand Junction Projects Office

Work Performed Under DOE Contract No. DE-AC04-94AL96907 for the U.S. Department of Energy

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PO*WW*ER Mobile Treatment Unit Process Hazards Analysis

June 1996

Prepared for
U.S. Department of Energy
Albuquerque Operations Office
Grand Junction Projects Office

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Executive Summary

In response to the need for increased mixed-waste treatment capability, the Department of Energy (DOE) Albuquerque Operations Office (AL) organized a Treatment Selection Team to match mixed wastes with treatment options and develop a strategy for treatment of its mixed waste. The strategy developed by the Treatment Selection Team was to use off-site commercial treatment facilities where available, and for those wastes which could not be treated using commercial treatment facilities, to develop mobile treatment capability to treat the wastes at the DOE–AL sites where the wastes were generated, eliminating the necessity for shipment of wastes from one site to another. The development of mobile waste treatment capability included the development and demonstration of treatment technologies for use with mixed wastes. Responsibility for development of several of these technologies was assigned to the DOE Grand Junction Projects Office (GJPO) under the Mixed-Waste Treatment Program (MWTP). One of the waste-treatment technologies assigned to GJPO was evaporative oxidation (EO), which is used primarily in the treatment of aqueous wastes containing hazardous organic compounds.

Rust Geotech, contractor to DOE–GJPO, conducted pilot-scale EO treatability testing using the Rust-patented PO*WW*ER process. Information obtained from the treatability testing was used to design a full-scale PO*WW*ER mobile treatment unit (MTU). The PO*WW*ER MTU uses evaporation to separate organics and water from radionuclides and solids, and oxidation to convert the hazardous organics into innocuous byproducts.

A Process Hazards Analysis (PHA) is required for each MTU being developed. The objective of the PHA and this report is to demonstrate that a thorough assessment of the risks associated with the operation of the PO*WW*ER MTU has been performed and documented. This report has been prepared according to the methodology and report format guidelines provided in the DOE–AL *Guidance for the Preparation of MWT Process Hazards Analysis* (DOE 1995b).

Prior to initiation of the PHA, a detailed analysis of hazards associated with operation of the MTU was undertaken. The most significant potential hazards identified by this analysis were (1) foaming in the evaporator could result in carryover of liquid into the oxidizer heaters, which in turn could cause an explosion due to thermal stresses in the heaters; and (2) low or no flow in the Econobator inlet line, which could create an explosive situation due to high propane concentration. These hazards were mitigated by changes to the design (additional foam sensors and level indicators for the evaporator, and deletion of the propane addition system). The remaining potential hazards were evaluated for design improvements to further reduce their frequency and/or severity. No further action is required to reduce risks associated with these hazards.

The PHA evaluated a number of accident scenarios not directly related to the operation of the MTU, such as damage from natural phenomena (e.g., earthquakes) and from mishandling chemical containers. The worst-case accident scenarios were then evaluated to determine the risk potential to the MTU and to co-located workers, the public, and the environment. On the basis of this analysis, the overall risk to any population group from operation of the PO*WW*ER MTU has been determined to be very low. The MTU is classified as a Radiological Facility (i.e., less than a Hazard Category 3 facility), with low hazards (i.e., minor on-site impacts to people, with no impact to off-site people or the environment).

This PHA is considered adequate as the only safety basis documentation (i.e., a supplemental safety analysis and/or a full scope safety analysis report is not required) for supporting DOE authorization to operate the PO*WW*ER MTU at all DOE user sites. No further safety basis documentation is needed.

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Abbreviations, Acronyms, and Initialisms

AIT	autoignition temperature
AL	Albuquerque Operations Office
ASA	Auditable Safety Analysis
atm	atmosphere
BP	boiling point
°C	degrees Celsius
cal/g	calories per gram
CEDE	committed effective dose equivalent
CFR	*U.S. Code of Federal Regulations*
Ci	curie(s)
Ci/g	curie(s) per gram
CO	carbon monoxide
DBA	design basis accident
DCN	Design Change Notice
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
dp	differential pressure
EBSC	evaluation basis site characteristics
EBWC	evaluation basis waste characteristics
EO	evaporative oxidation
EPA	U.S. Environmental Protection Agency
ERPG	Emergency Response Planning Guidelines
ESF	engineered safety features
°F	degrees Fahrenheit
FFCA	Federal Facilities Compliance Act
fp	flash point
ft	foot (feet)
ft^2	square foot (feet)
ft^3	cubic foot (feet)
FXETIBO	fire, explosion, environmental damage, toxic release, bodily injury, business loss, operability loss
gal	gallon(s)
gal/h	gallon(s)s per hour
gal/min	gallon(s) per minute
GJPO	Grand Junction Projects Office
h	hour(s)
HASP	health and safety plan
HAZOP	hazards and operability analysis
HEPA	high-efficiency particulate air
ICRP	International Commission on Radiological Protection
IDLH	immediately dangerous to life or health
IH	Industrial Hygienist
KAFB	Kirkland Air Force Base
kg	kilogram(s)
kg/m^3	kilogram(s) per cubic meter
km	kilometer(s)

Abbreviations, Acronyms, and Initialisms (continued)

km/h	kilometer(s) per hour
LANL	Los Alamos National Laboratory
lb	pound(s)
lb/ft^3	pounds per cubic foot
LDR	land disposal restriction
LEL	lower explosive limit
LFC	lowest feasible concentration
LTA	less than adequate
m	meter(s)
MAR	material at risk
μCi/g	microcurie(s) per gram
mb	millibar(s)
mi	mile(s)
m^3	cubic meter(s)
m^3/h	cubic meter(s) per hour
mm	millimeter(s)
mrem	milliroentgen(s)
mrem/h	milliroentgen(s) per hour
m/s	meter(s) per second
MTU	mobile treatment unit
mw	molecular weight
MWT	mixed-waste treatment
MWTP	Mixed-Waste Treatment Program
NA	not applicable
nCi/g	nanocuries per gram
NO_x	nitrogen oxide
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
NRC	U.S. Nuclear Regulatory Commission
PCB	polychlorinated biphenyl
PFD	process flow diagram
P&ID	piping and instrumentation diagram
pCi/g	picocuries per gram
PHA	Process Hazards Analysis
PM	preventive maintenance
PPE	personal protective equipment
ppm	parts per million
PSE	pressure safety element
PSV	pressure safety valve
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PTX	Pantex
Pu	plutonium
QA/QC	quality assurance/quality control
RAD	radiologic
RCRA	Resource Conservation and Recovery Act
rem	roentgen(s)
RMWMF	Radioactive and Mixed Waste Management Facility
RMMA	radioactive material management area

Abbreviations, Acronyms, and Initialisms (continued)

RQ	reportable quantity
SAR	safety analysis report
SCR	silicon-controlled rectifier
SNL/NM	Sandia National Laboratories/New Mexico
SOP	standard operating procedure
SSC	structure, system, or component
STEL	short-term exposure limit
SVOC	semivolatile organic compound
TA–3	Technical Area 3
TD	thermal desorption
TSCA	Toxic Substance Control Act
TSR	technical safety requirement
TWA	time-weighted average
U	uranium
UEL	upper explosive limit
UBC	Uniform Building Code
USQ	unreviewed safety question
VOC	volatile organic compound
vp	vapor pressure
wt. %	weight percent

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1.0 Introduction

1.1 Scope

In 1992, Congress passed the Federal Facilities Compliance Act (FFCA) that requires the U.S. Department of Energy (DOE) to treat and dispose of its mixed waste in accordance with the Resource Conservation and Recovery Act (RCRA) land disposal restrictions (LDRs). Adequate treatment capability does not currently exist to treat the mixed wastes that are generated and stored at the nine sites under DOE Albuquerque Operations Office (AL) oversight. In response to the need for increased mixed-waste treatment capability, DOE–AL organized a Mixed-Waste Treatment Program (MWTP) to match mixed wastes with treatment options and develop a strategy for treatment of its mixed waste.

The strategy developed by the MWTP, as described in the *AL Mixed-Waste Treatment Plan* (DOE 1994), was to use available off-site commercial treatment facilities where possible and, where commercial treatment facilities could not be used, to develop mobile treatment capability to treat wastes at the DOE–AL sites where wastes are generated. Treatment processes used for mixed waste must not only address the hazardous component to comply with LDRs, but must also contain the radioactive component in a form that allows final disposal while protecting workers, the public, and the environment.

On the basis of recommendations of the Treatment Selection Team, the MWTP assigned projects to various DOE–AL sites to bring mixed-waste treatment on line. One of the technologies assigned to the DOE Grand Junction Projects Office (GJPO) for development was evaporative oxidation (EO). Rust Geotech, contractor to DOE–GJPO, conducted pilot-scale EO treatability testing with the Rust-patented PO*WW*ER process. Information gained from the treatability testing was used to design a full-scale PO*WW*ER mobile treatment unit (MTU).

The overall scope of this *PO*WW*ER MTU Process Hazards Analysis* (PHA) report is to document the hazards analysis performed by GJPO on the PO*WW*ER MTU. To date, the DOE–AL sites that plan to use the PO*WW*ER MTU for treating their mixed waste inventories are Los Alamos National Laboratory (LANL), Sandia National Laboratories/New Mexico (SNL/NM), and Pantex (PTX).

The PO*WW*ER process, an EO technology, is designed to treat aqueous mixed waste streams containing volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), volatile inorganics, and dissolved or suspended solids that may contain heavy metals and radionuclides. The mixed waste treatment process combines three essential unit operations: (1) evaporation; (2) catalytic oxidation; and (3) gas scrubbing. The evaporator concentrates the nonvolatiles by vaporizing most of the water along with the volatile constituents. The catalytic Econobator (oxidation unit) converts the volatilized contaminants into water, carbon dioxide, and trace quantities of acid gas. The acid gas is then neutralized and removed as a salt in the gas scrubber.

The process products include: (1) the brine from the evaporator which contains the concentrated radionuclides; (2) the "blowdown" from the scrubber containing sodium halide and sodium hydroxide; and (3) the vent gas and combustion products.

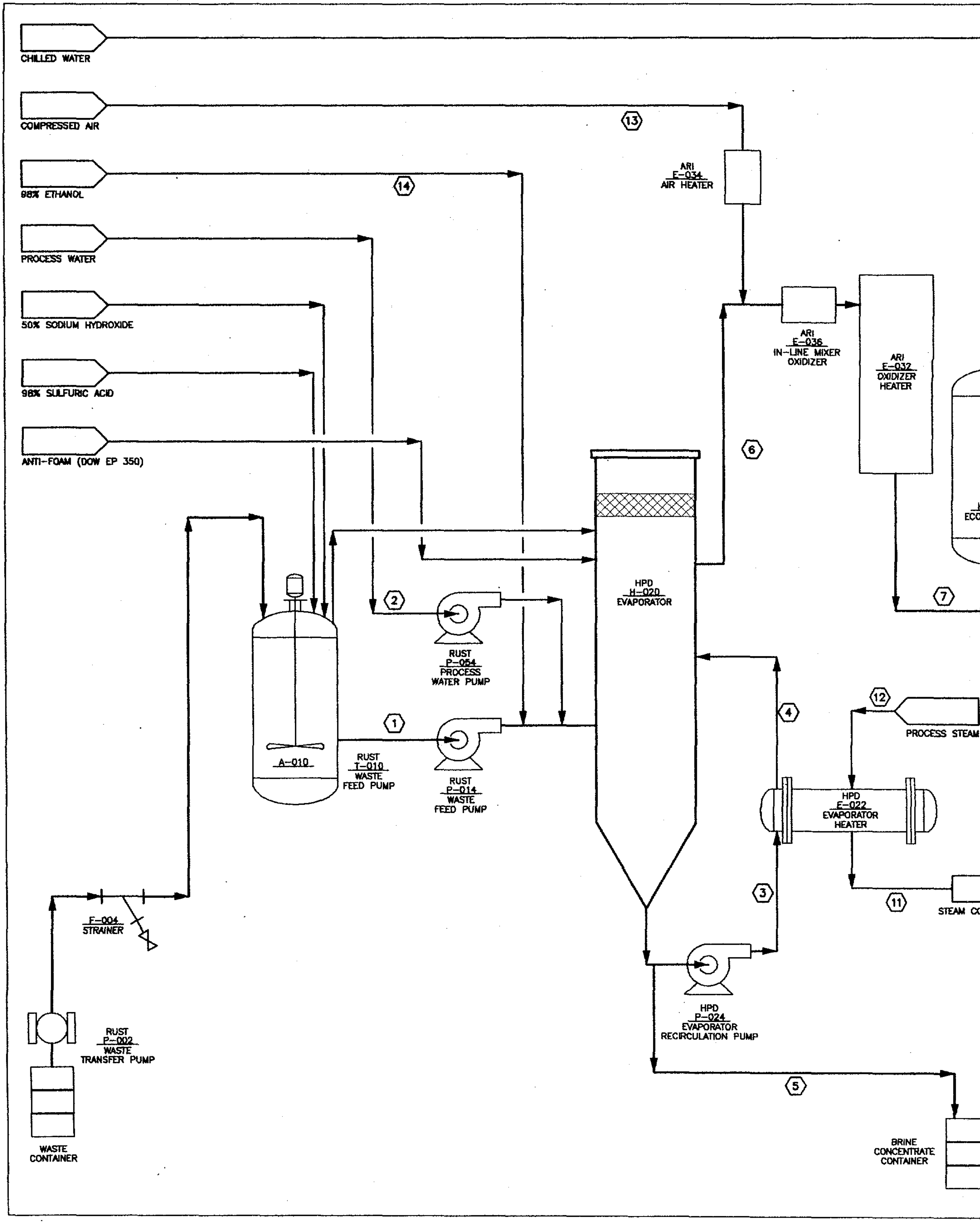
Figure 1–1 is a Process Flow Diagram (PFD) that graphically illustrates the EO process. The following description highlights the engineering features that make the system a unique mixed waste treatment process. Although this is the first mixed waste application for the EO technology, this is not the first unit to be constructed for treatment. Three PO*WW*ER units have been fabricated and operated to date. A 1-gallon-per-minute (gal/min) unit in Lake Charles, Louisiana; a 50-gal/min unit in Hong Kong, China;

and a 1.5-gallon-per-hour (gal/h) test unit (the "mini-PO*WW*ER unit," which was used for the treatability tests at GJPO) based in Clemson, South Carolina. The Hong Kong unit is the only one in full-scale treatment of industrial hazardous aqueous waste. The smaller units are used exclusively for treatability studies.

1.2 Objectives

The overall EO project objective is to bring the PO*WW*ER MTU on line for treating DOE mixed-waste inventories, therefore enabling specific DOE–AL sites to meet their FFCA commitments.

The objective of this PHA report is to demonstrate that a thorough assessment of the risks associated with the operation of the PO*WW*ER MTU has been performed and documented. This report has been prepared according to the methodology and report format guidelines provided in the DOE–AL Guidance for the Preparation of MWT Process Hazards Analysis (DOE 1995b).



CHILLED WATER
COMPRESSED AIR
98% ETHANOL
PROCESS WATER
50% SODIUM HYDROXIDE
98% SULFURIC ACID
ANTI-FOAM (DOW EP 350)
ARI E-034 AIR HEATER
ARI E-036 IN-LINE MIXER OXIDIZER
ARI E-032 OXIDIZER HEATER
HPD H-020 EVAPORATOR
RUST P-054 PROCESS WATER PUMP
A-010
RUST T-010 WASTE FEED PUMP
RUST P-014 WASTE FEED PUMP
PROCESS STEAM
HPD E-022 EVAPORATOR HEATER
F-004 STRAINER
HPD P-024 EVAPORATOR RECIRCULATION PUMP
RUST P-002 WASTE TRANSFER PUMP
WASTE CONTAINER
BRINE CONCENTRATE CONTAINER
STEAM CO
1
2
3
4
5
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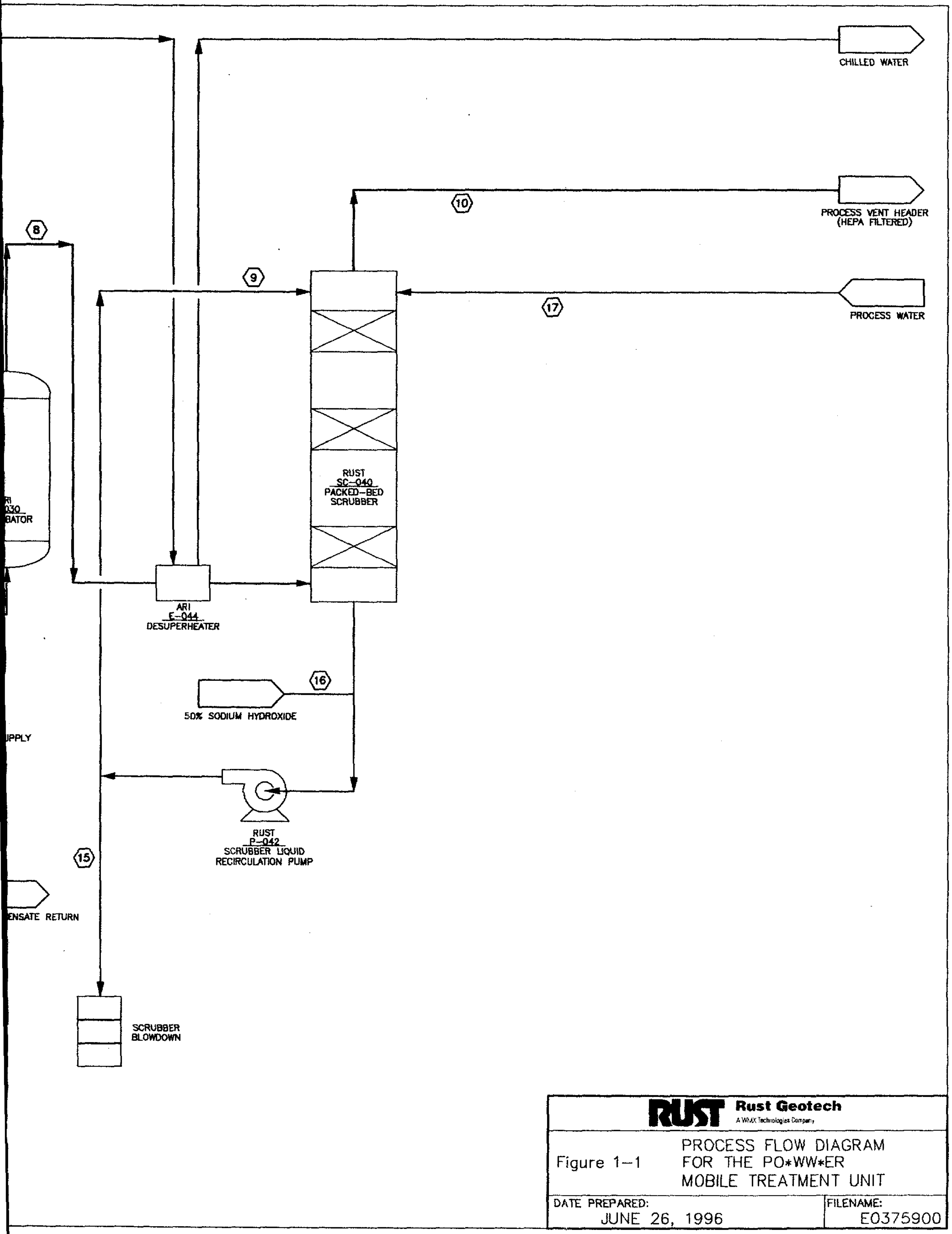
11
12
13
14


CHILLED WATER
10
PROCESS VENT HEADER
(HEPA FILTERED)
8
9
17
PROCESS WATER
RUST
SC-040
PACKED-BED
SCRUBBER
RI
030
BATOR
ARI
E-044
DESUPERHEATER
16
50% SODIUM HYDROXIDE
UPPLY
RUST
P-042
SCRUBBER LIQUID
RECIRCULATION PUMP
15
ENSATE RETURN
SCRUBBER
BLOWDOWN
Rust Geotech
A WMX Technologies Company
Figure 1-1
PROCESS FLOW DIAGRAM
FOR THE PO*WW*ER
MOBILE TREATMENT UNIT
DATE PREPARED:
JUNE 26, 1996
FILENAME:
E0375900

2.0 Site Description

2.1 Site Information

The PO*WW*ER MTU is proposed for use at three DOE–AL sites: Los Alamos National Laboratory (LANL), Sandia National Laboratories/New Mexico (SNL/NM), and Pantex (PTX). The MTU is designed to be housed in a climate-controlled environment and is not suitable for outdoor use. However, barometric pressures, seismic zones, and maximum ambient temperatures were taken into account during the design. Locations, elevations above sea level in feet (ft) and meters (m), average barometric pressures in millibars (mb) and pounds per square inch absolute (psia), seismic zone designations, and reasonable maximum temperature in degrees Fahrenheit (°F) for the three sites proposed for MTU treatment operations are

LANL

- Location — Los Alamos, New Mexico
- Elevation — 7,300 ft (2,225 m)
- Average barometric pressure — 779 mb (11.3 psia)
- Seismic zone: 2B
- Reasonable maximum temperature — 88 °F

SNL/NM

- Location — Albuquerque, New Mexico
- Elevation — 4,958 ft (1,511 m)
- Average barometric pressure — 841 mb (12.2 psia)
- Seismic zone: 2B
- Reasonable maximum temperature — 98 °F

PTX

- Location — Amarillo, Texas
- Elevation — 3,600 ft (1098 m)
- Average barometric pressure — 889 mb (12.9 psia)
- Seismic zone: 1
- Reasonable maximum temperature — 101 °F

Because SNL/NM has provided more site-specific information and has proposed a specific building to house the PO*WW*ER MTU for treating its mixed-waste inventories, SNL/NM was chosen for the site-specific risk assessment. Because LANL and PTX have not determined where the MTU will be located on site, analyses were conducted in a very conservative manner to ensure all sites could apply the results to their facilities. Appendix A presents the site characteristics used for the evaluation basis of the risk assessment. Site-specific risk assessment evaluations of each MTU user site will be required during permitting activities and before transporting the MTU to the user site.

2.1.1 SNL/NM Site Description

The PO*WW*ER MTU will be located within the SNL/NM Radioactive and Mixed Waste Management Facility (RMWMF) in Technical Area 3 (TA–3). The RMWMF is in the southeast corner of TA–3 and consists of Buildings 6920 and 6921, two skid-mounted storage buildings for reactive and ignitable/flammable waste, a 4,000-square-foot (ft^2) prefabricated waste storage building, a 7,000-gallon (gal) fuel-storage tank, an office trailer, and a rubber-lined retention basin. The location of these facilities are shown in Figure 2–1.

Mixed-Waste Treatment Location

Building 6920 is the principal structure in the RMWMF. Treatment of mixed waste with the PO*WW*ER MTU is planned to be performed in the north bay of Building 6920. No ignitable, flammable, or reactive waste will be stored in Building 6920. Two skid-mounted storage buildings, for storage of reactive and ignitable/flammable waste, are located approximately 100 ft to the northeast and northwest of Building 6920, respectively.

The primary radiological buffer area for Building 6920 has been engineered to minimize the generation of airborne contamination and the spread of contamination. Pressure zones are maintained throughout the building to cause air to flow from areas of no airborne contamination to areas of progressively greater potential for airborne contamination. Air from the north bay is exhausted through one stage of prefilters and high-efficiency particulate air (HEPA) filters.

Geography

SNL/NM is on Kirtland Air Force Base (KAFB), which is located in Bernalillo County, New Mexico. KAFB is bordered on the north and west by densely populated residential areas of Albuquerque. To the east of KAFB is the Four Hills residential area of Albuquerque. To the south of KAFB is the Isleta Indian Reservation and Valencia County. Valencia County is a rural, sparsely populated area. Surrounding populations, as of 1990, were as follows:

Bernalillo County:	480,577
Albuquerque:	384,736
Isleta Reservation:	2,915
Valencia County:	45,235
KAFB:	5,761

The metropolitan population center closest to SNL/NM is Albuquerque, located along the northern boundary of the site (Figure 2–2). Distances from the RMWMF to the nearest KAFB housing and the nearest Albuquerque residential housing are approximately 9.2 kilometers (km) or 5.7 miles (mi) and

8.5 km (5.3 mi), respectively. The nearest on-site individual is located about 300 m northeast of the RMWMF. The nearest boundary to public land is approximately 2.8 km (1.7 mi) to the south. The main east-west runway of the Albuquerque/KAFB airport lies 8.5 km (5.3 mi) north-northwest of the RMWMF.

Meteorology

SNL/NM and KAFB are located in the Albuquerque-Belen Basin which is characterized by low precipitation; wide temperature extremes; frequent, dry winds; and occasional heavy rain showers. Strong winds usually occur in late winter and early spring. Wind speeds reach a velocity of 50 kilometers per hour (km/h) on an average of 46 days per year. Every 2 years, a 1-minute duration gust of 97-km/h wind is expected. Prevailing surface winds on KAFB are from the east.

Surface Hydrology

The major surface hydrologic feature in central New Mexico is the Rio Grande River, which flows north to south through Albuquerque and lies approximately 10 km (6.2 mi) west of KAFB. Water from the Rio Grande River is used primarily for irrigation of agricultural crops. There are no continuously running streams on SNL/NM property.

Subsurface Hydrology

A fault complex (including a normal fault and an inferred fault) separates the regional aquifer system into a deeper zone west of the faults and a relatively shallower zone east of the faults. The depth to groundwater underlying SNL/NM facilities varies from approximately 15 to 30 m east of the faults and from approximately 116 to 153 m west of the faults.

2.2 RCRA Site Permitting

The sites currently targeted to receive the PO*WW*ER MTU for treatment of mixed wastes all possess a RCRA permit for some form of treatment, storage, or disposal. As a result, it is expected that permitting of the MTU can be accomplished through a modification to the existing RCRA permits. PO*WW*ER MTU technical information required for modifying the RCRA permits is provided in the *PO*WW*ER Mobile Treatment Unit Design Report* (DOE 1996b). The MWTP Manager will provide the technical information to DOE–AL, and DOE–AL will make the information available to the user sites to assist the sites in preparing the required permit modifications.

The PO*WW*ER MTU user sites must obtain a RCRA permit modification for operation of the unit. RCRA Section 3005(a), as amended by the Hazardous and Solid Waste Amendments of 1984, requires owners and operators of all hazardous waste treatment, storage, and disposal facilities to obtain a RCRA permit prior to installing the MTU at a RCRA facility. The MTU may be prefabricated and transported to the proposed treatment site; however, construction on the site itself, such as pouring concrete foundations and connecting the MTU to physical structures on site, cannot occur until the RCRA operation permit is issued (RCRA Section 1004[2]).

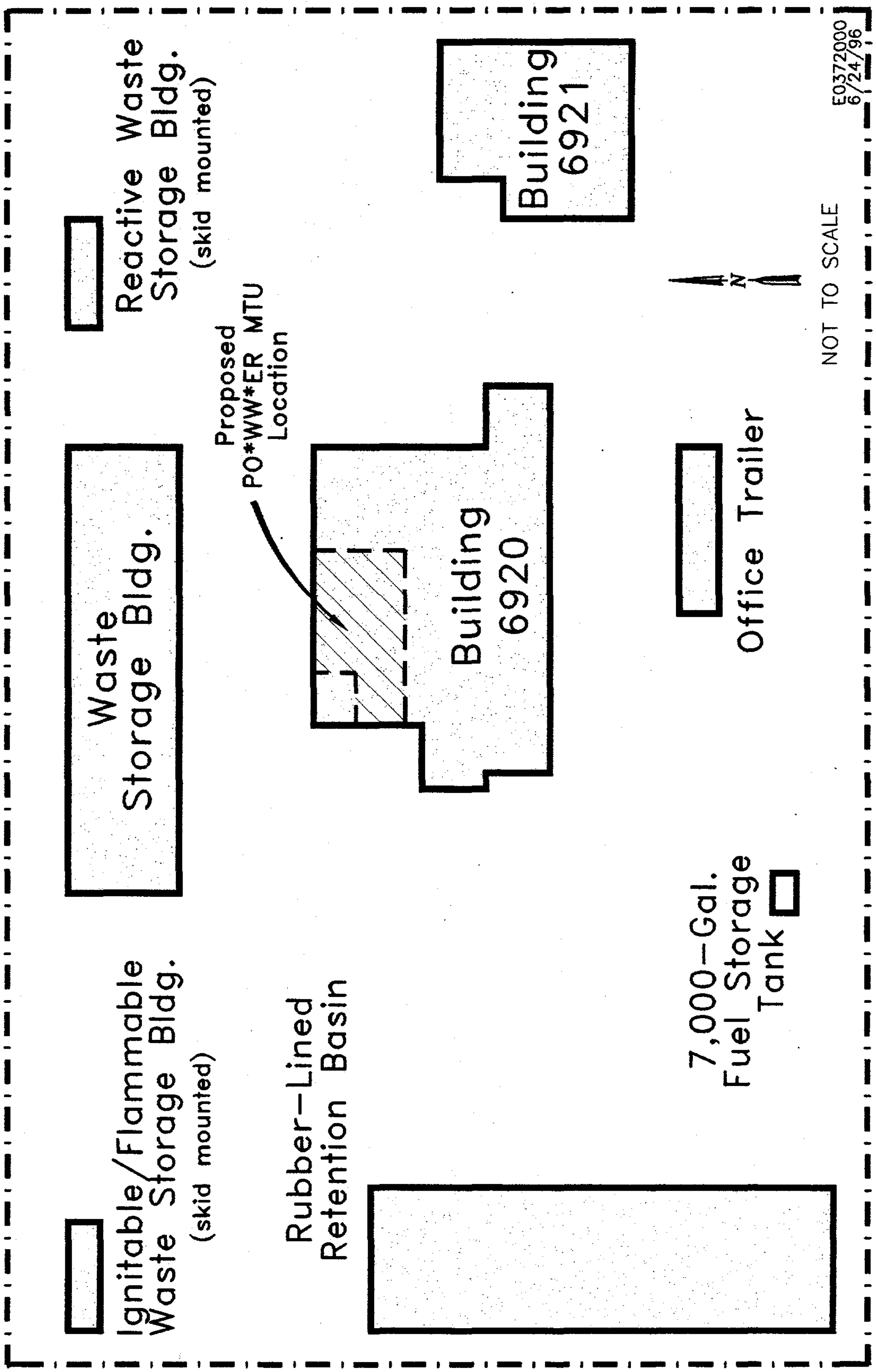


*Figure 2-1. SNL/NM — RMWMF Location Map of Proposed PO*WW*ER MTU*

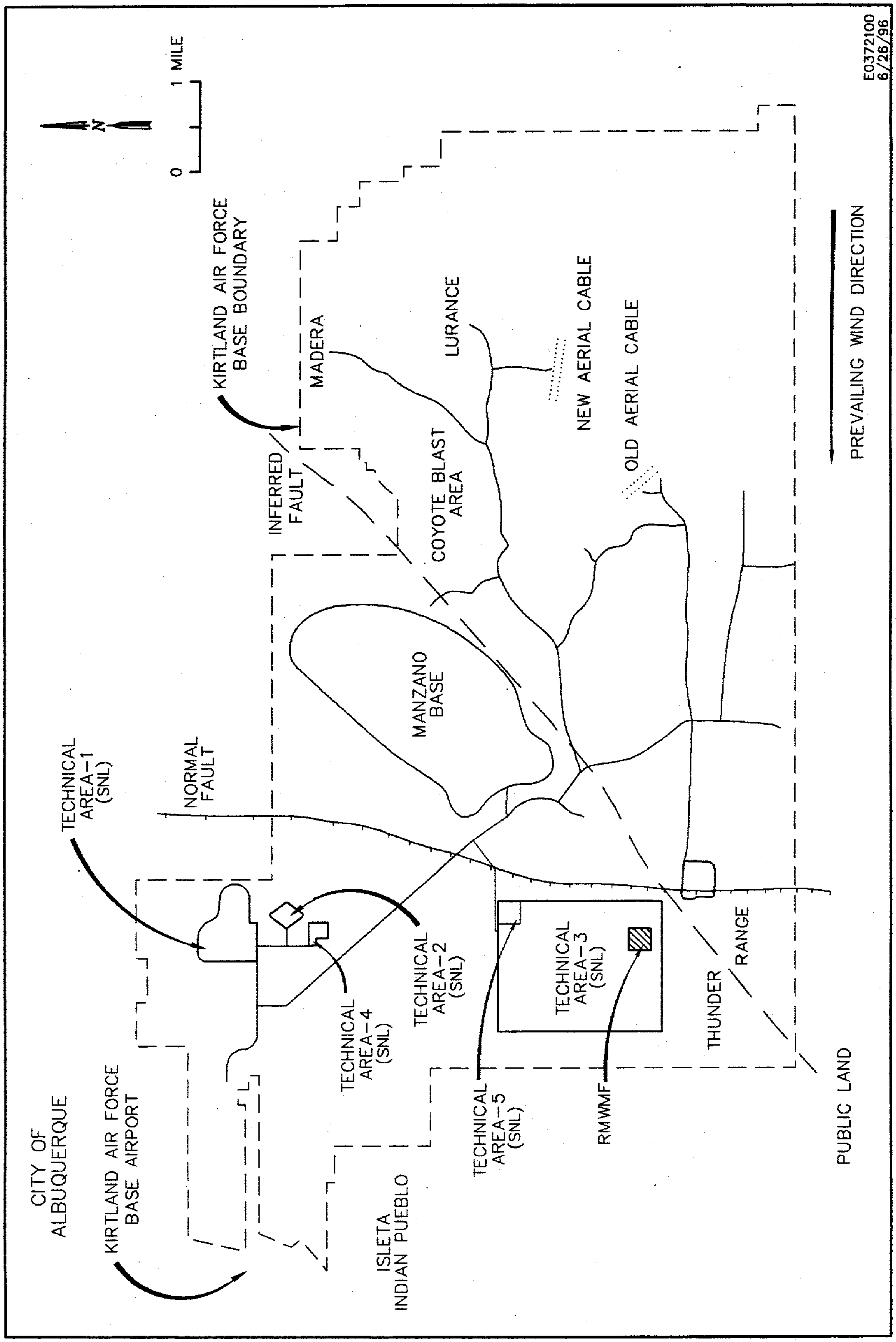


Figure 2–2. Sandia National Laboratories/New Mexico—Location Map

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3.0 Process Description

3.1 PO*WW*ER Mixed-Waste Treatment Process

The PO*WW*ER MTU utilizes Rust's patented PO*WW*ER EO technology to treat aqueous mixed waste streams containing VOCs, SVOCs, volatile inorganics, and dissolved or suspended solids that may contain heavy metals and radionuclides. VOCs and SVOCs are vaporized and destroyed at efficiencies as high as 99.9995 percent, and the harmless products are vented to the atmosphere along with most of the water from the original waste feed. The volume of the concentrated brine, which contains the nonvolatile constituents and is suitable for stabilization, will be less than 5 percent of the volume of the original waste. The technology combines three unit operations: (1) evaporation; (2) catalytic oxidation; and (3) gas scrubbing.

Aqueous mixed-waste is fed to the evaporator which is of forced-circulation design and operates at a slight positive pressure. The evaporator vaporizes the volatile constituents along with most of the water. The nonvolatiles, including radionuclides, dissolved and suspended solids, and heavy metals, are retained in the evaporator and are periodically discharged as a concentrated brine. Dilution water, to control the Econobator bed temperature, and ethanol, which serves as a halide scavenger to maximize catalyst life, also are added in the evaporator. The evaporator is designed to prevent foaming and carryover of radionuclides.

The Econobator (catalytic oxidation) section includes the feed and air heaters, the catalytic Econobator, and the desuperheater. The aqueous waste and air makeup are heated to between 400 and 650 °C, depending on the heating value of the waste, in the feed and air heaters. The waste/air mixture then enters the catalytic Econobator, a fluidized-bed reactor in which the volatilized organic contaminants are catalytically converted into water, carbon dioxide, and trace quantities of acid gas. The temperature of the Econobator is controlled by adjusting the input of the heaters, and the temperature rise is controlled by adjusting the amount of dilution water added to the evaporator. The off gases from the Econobator pass through the desuperheater, in which they are cooled from 650 °C to approximately 150 °C, before passing on to the scrubber.

The acid-gas scrubber is a packed column in which acid gases (chiefly hydrogen chloride) produced from oxidation of volatile waste compounds are neutralized. The medium for neutralization is a weak solution of sodium hydroxide which is circulated counter currently in the scrubber. The neutralized acids are removed as a salt solution, and the remaining gases are vented to the atmosphere.

The process products include the brine from the evaporator which contains the concentrated radionuclides, the "blowdown" from the scrubber containing sodium halide and sodium hydroxide; and the vent gas which contains combustion products and water.

3.1.1 Feed Rate

The maximum waste feed flow rate of the PO*WW*ER MTU covered in this design is 20 gal/h. This rate was based on the streams listed in the DOE–AL mixed waste inventory which were designated for PO*WW*ER as of the time the DDR was prepared. Treatment times based on those waste volumes were on the order of one to two weeks per waste stream. Waste inventories and treatment options have been extensively revised since that time, with the consequence that all DOE–AL mixed-waste streams that would be possible candidates for treatment using PO*WW*ER have been designated for other treatment options. Continued design of the PO*WW*ER MTU uses the original design basis on the assumption that use of outside commercial treatment facilities will prove unfeasible or highly uneconomic for at least some of the DOE–AL aqueous mixed wastes.

3.1.2 Operating Cycle

PO*WW*ER is a continuous process requiring about eight hours just to start up and shut down, so around-the-clock operation is essential. Operation of the MTU must be performed according to the operation and maintenance (O&M) procedures to be prepared prior to the operation of the MTU at user sites. Hereafter in this PHA, the O&M procedures are referred to as standard operating procedures (SOPs).

The MTU must be started up using only water as feed, and the evaporator and Econobator must reach a steady state with water feed before any waste is introduced. The SOPs will not allow any latitude on this point; starting up with waste feed will not be permitted under any circumstances. During this startup period, there is no need to add ethanol to the evaporator, or to add sodium hydroxide to the scrubber. Once the MTU has stabilized with water feed at 20 gal/h, waste will be gradually introduced, replacing water feed with waste feed on a 1:1 basis, until the optimum waste feed rate is achieved. During this time, ethanol and/or sodium hydroxide feed may also be initiated if required.

Shutdown of the MTU also requires operation on water feed only. The waste feed is discontinued and operation continues using only water to strip residual organics from the evaporator. The period of water feed will normally last two to six hours, but longer periods of water feed may be required if the waste feed contained semivolatiles. Ethanol is not required during this period, and sodium hydroxide consumption will very quickly drop to zero as the remaining organics are consumed.

Evaporator brine is removed from the area in sealed drums as required, although it is anticipated that the volume of evaporator brine will not exceed 55 gal until the evaporator is drained at the end of a waste run. Scrubber blowdown also is removed as needed. However, there is no process requirement to drain the scrubber between waste runs, because it will contain no radionuclides or hazardous constituents. Combining the scrubber blowdown from several waste runs into a single drum thus does not constitute mixing hazardous-waste streams.

3.1.3 Waste Characteristics

The PO*WW*ER MTU can treat organic and inorganic (e.g. ammonia) compounds having normal boiling points equal to or lower than 100 °C. Semivolatile compounds, having normal boiling points higher than 100 °C, can be treated with PO*WW*ER although such compounds will accumulate in the evaporator. Semivolatile compounds that have boiling points relatively close to that of water may reach a steady-state concentration in the evaporator when the equilibrium concentration in the vapor leaving the evaporator equals the concentration in the feed liquid. Treatment of higher-boiling semivolatiles will require feeding waste in a "semi-batch" mode alternating periods of waste feed with periods where only water is fed to allow the semivolatile(s) to be stripped from the evaporator.

3.2 Treatment of Radioactive Waste By-Products

The liquid products of the PO*WW*ER process are the evaporator "brine" (the circulating solution in the evaporator) and the blowdown liquid from the scrubber. The PO*WW*ER process is designed to contain nonvolatile radionuclides within the evaporator. The evaporator brine, which contains all radionuclides (with the exception of tritium), is purged off during operation as required to maintain the target specific gravity. At the end of treatment, residual organics are stripped from the brine by feeding water to the evaporator for 2 to 6 hours.

Treatment with PO*WW*ER removes hazardous characteristics such as corrosivity, toxicity, and ignitability. The brine produced from treatment of wastes which exhibit such properties is not characteristic for those properties, and may be disposed of as radioactive waste if no other hazardous characteristics or underlying hazardous constituents are present. If the original waste contained any RCRA-listed hazardous constituents, the brine retains the listing(s) of the original waste. However, analysis of the brine should confirm that it meets RCRA LDRs for all listed constituents, so the brine may be disposed of as a radioactive waste. Any RCRA-regulated metals in the original waste concentrate in the evaporator. If the waste was RCRA-listed for metals, the evaporator brine is considered a mixed waste and requires additional treatment (e.g., stabilization) prior to disposal.

The scrubber blowdown liquid will be a weakly basic (pH ~ 8-9) salt solution. Based on the GJPO treatability tests, it is not expected to contain any hazardous organic compounds. However, some corrosion of the scrubber and the circulating piping is expected, and the products of corrosion will report to the circulating solution. The scrubber blowdown must be analyzed for RCRA-listed corrosion products (e.g., hexavalent chrome) before disposal.

The PO*WW*ER MTU waste acceptance criteria allows for treatment of mixed waste containing low-level (<100 nCi/g) radioactivity. The evaporator can concentrate radionuclides by as much as 100 to 1, so it is possible that the brine produced during treatment of a low-level waste may have a radioactivity level much higher than 100 nCi/g. If the original waste contains a significant portion of transuranic elements, the brine will be transuranic. This will not affect the operation of the MTU in any way, nor will there be any potential for operator exposure to significant radiation dosages, but that fact should be considered prior to final disposal of the brine. See Attachment C.5.3–1 for the dose rate calculation report.

Based on the GJPO treatability tests, the scrubber blowdown liquid is not expected to be radioactive. The exception will occur if tritium is present in the mixed-waste feed. Tritium will either exist as tritiated water, or as tritiated organics that will be converted to tritiated water in the Econobator. When the scrubber is not in use (e.g., when the waste feed does not contain any halogenated organics), all of the tritiated water will be vented directly to the atmosphere along with the rest of the vaporized water and the water of reaction. The sites will have to confirm that the vented tritium does not exceed release limits. When the scrubber is in use, a portion of the vaporized water and the water of reaction, including any tritiated water present, partitions to the scrubber blowdown. Scrubber blowdown from treatment of wastes containing tritium will have to be tested for radiation levels, as well as for RCRA-listed corrosion products as described above, before final disposal requirements can be determined.

3.3 Decontamination and Decommissioning Prior to Shipment to Next Host Site

The interior and exterior surfaces of the PO*WW*ER MTU equipment are designed for decontamination between runs of dissimilar wastes and before shipping the MTU to the next host site. The MTU is designed to withstand frequent decontamination and decommissioning (D&D) without damage to the equipment surfaces or functionality. Decontamination to meet health and safety, permitting, and transportation requirements will be accomplished primarily by draining and chemically flushing the equipment and, if necessary, by dismantling and physically cleaning select pieces of equipment.

The decontamination criteria for shipment of the PO*WW*ER MTU to the next host site will be the requirements for shipping the MTU as nonhazardous material, as defined by U.S. Department of Transportation (DOT) requirements and as low specific-activity material as defined by 49 CFR 173.403. Free release of equipment in radioactive service is not expected. If the equipment is shown to have a specific activity of less than 2,000 picocuries per gram (pCi/g), it is not considered radioactive and may not require special DOT shipping requirements.

In general, the equipment must be completely drained of all liquid, cleaned, sealed, and secured to facilitate shipment. There are no known unique hazards expected to arise as a result of the decontamination effort. Portable local ventilation can be provided to prevent either hazardous or radioactive material from becoming airborne. All decontamination work must be done inside a radioactive materials management area (RMMA).

The only equipment that will be radiologically contaminated are those items in the waste feed system (waste transfer pump, waste feed tank, and waste feed pump) and the evaporator system (evaporator, evaporator heater, and circulating pump). This equipment will be completely drained to satisfy RCRA requirements for empty equipment. The equipment comprising the evaporator system will be internally decontaminated by flushing with hot sodium bicarbonate, followed by rinsing with water. The spent bicarbonate solution and rinse water will be treated as a low-level radioactive waste. If necessary (e.g., if repeated bicarbonate rinses show continued high levels of radioactivity), the evaporator and the evaporator heater can be opened up and the internal surfaces physically decontaminated. The external surfaces of the evaporator system must be decontaminated to the limits given in 49 CFR 173.

Radiological contamination downstream of the evaporator system is not expected unless tritium was present in one or more of the waste streams. If tritium was not present in any waste, the catalyst and the scrubber liquid may be sampled if desired to confirm that they are nonradioactive. Equipment downstream of the evaporator system may be decontaminated for shipment by draining all free liquid and sealing open piping. The HEPA filters will be surveyed to confirm that they are not contaminated, and may then be reused at the next site. If tritium was present in one or more waste streams, the scrubber and all downstream piping must be purged with heated air (using the process air heater) for several hours to volatilize the tritium, and external surfaces must be surveyed to confirm that they conform to the limits given in 49 CFR 173.

4.0 Facility Description

This section covers both primary and secondary containment. The primary containment includes sumps that are part of the design of the PO*WW*ER MTU. It is assumed that secondary containment will be provided by the host sites and is not included in the MTU design.

4.1 Mixed Waste Treatment Skids

The PO*WW*ER MTU skids are designed to be structurally stable to withstand the design basis earthquake, based on the SNL/NM and LANL seismic zone designations of 2B, and rigid to avoid damage during transit. Secondary containment must be a building large enough to house the skids. The building must be a RCRA-permitted building in compliance with DOE Standard DOE–SEO–1020–92, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*, particularly for flood and wind design basis accidents (DBAs).

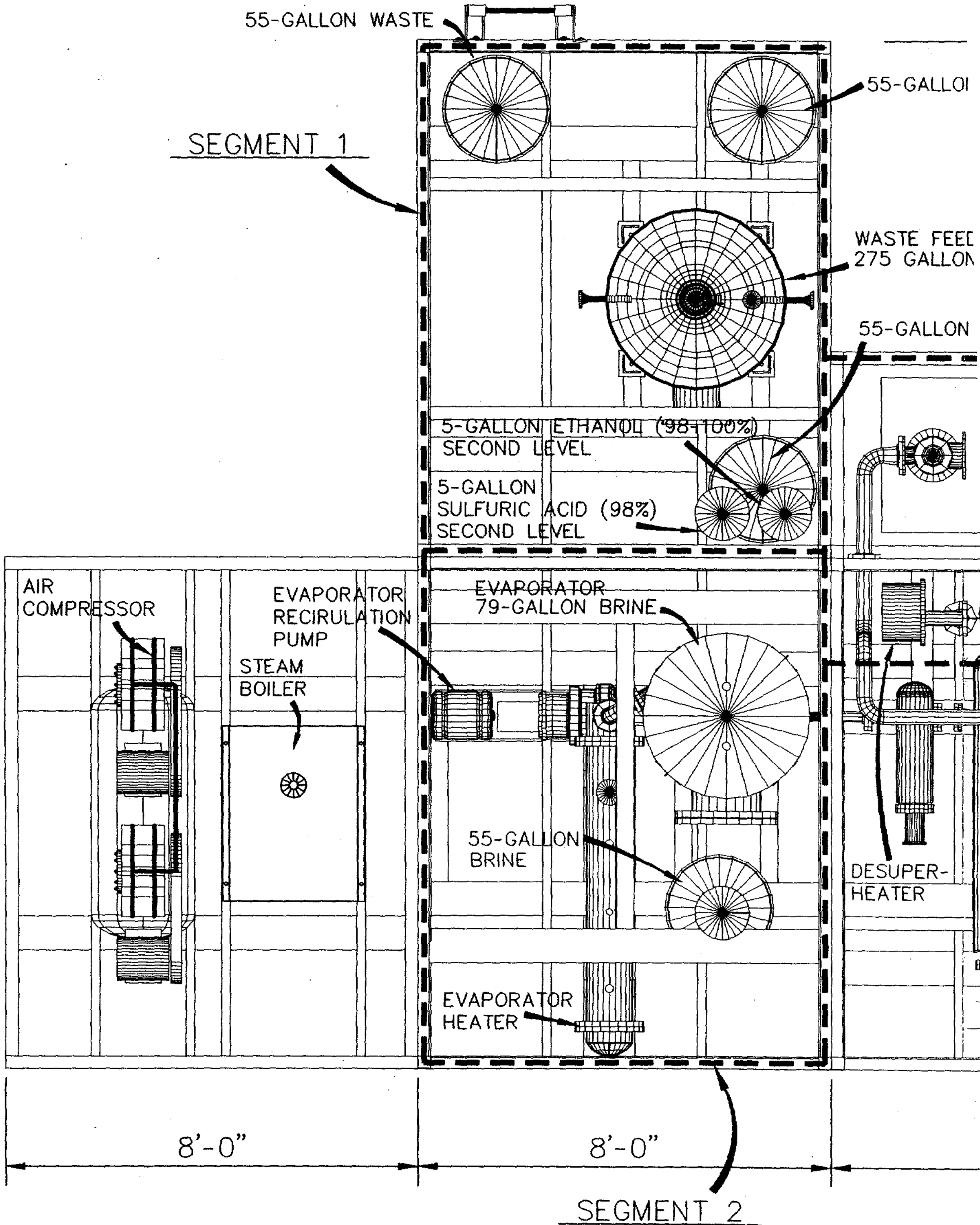
Figure 4–1 shows the layout of the skids for the PO*WW*ER MTU. The MTU is comprised of five primary skids: (1) the waste-feed tank skid; (2) the evaporator skid; (3) the Econobator skid; (4) the scrubber skid; and (5) the utilities skid. For purposes of determining the facility hazard classification (see Section 5), the MTU is divided into three segments, as shown on Figure 4–1. Segment 1 corresponds to Skid 1, Segment 2 to Skid 2, and Segment 3 to Skid 4. Skid 3 operates in vapor phase and contains less than 1 pound of vaporized organics, while Skid 5 is a utilities skid that does not contain any hazardous or radioactive materials, so neither of these skids is included in a hazard segment. The skid arrangement will occupy approximately 276 ft^2 of floor space within the secondary containment. Primary containment is provided by sumps to catch spills on Skids 1, 2, and 4.

The PO*WW*ER MTU skids were designed by a registered structural engineer with more than 20 years experience, and were reviewed by a civil engineer knowledgeable in structural design with more than 12 years experience. The MTU skid design structural sketches, drawings, and calculations show centers of gravity, connection details, points of load application, and stresses in the structural members restraining the assemblies.

4.2 Secondary Containment

The PO*WW*ER MTU design does not include the design or specifications for secondary containment because the host sites will provide secondary containment compliant with RCRA (40 CFR 264) storage requirements, and will be able to meet the requirements for a radiological area. The materials at risk (MAR) and hazard classification analyses indicate no special structure is required. The structure will be designed to comply with DOE–STD–1020–92 for a Category I or II structure for the naturally occurring phenomena accidents for the particular site. Appendix A contains additional information on the requirements for the host-site structure and rationale for the structure specifications.

For seismic design, the worst case for sites hosting this MTU is SNL/NM and LANL, both situated in seismic zone 2B. The existing structures at SNL/NM and LANL are designed to withstand a Seismic Zone 2B earthquake through compliance with building codes such as the Uniform Building Code (UBC). A static force analysis was performed during the MTU design using methods described in the UBC. A performance category of either I or II, as defined by DOE–STD–1020–92, is appropriate for the building and the MTU because (1) there will be a low quantity of MAR, as discussed in Appendix B; (2) the operation can be instantly shut down and the MARs contained; and (3) the two levels of containment are not likely to be breached when the contaminants of concern are being processed. Based on the unmitigated accident analysis as presented in Appendix C.5, even if containment is breached, it is improbable that a life-threatening event would result.


55-GALLON WASTE
55-GALLO
SEGMENT 1
WASTE FEEI
275 GALLON
55-GALLON
5-GALLON ETHANOL (98-100%)
SECOND LEVEL
5-GALLON
SULFURIC ACID (98%)
SECOND LEVEL
AIR
COMPRESSOR
EVAPORATOR
RECIRULATION
PUMP
STEAM
BOILER
EVAPORATOR
79-GALLON BRINE
55-GALLON
BRINE
DESUPER-
HEATER
EVAPORATOR
HEATER
8'-0"
8'-0"
SEGMENT 2

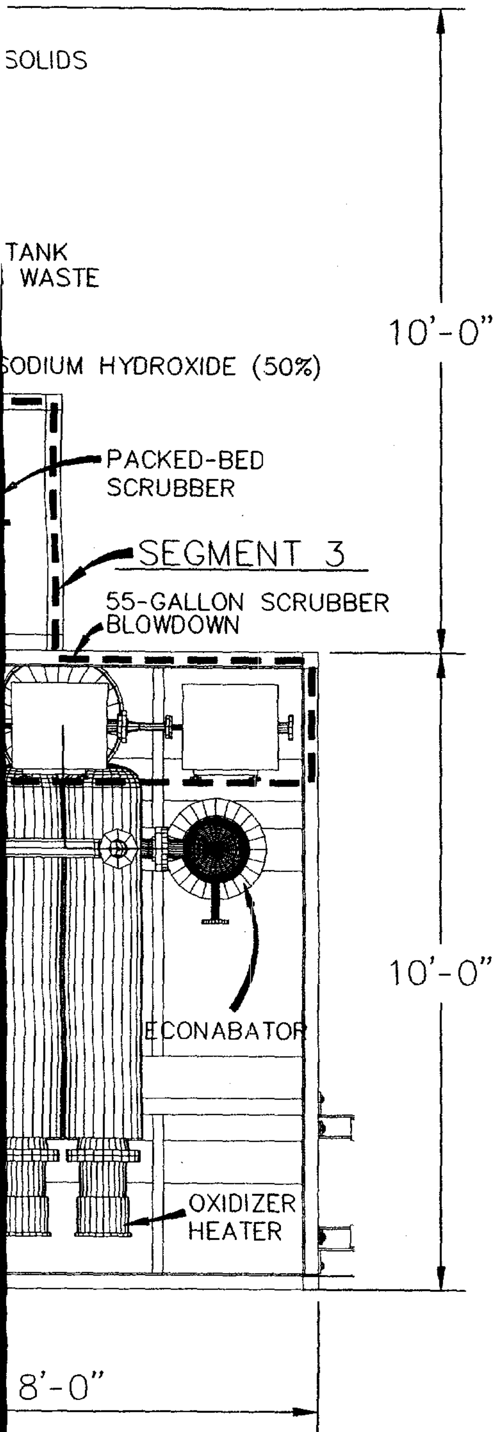


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Figure 4–1	PO*WW*ER MTU PLAN VIEW AND SEGMENTATION FOR HAZARD CLASSIFICATION
DATE PREPARED: JUNE 19,1996	FILENAME: E0372300

5.0 Process Hazards Analysis Summary

5.1 Purpose

The purpose of this PHA report is to provide a formal determination of facility class and hazard category for the PO*WW*ER MTU operation, identify the hazards of the operation, estimate the bounding unmitigated accident consequences, and evaluate the adequacy of safeguards and mitigating controls.

The PO*WW*ER MTU will be used to treat mixed wastes at LANL, SNL/NM, and PTX. This document provides a basis for the user sites to perform an unreviewed safety question analysis, as described in DOE Order 5480.21, *Unreviewed safety Questions*. This PHA determines whether additional site-specific safety analysis and/or a full scope safety analysis report (SAR) will be required prior to DOE authorization to operate the MTU. This PHA also provides the basis for changes to site-specific health and safety plans, process safety management programs, full scope SARs, or environmental assessments as needed.

The scope of this PHA is the operation of the PO*WW*ER MTU, including routine startup and shutdown. Commissioning, decommissioning, and transportation hazards associated with the MTU are outside the scope of this PHA because there will be no material at risk in the MTU during these activities. Commissioning hazards will be analyzed during the readiness review processes (DOE Order 5480.31, *Startup and Restart of Nuclear Facilities*). Hazards specific to decommissioning the MTU will be handled through a task-specific decommissioning plan. Transportation hazard analysis will be controlled through a safety review of the MTU SOP and DOT requirements.

5.2 Methodology

The general PHA process entails data evaluation to determine material at risk; hazards identification, evaluation, and resolution; accident scenario analysis; and consequence analysis. These steps build one upon another to arrive at a determination of the degree of hazard involved in the process being studied.

The PO*WW*ER MTU PHA was performed according to the DOE–AL *Guidance for the Preparation of MWT Process Hazards Analysis* (DOE 1995b). DOE Standards 1027–92, 5502–94, and 3009–94 also were used to ensure the PHA met all requirements. The quantities of hazardous and radioactive substances for the MTU do not require compliance with 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," but the intent of this regulation was met as well.

The hazards and operability (HAZOP) analysis tool was chosen for the operating hazards identification, evaluation, and resolution portion of this PHA. HAZOP analysis provides a framework for the investigation of hazards using a methodical, meticulous investigative approach. The HAZOP analysis of the PO*WW*ER MTU was performed in July 1995, during conceptual design. Engineering and technical personnel from Rust Geotech, Rust Federal Services, and Wheelabrator Clean Air and Clean Water participated in the HAZOP analysis, under the direction of a facilitator from Rust Engineering. Section 5.3 describes the HAZOP analysis process and results.

During the weeks following the HAZOP analysis, Rust Geotech Engineering personnel resolved the action items identified during the HAZOP analysis and made changes to the design accordingly. Appendix C.2 shows the tracking and resolution of all HAZOP analysis action items. At the time the PHA team met in April 1996, resolution of those hazards directly associated with the operation of the MTU that had been identified during the HAZOP analysis was essentially complete. The PHA therefore concentrated on identifying hazards indirectly associated with the operation (e.g., drum handling and damage due to external incidents such as forklift penetrations).

The PHA was developed by a Rust Geotech team with expertise in operations, engineering, health physics, industrial hygiene, and quality assurance. The following assumptions and variations to the DOE–AL PHA guidance document were used in the development of this PHA; these reflect the purpose and intent of the guidance document.

- This PHA was prepared late in the design stage, which affected the content of this report. For example, design change recommendations made as a result of the July 1995 HAZOP analysis had been incorporated in the design prior to performing the rest of the PHA. There were also changes to design made concurrent with the production of this report resulting from the PHA team meetings. Therefore, this report does not recommend actions to reduce risks. Recommended actions have already resulted in design changes to reduce the risks to acceptable levels, incorporate cost-effective features, and improve design operability.

- Hazards classification was based on conservative estimates using available data for MAR and the results of the unmitigated accident scenarios. Hazard classification is required by DOE Order 5480.23, *Nuclear Safety Analysis Reports.* DOE–STD–1027–92 (*Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*) and DOE–STD–5502–94 (*Hazard Baseline Documentation*) were used as guidance.

- A fault-tree analysis was performed for accident scenarios that shows a high safety risk during the accident selection process. The accident consequence, frequency, and risk criteria are presented in Figures C.4–1 through C.4–8. Appendix C.4 contains the fault trees for the DBAs and the accident scenarios are described in Section 5.5.

- Chemical doses, radiological doses for workers, co-located workers, and the general public at the site boundary were calculated for the unmitigated accident scenarios. Appendix C.5.3 describes the calculations and use of EPI-Code and HOTSPOT software. A summary of accident consequences is presented in Section 5.6.

No credit was taken for the secondary containment building in the unmitigated accident analysis. This approach maximizes the radiological doses and contaminant concentrations. However, for the MTU user sites, this PHA assumes a RCRA-permitted building will be provided for the MTU operation.

5.3 Hazard Identification from HAZOP

The process and operating hazards associated with the PO*WW*ER MTU were identified during a HAZOP analysis performed on July 10-12, 1995. Identified hazards were quantified and ranked using an integrated risk assessment which evaluated both the expected frequency of the deviation (hazard or accident) and the consequence. Appendix C.1 provides the results of the HAZOP analysis (see Attachment C.1–1) and details about the ranking and evaluation methods used. After each deviation was quantified according to these criteria, priority rankings were assigned to each deviation by combining the frequency rating with the highest consequence rating. Only two deviations received the highest overall risk ranking: (1) foaming or undetected high level in the evaporator resulting in carryover of liquid into the oxidizer heaters, which in turn could cause an explosion due to thermal stresses in the heaters; and (2) low/no process flow in the Econobator inlet line, which could create an explosive situation due to high propane concentration (propane was originally used as a halide scavenger).

The HAZOP analysis identified 159 "action items" to be considered as possible mitigators for various hazards. These action items are enumerated in the right-hand column of Attachment C.1–1 ("Actions"). Table C.2–1 lists each action item in numerical order, along with the deviation it addressed, the priority of that deviation, a description of the action item, and a statement giving the resolution of the action item.

A number of the HAZOP analysis action items were related to liquid carryover from the evaporator or to the propane addition system, the two highest risk priority hazards identified during the HAZOP analysis. Liquid carryover from the evaporator was mitigated by adding redundant level and foam instrumentation and by modifying the design of the evaporator to the current multichambered design that adds two stages of demisting and a very circuitous flow path. The risk of the low/no Econobator inlet flow scenario was mitigated by deleting the propane addition and replacing it with ethanol, added as a liquid to the evaporator feed. The presence of a small concentration of ethanol, a flammable liquid, at a point in the process (the evaporator) where small concentrations of flammable liquids are normal, adds no additional hazards to the system. Problems with the propane addition caused a number of serious hazard scenarios during the HAZOP analysis, and deletion of the propane resolved 17 of the HAZOP analysis action items. Another source of major hazards was the quench system on the Econobator off gas; deletion of this system and replacement with the noncontact desuperheater resolved an additional 10 action items.

5.4 Hazard Classification

DOE–STD–1027–92 and DOE–EM–STD–5502–94 were used as guidance for the preliminary and final hazard classification of the PO*WW*ER MTU. Both the preliminary and final hazard classifications are based on a segmented system, as shown in Figure 4–1. The concept is allowed by DOE Order 5480.23 when MAR from one segment cannot interact with MAR from another segment. A detailed analysis of hazard classification is presented in Appendix B.

Preliminary Hazard Classification

The preliminary PO*WW*ER MTU hazard classification is "Radiological Facility," based on the total inventory considered MAR in the process. The MAR is described in detail in Appendix B.

Final Hazard Classification

The final hazard classification is based on the results of the unmitigated accident consequences presented in Appendix C.5. The results of the selected DBAs, based on the quantitative results of the unmitigated accident scenarios, indicate that the preliminary hazard classification was appropriate. Therefore, the PO*WW*ER MTU is classified as a "Radiological Facility" according to the classification scheme presented in DOE–EM–STD–5502–94. The unmitigated accident consequences at the site boundary are several orders of magnitude less than the guidelines, indicating that the MTU is a low-hazard facility.

5.5 Accident Scenarios

Accident analysis entails the formal quantification of a limited subset of accidents (i.e., DBAs). These accidents represent, as noted in DOE Order 5480.23, "a complete set of bounding conditions." The identification of DBAs for the PO*WW*ER MTU was based on the hazard evaluation ranking of the complete spectrum of facility accidents described in Appendix C.3.

Four possible accident scenarios were chosen for possible DBAs as a result of the hazard survey performed during the PHA. These scenarios were divided in "sub-scenarios" where appropriate. These scenarios and subscenarios were:

1. Natural phenomenon

2. Ethanol fire
   a. Major ethanol fire
   b. Minor ethanol fire

3. Personnel injury from steam release
   a. Steam fatality due to catastrophic steam release
   b. Chronic steam release due to a slow leak that is not immediately apparent

4. Personnel injury from chemical exposure
   a. Personnel injury from loss of containment of sulfuric acid
   b. Personnel injury from loss of containment of sodium hydroxide
   c. Personnel injury from chemical reaction of sodium hydroxide and sulfuric acid

A fault tree analysis was done for each of these scenarios to evaluate the probability of the occurrences. The fault tree analyses are shown in Appendix C.4. Based on the fault tree analyses, the only scenarios that needed to be considered in additional detail were those with a risk ranking of 3 or higher. This eliminated from further consideration all of the scenarios in Group 4, personnel injury from chemical exposure. The determination of overall risk rankings for the remaining scenarios is discussed in detail in Appendix C.4 and the fault trees are presented in Figures C.4–1 through C.4–8. The highest overall risk ranking for any scenario is 2, for a major ethanol fire. This therefore becomes the DBA for the facility.

5.5.1 Design Basis Accident for the PO*WW*ER MTU

The PO*WW*ER MTU DBA, which is considered bounding for all potential accidents, is the loss of containment on the 5-gal carboy of ethanol on the waste feed skid. The 5-gal carboy is assumed to be ruptured or spilled, and the spilled ethanol results in a concentration in the containment room at the lower explosive limit (LEL). An explosion, or rapidly expanding fire, is assumed to result in the loss of containment in the waste feed system and the evaporator. All waste contents of these units are then assumed to be involved in the ensuing fire/explosion.

The fire/explosion scenario involves the worker in the building containing the MTU, the nearest non-MTU worker on the site, and the off-site public. The MTU worker is assumed to reside in the building during the fire for 30 minutes, thus allowing time for rescue if the worker is not capable of self rescue. The nearest non-MTU worker and the offsite public member is assumed to reside at their location for the duration of the atmospheric plume passage.

5.5.2 Design Basis Accident Scenarios

For this process hazards analysis, three scenarios were selected on the basis of available site information, the EO treatability testing analytical data, and the PO*WW*ER MTU design waste acceptance criteria.

Worst Case: The concentration of contaminants of concern are double the concentrations found in the treatability studies. (There is no evidence that any of the waste streams identified for treatment with the PO*WW*ER MTU contain this level of organics or radionuclides). Uranium-238 and plutonium-239 are both present at 0.1 μCi/g. Hazardous concentrations are 8 weight percent isopropyl alcohol, 10 percent ammonium hydroxide, and 1.3 percent methylene chloride.

Worst Likely Case: Based on the data from treatability testing, the most likely worst case would be uranium-238 at 5.6 x 10^{-4} μCi/g and plutonium-239 at 3.34 x 10^{-6} μCi/g; hazardous constituents are 4.3 percent isopropyl alcohol, 5 percent ammonium hydroxide, and 1.3 percent methylene chloride.

Likely Low-Activity and Low-Hazardous Concentrations Case: Presently, this case represents the waste identified to be treated with the PO*WW*ER MTU. The basis is uranium-238 at 2.8 x 10^{-4} μCi/g and plutonium-239 at 2.38 x 10^{-6} μCi/g; hazardous constituents are 4 percent isopropyl alcohol, 2.8 percent ammonium hydroxide, and 0.88 percent methylene chloride.

In each case, the maximum quantities of material used are those given in Appendix B.1.4.

5.6 Accident Consequences

Fire/explosion DBA consequences were assessed for each source-term scenario for the PO*WW*ER MTU, as described in Section 5.5. Concentrations and doses of hazardous constituents are presented in Appendix A and summarized in Table 5–1 for the distances determined from the evaluation basis site characteristics. Additional consequences at several other distances are addressed in Appendix C.

The ethanol fire/explosion DBA analysis resulted in significant consequences to the PO*WW*ER MTU worker. High doses from radionuclides and hazardous chemical concentrations at levels greater than the immediately dangerous to life or health (IDLH) level were calculated.

The ethanol fire/explosion DBA analysis for the on-site nearest worker and the site boundary, where a member of the public resides, resulted in minimal impacts with very low dose levels from radionuclides and chemical concentrations several orders of magnitude less than the IDLH values.

The *Guidance for the Preparation of MWT Process Hazards Analysis* (DOE 1995b) document references Appendix A of DOE-STD-3009-94 for evaluation criteria for unmitigated accident consequences; however, Appendix A was never published. Vince Wahler* of the DOE–AL Nuclear Safety Division indicated that the criteria of interest in the unpublished document was that equipment that mitigates a site boundary dose to a member of the public in excess of 25 rem committed effective dose equivalent should be designated as safety classification equipment (Wahler 1996). For chemicals, the Emergency Response Planning Guidelines (ERPG) III level is not exceeded at the site boundary, therefore the facility is classified as a low hazard. For chemicals without ERPGs, a similar criteria may be used, such as a facility is considered to be low hazard if the IDLH concentration is not exceeded at the site boundary. Using this guidance, the PO*WW*ER MTU is considered a low-hazard facility.

*Per telephone conversation between R. L. Morris of Rust Geotech and Vince Wahler of DOE–AL Nuclear Safety Division on March 8, 1996 (Wahler 1996), the applicable guideline indicates a fence line dose to a member of the public in excess of 25 rem committed effective dose equivalent.

Table 5–1. Radiological Dose and Hazardous Concentrations for the Fire DBA

Fire DBA Event	Source Term	PO*WW*ER Worker[a]	Onsite Nearest Worker (0.3 km)	Site Boundary (2.8 km)
Worst Case	100 nCi/g Pu	109 rem	2.4 mrem	0.046 mrem
	100 nCi/g U	26 rem	0.87 mrem	0.015 mrem
	10% wt. ammonia	> IDLH	110 ppm	0.36 ppm
	8% wt. isopropyl alcohol	> IDLH	29 ppm	0.094 ppm
	1.3% wt. methylene chloride	> IDLH	5.5 ppm	0.018 ppm
	7.5 kg ethanol	> IDLH	4.3 ppm	0.014 ppm
Likely Worst Case	3.3×10^{-6} µCi/g Pu	36 mrem	7×10^{-4} mrem	1.3×10^{-5} mrem
	5.6×10^{-4} µCi/g U	1.4 rem	0.043 mrem	8.1×10^{-4} mrem
	5% wt. ammonia	> IDLH	55 ppm	0.18 ppm
	4.3% wt. isopropyl alcohol	> IDLH	15 ppm	0.051 ppm
	1.3% wt. methylene chloride	> IDLH	5.5 ppm	0.018 ppm
	7.5 kg ethanol	> IDLH	4.3 ppm	0.014 ppm
Likely Low-Activity, Low-Hazardous Concentration	2.38×10^{-6} µCi/g Pu	26 mrem	1.4×10^{-3} mrem	2.7×10^{-5} mrem
	2.8×10^{-4} µCi/g U	728 mrem	0.021 mrem	4.0×10^{-4} mrem
	2.8% wt. Ammonia	> IDLH	31 ppm	0.10 ppm
	4% wt. isopropyl alcohol	> IDLH	15 ppm	0.051 ppm
	0.88% wt. methylene chloride	> IDLH	5.5 ppm	0.018 ppm
	7.5 kg ethanol	> IDLH	4.3 ppm	0.014 ppm

[a]Unprotected worker: no credit is given for mitigators such as respirators or other emergency equipment available in the work area.

Key:
- DBA = design basis accident
- IDLH = immediately dangerous to life or health
- kg = kilogram(s)
- km = kilometer(s)
- mrem = milliroentgen(s)
- nCi/g = nanocuries per gram
- ppm = parts per million
- Pu = plutonium
- U = uranium
- wt. % = weight percent

6.0 Defense-In-Depth

This section summarizes the defense-in-depth (i.e., prevention of uncontrolled hazardous or radioactive material releases) provided by the passive design features, engineered safety features (ESFs), and administrative controls for each type of hazard identified in the PO*WW*ER MTU PHA. ESFs and administrative controls that mitigate potential hazards were identified and evaluated during the HAZOP analysis. Attachment C.1–1, Table C.1–3, HAZOP analysis action items, contains a list of all potential hazards identified and their respective safeguards. Sections 3.0 and 4.0 also describe some of the major safety design features of the MTU.

Of the potential hazards identified during the HAZOP analysis, only two were given the highest combined overall hazard ranking. Those hazards are addressed in this section. The remaining hazards were evaluated for potential design improvements to lessen their severity and/or their frequency.

As presented in Section 5.3, the two most significant hazards identified during the HAZOP analysis of the PO*WW*ER MTU design were: (1) foaming or undetected high level in the evaporator resulting in carryover of liquid into the oxidizer heaters, which in turn could cause an explosion due to thermal stresses in the heaters; and (2) low/no process flow in the Econobator inlet line, which could create an explosive situation due to high propane concentration. Resolution of the first hazard was effected by adding redundant level and foam instrumentation and by modifying the design of the evaporator to the current multichambered design, which adds two stages of demisting and a very circuitous flow path. The second hazard was resolved by eliminating the propane addition (which was the detonation source) and replacing it with addition of ethanol as part of the evaporator feed. All other significant hazard initiators identified during the HAZOP analysis have been similarly mitigated.

The DBA for the PO*WW*ER MTU, an ethanol release and subsequent fire, results from human error not directly related to the operation of the process. Mitigation of such a hazard must depend on physical design elements (e.g., layout) and administrative controls rather than on process elements such as interlocks. The primary safeguard against catastrophic damage to the ethanol container is its location in the interior of the skid where the structural members will protect it from most major hazards. The design also minimizes the volume of ethanol and other hazardous compounds which will be kept on the skid at any time. Because ethanol is only needed by the process as a halide scavenger during treatment of highly halogenated waste streams, the SOPs will require that ethanol not be stored on the skid except when needed. The SOPs will also require that containers of ethanol and other hazardous chemicals be removed from the skid to a secure area before major maintenance is undertaken

The design employs a proven programmable logic control system with all critical instrumentation alarmed, including the capability for automatic shut-down of the MTU should critical operating parameters be exceeded. The SOP for the MTU and operators trained to the SOP will ensure the safe operation of the MTU. The instrumentation ensures that the information is available to the operator to safely operate the unit.

On the basis of the PHA, there are no structures, systems, or components (SSCs) of the PO*WW*ER MTU that are considered safety class SSCs. In accordance with the guidance provided in DOE–STD–3009–94 (*Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*), safety class SSCs are those which accident analyses indicates are needed to prevent accident consequences to the public from exceeding the evaluation guidelines. As presented in Appendix C.5, the unmitigated accident consequence results for the MTU are several orders of magnitude less than the guidelines at the site boundary; therefore, no SSCs are considered safety class SSCs. This identification of no safety class SSCs is consistent with DOE–STD–3009–94, which indicates that safety class SSCs normally will not be associated with Hazard Category 2 and 3 facilities due to their limited potential for off-site impact.

Safety significant SSCs are those SSCs not designated as safety class SSCs, but their preventive or mitigative function is a major contributor to defense-in-depth and/or worker safety as determined from the hazard analysis. According to the guidance provided in DOE–STD–3009–94, safety significant SSC designations based on worker safety are limited to those SSCs whose failure is estimated to result in a worker fatality or serious injuries to workers. The guidance also indicates that the distribution of the hazardous material inventory is a key consideration in designating safety significant SSCs (e.g., if the total hazardous material inventory is distributed over a hundred containers, the failure of any one container does not constitute a major uncontrolled hazardous material release). As presented in Section 5.4 and Appendix C.5, the PO*WW*ER MTU is a low-hazard Radiological Facility; this is a facility that does not meet or exceed the Hazard Category 3 threshold criteria of the potential for only significant localized consequences, and has hazards that present minor on-site and negligible off-site impacts to people and the environment. The risk of any injury to an MTU worker is low and the risk of serious injury or death from operation of the MTU is considered nonexistent. Therefore, based on the guidance and the design of the MTU, no SSCs are considered safety significant SSCs.

7.0 Conclusions and Recommendations

On the basis of this PHA, the overall risk to any population group from operation of the PO*WW*ER MTU has been determined to be very low. The MTU is classified as a Radiological Facility (i.e., less than a Hazard Category 3 facility) with low hazards (i.e., minor on-site and negligible off-site impacts to people and the environment).

The unmitigated accident consequence results for the MTU are several orders of magnitude less than the guidelines at the site boundary; therefore, no SSCs are considered safety class SSCs. The risk of any injury to an MTU worker is low, and the risk of serious injury or death from operation of the MTU is considered nonexistent. Therefore, no SSCs are considered safety significant SSCs.

No credit was taken for the secondary containment building in the unmitigated accident analysis. This approach maximizes the radiological doses and contaminant concentrations. However, for the MTU user sites, this PHA assumes a RCRA-permitted building will be provided for the MTU operation.

No further action is required to reduce risks because changes to the design of the PO*WW*ER MTU were made concurrent with the hazard identification and analysis. Recommended actions have already resulted in design changes to reduce the risks to acceptable levels, incorporate cost-effective features, and improve design operability. The evaluation of the frequency or consequence of the risks and the mitigative features implemented in the PO*WW*ER MTU design are documented in Attachment C.1–1 and Table C.2–1 and summarized in Section 5.3. All hazards with initial risk rankings of 1 or 2 have been reduced to acceptable risk rankings of 3 or 4.

Based on the final hazard classification as a Radiological Facility and the guidance given for facilities with a final radiological classification (Section 6.3 of the *Guidance for The Preparation of MWT Process Hazards Analysis* [DOE 1995b]), this PHA is the only safety basis documentation necessary to support DOE authorization to operate the PO*WW*ER MTU at all user sites. No additional safety basis documentation (supplemental safety analysis and/or a full scope SAR) is required or recommended.

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Appendix A

Evaluation Basis Site Characteristics

A.1 Assumed Generic Site Characteristics

A.2 Assumed Attributes of Generic Secondary Containment

A.3 MTU Accidents as Initiators of External Accidents

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Appendix A. Evaluation Basis Site Characteristics

This appendix provides information on the methodology and assumptions used to develop the site characteristics. These characteristics are referred to as the evaluation basis site characteristics (EBSC). The EBSC were considered during the PO*WW*ER mobile treatment unit (MTU) Process Hazards Analysis (PHA). Because the unmitigated accident analysis is based on a generic set of site characteristics, simplified assumptions were used in the development of the characteristics to ensure conservatism. The design basis accident (DBA) selected as bounding for all potential PO*WW*ER MTU accidents was a fire/explosion from leakage of the ethanol drum in the waste feed system.

A.1 Assumed Generic Site Characteristics

The unmitigated accident analyses were conducted in a generic fashion to ensure that the consequences would be bounding for each site using the PO*WW*ER MTU. The distances to the nearest on-site facility and site boundary were determined based on information from Sandia National Laboratories, New Mexico (SNL/NM). SNL/NM has proposed a location for the MTU. Los Alamos National Laboratory (LANL) and Pantex (PTX) have not determined where the MTU will be located on site. Therefore, the analyses were conducted in a conservative manner to ensure that all sites could apply the results to their facilities. Table A.1–1 presents a summary of the EBSC considered during the unmitigated accident analyses.

Table A.1–1. Evaluation Basis Site Characteristics Summary (EBSC)

Site Attribute	SNL/NM	EBSC
Closest distance to site boundary	2.8 km (1.736 mi)	2.8 km
Distance to nearest occupied building or area	0.3 km (0.186 mi)	0.3 km
Distance from MTU to MTU-exclusion-area boundary	Unknown	Not needed for analyses
Pertinent meteorology	Worst case	Worst case

Key:
km = kilometer(s)
mi = mile(s)
MTU = mobile treatment unit
SNL/NM = Sandia National Laboratories, New Mexico

Note: EBSC distances are assumed, based on SNL/NM facility information. The worst case meteorology was used for the unmitigated accident analyses, which included a ground-level release with Category-F stability and a 1-meter-per-second wind speed.

The PO*WW*ER MTU is not expected to be significantly impacted by external events. Reactive and ignitable/flammable waste is stored at SNL/NM in skid-mounted storage buildings located approximately 100 feet to the northeast and to the northwest of Building 6920, the proposed location of the PO*WW*ER MTU.

A.2 Assumed Attributes of Generic Secondary Containment

The unmitigated accident analyses do not take into account secondary containment. Therefore, radiological doses and hazardous contaminant concentrations are maximized in the analyses.

Treatment, storage, and disposal facility regulations (40 CFR 264) include requirements for secondary containment for tanks and containers. These standards, or equivalent standards administered by a State, must be incorporated into a Resource Conservation and Recovery Act (RCRA) Part B permit for each facility. Thus, the Part B permit must interpret these standards and state the specific requirements. At a minimum, Part B permit requirements include secondary containment for vessels and containers containing free liquids. This secondary containment could be incorporated either in the skid or in the construction of the facility housing the PO*WW*ER MTU.

To be independent of the design of host facilities, the PO*WW*ER MTU skids have been designed to incorporate secondary containment for the vessels and piping. Secondary containment for spill control, in the form of a sump built into the bottom of the skids, is included in the PO*WW*ER MTU design. The floor of the skids will be constructed with grated material to allow spilled materials to fall through to the sump, where they will be contained.

It is the responsibility of the host site to ensure that the PO*WW*ER MTU is located in an area where external events would not impact the unit.

A.3 MTU Accidents as Initiators of External Accidents

The potential unmitigated accidents, developed from Appendix C, are not considered to be potential initiators of further external accidents. The fire/explosion DBA would result in a rapidly expanding fire; however, it would not have enough force to create events at other facilities at the site. In addition, the mitigators for the fire/explosion DBA would likely stop a fire before it spread to other areas of the building where the PO*WW*ER MTU is located.

This PHA report did not considered the PO*WW*ER MTU accidents as initiators of external accidents. Because the MTU will be located at multiple sites, it would be prudent for site personnel to ensure that the MTU is not located next to areas containing highly reactive or flammable material and that an adequate fire suppression system be installed.

Appendix B

Materials at Risk

B.1 Assumed Materials at Risk

B.2 Evaluation Basis Waste Characteristics

B.3 Assumed Cases for Process Hazards Analysis

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Appendix B. Materials at Risk

B.1 Assumed Materials at Risk

Characterization data for the mixed-waste streams proposed for treatment in the PO*WW*ER MTU is inadequate. To determine a maximum worst-case scenario for a Process Hazards Analysis of the MTU, available information, including data from characterization of the waste samples fed to the pilot-scale PO*WW*ER unit during treatability testing at the U.S. Department of Energy, Grand Junction Projects Office (DOE–GJPO), was reviewed. Data collected from the PO*WW*ER treatability test feed preparation analytical results for Sandia National Laboratories/New Mexico (SNL/NM), Los Alamos National Laboratory (LANL), and GJPO waste feed samples were used to determine the expected maximum worst-case scenario and a generic list of materials at risk (MAR).

It is assumed that the waste acceptance criteria for the PO*WW*ER MTU will be met by the host sites. The primary factors effecting MAR acceptability for PO*WW*ER MTU treatment are packaging and content characteristics.

B.1.1 Packaging

Waste shall be received in containers approved by the U.S. Department of Transportation (DOT) (i.e., authorized for the waste contained and chemically compatible with the wastes). The containers shall be 85-gallon (gal) overpack, 55-gal drums, or 30-gal drums that are free of surface defects, bulges, dents, or similar physical evidence of degradation, ice, snow, or mud. The containers shall have visible, legibly printed, stenciled, or hand-written markings. The markings shall include all of the following:

- Name and address of the generator.
- Gross package weight.
- Waste-stream identification number.
- Major radionuclides present.
- Maximum radiation level on contact and at 1 meter in air.
- Proper DOT labels and markings.
- Resource Conservation and Recovery Act (RCRA) hazardous waste markings.
- No extraneous markings.

B.1.2 Content Characteristics (waste acceptance criteria)

According to 40 CFR 264.13, the owner or operator of a waste treatment facility must obtain a detailed physical and chemical analysis of a representative sample of the waste, which must contain all of the information needed to treat, store, and/or dispose of the waste. The responsibility for confirming that wastes to be treated with the MTU conform to the waste acceptance criteria for the MTU belongs to the generators.

The waste shall contain none of the following:

- Reactive wastes as defined in 40 CFR 261.23
- Wastes containing semivolatile organic contaminants which are immiscible in water
- Compounds having normal boiling points higher than 150 °C
- Toxic Substance Control Act wastes, including polychlorinated biphenyls (PCBs), due both to immiscibility and low volatility
- Phenolics
- Radioactivity levels greater than 100 nanocuries per gram (nCi/g)

In addition, no waste which exceeds the worst case concentrations for organic compounds given in Appendix B.3.1 should be accepted for treatment with the PO*WW*ER MTU without a thorough safety review.

B.1.3 Waste Processing Limitations

The PO*WW*ER MTU process is intended for treatment of volatile liquid waste, typically aqueous waste contaminated with less than 5 percent by weight RCRA-regulated volatile organics. Because the unit is an evaporator followed by a catalytic Econobator, any compounds that can be vaporized at or near the boiling point of water can be accepted as a feed material.

Because there are an infinite number of combinations of waste that the unit is capable of treating, the MAR was taken from a composite of the aqueous wastes treated by the pilot unit in the treatability studies performed at GJPO.

B.1.4 Quantity of MARs

For the basis of this analysis, it is assumed that the PO*WW*ER MTU will be installed in a RCRA-permitted building at the host site. Installing the MTU inside a building constitutes the secondary containment for the MAR. If a large building is chosen, it can be partitioned off to minimize the size of the process area. The minimum square footage required for the operation of the PO*WW*ER MTU is 1,296 square feet (ft^2), of which 276 ft^2, based on the primary skid layout as shown on Figure 4–1, needs to be in a radioactive material management area (RMMA).

Segmentation of the PO*WW*ER MTU

The PO*WW*ER MTU was divided into three primary segments: (1) waste feed tank/chemical addition skid; (2) evaporator skid; and (3) scrubber skid. The three segments for the MTU are independent systems, thus ensuring that an accident in one segment would not precipitate a release in the other segments of the MTU. The skids represent primary segments of the facility. The skids are bolted together and have their own independent spill control sumps. Figure 4–1 illustrates the PO*WW*ER MTU segmentation for hazard classification.

Segment 1: The waste feed tank skid is included in the total MAR inventory for the hazard classification. The waste feed tank skid will contain five drums of aqueous waste or 36.8 cubic feet (ft^3), a drum of

50 percent sodium hydroxide (caustic) or 7.4 ft^3, a 5-gal carboy of 98 to 100 percent ethanol or 0.67 ft^3, and a 5-gal carboy of 98 percent sulfuric acid or 0.67 ft^3. Only one drum of waste will be opened at any time. The caustic, acid, and ethanol will be hard-piped to their respective metering pumps and to the waste feed tank. Unopened waste drums (i.e., those awaiting treatment) are excluded from the total MAR inventory as per DOE–STD–1027–92, which states that material contained in a DOT Type B shipping container, with or without overpack, may be excluded from assessment of a facility's radioactive inventory. Therefore the total maximum MAR for Segment 1 will be 3,091 pounds (lb) or 1,403 kilograms (kg) divided between the waste feed tank, weighing a total of 2,280 lb or 1,035 kg at a specific gravity of 1.0, the caustic drum weighing 702 lb or 319 kg at a specific gravity of 1.53, the acid carboy weighing 76 lb or 34 kg at a specific gravity of 1.83, and the ethanol drum weighing 33 lb or 14.8 kg at a specific gravity of 0.79.

Segment 2: The evaporator skid is included in the total MAR inventory for the hazard classification. The evaporator skid and associated heat exchanger, pump, and piping will contain up to 10.5 ft^3 of brine. In addition a collection drum for the brine will contain 7.4 ft^3. The total maximum MAR for Segment 2 will be 1,377 lb or 625 kg divided between the brine collection drum weighing a total of 570 lb or 259 kg at a specific gravity of 1.24, and the contents of the evaporator system weighing a total of 807 lb or 366 kg at a specific gravity of 1.24.

Segment 3: The scrubber skid is included in the inventory for the hazard classification. The scrubber sump and associated piping contain approximately 8.0 ft^3 of scrubber liquor and the scrubber blowdown collection drum contains 7.4 ft^3 of scrubber blowdown liquor. The total maximum MAR for Segment 3 will be 1,012 lb or 460 kg divided between the scrubber blowdown drum weighing a total of 486 lb or 221 kg at a specific gravity of 1.06, and the scrubber sump weighing a total of 526 lb or 239 kg at a specific gravity of 1.06.

The residuals from processing include brine from the evaporator, scrubber liquor from the scrubber, and the vent gas. The brine from the evaporator will contain all of the radioactive components of the waste feed, excluding tritium, as well as any heavy metals or non-volatile organics. The scrubber liquor is essentially a 10 percent solution of sodium chloride (table salt) with a pH of 8 to 10. Depending on the waste feed the vent gas will be a mixture of nitrogen, oxygen, carbon dioxide, water vapor, nitrogen and nitrous oxides, trace amounts of hydrochloric acid, and carbon monoxide. Tritiated water vapor would be present in the event that the waste feed contained tritium. The brine residual will be sealed in 55-gal drums for disposal as a low-level radioactive waste.

Table B.1.4–1 presents a summary of the maximum quantities of MAR allowed, or estimated, at each stage of the PO*WW*ER MTU process.

Table B.1.4–1. Summary of Volume and Weight of Materials at Risk

Segment	Volume (ft³)	Pounds (kg)	Containment
1 Waste feed tank Caustic drum Acid carboy Ethanol drum	36.8 7.4 0.67 0.67	2,280 (1,035) 702 (319) 76 (34) 33 (14.8)	Sealed drums or tank and two hard-piped drums and a hard-piped carboy
2 Evaporator Brine drain drum	10.5 7.4	807 (366) 570 (259)	Sealed evaporator and piping and hard-piped drum
3 Scrubber sump Blowdown drum	8.0 7.4	526 (239) 486 (221)	Sealed scrubber and two hard-piped drums
	Total	5,480 (2,488)	All normally sealed

Key:
ft^3 = cubic feet
kg = kilograms

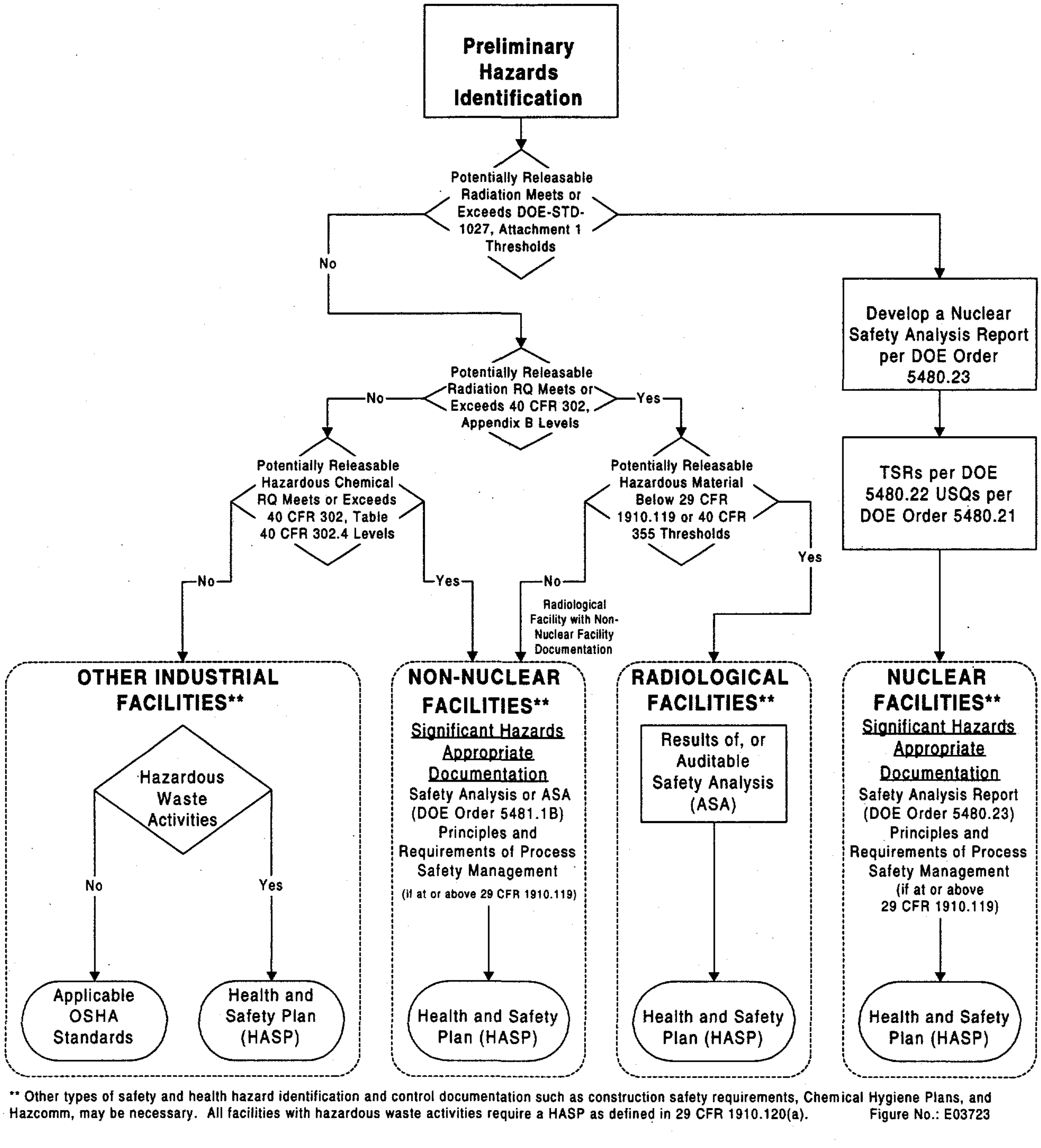
B.1.5 Hazard Classification

Hazard classification as required by DOE Order 5480.23, *Nuclear Safety Analysis Reports*, is a two-fold system. The first element involves the initial, or preliminary assessment of the inventory of hazardous MAR and the estimate of the hazard classification. Once a hazards analysis has been performed the hazard classification can be finalized. The final classification is based on an "unmitigated release" of available material. For the purposes of hazard classification, "unmitigated" is meant to consider material quantity, form, location, dispersability, and interaction with available energy sources, but does not consider safety features (e.g., ventilation system, fire suppression), which will prevent or mitigate a release. Figure B.1.5–1 presents a flow chart of the hazard classification process.

DOE Standards 1027–92 and 5502–94 were used as guidance for the preliminary and final hazard classification of the PO*WW*ER MTU. DOE–STD–1027–92 provides guidance on the requirements for the development of a safety analysis report based upon the hazard classification for nuclear facilities with Category 1 through Category 3 hazards. DOE–EM–STD–5502–94 provides additional guidance for further classification of facilities that are below the nuclear facility Category 3 hazard classification, and contains criteria for grouping environmental management facilities into nuclear, radiological, nonnuclear, or industrial categories. Only facilities that fall below the Category 3 classification threshold are exempt from the requirements of DOE Order 5480.23.

DOE–STD–1027–92 identifies a threshold for the total segmented inventory of a Category 3 nuclear facility. The quantity limits in Attachment 1 of DOE–STD–1027–92 were developed by taking the product of the airborne release fraction and effective dose equivalents from different pathways or sources (e.g., inhalation, ground contamination, and cloud shine).

To establish a hazard classification system based on inventories in DOE–STD–1027–92, DOE modified the U.S. Environmental Protection Agency (EPA) reportable quantities (RQs) for radionuclides defined in 40 CFR 302.4, Appendix B. The values for radionuclides represent levels of material that, if released, would produce less than 10-rem doses at 30 meters (m) based on a 24-hour exposure. For the period of exposure, the DOE hazard classification models assume that persons are exposed for one day for inhalation and direct exposure, but that persons are exposed for longer periods through the ingestion



** Other types of safety and health hazard identification and control documentation such as construction safety requirements, Chemical Hygiene Plans, and Hazcomm, may be necessary. All facilities with hazardous waste activities require a HASP as defined in 29 CFR 1910.120(a). Figure No.: E03723

Figure B.1.5–1. Hazard Classification Process pathway in order to account for the slow movement of radionuclides in groundwater. For the sake of conservatism and simplicity, radioactive decay is not taken into account.

DOE–STD–1027–92 also modifies the hazardous release fractions used by the U.S. Nuclear Regulatory Commission (NRC) in NUREG–1140 and assumed a value of 10^{-3} for solids, powder, and liquid. DOE believes that the 10^{-3} value is a reasonably conservative approximation because it will be applied to an entire building without scenario-specific considerations. DOE recognizes that some accidents, particularly those involving powders and liquids, can produce much higher values, whereas accidents involving metals would normally produce slightly smaller release fractions. However, it is unlikely that any event will affect all material in a building, and high release phenomena such as explosions and pressurization will affect only a localized fraction of the material. Therefore, 10^{-3} is a reasonable average for hazard categorization purposes and was considered acceptable for hazard classification of the PO*WW*ER MTU.

The radionuclides of interest for the MTU are plutonium-239 (Pu-239) and uranium-238 (U-238) because these are the most likely radionuclides to be in the nontransuranic waste streams to be treated. Pu-239 also is among the most limiting radionuclides in regard to concentration and inventory limits. Ethanol, methylene chloride, isopropyl alcohol, and ammonia were chosen as the worst case hazardous chemicals because of past processing knowledge. See Table B.2.2–1 for the evaluation basis waste characteristics.

Preliminary Hazard Classification

The preliminary hazard classification of the PO*WW*ER MTU required identification of the MAR. The quantity of MAR for the MTU, as described in detail in Appendix B.1.4, provides the basis for the preliminary hazard classification. A preliminary hazard classification does not require assessment of specific accident scenarios; rather, it is based upon the total inventory considered at risk in the process.

DOE Order 5480.23 states that an analysis and categorization is to be performed on "processes, operations, or activities" and not necessarily whole facilities. For the purpose of categorizing hazards and estimating the MAR inventory for the PO*WW*ER MTU, the objective was to understand the possible hazards that could interact and cause harm to individuals or the environment. It is not desirable to estimate the potential consequences from an inventory of hazardous materials when facility features would preclude bringing this material together. Therefore, DOE Order 5480.23 allows the concept of facility segmentation, provided the MAR in one segment could not interact with MAR in other segments. The concept of independent facility segments was applied to the MTU where facility features preclude bringing MAR together or causing harmful MAR interaction from a common severe phenomenon.

Facility Classification

The most conservative estimate of MAR for the PO*WW*ER MTU hazard classification includes MAR from the evaporator, consisting of 626 kg divided between the brine collection drum weighing a total of 260 kg and the contents of the evaporator system weighing a total of 366 kg. The likely worst-case concentration of contaminants assumed is Pu-239 at 3.3×10^{-6} µCi/g and U-238 at 5.6×10^{-4} µCi/g. The evaporator will concentrate these radionuclides, and a concentration factor of 100 was assumed. This assumption results in a MAR of 2.09×10^{-4} Ci for Pu-239 and 3.5×10^{-2} Ci for U-238. Table A.1 of DOE–STD–1027–92 states that the Category 3 threshold of radionuclides is 0.52 Ci for Pu-239 and 4.2 Ci for U-238. Therefore, the MAR estimates for the PO*WW*ER MTU result in a hazard classification of less than a Category 3 facility.

DOE–EM–STD–5502–94 provides additional requirements for determining the hazard classification based on comparison of the MAR estimates to Table 302.4 of 40 CFR 302. The RQ for Pu-239 in Table 302.4 is

0.01 Ci, and 0.1 Ci for U-238. The PO*WW*ER MTU "likely worst case MAR" does not exceed the RQ value. However, since the exact contaminant concentrations and concentration factors in the evaporator are not known, it is considered prudent to classify the PO*WW*ER MTU as either a "Radiological Facility" or a "Radiological Facility with Non-Nuclear Documentation."

The determination of whether the PO*WW*ER MTU is a "Radiological Facility" or a "Radiological Facility with Non-Nuclear Documentation" is accomplished by comparing the estimates of the hazardous MAR to the RQ thresholds in 29 CFR 1910.119 and 40 CFR 355. The MAR estimates indicate that the chemicals listed in 29 CFR 1910.119 and 40 CFR 355 are not anticipated to be in the waste treated with the MTU. Therefore, the MTU is classified as a "Radiological Facility."

Although not part of the hazard classification for "Radiological Facilities," the RQs for hazardous substances in the waste are included in Table 302.4 of 40 CFR 302. A list of RQs of MAR from Table 302.4 of 40 CFR 302 are provided in Table B.1.5–2.

Final Hazard Classification

The final hazard classification of the PO*WW*ER MTU is based on the results of the unmitigated accident consequences presented in Appendix C.5. The results of the selected DBAs, based on the quantitative results of the unmitigated accident scenarios, indicate that the preliminary hazard classification was appropriate. The unmitigated consequences result in localized hazards without significant consequences for surrounding facilities or the off-site public. Therefore, the facility is classified as a "Radiological Facility" according the classification scheme presented in DOE–EM–STD–5502–94. The unmitigated accident consequences at the site boundary, as presented in Appendix C.5, are several orders of magnitude less than the guidelines, indicating that the MTU is a low-hazard facility.

Table B.1.5–2. Reportable Quantities for Hazardous Substances from 40 CFR 302

Hazardous Substance	Regulatory Synonyms	RQ (lb)	RQ (kg)
ammonia	none	100	45.4
methylene chloride	methylene chloride	1,000	454
ethanol	none	none	none
isopropyl alcohol	none	none	none

Key: kg = kilogram(s)
lb = pound(s)
RQ = reportable quantity

B.2 Evaluation Basis Waste Characteristics

The concentration of the contaminants of concern has not been completely characterized for most of the wastes selected for treatment with the PO*WW*ER MTU. However, as a result of treatability testing with the pilot-scale PO*WW*ER unit, some waste characterization data exist. Initially, the PO*WW*ER MTU will be deployed to LANL, SNL/NM, or PTX. Characterization data from treatability tests performed with waste-stream samples from these three sites was used to set the limits for the hazardous and radioactive MAR that constitute the evaluation basis waste characteristics.

B.2.1 Primary Constituents Expected

Data obtained from pilot-scale PO*WW*ER treatability testing of LANL waste-stream samples indicate the primary hazardous wastes, excluding RCRA heavy metals, are isopropyl alcohol, methylene chloride, and ammonium hydroxide. Table B.2.1–1 presents a summary of the properties of the hazardous constituents known to exist in the LANL waste streams. Also included is the ethanol added to the process as a chloride scavenger.

Table B.2.1–1. Summary of Hazardous Waste Properties

Chemical	MW	BP (°F)	LEL[a] (%)	IDLH (ppm[b])	VP (mm)	FP (°F)
(%) isopropyl alcohol	60	180	2	2,000	478	– 35
ammonia	17	– 28	16	300	> 1	NA
methylene chloride	85	104	12	2,300	350	c
ethanol	46	173	3.3	3,300	44	– 173

[a]All LEL values are in air.
[b]The ppm values can be converted to mg/m^3 by multiplying ppm x MW/24.45 at 760 torr and 77 °F.
[c]Constituent is nearly nonflammable or nonflammable.

Key:

AIT = autoignition temperature
atm = atmosphere
BP = boiling point
FP = flash point
IDLH = immediately dangerous to life or health
LEL = lower explosive limit
LFC = lowest feasible concentration
mm = millimeters
MW = molecular weight
NA = not applicable
ppm = parts per million
STEL = short-term exposure limit
TWA = time weighted average
VP = vapor pressure

References: *Handbook of Chemistry,* Tenth Addition (Lange 1961), and *NIOSH Pocket Guide to Chemical Hazards* (U.S. Department of Health and Human Services 1990).

B.2.2 Concentrations of Major Hazardous Constituents

Limited data exist on the actual concentrations of hazardous constituents in the waste streams slated for treatment with the PO*WW*ER MTU. The Mixed-Waste Treatment Program, *Evaporative Oxidation Treatability Test Report* (DOE 1995a) documents the design considerations. The conclusion from the treatability testing is that the PO*WW*ER system is very adaptable to variations in volatile or radioactive concentrations in wastes. The limitation is the amount of heat given off in the catalyst bed which is a function of the type and concentration of any combustible organic present in the waste feed. With the exception of tritium, radionuclides and heavy metals have little effect on the operation.

Data from the pilot scale PO*WW*ER treatability testing of LANL waste samples indicate the maximum and minimum concentrations of the hazardous components as shown in Table B.2.2–1.

Table B.2.2–1. Evaluation Basis Waste Characteristics

Chemical	LANL	
	Minimum (wt. %)	Maximum (wt. %)
isopropyl alcohol	0	4.3
ammonia	0	5.1
methylene chloride	0	1.5

Note: The data indicate the range of values found.
Key: LANL = Los Alamos National Laboratory
wt. % = weight percent

B.2.3 Radioactive Contaminants

The PO*WW*ER MTU will treat mixed waste with a radioactivity level less than 100 nCi/g. With the exception of tritium and carbon-14, neither of which were present in any of the GJPO treatability test waste samples, the radioactivity is contained and concentrated in the evaporator and consequently has little effect on the process.

B.3 Assumed Cases for Process Hazards Analysis

For this process hazards analysis, three scenarios were selected on the basis of available site information, the EO treatability testing analytical data, and the PO*WW*ER MTU design waste acceptance criteria.

B.3.1 Worst Case

The first case depicts a worst case where the concentration of contaminants of concern are double the concentrations found in the treatability studies (with the exception of methylene chloride, which is included in this group at its solubility limit of 1.3 weight percent in water). On the basis of available information and recent testing, it is highly unlikely this scenario would ever be experienced. The basis is

Radioactivity: Uranium-238 at 0.1 μCi/g
Plutonium-239 at 0.1 μCi/g.

Hazardous Constituents: Isopropyl alcohol at 8 weight percent.
Methylene chloride at 1.3 weight percent.
Ammonium hydroxide at 10 weight percent.

There is no evidence that any of the waste streams identified for treatment with the PO*WW*ER MTU contain this level of organics. The concentrations were derived by doubling the likely worst case data.

B.3.2 Likely Worst Case

Based on the data from treatability testing, the most likely worst case would be

Radioactivity: Uranium-238 at 5.6×10^{-4} μCi/g
Plutonium-239 at 3.34×10^{-6} μCi/g

Hazardous Constituents: Isopropyl alcohol at 4.3 weight percent.
Methylene chloride at 1.3 weight percent.
Ammonium hydroxide at 5 weight percent.

This case more realistically depicts the expected worst case.

B.3.3 Likely Low-Activity and Low-Hazardous Concentrations

Presently, this case represents the waste identified to be treated with the PO*WW*ER MTU. The basis is

Radioactivity: Uranium-238 at 2.8×10^{-4} µCi/g
Plutonium-239 at 2.38×10^{-6} µCi/g.

Hazardous Constituents: Isopropyl alcohol at 4 weight percent.
Methylene chloride at 0.88 weight percent.
Ammonium hydroxide at 2.8 weight percent.

Appendix C

Process Hazards Analysis

C.1 Hazards and Operability Analysis

C.2 HAZOP Analysis Action Item Tracking and Risk Reduction

C.3 Hazard Identification and Evaluation

C.4 Design Basis Accident Analysis Scenarios for Selected Accidents (Fault Trees)

C.5 Unmitigated Accident Consequences

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Appendix C. Process Hazards Analysis

The general process hazards analysis (PHA) process entails data evaluation to determine material at risk; hazards identification, evaluation, and resolution; accident scenario analysis; and consequence analysis. These steps build on one-another to arrive at a determination of the degree of hazards involved in the process being studied. This PHA followed the roadmap presented in *Guidance for the Preparation of MWT Process Hazards Analysis* (DOE 1995b).

C.1 Hazards and Operability Analysis

The hazards identification, evaluation, and resolution portion of this PHA chose the hazards and operability (HAZOP) analysis tool for its investigation of the hazards in a methodical meticulous manner. The HAZOP analysis process is a highly structured analysis and review of hazards associated with the operation of a chemical facility. The process is divided into a number of small sections, or nodes, selected from the piping and instrument diagrams (P&IDs). A node is a specific piece of equipment or section of piping that normally only has one function. For instance, the waste transfer pump node includes the strainer and supply piping to the waste feed tank. The design intention for normal operation of each node is explained, and then a standard list of deviations from normal operation (e.g., high and/or low temperature, high and/or low pressure, high and/or low level, high and/or low/no flow) is applied to that node. Deviations which do not apply (e.g., high or low level for a line not containing any vessels) are removed from the list. Each remaining deviation is studied in terms of three factors:

1. All possible causes of that deviation (e.g., a plugged line for low/no flow). The causes are ranked according to their expected frequency.

2. The consequences to personnel and public safety, environmental contamination, financial loss, and general (miscellaneous) loss which will be realized if the deviation occurs. The consequences are quantified according to standard criteria.

3. Existing safeguards in the current design which tend to prevent the deviation from occurring.

The expected frequency of each deviation is combined with the consequence rating for the deviation in a "risk matrix" to generate an overall risk factor for the deviation. The risk factors are evaluated using standard decision criteria to determine whether the overall risk is high enough that the design must be modified to provide additional mitigation. Items requiring mitigation are then identified and responsibility for satisfactory completion of each item is assigned.

The HAZOP analysis of the PO*WW*ER MTU was performed on July 10–12, 1995. Attachment C.1–1 gives the results of the HAZOP analysis. The expected frequency of each deviation (column title "FC" in Table C.1–3) was quantified according to the guidelines listed in Table C.1–1.

Table C.1–1. Deviation Frequency Categories

Category	Description
1	Not expected to occur during the lifetime of the MTU
2	Expected to occur no more than once during the lifetime of the MTU
3	Expected to occur several times during the lifetime of the MTU
4	Expected to occur more than once in a year

Consequences were further divided into seven subcategories: Fire, Explosion, Environmental Damage, Toxic Release, Bodily Injury, Business Loss, and Operability Loss. The consequences were then quantified according to the guidelines listed in Table C.1–2; the results are given in the column headed "FXETIBO" (for **F**ire – E**X**plosion – **E**nvironmental Damage – **T**oxic Release – Bodily **I**njury – **B**usiness Loss – **O**perability Loss) in Attachment C.1–1.

Table C.1–2. Deviation Consequence Categories

Category	Description
Fire	
1	No injury or health effects
2	Minor injury or minor health effects
3	Injury or moderate health effects
4	Death or severe health effects
Explosion	
1	No injury or health effects
2	Minor injury or minor health effects
3	Injury or moderate health effects
4	Death or severe health effects
Environmental Damage	
1	No environmental impact
2	Minor environmental impact
3	Moderate environmental impact
4	Severe environmental impact
Toxic Release	
1	No injury or health effects
2	Minor injury or minor health effects
3	Injury or moderate health effects
4	Death or severe health effects
Bodily Injury	
1	No injury or health effects
2	Minor injury or minor health effects
3	Injury or moderate health effects
4	Death or severe health effects
Business Loss	
1	Less than $10,000
2	Between $10,000 and $100,000
3	Between $100,000 and $1,000,000
4	More than $1,000,000

Table C.1–2 (continued). Deviation Consequence Categories

Category	Description
Operability Loss	
1	Less than 1 day
2	Between 1 day and 1 week
3	Between 1 week and 1 month
4	More than 1 month

Once each deviation had been quantified according to these criteria it was possible to assign a priority ranking to each deviation by combining the frequency rating with the highest rating from the consequences. This gave a risk priority ranking for each deviation from 1 to 8, with 8 being the highest.

Attachment C.1–1 lists the results of the HAZOP analysis and includes a description of each deviation studied, the cause(s) and consequence(s) of that deviation, and existing safeguards, as well as the information on the expected frequency and hazard rating of the deviation. The right-hand column of Attachment C.1–1 provides the number for each action item associated with mitigation of the deviation.

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Attachment C.1–1

Table C.1–3. HAZOP Analysis Action Items

Source: *PO*WW*ER Transportable Mixed-Waste Treatment Facility Process Hazard Analysis*, prepared by Rust Engineering Company, Process Technology Department, 1995.

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Table C.1–3. HAZOP Analysis Action Items

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		1.0 LINE - Waste Transfer to Waste Feed Tank (dwg: E03025-RAA-102-D)					
1.1	High Flow			None	....		
1.2	Low/No Flow	Clogged Strainers	4	Possible Maintenance Personnel Exposure	1	Pump Selection	001
		Closed Valve	4				
		Clogged Suction Line	4				
1.3	REVERSE FLOW	Strainer Change out procedure not followed	1	Waste Spill	3313323	Pressure Release Valves on Tank	002 003
		Overpressure in Waste Tank	1			Operating / Maintenance Training	
1.5	High Temperature	External Fire	1	Line Rupture / Fire	3313323	Waste Sampling procedures (reaction possibility)	
		Reaction in Pipe	1			Fire Protection Systems	
						Hot Work Permit procedures	
1.5	Low Temperature	No viable cause	.				
1.6	High Pressure	High Temperature	1	Line rupture	3313323	Fire protection systems	
		Clogged Strainer	4			Pump selection (low discharge pressure)	
		Closed Valve	4				
1.7	Low Pressure			None	....		
1.8	LOW/HIGH CONCENTRATION			None	....		

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		1.0 LINE - Waste Transfer to Waste Feed Tank (continued)					
1.9	CONTAMINATION	High suspended solids in waste	4	Clogged Strainer / pump (low/no flow) (Item 1.2)	1	Waste Sampling	004 005
				High Pressure (Item 1.6)	3313323		
1.10	EXTERNAL LEAK	Flange gasket leak	2	waste leak	1..1211	Operating / Maintenance procedures	006
		over pressure (Item 1.6)	.				
		corrosion	1				
		Filter Leak	2				
		Maintenance Procedures not followed	.				
1.11	EXTERNAL RUPTURE	External Fire	1	Waste spill	3313323	PM procedures	
		High Pressure	1			Fire protection systems	
		Corrosion	1			Proper materials of construction	
		Drum Drop / External strike	1			Proper general arrangement	

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				2.0 VESSEL - WASTE FEED TANK (dwg: E03025-RAA-102-D)			
2.1	LOW PRESSURE			None	....		
2.2	HIGH PRESSURE	External Fire	1	relief valve release	23	Vent to evaporator	007 008
		Unexpected reaction	1	High pressure in the Waste feed line from tank to evaporator (Item 3.7)	....	Relief valve	
		High pressure in the Waste feed line from tank to evaporator (Item 3.7)	.			Fire protection systems	
				HIGH TEMPERATURE (Item 2.4)	....	Properly designed tank	
2.3	LOW TEMPERATURE			None	....		
2.4	HIGH TEMPERATURE	HIGH PRESSURE (Item 2.2)	.	High temperature in the Waste Feed Return Line (Item 9.5)	....	Vent to evaporator	
		High temperature in the Waste feed line from tank to evaporator (Item 3.5)	.			Relief valve	
				High temperature in the Waste feed line from tank to evaporator (Item 3.5)	....	Fire protection system	
		High temperature in the Waste Feed Return Line (Item 9.5)	.			Properly designed tank	
				Relief valve relief	23		
2.5	LOW LEVEL	Instrumentation failure	2	agitator / tank damage	22	Low level interlock	009
		Operator error	2	Loss of evaporator feed	11	Training	
2.6	HIGH LEVEL	Instrumentation failure	2	Liquid waste release to evaporator via line 23	12		010 011
				Liquid waste release via vacuum breaker relief valve (Spill)	3313323		

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				2.0 VESSEL - WASTE FEED TANK (continued)			
2.7	LOW/HIGH CONCENTRATION	Too much solvent in waste tank	1	Agitator / pumping problems	11	Waste sampling and feed procedures	012 013
		Too high suspended solids in waste tank	1	pH out of specification	11	Basket Strainer	014 015
				Criticality Concerns	4444444		
		Improper pH adjustment (Inst./equip/operator malfunction)	3	Cyanide complex requires system shutdown	12		
		High RAD content	1	High/Low concentration in the Waste Feed Return Line (Item 9.9)	....		
		Presence of complex cyanides	1				
		High/Low concentration in the Waste Feed Return Line (Item 9.9)	.				
		High flow in the Sodium Hydroxide Feed Line (Item 21.1)	.				
		Low/no flow in the Sodium Hydroxide Feed Line (Item 21.2)	.				
2.8	CONTAMINATION	Contamination in the Waste Feed Return Line (Item 9.10)	.	Contamination in the Waste Feed Return Line (Item 9.10)	....		
2.9	EXTERNAL LEAK	Gasket Failure	2	Small waste spill	3313323	System setup procedure (hydro testing)	016 011
		Agitator seal failure	2	External Leak in the Waste Feed Return Line (Item 9.11)	....	PM procedures	018 019
		Unexpected reaction in tank	3				020
		Corrosion	1			Sampling and waste acceptance criteria	
		Vacuum breaker leak	4			Containment	
		PSV leak	2				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				2.0 VESSEL - WASTE FEED TANK (continued)			
2.10	EXTERNAL RUPTURE	Unexpected reaction	1	Large waste spill	4434444	Sampling / waste acceptance criteria	021 022
		Vessel Puncture (forklift, etc.)	1			Fire protection systems	
		External Fire	1			Limited access to area	
						Electrical Class 1, Div. 2	
				3.0 LINE - Waste feed line from tank to evaporator (dwg: E03025-RAA-102-D)			
3.1	High flow	Metering pump mis-set	2	High level in evaporator	....		
3.2	Low/no flow	Pump Failure	3	Low Level in evaporator	11		023 024 025
		Plugged line	3				
		Clogged Check valve	4				
3.3	Reverse flow	None	.				
3.4	Misdirected flow	Metering pump (P-014) failure	2	Back flow of waste into process water and/or anti-foam line	11	Possibly check valves in metering pumps Air break in process water tank	026
3.5	High temperature	HIGH TEMPERATURE in the WASTE FEED TANK (Item 2.4)	.	HIGH TEMPERATURE in the WASTE FEED TANK (Item 2.4)	....		
3.6	Low temperature			None	....		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		3.0 LINE - Waste feed line from tank to evaporator (continued)					
3.7	High pressure	HIGH PRESSURE in the WASTE FEED TANK (Item 2.2)	.	Rupture (Spray)	3313323	Standard Operating Procedures	027 028 029
		Valve closed on metering pump discharge	1	HIGH PRESSURE in the WASTE FEED TANK (Item 2.2)	....	Metering pumps internal PSV	
3.8	Low pressure			None	....		
3.9	Low/High Concentration	High suspended solids	3	Line plug	11	Waste Feed Tank (Dampens waste variation)	
		High concentration of organics	3	Corrosion (leak)	1..1211	Control systems	
		Low pH	3	Process upset	11	Feed strainer	
		High pH	4				
3.10	Contamination			None	....		
3.11	External Leak	Corrosion	1	Waste leak	..22112	Preventive maintenance	
		Gasket failure	1			Standard Operating Procedures - startup	
		Pump seal failure	1				
		Erosion	1				
3.12	External Rupture	External Fire	1	Waste Spill	3313323	Fire Protection Systems	
		External strike	1			Material handling equipment selection	
						Containment	

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		4.0 HEAT_EXCHANGER - Evaporator Heater (dwg: E03025-RAA-102-D)					
4.1	Shell leak (Steam)	Flange leak	1	Steam leak - Personnel injury	313	SOP	030 031 032
		Corrosion	1			Preventive maintenance	
		Relief valve leak	2				
		Vacuum breaker leak	4				
4.2	High temperature	Steam control valve failure	.	Brine flashing in heater	....		
		High temperature in the Brine recirculation line w/ pump (Item 6.5)	.	High temperature in the Brine recirculation line w/ pump (Item 6.5)	....		
4.3	Low temperature	Loss of steam	2	Possible solidification of brine	12		
		Waste tank overflow	1	High organics to oxidizer (vapor or liquid)	.2.2334		
		Low temperature in the Brine recirculation line w/ pump (Item 6.6)	.	Possible aqueous liquid to oxidizer	3433444		
			.	Low temperature in the Brine recirculation line w/ pump (Item 6.6)	....		
4.4	High pressure	None	.				
4.5	Low pressure			None	....		033
4.7	High Level	Steam trap failure	2	Loss of heating (see low temperature in evaporator)	11	SOP	034
		Closed drain valve	1			PM	
		Clogged check valve	1				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				4.0 HEAT_EXCHANGER - Evaporator Heater (continued)			
4.8	High/Low concentration	Low pH	3	Corrosion	24	pH meter in system	
		High suspended solids	3	Erosion	24	Inline density meter	
		High/low concentration in the Evaporator (Item 5.13)	.	Plugging	...2223	SOP/PM	
		High/Low concentration in the Brine recirculation line w/ pump (Item 6.9)	.	Scaling (carbonate worst scaling)	24	Sample RAD and maintain a RAD balance	
				Criticality	1344444		
				High/low concentration in the Evaporator (Item 5.13)	....		
				High/Low concentration in the Brine recirculation line w/ pump (Item 6.9)	....		
4.9	Contamination			None	....		
4.10	Tube leak (Waste)	Corrosion	1	Contamination of steam system (Normal venting of inerts)	...2224	Conductivity on condensate	035
		Erosion	1				
4.11	Criticality	High level RAD in waste stream (mis-sampling)	1	System shutdown	11	Waste acceptance criteria	
						Grab samples of waste and brine	
						RAD monitoring	

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				5.0 REACTOR_V - Evaporator (dwg: E03025-RAA-102-D)			
5.1	High flow	Too much steam	2	Water entrainment to oxidizer	12	Waste feed tank blending	
		Too high organics in waste stream	2	RAD entrainment to oxidizer	...2224	High temperature shut-off	
		Loss of back pressure	2	Solvent entrainment to oxidizer	224	SOP	
		High flow in the Evaporator Vapor Discharge Line (Item 10.1)	.	Loss of oxidizer heater control when upset stops.	24		
		High concentration of contaminants in the Evaporator Vapor Discharge Line (Item 10.9)	.	High flow in the Evaporator Vapor Discharge Line (Item 10.1)	....		
				High concentration of contaminants in the Evaporator Vapor Discharge Line (Item 10.9)	....		
				High flow in the Packed-Bed Scrubber (Item 15.1)	....		
5.2	Low/no flow	Plugged system downstream of evaporator	3	Overpressure of evaporator - RAD release	..23324	Preventive Maintenance	036 037 038
		Steam valve fail closed (normal failure mode)	2	Low flow in catalytic oxidizer causing explosion	....		
		Plugged mesh pads	1	Low/no flow in the Evaporator Vapor Discharge Line (Item 10.2)	....		
		Low/no flow in the Evaporator Vapor Discharge Line (Item 10.2)	.				
5.3	Reverse flow	None	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		5.0 REACTOR_V - Evaporator (continued)					
5.4	Misdirected flow	Pressure loss in propane and/or oxidizer air lines	1	Contamination of propane and/or oxidizer air lines (corrosion possibility)	11	Flow meters in propane and oxidizer air lines	
						pressure indicator on propane regulator	
5.5	High temperature	External Fire	1	Rupture / relief (spill)	...2224	Fire protection equipment	039
		Criticality	1	Stop waste feed and system contamination	11	RAD balance and monitoring	
		High pressure (Item 5.7)	.	High pressure (Item 5.7)	....		
5.6	Low temperature	Loss of steam	.	None	....		
5.7	High pressure	External Fire	1	High temperature (Item 5.5)	....	Relief vent	040
		System blockage downstream of evaporator	3			Fire protection system	
		High temperature (Item 5.5)	.				
5.8	Low pressure			None	....		
5.9	High level	Overflow from the Waste feed tank	1	Liquid to oxidizer heater - RAD contamination	24	Spare heater	041
						Spare catalyst	
		Instrumentation failure	2	Burn out heater	24	Positive slope to heater - evaporator low point in line.	
		Foaming	4				
5.10	Low level	Plugged waste feed line	1	Pump failure if level is very low	22	Level indicators	042 043
		Instrument failure	2			Low low level interlock	

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				5.0 REACTOR_V - Evaporator (continued)			
5.13	High/low concentration	High/Low concentration in the Evaporator Heater (Item 4.8)	.	High/Low concentration in the Evaporator Heater (Item 4.8)	....	pH meter in system Inline density meter SOP/PM	
		Low pH	3	Corrosion	24		
		High suspended solids	3	Erosion	24		
				Plugging	...2223		
				Scaling (carbonate worst scaling)	24		
				Criticality	1344444		
5.14	Contamination			None	....		
5.15	External Leak	Gasket failure	1	Waste leak	..22112	PM SOP	044
5.16	External Rupture	External Fire	.	Waste spill	3313323	Fire protection systems relief valve	
5.17	Criticality	High level RAD in waste stream (mis-sampling)	1	System shutdown	11	Waste acceptance criteria Grab samples of waste and brine Monitoring of RAD	

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		6.0 LINE_P - Brine recirculation line w/ pump (dwg: E03025-RAA-102-D)					
6.1	High flow			None	....		
6.2	Low/no flow	Plugged lines	2	Scaling in heater	...2222	Flow meter	045
		Plugged tubes	2	Corrosion in lines and tubes	24		
		Pump failure	3	Loss of vapor flow to oxidizer (Item 5.2)	....		
		Cavitation	3	High temperature (Item 6.5)	....		
		Bumping in heat exchanger	3				
		High temperature (Item 6.5)	.				
		Low pressure (Item 6.8)	.				
6.3	Reverse flow	None	.				
6.4	Misdirected flow	Open valve in line 7	.	Waste spill	....	Line 7 feeds brine concentration container	046
		Sample valve in line 7 leaking	.				
6.5	High temperature	High temperature in the Evaporator Heater (Item 4.2)	.	High temperature in the Evaporator Heater (Item 4.2)	....		
		Low/no flow (Item 6.2)	.	Low/no flow (Item 6.2)	....		
6.6	Low temperature	Low temperature in the Evaporator Heater (Item 4.3)	.	Low temperature in the Evaporator Heater (Item 4.3)	....		
		Precipitation of salts at solubility limit	.	Erosion (leak)	....		

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				6.0 LINE_P - Brine recirculation line w/ pump (continued)			
6.7	High pressure	Plugged tubes	1	Rupture - line/tube	....	Relief valve	047
		External Fire	1			Fire protection systems	
6.8	Low pressure	Pump failure	1	Low/no flow (Item 6.2)	....	Flow meter	045 048
		low low evaporator level	1			Pressure indicator	
						Low Low alarm	
						Pressure differential across heater	
6.9	High/Low concentration	High/Low concentration in the Evaporator Heater (Item 4.8)	.	High/Low concentration in the Evaporator Heater (Item 4.8)	....	pH meter in system	
				Corrosion	24	Inline density meter	
				Erosion	24	Sample RAD and maintain a RAD balance	
				Plugging	...2223	Waste acceptance criteria	
				Scaling (carbonate worst scaling)	24		
				Criticality	1344444		
6.10	Contamination			None	....		
6.11	External Leak	Gasket leak	1	Waste leak	..22112	Preventive maintenance	
		Pump seal leak	1			Standard Operating Procedures	
		Valve packing leak	1				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		6.0 LINE_P - Brine recirculation line w/ pump (continued)					
6.12	External Rupture	External Fire	.	Waste Spill	3313323	Fire Protection Systems Relief valve	
6.13	Criticality	High level RAD in waste stream	.	System Shutdown	11	Waste acceptance criteria Grab samples of waste and brine Monitoring of RAD	
		7.0 LINE - Brine Concentrate drain line (dwg: E03025-RAA-102-D)					
7.1	High flow	Valve failed in open position	3	Waste spill	...2212	PM and operation test	049
		Operator Error	2	High Level in the Brine Concentrate Storage Container (Item 8.3)	....		
7.2	Low/no flow	Plugged line	3	Can't drain evaporator - high solids	11		050 051
		Valve failure in closed position	3				
7.3	Reverse flow	None	.				
7.5	High temperature	None	.				
7.6	Low temperature	Low ambient temperature	.	Solidification of brine	...2211		052 053
7.7	High pressure	None	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		7.0 LINE - Brine Concentrate drain line (continued)					
7.8	Low pressure	None	.				
7.9	High/low concentration	None	.				
7.10	Contamination	None	.				
7.11	External Leak	Valve packing leak	.				
7.12	External Rupture	Hose not in drum - Operator error	1	Waste spill	...2212	SOP Operator hiring and training	
7.14	Criticality	None	.				
		8.0 VESSEL - Brine Concentrate Storage Container (dwg: E03025-RAA-102-D)					
8.1	High Temperature	None	.				
8.2	Low Temperature	None	.				
8.3	High Level	High flow in the Brine Concentrate drain line (Item 7.1)	.	Spill	...2212	Evaporator level indicator/ calculation	054 055
		No level indication	.				
8.4	Low Level	None	.				
8.5	Contamination	None	.				

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				8.0 VESSEL - Brine Concentrate Storage Container (continued)			
8.6	Leak	Bad Drum	2	Waste leak	...2212	QA/QC on drum supply	056 057
				Leak in the Scubber Blowdown Storage Container (Item 19.6)	....	Containment	
8.7	Rupture	Static explosion	1	Explosion	3323324	SOP	058 059 060
		Dropped drum	2	Waste Spill	..32214	Training	
						Pre-dump sample	
				9.0 LINE - Waste Feed Return Line (dwg: E03025-RAA-102-D)			
9.1	High flow	None	.				
9.2	Low/no flow	Valve closed	2	Loss of feed to evaporator	11	SOP	061 062
		Orfice plugged	3	Pump damage	11	Preventive Maintenance	
		Pump Failure	3	Loss of pH control (Corrosion)	11		
		Suction clogged to pump	2				
9.3	Reverse flow	None	.				
9.5	High temperature	HIGH TEMPERATURE in the WASTE FEED TANK (Item 2.4)	.	HIGH TEMPERATURE in the WASTE FEED TANK (Item 2.4)	....		
				Relief valve release	23		
9.6	Low temperature			None	....		
9.7	High pressure	Valve closed	1	Loss of pH control	11	SOP	063

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				9.0 LINE - Waste Feed Return Line (continued)			
9.8	Low pressure	Pump Failure	2	Loss of pH control	11	Instrumentation - pump motor failure indicator	
				Low or no feed to evaporator	11	Pressure guage	
9.9	High/Low concentration	LOW/HIGH CONCENTRATION in the WASTE FEED TANK (Item 2.7)	.	LOW/HIGH CONCENTRATION in the WASTE FEED TANK (Item 2.7)	....	Waste sampling and feed procedures	
		Too much solvent in waste tank	1	Agitator/pumping problems	11		
		Too high suspended solids in waste tank	1	pH out of specification	11		
				Criticality concerns	4444444		
		Improper pH adjustment (Inst./equip./operator error)	3	Cyanide complex requires system shutdown	12		
		High RAD content	1				
		Presence of complex cyanides	1				
9.10	Contamination	CONTAMINATION in the WASTE FEED TANK (Item 2.8)	.	CONTAMINATION in the WASTE FEED TANK (Item 2.8)	....	Waste sampling and feed procedures	
						Basket strainer	
		Too much solvent in waste tank	1	Agitator/pumping problems	11		
		Too high suspended solids in waste tank	1	pH out of specification	11		
				Cyanide complex requiring system shutdown	12		
		Improper pH adjustment	3				
		Presence of complex cyanides	1				
9.11	External Leak	EXTERNAL LEAK in the WASTE FEED TANK (Item 2.9)	.				
9.12	External Rupture			No consequences of interest			

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		10.0 LINE - Evaporator Vapor Discharge Line (dwg: E03025-RAA-102-D)					
10.1	High flow	High flow in the Evaporator (Item 5.1)	.	High flow in the Evaporator (Item 5.1)	....	High temperature shut-off	064 065
						Waste feed tank blending	
		High pressure in the Oxidizer Heater (Item 11.13)	.	High Oxidizer air flow in the Oxidizer Heater (Item 11.1)	....		
		Too much steam	2	High process flow in the Oxidizer Heater (Item 11.8)	....		
		Too high organics in waste stream	2	Low process temperature in the Oxidizer Heater (Item 11.12)	....		
		Loss of back pressure	2	Waster entrainment to oxidizer	12		
				Solvent entrainment to oxidizer	224		
				Loss of oxidizer heater control when upset stops	24		
10.2	Low/no flow	Low/no flow in the Evaporator (Item 5.2)	.	Low/no flow in the Evaporator (Item 5.2)	....	Preventive Maintenance	
		Plugged system downstream of evaporator	3	Overpressure of evaporator	23		
		Steam valve fail closed (normal failure mode)	2				
		Plugged mesh pads	1				
10.3	Reverse flow	During unplanned evaporator shutdown or loss of steam to evaporator heater	2	Propane and/or air could be drawn into evaporator	4434444	None	066 067 068 069 070
				Low pressure (Item 10.8)	....		
		Low pressure (Item 10.8)	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		10.0 LINE - Evaporator Vapor Discharge Line (continued)					
10.4	Misdirected flow	Propane line loss of pressure Oxidizer air loss of pressure Condensation in vapor line	1 1 1	Corrosion in propane line and air line Instrument damage	.....12 12	Heat tracing of vapor line Good piping practice (tie-in above vapor line)	071 072
10.5	High temperature	Internal fire during unplanned shutdown Plugged line downstream from oxidizer heater	1 2	Pipe/vessel rupture Propane backflow into evaporator (explosion in evaporator)	4444444 4444444		073 074 075
10.6	Low temperature	Ambient heat loss Excessive liquid entrainment / Foaming Valve failure on warmup air (if relocated)	4 3 2	Condensation causing heater / catalyst damage RAD contamination in heater / catalyst System plug High concentration of contaminants (Item 10.9)	.....22 ...2223 ...2222	Insulation and tracing Line slope back to evaporator	076
10.7	High pressure	Line / System plug Steam fail open Warmup air valve fail open	3 2 2	Evaporator PSV release	24	PSV on evaporator	077 078 079
10.8	Low pressure	Reverse flow (Item 10.3)	.	Reverse flow (Item 10.3)	....		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		10.0 LINE - Evaporator Vapor Discharge Line (continued)					
10.9	High concentration of contaminants	Low temperature (Item 10.6)	.	High flow in the Evaporator(Solvent) (Item 5.1)	....	Waste blending in waste tank	080 081 082
		High solvent in waste feed	1	Possible flamable mixture to heater	.333334		
		High flow in the Evaporator (Item 5.1)	.				
		Large increases in waste feed rate	.				
10.10	External Leak	Corrosion	1	Leak of vapor	...2222	PM	
		Flange / gasket leak	2			SOP	
						Design standards	
10.11	External Rupture	Internal Fire / detonation	1	Vapor release	4444444	PM	
						SOP	
						Design Standards	
		11.0 FURNACE - Oxidizer Heater (dwg: E03025-RAA-102-D)					
11.1	High Oxidizer air flow	High flow in the Evaporator Vapor Discharge Line (Item 10.1)	.	Waste entrainment to oxidizer	12	High temperature shut-off	
		Warmup air valve fail open	1	Solvent entrainment to oxidizers	224	Waste feed tank blending	
		FCV-032-6 driven or fails open	1	Loss of oxidizer heater control	24		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		11.0 FURNACE - Oxidizer Heater (continued)					
11.8	High process flow	High flow in the Evaporator Vapor Discharge Line (Item 10.1)	.	Incomplete reaction	11		083 084
				Explosive mixture sent to heater	4434444		
		Warmup air valve fails open	.	High flow in the Oxidized Discharge Line (Item 12.1)	....		
		Valve FCV-032-6 driven or fails open	.	High Flow in the Catalytic Oxidizer (Item 13.1)	....		
		High propane flow due to propane valve fails open	.	High flow in the Discharge line from oxidizer to scrubber (Item 14.1)	....		
		High flow in the Oxidized Discharge Line (Item 12.1)	.				
		High Flow in the Catalytic Oxidizer (Item 13.1)	.				
		High flow in the Discharge line from oxidizer to scrubber (Item 14.1)	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				11.0 FURNACE - Oxidizer Heater (continued)			
11.9	Low/no process flow	Plugged lines	3	Detonation	4433444	Heater internal safety devices (High Temp sensors, etc.)	085 086 087 088
		Low vapor flow	4	Heater damage	22		
		Low propane flow	3	High process temperature (Item 11.11)	....		
		Low air flow	4	Low pressure (Item 11.14)	....		
		High process temperature (Item 11.11)	.	Low/no flow in the Oxidized Discharge Line (Item 12.2)	....		
		Low pressure (Item 11.14)	.	Low Flow in the Catalytic Oxidizer (Item 13.2)	....		
		Low/no flow in the Oxidized Discharge Line (Item 12.2)	.	High pressure in the Catalytic Oxidizer (Item 13.7)	....		
		Low Flow in the Catalytic Oxidizer (Item 13.2)	.				
		High pressure in the Catalytic Oxidizer (Item 13.7)	.				
11.10	Misdirected process flow	None	.				
11.11	High process temperature	Low/no process flow (Item 11.9)	.	Low/no process flow (Item 11.9)	....	Internal Heater safeties	
		Runaway heater	2	Heater damage and Catalytic Oxidizer damage	22	High temp sensor at oxidizer	
		High temperature in the Oxidized Discharge Line (Item 12.5)	.	High temperature in the Oxidized Discharge Line (Item 12.5)	....		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				11.0 FURNACE - Oxidizer Heater (continued)			
11.12	Low process temperature	Heater failure	2	Incomplete reaction	11	Low Low interlock cuts feed	089
		Control system failure	2	Low temperature in the Oxidized Discharge Line (Item 12.6)	....		
		High flow in the Evaporator Vapor Discharge Line (Item 10.1)	3				
		Low temperature in the Oxidized Discharge Line (Item 12.6)	.				
11.13	High pressure	Plugged lines downstream of heater	3	Heater damage	22		090 091
		Liquid stream entering heater	2	Gasket failure (Waste vapor leak)	3..3323		
		Tube leak or rupture (Item 11.15)	.	High flow in the Evaporator Vapor Discharge Line (Item 10.1)	....		
				Tube leak or rupture (Item 11.15)	....		
11.14	Low pressure	Low/no process flow (Item 11.9)	.	Low/no process flow (Item 11.9)	....		
		Low pressure in the Oxidized Discharge Line (Item 12.8)	.	Low pressure in the Oxidized Discharge Line (Item 12.8)	....		
		Low pressure in the Catalytic Oxidizer (Item 13.8)	.	Low pressure in the Catalytic Oxidizer (Item 13.8)	....		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		11.0 FURNACE - Oxidizer Heater (continued)					
11.15	Tube leak or rupture	High pressure (Item 11.13)	.	High pressure (Item 11.13)	3..3323	SOP	092
		Detonation	1	Rupture	4433444	Design standards	
		Corrosion	.	External Leak in the Catalytic Oxidizer (Item 13.11)	....	PM	
		External Leak in the Catalytic Oxidizer (Item 13.11)	.			PSV - high pressure	
		12.0 LINE - Oxidized Heater and Oxidizer Discharge Line to Quench (dwg: E03025-RAA-102-D)					
12.1	High flow	High process flow in the Oxidizer Heater (Item 11.8)	.	High process flow in the Oxidizer Heater (Item 11.8)	....		
		Warmup air valve fails open	1	Incomplete reaction	11		
		Valve FCV-032-6 driven or fails	1	Explosive mixture sent to heater	4434444		
		High propane flow due to propane valve failing open	1				
12.2	Low/no flow	Low/no process flow in the Oxidizer Heater (Item 11.9)	.	Low/no process flow in the Oxidizer Heater (Item 11.9)	....	Heater internal safety devices (high temp sensors, etc.)	
		Plugged lines	3	Detonation	4433444		
		Low vapor flow	4	Heater damage	22		
		Low propane	3				
		Low air flow	4				
12.3	Reverse flow	None	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		12.0 LINE - Oxidized Heater and Oxidizer Discharge Line to Quench (continued)					
12.5	High temperature	High process temperature in the Oxidizer Heater (Item 11.11)	.	High process temperature in the Oxidizer Heater (Item 11.11)	....	Internal safeties in heater High temp sensor at oxidizer	
		Runaway heater	2	Heater damage and catalytic oxidizer damage	22		
12.6	Low temperature	Low process temperature in the Oxidizer Heater (Item 11.12)	.	Low process temperature in the Oxidizer Heater (Item 11.12)	....		
		Heater failure	2	Incomplete reaction	11		
		Control system failure	2				
12.7	High pressure	High pressure in the Catalytic Oxidizer (Item 13.7)	.	Gasket failure (13.7 / 11.11)	3..3323		
		Plugged lines downstream of heater	3	High pressure in the Catalytic Oxidizer (Item 13.7)	....		
		Liquid stream entering heater	2				
12.8	Low pressure	Low pressure in the Oxidizer Heater (Item 11.14)	.	Low pressure in the Oxidizer Heater (Item 11.14)	....		
12.9	High concentration of contaminants			None	....		
12.10	External Leak	High Pressure causing gaskjet failure	1	Waste spill	3..3323		
12.11	External Rupture	Internal Detonation	1	Waste spill	4433444		
		Very high pressure	1				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				13.0 VESSEL - Catalytic Oxidizer (dwg: E03025-RAA-102-D)			
13.1	High Flow	High process flow in the Oxidizer Heater (Item 11.8)	.	High process flow in the Oxidizer Heater (Item 11.8)	....	See 11.8	
				Carry-over of catalyst beads/dust	22		
				Process upset (back pressure increase at evaporator)	1		
				Incomplete reaction	22		
13.2	Low Flow	Low/no process flow in the Oxidizer Heater (Item 11.9)	.	Low/no process flow in the Oxidizer Heater (Item 11.9)	....	Delta Pressure indicator	093
				High temperature (Item 13.5)	11		
13.5	High temperature	Low Flow (Item 13.2)	.	Catalyst damage	12	Waste Blending	094 095
		High Organics	3	Vessel damage (leak/rupture)	22.2223	Internal Heater safety	096 097
		Electric heater SCR runaway	2	Gasket failure	22.2223	High bed temp interlock to general shutdown	
		External Fire	1	High concentration of contaminants (Item 13.9)	....		
		High concentration of contaminants (Item 13.9)	.				
13.6	Low temperature			None	....	Low low interlock to waste shutoff	
13.7	High pressure	High pressure in the Oxidized Discharge Line (Item 12.7)	.	High pressure in the Oxidized Discharge Line (Item 12.7)	....		
		Plugged lines	.	Low/no process flow in the Oxidizer Heater (Item 11.9)	....		
		Low/no process flow in the Oxidizer Heater (Item 11.9)	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				13.0 VESSEL - Catalytic Oxidizer (continued)			
13.8	Low pressure	Low pressure in the Oxidizer Heater (Item 11.14)	.	Low pressure in the Oxidizer Heater (Item 11.14)	....		
13.9	High concentration of contaminants	High temperature (Item 13.5)	.	High temperature (Item 13.5)	....	High high temp shutdown	
		RAD	1	Mixed waste (cleanup problem)	...2223	See 10.1	
						RAD sensor in vapor discharge of evaporator	
						Foam sensors	
						level sensors anti-foam injections	
13.11	External Leak	Overpressure/Overtemperature	.	Tube leak or rupture in the Oxidizer Heater (Item 11.15)	....	Design standards	098
		Tube leak or rupture in the Oxidizer Heater (Item 11.15)	.	Acid gas release	..32314	SOP	
		External Rupture (Item 13.12)	.	CO release	...4214		
				External Rupture (Item 13.12)	....		
13.12	External Rupture	External Leak (Item 13.11)	.	External Leak (Item 13.11)	..32424	See 13.11	
13.13	High reaction rate	None	.				
13.14	Low reaction rate	Catalyst poison/deactivation	2	Incomplete reaction	12	SOP	

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		14.0 LINE_X - liquid line from scrubber to Quench (dwg: E03025-RAA-102-D)					
14.1	High flow	High process flow in the Oxidizer Heater (Item 11.8)	.	High process flow in the Oxidizer Heater (Item 11.8)	....		099 100 101
		High liquid flow to quench	2	High back pressure to oxidizer	1		
14.2	Low/no flow	Plugged liquid feed / spray nozzle to quench	3	High temperature to scrubber	..2..12	High level alarm in scrubber	102 103 104 105
		High level in scrubber (above quench discharge)	3	No Flow/High back pressure	11	Low level alarm in scrubber	
		Recirculation pump shutdown	3	Corrosion in scrubber and quench	23	Pump motor operation indication	
		High temperature (Item 14.5)	.	Low back pressure due to no liquid flow (high temp scrubber)	..2..12	Low flow interlock on line 17	
		High pressure (Item 14.7)	.	Pulsating liquid flow causing pulsating back pressure	12		
		High concentration of contaminants (Item 14.9)	.	High temperature (Item 14.5)	....		
				High pressure (Item 14.7)	....		
				High concentration of contaminants (Item 14.9)	....		
14.3	Reverse flow	Plugging in two phase line	3	Liquid back to oxidizer(steam explosion)	.322434	Design standards	106
14.5	High temperature	Loss of quench liquid	3	Low/no flow (Item 14.2)	....		107
		Low/no flow (Item 14.2)	3				
14.6	Low temperature	None	.				
14.7	High pressure	Low/no flow (Item 14.2)	.	Low/no flow (Item 14.2)	....		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		14.0 LINE_X - liquid line from scrubber to Quench (continued)					
14.8	Low pressure	None	.				
14.9	High concentration of contaminants	High salt content	.	Low/no flow (Item 14.2)	....		
		Low/no flow (Item 14.2)	.	Plugging of quench	....		
		High concentration of contaminants in the Packed-Bed Scrubber (Item 15.11)	.	High concentration of contaminants in the Packed-Bed Scrubber (Item 15.11)	....		
14.10	External leak	Gasket failure	2	Waste leak	..34312	PM	108
		Corrosion	3	Loss of containment in the Packed-Bed Scrubber (Item 15.12)	....	SOP	
		Erosion	2			Materials of Construction	
		Loss of containment in the Packed-Bed Scrubber (Item 15.12)	.				
14.11	External Rupture	None	.				
		15.0 REACTOR_L - Packed-Bed Scrubber (dwg: E03025-RAA-102-D)					
15.1	High flow	High flow in the Evaporator (Item 5.1)	.	Toxic vapors to HEPA	..23322	See 5.1	109 110 111
				Salts and corrosives to HEPA	..21322	Mist eliminator in scrubber	
				Water to HEPA	..2..12		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		15.0 REACTOR_L - Packed-Bed Scrubber (continued)					
15.2	Low/no flow	Clogged vent line	2	High back pressure (See previous high pressure consequences)	....	Delta P across scrubber	112 113 114
		High flow in the Scrubber Liquid Recirculation Line (Item 17.1)	.	Corrosion (from condensed acid gases)	12	Pressure indication on vent line	
		Clogged packing	3	High pressure (Item 15.9)	....	Conductivity of scrubber liquor	
		High pressure (Item 15.9)	.	High flow in the Scrubber Liquid Recirculation Line (Item 17.1)	....	Pressure indications throughout system	
15.3	Reverse flow	None	.				
15.4	Misdirected flow	None	.				
15.5	High temperature	Quench failure	3	Packing Plugging	...2211	Temperature indicator on scrubber vent'	115
		Loss of scrubber solution (instrument and/or pump failure)	2	Over temperature of scrubber(Scrubber failure)	..12312		
		Low Level (Item 15.14)	.	Uncontrolled release of acid gas to HEPA	..23322		
15.6	Low temperature	None	.				
15.7	High reaction rate	Heat of dilution of caustic (possible during startup)	2			SOP	

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		15.0 REACTOR_L - Packed-Bed Scrubber (continued)					
15.8	Low reaction rate	Loss of caustic	4	No scrubbing action	..23122	Inline pH monitor	116
		High concentration of contaminants (Item 15.11)	.	BiCarb plugging (shutdown and dig out)	23	Manual sampling	
						Conductivity monitor	
		Low/no flow in the Scrubber Liquid Recirculation Line (Item 17.2)	.	Corrosion	23	Pressure Delta across packing	
				High concentration of contaminants (Item 15.11)	....		
15.9	High pressure	Low/no flow (Item 15.2)	.	Low/no flow (Item 15.2)	....		
15.10	Low pressure	None	.				
15.11	High concentration of contaminants	High concentration of contaminants in the Discharge line from oxidizer to scrubber (Item 14.9)	.	High concentration of contaminants in the Discharge line from oxidizer to scrubber (Item 14.9)	....		
		Low reaction rate (Item 15.8)	.	Low reaction rate (Item 15.8)	....		
		High concentration of contaminants in the Process Vent Line from Scrubber (Item 16.13)	.	High concentration of contaminants in the Process Vent Line from Scrubber (Item 16.13)	....		
15.12	Loss of containment	External leak in the Discharge line from oxidizer to scrubber (Item 14.10)	.	External leak in the Discharge line from oxidizer to scrubber (Item 14.10)	....		

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		15.0 REACTOR_L - Packed-Bed Scrubber (continued)					
15.13	High Level	Instrument Failure	2	Flood scrubber	11	Pressure indicators in system	117 118
		Water line left open	2	Flood system when system down and water valve open.	..23.23	Delta P indicators	
		Blowdown valve sticks closed	2	High System backpressure	11		
		Low/no flow in the Scrubber Blowdown line (Item 18.2)	.				
15.14	Low Level	Blowdown valve stuck open	3	Loss of scrubber effiency	..32112	Flow meter	119 120 121 122
		Water addition valve sticks closed	2	High temperature (Item 15.5)	....	Low level alarm	
		Level transmitter failure	2	Loss scrubber liquid flow	..32112		
				Low/no flow in the Scrubber Liquid Recirculation Line (Item 17.2)	....		
		16.0 LINE - Process Vent Line from Scrubber (dwg: E03025-RAA-102-D)					
16.1	High flow	High flow anywhere else	.	Overload HEPA filter	..3..13	Flow monitor / pressure / temperature	123
						Delta P across first HEPA	
						RAD monitor	
16.2	Low/no flow	HEPA Plug	.	Process shutdown	11	Pressure indicator	
		High pressure (Item 16.7)	.	High pressure (Item 16.7)	....	Delta P across first HEPA filter	
						Flow meter in line	
16.3	Reverse flow	None	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		16.0 LINE - Process Vent Line from Scrubber (continued)					
16.5	High temperature	Runaway heat tracing	2	Burnout downstream instruments	11	Temperature control on trace	124 125 126
16.6	Low temperature	Failure of heat trace	.	Condensation (HEPA damage)	11	Low low temperature interlock	127
16.7	High pressure	HEPA Plug	2	Low/no flow (Item 16.2)	....		128 129
		Low/no flow (Item 16.2)	.				
		Valve not open	2				
16.8	Low pressure	None	.				
16.13	High concentration of contaminants	Mercury in waste	2	Mercury vapor in building ventilation system	..34.44		130 131
		Liquid overspray	.				
		High concentration of contaminants in the Packed-Bed Scrubber (Item 15.11)	.	High concentration of contaminants in the Packed-Bed Scrubber (Item 15.11)	....		
16.14	Loss of containment	Gasket Failure	2	Vapor release	211	SOP	

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Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		17.0 LINE_P - Scrubber Liquid Recirculation Line (dwg: E03025-RAA-102-D)					
17.1	High flow	Low/no flow in the Packed-Bed Scrubber (Item 15.2)	.	Low/no flow in the Packed-Bed Scrubber (Item 15.2)	....	Flow meter in line with alarm	132 133
		Quench throttle valve left closed	3	No safety problem	....		
		Leak in the Scubber Blowdown Storage Container (Item 19.6)	.				
		Clogged Packing in Scrubber	3				
		Clogged vent line	2				
17.2	Low/no flow	Pump failure	2	Low reaction rate in the Packed-Bed Scrubber (Item 15.8)	....	Level indicator in scrubber	134
		Line clogged	3			Flow meter with low low waste feed shutoff	
		Throttle valve closed	3	High pressure (Item 17.7)	....	Pump fail indicator	
		Scrubber blodown valve open	2	No scrubbing action	..23122		
		Packing clog	2	Bicarbonate plugging	23		
		Low Level in the Packed-Bed Scrubber (Item 15.14)	.	Corrosion	23		
		High pressure (Item 17.7)	.				
		Low pressure (Item 17.8)	.				
17.3	Reverse flow			None	....		
17.4	Misdirected flow	Blowdown valve open	.	Misdirected to line 18 (possible waste spill)	..22112	SOP	
17.5	High temperature	None	.				135

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		17.0 LINE_P - Scrubber Liquid Recirculation Line (continued)					
17.6	Low temperature	None	.				
17.7	High pressure	Low/no flow (Item 17.2)	.	Low/no flow (Item 17.2)	....		
17.8	Low pressure	Pump Failure	2	Low/no flow (Item 17.2)	....	SOP (sample valve)	136
		Instrumentation Failure	2	Scrubber liquid spill	..113.2		
		Blowdown / sample valve open	2				
17.9	High concentration of contaminants	CO2 absorption at high pH followed by pH drop	2	Bicarbonate plugging of line	12	SOP	137
		Low pH - failure to neutralize acid gases	2	Corrosion	12	pH control system	
		High flow in the Sodium Hydroxide Feed Line (Item 21.1)	.				
		Low/no flow in the Sodium Hydroxide Feed Line (Item 21.2)	.				
17.10	External Leak	Gasket leak	2	Scrubber liquid spill	212	Materials of construction	138 139
		Corrosion	1	External Leak in the Scrubber Blowdown line (Item 18.10)	....	pH control system	
		Pump seal	3				
		External Leak in the Scrubber Blowdown line (Item 18.10)	.				
		Rupture in the Scubber Blowdown Storage Container (Item 19.7)	.				

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				17.0 LINE_P - Scrubber Liquid Recirculation Line (continued)			
17.11	External Rupture	None	.				
				18.0 LINE - Scrubber Blowdown line (dwg: E03025-RAA-102-D)			
18.1	High flow	Valve stuck open	3	Scrubber liquid spill	212		140 141
18.2	Low/no flow	Plugged line	3	High Level in the Packed-Bed Scrubber (Item 15.13)	....	High level interlock on scrubber	
		Valve stuck shut	3	Slow filling rate in the Scubber Blowdown Storage Container (Item 19.9)	....		
		Slow filling rate in the Scubber Blowdown Storage Container (Item 19.9)	.	High pressure in the Sodium Hydroxide Feed Line (Item 21.7)	....		
18.3	Reverse flow	None	.				
18.5	High temperature			None	....		
18.6	Low temperature	None	.				
18.7	High pressure	None	.				
18.8	Low pressure	None	.				
18.9	High concentration of contaminants	None	.				

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
		18.0 LINE - Scubber Blowdown line (continued)					
18.10	External Leak	External Leak in the Scrubber Liquid Recirculation Line (Item 17.10)	.	External Leak in the Scrubber Liquid Recirculation Line (Item 17.10)	....		
		Valve packing leak	3	Scrubber liquid leak	212		
		19.0 VESSEL - Scubber Blowdown Storage Container (dwg: E03025-RAA-102-D)					
19.1	High Temperature	None	.				
19.2	Low Temperature	None	.				
19.3	High Level	Valve stuck open in line 18	3	Scrubber liquid spill	212		141 142
		No level instrumentation	5				
19.4	Low Level	None	.				
19.5	Contamination	Corrosion	1	Chromium in scrubber liquid	..32.2.	pH control system	143
		Catalyst breakdown	1	RAD contamination	..32.34		
		Evaporator Burp	2				
19.6	Leak	Leak in the Brine Concentrate Storage Container (Item 8.6)	.	High flow in the Scrubber Liquid Recirculation Line (Item 17.1)	....		
				Scrubber liquid leak	..34312		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				19.0 VESSEL - Scubber Blowdown Storage Container (continued)			
19.7	Rupture	Dropped drum	2	External Leak in the Scrubber Liquid Recirculation Line (Item 17.10)	....		
				Scrubber liquid spill	..34312		
19.8	High Filling Rate			None	....		
19.9	Slow filling rate	Low/no flow in the Scrubber Blowdown line (Item 18.2)	.	Low/no flow in the Scrubber Blowdown line (Item 18.2)	....		
				No safety problem	....		
				20.0 LINE - Propane Feed Line (dwg: E03025-RAA-102-D)			
20.1	High flow	Pressure regulator failure	2	Possible mixture above LEL	33..324	Flow meter in propane line	144 145
		Control valve stuck open	2			Pressure indicator on propane regulator	146 147
		Instrumentation failure	1				
20.2	Low/no flow			No safety concern	....		
20.3	Reverse flow	Regulator failure	1	Contamination of propane line	11	Pressure indicator in propane line	148
		Empty cylinder	2			Flow meter in propane line	
20.4	Misdirected flow			No consequences of interest			
20.5	High temperature	External Fire	1	Propane line rupture	44..424	Fire protection systems	

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
				20.0 LINE - Propane Feed Line (continued)			
20.6	Low temperature					Ambient room temperature Low flow rate	
20.7	High pressure	Regulator failure	.	Not a safety concern	....		
20.8	Low pressure			None	....		
20.9	High concentration of contaminants	None	.				
20.10	External Leak	Leaking valve	2	Propane leak	3...312	SOP	
		Fitting leaks	.			PM	
20.11	External Rupture	Knock head off cylinder	1	Large release of propane / flying cylinder	....	SOP	
				21.0 LINE - Sodium Hydroxide Feed Line (dwg: E03025-RAA-102-D)			
21.1	High flow	Uncontrolled pumps due to instrumentation failure (pH probe in waste feed tank)	1	Loss of pH control	11	Conductivity meter on scrubber	
				High concentration of contaminants in the Scrubber Liquid Recirculation Line (Item 17.9)	....	Pump sizing Temperature / pH meter on evaporator	
				LOW/HIGH CONCENTRATION in the WASTE FEED TANK (Item 2.7)	....		
				High flow in the Sulfuric Acid Feed Line (Item 22.1)	11		

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		21.0 LINE - Sodium Hydroxide Feed Line (continued)					
21.2	Low/no flow	Plugged line	.	Loss of pH control	11	SOP	
		Pump failure	.	High concentration of contaminants in the Scrubber Liquid Recirculation Line (Item 17.9)	....	PM	
		Empty caustic drum	.			Conductivity meter on scrubber	
		Frozen line	.			pH meter on evaporator	
		Valve closed	.	LOW/HIGH CONCENTRATION in the WASTE FEED TANK (Item 2.7)	....		
		Low pressure (Item 21.8)	.	Low pressure (Item 21.8)	....		
				Low/no flow in the Sulfuric Acid Feed Line (Item 22.2)	....		
21.3	Reverse flow	None	.			Check valves	
						Positive displacement pumps	
21.4	Misdirected flow	None	.				
21.5	High temperature	Condensation in line	.			Check valves	
						SOP	
21.6	Low temperature	Low Room temperature	.	Loss of pH control	11	SOP	149
21.7	High pressure	Low/no flow in the Scrubber Blowdown line (Item 18.2)	.	Caustic Spill	311	Internal relief specified for pumps	150
		High pressure in the Sulfuric Acid Feed Line (Item 22.7)	.	High pressure in the Sulfuric Acid Feed Line (Item 22.7)	....		
21.8	Low pressure	Low/no flow (Item 21.2)	.	Low/no flow (Item 21.2)	....		

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				21.0 LINE - Sodium Hydroxide Feed Line (continued)			
21.9	High concentration of contaminants	None	.				
21.10	External Leak	Leaking fitting	.	Caustic leak	311	PM	151
		Valve packing	.	External Leak in the Sulfuric Acid Feed Line (Item 22.10)	....	Material of construction	
				22.0 LINE - Sulfuric Acid Feed Line (dwg: E03025-RAA-102-D)			
22.1	High flow	High flow in the Sodium Hydroxide Feed Line (Item 21.1)	.	Acid spill	322	pH probes in evaporator	152 153
				pH control loss in waste feed tank (corrosion problems)	....		
22.2	Low/no flow	Low/no flow in the Sodium Hydroxide Feed Line (Item 21.2)	.	Loss of pH control (hydroxide gel problems)	11	pH probes SOP PM	
		except freezing	.				
22.3	Reverse flow	None	.			Check valve pump selection	
22.4	Misdirected flow	None	.				
22.5	High temperature	None	.				
22.6	Low temperature	None	.				

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				22.0 LINE - Sulfuric Acid Feed Line (continued)			
22.7	High pressure	High pressure in the Sodium Hydroxide Feed Line (Item 21.7)	.	High pressure in the Sodium Hydroxide Feed Line (Item 21.7)	....		
22.8	Low pressure	None	.				
22.9	High concentration of contaminants	None	.				
22.10	External Leak	External Leak in the Sodium Hydroxide Feed Line (Item 21.10)	.	Acid spill and fume	414	SOP	154
			.	External Rupture (Item 22.11)	....	PM	155
22.11	External Rupture	External Leak (Item 22.10)	.	Large spill and fuming	..3.424	SOP	156 157
		Drop the drum	1			PM	
				23.0 LINE - Feed Tank Vent Line (dwg: E03025-RAA-102-D)			
23.1	High Flow	None	.				
23.2	Low/No Flow	Closed valve	2	Pressure build up in tank	14	Relief valve	
		Plugged check valve	2	Can't feed waste tank	11	Pressure guage	
						Delta P interlock on feed tank and evaporator	
23.3	REVERSE FLOW	Check valve failure	1	Vapor from evaporator feed back to waste tank	11		158

(continued)

Item Number	Deviation	Causes	FC	Consequences	FXETIBO	Safeguards	Actions
		23.0 LINE - Feed Tank Vent Line (continued)					
23.5	High Temperature	External Fire	1	See tank and evaporator consequences	....		159
		Check valve failure allowing hot gas to enter waste feed tank	.				
23.5	Low Temperature			None	....		
23.6	High Pressure	Line block	.	Relief valve release	23	Pressure indicator on tank	
		Check valve failure	.	Vent line rupture	3313323	Differential pressure between tank and evaporator	
23.7	Low Pressure			None	....		
23.8	LOW/HIGH CONCENTRATION	Overfilling feed tank	2	Agitator/pumping problems	11	Waste sampling and feed procedures	
		Too much solvent in aste tank	1	ph out of specification (corrosion)	11	Waste acceptance criteria	
		Too high suspended solids in waste tank	1				
		Improper pH adjustment	3				
23.9	CONTAMINATION	Improper waste feed	1	Clogging of waste line	11	Waste acceptance criteria	
23.10	EXTERNAL LEAK	Gasket failure	2	Small waste vapor spill	...2222	System setup procedures	
		Unexpected reaction in tank	2			Waste acceptance criteria	
		Corrosion	1			PM	
		Vacuum breaker leak	2				
		PSV leak	2				

(continued)

Item Number	Deviation	Causes	F C	Consequences	FXETIBO	Safeguards	Actions
				23.0 LINE - Feed Tank Vent Line (continued)			
23.11	EXTERNAL RUPTURE	Unexpected reaction in tank	1	Waste vapor release	...2222	Sampling/waste acceptance criteria	

C.2 HAZOP Analysis Action Item Tracking and Risk Reduction

The HAZOP analysis review identified 159 "action items" to be considered as possible mitigators for the various deviations. These action items are enumerated in the right-hand column of Attachment C.1–1, Table C.1–3, HAZOP Analysis Action Items. Table C.2–1 lists each action item in numerical order, along with the deviation it addressed, the priority of that deviation, a description of the action item, and a statement giving the resolution of the action item or the current status if an item has not been closed out. (An example of an item that is not yet closed out is one that must be addressed during preparation of standard operating procedures [SOPs], which is outside the scope of this project.)

The "Priority" shown for each action item listed in Table C.2–1 was determined by combining the frequency and consequence ratings for the deviation associated with that item. These ratings ranged from 1 to 4, with 4 being the highest. Therefore, the highest priority items were those with a rating of 8. Only two high-priority items were identified: (1) foaming or undetected high level in the evaporator resulting in carryover of liquid into the oxidizer heaters, which in turn could cause an explosion due to thermal stresses in the heaters; and (2) low/no process flow in the Econobator inlet line, which could create an explosive situation due to high propane concentration.

Liquid carryover from the evaporator was mitigated by adding redundant level and foam instrumentation and by modifying the design of the evaporator to the current multichambered design which adds two stages of demisting and a very circuitous flow path. The risk of the low/no Econobator inlet flow scenario was mitigated by deleting the propane addition and replacing it with ethanol, added as a liquid to the evaporator feed. The presence of a small concentration of ethanol, a flammable liquid, at a point in the process (the evaporator) where small concentrations of flammable liquids are normal, adds no additional hazards to the system.

Deletion of propane addition resolved a total of 17 of the HAZOP analysis action items. Another source of major hazards was the quench system on the Econobator off gas; deletion of this system and replacement with the noncontact desuperheater resolved an additional 10 items.

Table C.2–1. Mitigation of HAZOP Analysis Action Items

Item No.: 1
Deviation: 1.2 — Low/No Flow, Waste Transfer to Waste Feed Tank
Priority: 5
Description: Maintenance training
Status: To be resolved during training

Item No.: 2
Deviation: 1.3 — Reverse Flow, Waste Transfer to Waste Feed Tank
Priority: 4
Description: Review maintenance procedures including PPE
Status: To be resolved during training

Item No.: 3
Deviation: 1.3 — Reverse Flow, Waste Transfer to Waste Feed Tank
Priority: 4
Description: Siphon break on dip tube
Status: Complete
Action: Added per DCN-01

Item No.: 4
Deviation: 1.9 — Contamination, Waste Transfer to Waste Feed Tank
Priority: 7
Description: Consider drum mixer on waste feed drum
Status: To be resolved during training

Item No.: 5
Deviation: 1.9 — Contamination, Waste Transfer to Waste Feed Tank
Priority: 7
Description: Consider settling and decantation possibility in waste feed drum
Status: To be resolved during training

Item No.: 6
Deviation: 1.10 — External Leak, Waste Transfer to Waste Feed Tank
Priority: 4
Description: Hydro testing before startup included in SOP
Status: To be resolved during training

Item No.: 7
Deviation: 2.2 — High Pressure, Waste Feed Tank
Priority: 4
Description: Rate tank at same pressure as evaporator
Status: Complete
Action: Done

Item No.: 8
Deviation: 2.2 — High Pressure, Waste Feed Tank
Priority: 4
Description: Relief valve discharge management requirements
Status: Complete
Action: Will route to unit vent line

Item No.: 9 (Duplicated by Items 10 and 82)
Deviation: 2.5 — Low Level, Waste Feed Tank
Priority: 4
Description: Two independent indicators on waste feed tank
Status: Complete
Action: Added float switch

Item No.: 10 (duplicate of Item 9)

Item No.: 11
Deviation: 2.6 — High Level, Waste Feed Tank
Priority: 7
Description: Remove vacuum breaker from waste feed tank
Status: Complete
Action: Deleted per DCN-01

Item No. 12
Deviation: 2.7 — Low/High Concentration, Waste Feed Tank
Priority: 7
Description: Revisit waste acceptance of complex cyanides
Status: To be resolved during training

Item No.: 13
Deviation: 2.7 — Low/High Concentration, Waste Feed Tank
Priority: 7
Description: Evaluate high solvent consequences (Node 5 & 13)
Status: Complete
Action: High solvents will be fed directly to evaporator

Item No.: 14
Deviation: 2.7 — Low/High Concentration, Waste Feed Tank
Priority: 7
Description: Schedule drums to minimize acidification
Status: To be resolved during training

Item No.: 15 (Duplicated by Items 153, 154, 156, and 157)
Deviation: 2.7 — Low/High Concentration, Waste Feed Tank
Priority: 7
Description: Consider elimination or restricted use of acid (corrosion concerns in evaporator)
Status: Complete
Action: pH range > 7, acid volume 5 gals max

Item No.: 16
Deviation: 2.9 — External Leak, Waste Feed Tank
Priority: 7
Description: Use double agitator seal with vent to HEPA filter
Status: Complete
Action: Using air-driven agitator - no explosion source

Item No.: 18
Deviation: 2.9 — External Leak, Waste Feed Tank
Priority: 7
Description: PSV on waste feed tank should have a sealed bonnet
Status: Complete
Action: Added PSE per DCN-01

Item No.: 19
Deviation: 2.9 — External Leak, Waste Feed Tank
Priority: 7
Description: Rupture disk/blowout on waste feed tank
Status: Complete
Action: Added PSE per DCN-01

Item No.: 20
Deviation: 2.9 — External Leak, Waste Feed Tank
Priority: 7
Description: Review possibility of exothermic/detonation reaction
Status: Complete
Action: Add interlock for feed tank temperature

Item No.: 21
Deviation: 2.10 — External Rupture, Waste Feed Tank
Priority: 5
Description: Consider worst case situation for reaction possibility in feed tank
Status: Complete
Action: See item 20

Item No.: 22
Deviation: 2.10 — External Rupture, Waste Feed Tank
Priority: 5
Description: Class 1, Div 1 in waste feed area
Status: Complete
Action: Air-driven mixer

Item No.: 23
Deviation: 3.2 — Low/No Flow, Waste Feed Line from Tank to Evaporator
Priority: 5
Description: Add manual valves to be able to isolate evaporator from feed lines
Status: Complete
Action: Done per DCN-01

Item No.: 24 (Duplicated by Item 27)
Deviation: 3.2 —Low/No Flow, Waste Feed Line from Tank to Evaporator
Priority: 5
Description: Combine discharges of P-014, P-122, and P-054
Status: Complete
Action: Done per DCN-01

Item No.: 25
Deviation: 3.2 —Low/No Flow, Waste Feed Line from Tank to Evaporator
Priority: 5
Description: Relocate waste feed line above liquid level in evaporator
Status: Complete
Action: Done per DCN-01

Item No.: 26
Deviation: 3.4 — Misdirected Flow, Waste Feed Line from Tank to Evaporator
Priority: 3
Description: Confirm check valves in all metering pumps
Status: In progress

Item No.: 27 (duplicate of Item 24)

Item No.: 28
Deviation: 3.7 — High Pressure, Waste Feed Line from Tank to Evaporator
Priority: 4
Description: Verify metering pumps have internal PSV
Status: In progress

Item No.: 29
Deviation: 3.7 — High Pressure, Waste Feed Line from Tank to Evaporator
Priority: 4
Description: Check pressure rating of line.
Status: Complete
Action: Rating OK

Item No.: 30
Deviation: 4.1 — Shell Leak, Evaporator Heater
Priority: 7
Description: Delete vacuum breaker / elevate heater above trap
Status: Complete
Action: Vacuum breaker deleted per DCN-01

Item No.: 31
Deviation: 4.1 — Shell Leak, Evaporator Heater
Priority: 7
Description: Steam condensate receiver open to atmosphere
Status: Complete
Action: Done per DCN-01

Item No.: 32
Deviation: 4.1 — Shell Leak, Evaporator Heater
Priority: 7
Description: SOP to include hydrotest requirements, etc.
Status: To be resolved during training

Item No.: 33
Deviation: 4.5 — Low Pressure, Evaporator Heater
Priority: None given
Description: Confirm heater is designed for vacuum
Status: Complete
Action: Done

Item No.: 34
Deviation: 4.7 — High Level, Evaporator Heater
Priority: 3
Description: Vent shell to atmosphere
Status: Complete
Action: Vent added per DCN-01

Item No.: 35
Deviation: 4.10 — Tube Leak, Evaporator Heater
Priority: 5
Description: Consider testing condensate for gross Alpha and Beta
Status: To be resolved during training

Item No.: 36
Deviation: 5.2 — Low/No Flow, Evaporator
Priority: 7
Description: Design evaporator for higher pressure than boiler capacity
Status: Complete
Action: Not practical

Item No.: 37
Deviation: 5.2 — Low/No Flow, Evaporator
Priority: 7
Description: Differential pressure across mesh pads
Status: Complete
Action: Not required per Wheelabrator Clean Water

Item No.: 38
Deviation: 5.2 —Low/No Flow, Evaporator
Priority: 7
Description: Water spray under mesh pads
Status: Complete
Action: Not required per Wheelabrator Clean Water

Item No.: 39
Deviation: 5.5 — High Temperature, Evaporator
Priority: 5
Description: SOP - Sampling and analysis
Status: To be resolved during training

Item No.: 40
Deviation: 5.7 — High pressure, evaporator
Priority: 3
Description: Coordinate relief valve with boiler relief pressure
Status: Complete
Action: Not practical (see item 36)

Item No.: 41 (duplicated by Item 76)
Deviation: 5.9 — High Level, Evaporator
Priority: 8
Description: Wide spot in line 10 - knockout pot
Status: Complete
Action: Incorporated into evaporator design

Item No.: 42 (duplicate of Item 115)

Item No.: 43
Deviation: 5.10 — Low Level, Evaporator
Priority: 4
Description: Redundant low level switch (utilize density dP)
Status: Complete
Action: dP added per DCN-01

Item No.: 44
Deviation: 5.15 — External Leak, Evaporator
Priority: 3
Description: Corrosion coupons
Status: In progress

Item No.: 45
Deviation: 6.2 — Low/No Flow, Brine Recirculation Line w/ Pump
Priority: 7
Description: Motor amp monitor replacing flow meter
Status: In progress

Item No.: 46
Deviation: 6.4 — Misdirected Flow, Brine Recirculation Line w/ Pump
Priority: None listed
Description: Check current safeguard
Status: To be resolved during training

Item No.: 47
Deviation: 6.7 — High Pressure, Brine Recirculation Line w/ Pump
Priority: 1
Description: Replace throttling valve with fixed orifice - remove relief valve
Status: Complete
Action: Added orifice and removed PSV

Item No.: 48
Deviation: 6.8 — Low Pressure, Brine Recirculation Line w/ Pump
Priority: 1
Description: Redundant low-level indicator
Status: Complete
Action: dP added per DCN–01

Item No.: 49.
Deviation: 7.1 — High Flow, Brine Concentrate Drain Line
Priority: 5
Description: Consider a ram valve and a manual back-up valve
Status: Complete
Action: Manual ram valve added per DCN–01

Item No.: 50
Deviation: 7.2 — Low/No Flow, Brine Concentrate Drain Line
Priority: 4
Description: Ram valve and a manual back-up valve
Status: Complete
Action: Manual ram valve added per DCN–01

Item No.: 51
Deviation: 7.2 — Low/No Flow, Brine Concentrate Drain Line
Priority: 4
Description: Steam / water flush line
Status: Complete
Action: Added to P&ID

Item No.: 52
Deviation: 7.6 — Low Temperature, Brine Concentrate Drain Line
Priority: 2
Description: Preheat procedure before draining
Status: To be resolved during training

Item No.: 53
Deviation: 7.6 — Low Temperature, Brine Concentrate Drain Line
Priority: 2
Description: Steam trace line
Status: Complete
Action: Item 51 will be implemented

Item No.: 54
Deviation: 8.3 — High Level, Brine Concentrate Storage Container
Priority: 2
Description: Platform scale
Status: Complete
Action: Load cells will be utilized

Item No.: 55
Deviation: 8.3 — High Level, Brine Concentrate Storage Container
Priority: 2
Description: Drain procedures
Status: To be resolved during training

Item No.: 56
Deviation: 8.6 — Leak, Brine Concentrate Storage Container
Priority: 4
Description: Consider drum handling equipment requirements
Status: To be resolved during training

Item No.: 57
Deviation: 8.6 — Leak, Brine Concentrate Storage Container
Priority: 4
Description: Consider drum specification requirements
Status: To be resolved during training

Item No.: 58
Deviation: 8.7 — Rupture, Brine Concentrate Storage Container
Priority: 6
Description: Ventilation requirements
Status: Complete
Action: Fume vent added per DCN-01

Item No.: 59
Deviation: 8.7 — Rupture, Brine Concentrate Storage Container
Priority: 6
Description: Grounding requirements – electrical
Status: To be resolved during training

Item No.: 60
Deviation: 8.7 — Rupture, Brine Concentrate Storage Container
Priority: 6
Description: Class 1, Div. 1
Status: Complete
Action: Area will be ventilated

Item No.: 61
Deviation: 9.2 — High Flow, Waste Feed Return Line
Priority: 4
Description: Flow switch
Status: Complete
Action: Added per DCN–01

Item No.: 62
Deviation: 9.2 — High Flow, Waste Feed Return Line
Priority: 4
Description: Relocate pH meter (tank or pump suction before branch)
Status: Complete
Action: Moved per DCN-01

Item No.: 63
Deviation: 9.7 — High Pressure, Waste Feed Return Line
Priority: 2
Description: Remove or lock open manual valve in return line
Status: Complete
Action: Done per DCN–01

Item No.: 64
Deviation: 10.1 — High Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Add orifice between Evaporator and Oxidizer Heater
Status: Complete
Action: Done (FO 022–11)

Item No.: 65
Deviation: 10.1 — High Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Investigate dynamic response of evaporator due to step change in back pressure
Status: Complete
Action: Effect is minimal

Item No.: 66
Deviation: 10.3 — Reverse Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Relocate startup Econobator air connection point
Status: Complete
Action: Propane removed per DCN–01

Item No.: 67
Deviation: 10.3 — Reverse Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Interlock propane valve with low steam flow
Status: Complete
Action: Propane removed per DCN–01

Item No.: 68
Deviation: 10.3 — Reverse Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Consider ethanol instead of propane
Status: Complete
Action: Propane removed per DCN–01

Item No.: 69
Deviation: 10.3 — Reverse Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Interlock propane valve with negative differential between evaporator and point upstream of propane connection.
Status: Complete
Action: Propane removed per DCN–01

Item No.: 70
Deviation: 10.3 — Reverse Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Relocate propane injection point to downstream of heater
Status: Complete
Action: Propane removed per DCN–01

Item No.: 71
Deviation: 10.4 — Misdirected Flow, Evaporator Vapor Discharge Line
Priority: 3
Description: Check valve
Status: Complete
Action: Propane removed per DCN–01

Item No.: 72
Deviation: 10.4 — Misdirected Flow, Evaporator Vapor Discharge Line
Priority: 3
Description: Interlock on low pressure in propane and/or air
Status: Complete
Action: Propane removed per DCN–01

Item No.: 73
Deviation: 10.4 — Misdirected Flow, Evaporator Vapor Discharge Line
Priority: 6
Description: Relocate propane line feed after oxidizer heater
Status: Complete
Action: Propane removed per DCN–01

Item No.: 74
Deviation: 10.5 — High Temperature, Evaporator Vapor Discharge Line
Priority: 6
Description: Interlock differential pressure on Econobator with shutdown sequence
Status: Complete
Action: Propane removed per DCN–01

Item No.: 75
Deviation: 10.5 — High Temperature, Evaporator Vapor Discharge Line
Priority: 6
Description: Correct valve 032-5 to be fail open
Status: Complete
Action: Done per DCN–01

Item No.: 76 (duplicate of Item 41)

Item No.: 77
Deviation: 10.7 — High Pressure, Evaporator Vapor Discharge Line
Priority: 7
Description: High pressure interlock to system shutdown
Status: Complete
Action: Interlock exists on top of evaporator

Item No.: 78
Deviation: 10.7 — High Pressure, Evaporator Vapor Discharge Line
Priority: 7
Description: Route PSV discharge to safe location
Status: Complete
Action: Route to vent line

Item No.: 79
Deviation: 10.7 — High Pressure, Evaporator Vapor Discharge Line
Priority: 7
Description: Coordinate design pressure of steam, air, and process systems
Status: Complete
Action: Added PSV for air - not practical for steam

Item No.: 80
Deviation: 10.9 — High Concentration of Contaminants, Evaporator Vapor Discharge Line
Priority: 5
Description: Remove vent line from waste feed tank
Status: Complete
Action: Line will be retained; redundant instrumentation to be added

Item No.: 81
Deviation: 10.9 — High Concentration of Contaminants, Evaporator Vapor Discharge Line
Priority: 5
Description: Calculate percent increase in feed rate allowed by SOP
Status: Complete
Action: Changes will be limited to 10%

Item No.: 82 (duplicate of Item 9)

Item No.: 83
Deviation: 11.8 — High Process Flow, Oxidizer Heater
Priority: 4
Description: Add orifice or check valve size in propane line to limit maximum propane flow.
Status: Complete
Action: Propane removed per DCN–01

Item No.: 84
Deviation: 11.8 — High Process Flow, Oxidizer Heater
Priority: 4
Description: Add high propane pressure interlock to propane valve and electric heater shutoff.
Status: Complete
Action: Propane removed per DCN–01

Item No.: 85 (Duplicated by Item 95)
Deviation: 11.9 — Low/No Process Flow, Oxidizer Heater
Priority: 8
Description: Delta temperature sensor interlocked to system shutdown at catalytic Econobator.
Status: Complete
Action: Will be covered by Item 86

Item No.: 86 (duplicated by Item 94)
Deviation: 11.9 — Low/No Process Flow, Oxidizer Heater
Priority: 8
Description: High temperature shutoff at heater outlet and/or Econobator.
Status: Complete
Action: Interlock added per DCN–01

Item No.: 87
Deviation: 11.9 — Low/No Process Flow, Oxidizer Heater
Priority: 8
Description: Move interlock 11 to heater outlet
Status: Complete
Action: Redundant due to Item 86

Item No.: 88
Deviation: 11.9 — Low/No Process Flow, Oxidizer Heater
Priority: 8
Description: Delta pressure sensor across Econobator.
Status: Complete
Action: No detonation (propane removed)

Item No.: 89
Deviation: 11.12 — Low Process Temperature, Oxidizer Heater
Priority: 4
Description: Spare heater
Status: To be resolved during training

Item No.: 90
Deviation: 11.13 — High Pressure, Oxidizer Heater
Priority: 6
Description: Rate system for up to 35 psig
Status: In progress
Comment: Waiting on Haynes data

Item No.: 91
Deviation: 11.13 — High Pressure, Oxidizer Heater
Priority: 6
Description: Coordinate boiler pressure
Status: Complete
Action: Not practical (see item 79)

Item No.: 92
Deviation: 11.15 — Tube Leak, Oxidizer Heater
Priority: 5
Description: Corrosion coupons
Status: In progress

Item No.: 93
Deviation: 13.2 — Low Flow, Catalytic Econobator
Priority: 1
Description: Hard-wired dP switch — safety shutdown
Status: Complete
Action: Software interlock in place per item 74

Item No.: 94 (duplicate of Item 86)

Item No.: 95 (duplicate of Item 85)

Item No.: 96
Deviation: 13.5 — High Temperature, Catalytic Econobator
Priority: 6
Description: Econobator outlet temp hard wire shutdown (1450–1500)
Status: Complete
Action: Software interlock added per DCN–01

Item No.: 97
Deviation: 13.5 — High Temperature, Catalytic Econobator
Priority: 6
Description: Process water pump failure interlock
Status: Complete
Action: Interlock added per DCN–01

Item No.: 98
Deviation: 13.11 — External Leak, Catalytic Econobator
Priority: 4
Description: Ambient CO monitor
Status: To be resolved during training

Item No.: 99
Deviation: 14.1 — High Flow, Discharge Line from Econobator to Scrubber
Priority: 3
Description: Flow meter in quench liquid feed line
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 100
Deviation: 14.1 — High Flow, Discharge Line from Econobator to Scrubber
Priority: 3
Description: Sodium hydroxide in quench feed line
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 101
Deviation: 14.1 — High Flow, Discharge Line from Econobator to Scrubber
Priority: 3
Description: Check two-phase flow pressure drop in worst-case situation
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 102
Deviation: 14.2 — Low/No Flow, Discharge Line from Econobator to Scrubber
Priority: 6
Description: Flow meter on line 14 quench feed line
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 103
Deviation: 14.2 — Low/No Flow, Discharge Line from Econobator to Scrubber
Priority: 6
Description: Throttle valve on quench feed line
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 104
Deviation: 14.2 — Low/No Flow, Discharge Line from Econobator to Scrubber
Priority: 6
Description: High temperature indicator on drain line from quench
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 105
Deviation: 14.2 —Low/No Flow, Discharge Line from Econobator to Scrubber
Priority: 6
Description: Quench with water only
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 106
Deviation: 14.3 — Reverse Flow, Discharge Line from Econobator to Scrubber
Priority: 7
Description: Make two-phase line large diameter
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 107
Deviation: 14.5 — High Temperature, Discharge Line from Econobator to Scrubber
Priority: 3
Description: Spiral heat exchanger / indirect cooling
Status: Complete
Action: Heat exchanger will be added

Item No.: 108

Deviation: 14.10 — External Leak, Discharge Line from Econobator to Scrubber
Priority: 7
Description: Corrosion coupons
Status: In progress

Item No.: 109
Deviation: 15.1 — High Flow, Packed-Bed Scrubber
Priority: 3
Description: Stock HEPA filters
Status: To be resolved during training

Item No.: 110 (duplicated by Items 130 and 131)
Deviation: 15.1 — High Flow, Packed-Bed Scrubber
Priority: 3
Description: Mercury recovery unit
Status: To be resolved during training
Comment: Mercury wastes will be excluded or handled case-by-case

Item No. 111
Deviation: 15.1 —High Flow, Packed-Bed Scrubber
Priority: 3
Description: Show mist eliminator on P&ID
Status: Complete
Action: Mist eliminator added per DCN–01

Item No.: 112
Deviation: 15.2 — Low/No Flow, Packed-Bed Scrubber
Priority: 5
Description: Insulate process lines up to and including scrubber
Status: Complete
Action: Done

Item No.: 113
Deviation: 15.2 —Low/No Flow, Packed-Bed Scrubber
Priority: 5
Description: Delta P and water wash on mist eliminator
Status: Complete
Action: dP across packing and demister is adequate

Item No.: 114
Deviation: 15.2 —Low/No Flow, Packed-Bed Scrubber
Priority: 5
Description: Show insulation on P&ID
Status: Complete
Action: Done

Item No.: 115 (duplicated by Item 42)
Deviation: 15.5 — High Temperature, Packed-Bed Scrubber
Priority: 6
Description: High interlock to shut system down and water dump into scrubber
Status: Complete
Action: Use temperature signal from desuperheater (107), general shutdown

Item No.: 116
Deviation: 15.8 — Low Reaction Rate, Packed-Bed Scrubber
Priority: 7
Description: Spares
Status: In progress

Item No.: 117
Deviation: 15.13 — High Level, Packed-Bed Scrubber
Priority: 5
Description: Add high delta P alarm at scrubber bed
Status: Complete
Action: Done

Item No.: 118 (duplicated by Item 119)
Deviation: 15.13 — High Level, Packed-Bed Scrubber
Priority: 5
Description: High level gauge in scrubber (sight glass)
Status: Complete
Action: Added per DCN–01

Item No.: 119 (duplicate of Item 118)

Item No.: 120
Deviation: 15.14 — Low Level, Packed-Bed Scrubber
Priority: 6
Description: Manual or high quality auto blowdown valve
Status: Complete
Action: Selected valve is high quality

Item No.: 121
Deviation: 15.14 — Low Level, Packed-Bed Scrubber
Priority: 6
Description: City water supply to quench
Status: Complete
Action: Quench deleted per DCN–01

Item No.: 122
Deviation: 15.14 — Low Level, Packed-Bed Scrubber
Priority: 6
Description: Make distillate for makeup water
Status: Complete
Action: Use of condenser reviewed and rejected

Item No.: 123
Deviation: 16.1 — High Flow, Process Vent Line from Scrubber
Priority: 3
Description: Oversize HEPA filter
Status: Complete
Action: Will be done

Item No.: 124
Deviation: 16.5 — High Temperature, Process Vent Line from Scrubber
Priority: 3
Description: Add heat tracing indication to P&ID
Status: Complete
Action: Added per DCN–01

Item No.: 125
Deviation: 16.5 — High Temperature, Process Vent Line from Scrubber
Priority: 3
Description: High temperature to trace control
Status: Complete
Action: Use self-limiting heat tape

Item No.: 126
Deviation: 16.5 — High Temperature, Process Vent Line from Scrubber
Priority: 3
Description: Use self-limiting heat trace tape
Status: Complete
Action: Alternative to Item 125

Item No.: 127
Deviation: 16.6 — Low Temperature, Process Vent Line from Scrubber
Priority: 1
Description: HEPA filter higher than scrubber discharge
Status: Complete
Action: Note added to P&ID

Item No.: 128
Deviation: 16.7 — High Pressure, Process Vent Line from Scrubber
Priority: 2
Description: Delete carbon drum
Status: Complete
Action: Drum deleted per DCN–01

Item No.: 129
Deviation: 16.7 — High Pressure, Process Vent Line from Scrubber
Priority: 2
Description: Lock valve open
Status: Complete
Action: Done per DCN–01

Item No.: 130 (duplicate of Item 110)

Item No.: 131 (duplicate of Item 110)

Item No.: 132
Deviation: 17.1 — High Flow, Scrubber Liquid Recirculation Line
Priority: 3
Description: Add recirculation throttle valve
Status: Complete
Action: Not needed since quench eliminated

Item No.: 133
Deviation: 17.1 — High Flow, Scrubber Liquid Recirculation Line
Priority: 3
Description: Design pump to deliver only max allowable flow
Status: Complete
Action: Valve in process line will balance flow on startup

Item No.: 134
Deviation: 17.2 — Low/No Flow, Scrubber Liquid Recirculation Line
Priority: 6
Description: High delta P across packing interlock to shutdown unit
Status: Complete
Action: Interlocks elsewhere will shut down unit

Item No.: 135
Deviation: 17.5 — High Temperature, Scrubber Liquid Recirculation Line
Priority: None listed
Description: Add insulation to P&ID
Status: Complete
Action: Done

Item No.: 136 (duplicated by Item 140)
Deviation: 17.8 — Low Pressure, Scrubber Liquid Recirculation Line
Priority: 5
Description: Blowdown valve manual
Status: Complete
Action: Selected valve is high quality

Item No.: 137
Deviation: 17.9 — High Concentration of Contaminants, Scrubber Liquid Recirculation Line
Priority: 4
Description: Corrosion coupons
Status: In progress

Item No.: 138 (duplicated by Item 143)
Deviation: 17.10 — External Leak, Scrubber Liquid Recirculation Line
Priority: 5
Description: Teflon-lined pipe and scrubber
Status: To be resolved during training

Item No.: 139

Deviation: 17.10 — External Leak, Scrubber Liquid Recirculation Line
Priority: 5
Description: Magnetic drive pump
Status: Complete
Action: Use double mechanical seals

Item No.: 140 (duplicate of Item 136)

Item No.: 141
Deviation: 18.1 — High Flow, Scrubber Liquid Recirculation Line
Priority: 7
Description: Load cell on scrubber blowdown tank
Status: Complete
Action: Done

Item No.: 142
Deviation: 19.3 — High Level, Scrubber Blowdown Storage Container
Priority: 7
Description: Operating procedures
Status: To be resolved during training
Item No.: 143 (duplicate of Item 138)

Item No.: 144
Deviation: 20.1 — High Flow, Propane Feed Line
Priority: 6
Description: Orifice to limit max propane feed
Status: Complete
Action: Propane removed per DCN–01

Item No.: 145
Deviation: 20.1 — High Flow, Propane Feed Line
Priority: 6
Description: Change from propane to some other fuel
Status: Complete
Action: Propane removed per DCN–01

Item No.: 146
Deviation: 20.1 — High Flow, Propane Feed Line
Priority: 6
Description: Pressure switch or relief valve in propane line
Status: Complete
Action: Propane removed per DCN–01

Item No.: 147
Deviation: 20.1 — High Flow, Propane Feed Line
Priority: 6
Description: Set minimum air rate to insure mixture below LEL
Status: Complete
Action: Propane removed per DCN–01

Item No.: 148
Deviation: 20.3 — Reverse Flow, Propane Feed Line
Priority: 3
Description: Spring type check valve
Status: Complete
Action: Propane removed per DCN–01

Item No.: 149 (duplicated by Item 155)
Deviation: 21.6 — Low Temperature, Sodium Hydroxide Feed Line
Priority: 1
Description: Use diluted sodium hydroxide
Status: Complete
Action: Use 50% NaOH with careful piping and drum location

Item No.: 150
Deviation: 21.7 — High Pressure, Sodium Hydroxide Feed Line
Priority: 3
Description: Pump selection (deadhead pressure less than maximum line pressure)
Status: In progress
Comment: Will be confirmed and documented

Item No.: 151
Deviation: 21.10 — External Leak, Sodium Hydroxide Feed Line
Priority: 3
Description: Welded lines (sodium hydroxide)
Status: Complete
Action: Will use tubing rated for adequate pressure

Item No.: 152
Deviation: 22.1 — High Flow, Sulfuric Acid Feed Line
Priority: 3
Description: Add chemical feed descriptions to P&ID
Status: Complete
Action: Added per DCN–01

Item No.: 153 (duplicate of Item 15)

Item No.: 154 (duplicate of Item 15)

Item No.: 155 (duplicate of Item 149)

Item No.: 156 (duplicate of Item 15)

Item No.: 157 (duplicate of Item 15)

Item No.: 158
Deviation: 23.3 — Reverse Flow, Vent Line from Feed Tank to Evaporator
Priority: 2
Description: Remove check valve
Status: Complete
Action: Check valve will be retained

Item No.: 159
Deviation: 23.5 — High Temperature, Vent Line from Feed Tank to Evaporator
Priority: 1
Description: Slope line towards evaporator
Status: Complete
Action: Added to P&ID

C.3 Hazard Identification and Evaluation

The eight postulated accident scenarios chosen in this PHA follow the roadmap presented in "*Guidance for Preparation of the MWT Process Hazards Analysis*" (DOE 1995b). Binning of these scenarios used the maximum likely MAR, and each was evaluated for possible consequences to the public, co-located worker, worker, and environment. All eight scenarios resulted in no public or environmental risk as shown in Table C.3–1; however co-located worker and worker risks are summarized below. Fault trees were produced for those accident scenarios with consequence ratings of A, B, or C (refer to Table C.4–1).

Initiating Event 1

Spark when drum handling resulting in a fire.

Worker—may receive moderate exposure with minor health effects/injuries
1. radiological contamination—dermal/inhalation
2. chemical exposure—dermal/inhalation

Initiating Event 2

Exterior rupture of feed tank resulting in a fire.

Co-located worker—may incur a low exposure with negligible health effects

Worker—The worker may incur a significant exposure and associated health effects with the possibility of severe injury but no permanent disability.
1. burns—possible hospitalization
2. chemical exposure—dermal/inhalation
3. radiological contamination—dermal/inhalation

Initiating Event 3

Interior rupture of feed tank resulting in a fire.

Worker—may incur a moderate exposure with minor injury/health effects
1. radiological contamination—dermal/inhalation
2. chemical exposure—dermal/inhalation

Initiating Event 4

Exterior rupture of evaporator or evaporator leak, with ignition source, resulting in a fire.

Co-located worker—may incur a low exposure with negligible health effects

Worker—may incur a moderate exposure with minor injury/health effects
1. radiological contamination—dermal/inhalation
2. chemical exposure—dermal/inhalation

Initiating Event 5

Ethanol loss of containment with ignition source, resulting in a fire.

Co-located worker—may incur a significant exposure and health effects.
1. burns—possible hospitalization
2. chemical exposure—inhalation

Worker—may incur a potentially lethal/IDLH exposure.
1. severe burns—hospitalization
2. chemical exposure—dermal/inhalation

Initiating Event 6

A. Econobator loss of containment resulting in a 1200 °F steam release.

Co-located worker—may incur a high exposure with major health effects.
1. burns
2. chemical exposure—inhalation

Worker—may incur a potentially lethal exposure.
1. severe burns—hospitalization
2. chemical exposure—inhalation

B. Econobator loss of containment resulting in a release of 250 °F steam with possible CO and/or NO_x.

Co-located worker—may incur moderate exposure with minor health effects.
1. chemical exposure—inhalation

Worker—may incur high exposure with major health effects and severe injury but no permanent disability.
1. burns—possible hospitalization
2. chemical exposure—inhalation

Initiating Event 7

A. Sulfuric acid spill or release.

Co-located worker—may incur low exposure and negligible health effects .

Worker—may incur moderate exposure and minor injury/health effects.
1. chemical exposure—dermal/inhalation

B. Sodium hydroxide spill or release.

Co-located worker—may incur a moderate exposure with minor health effects.
1. chemical exposure—inhalation

Worker—May incur a significant exposure and health effects with possible severe injury but no permanent disability.
1. burns—possible hospitalization
2. chemical exposure—dermal/inhalation

C. Acid/base reaction from spill or release and combination of the two.

Co-located worker—may incur a low exposure and negligible health effects.

Worker—may incur a significant exposure and health effects with possible severe injury but no permanent disability.
1. burns—possible hospitalization
2. chemical exposure—dermal/inhalation

Initiating Event 8

Brine scrubber blowdown release or spill.

Co-located worker—may incur a low exposure with negligible health effects.
Worker—may incur a moderate exposure with minor health effects and minor injury.
1. radiological contamination—dermal

These events and their consequences are summarized in Table C.3–1.

Table C.3–1. Accident Initiating Event Binning

Accident Initiating Event Binning — Using Maximum Likely MAR					
Event Number	Initiating Events	Public	Co-Located Worker	Worker	Environment
1	Spark at drum being unloaded — Fire	None	None	D	None
2	Ruptured exterior of feed tank — Fire	None	D	C	None
3	Ruptured interior of feed tank — Fire	None	None	D	None
4	Evaporator loss of containment — Fire	None	D	D	None
5	Ethanol loss of containment — Release	None	B	A	None

Table C.3–1 (continued). Accident Initiating Event Binning

Accident Initiating Event Binning — Using Maximum Likely MAR					
Event Number	**Initiating Events**	**Public**	**Co-Located Worker**	**Worker**	**Environment**
6 (a)	Econobator loss of containment — a) Steam — 1,200 °F (large)	None	A	B	None
6 (b)	Econobator loss of containment — b) CO and/or NO_x release (small)	None	C	B	None
7 (a)	Process liquid spill or release — a) Sulfuric Acid (5-gal)	None	D	D	None
7 (b)	Process liquid spill or release — b) Sodium Hydroxide (55-gal)	None	C	C	None
7 (c)	Process liquid spill or release — c) Reaction between a and b	None	D	C	None
8	Breach of Brine container — Release Scrubber Blowdown — overflow of container	None	D	D	None

The hazard consequences (A through D) listed in Table C.3-1 are defined in Table C.4–1 with hazard consequence A being the most severe.

C.4 Design Basis Accident Analysis Scenarios for Selected Accidents (Fault Trees)

Postulated accident scenarios from Table C.3–1 that had consequence ratings of A, B, or C as described in Table C.4–1 were further studied to estimate their frequency according to the guidelines in Table C.4–2. The estimated consequence and severity ratings were combined to generate an overall risk ranking using the risk matrix from Table C.4–3. The decision criteria that were followed in action item resolution are identified in Table C.4–4. This PHA formally addresses only the safety risks, although action items from all risk categories were resolved.

Table C.4–1. Consequence Categories

Consequences Severity Categories				
Category	**Maximum Possible Consequences**			
	Public	**Co-Located**	**Worker**	**Environment**
A High	Significant public exposure with significant health effects	High co-located worker exposure with major health effects	Potentially lethal worker exposure, loss of life from energy release	Significant onsite and offsite contamination
B Moderate	Moderate exposure with minor health effects	Significant exposure with significant health effects	High exposure with major health effects, severe injury	Significant onsite and minor offsite contamination.
C Low	Low exposure with negligible health effects	Moderate exposure with minor health effects	Significant exposure with significant health effects, severe injury but no disability	Significant facility contamination
D Negligible	Negligible exposure with no health effects	Low exposure with negligible heath effects	Moderate exposure with minor health effects, minor injury	Minor facility contamination

Table C.4–2. Frequency Categories

Frequency (Likelihood) Categories	
I (> 0.1)	Normal operations; once per month
II (0.1 to 0.01)	Anticipated Events; once per waste stream
III (10^{-2} to 10^{-4})	Unlikely; once per site visit
IV (10^{-4} to 10^{-6})	Very likely; once in the life of the mobile treatment unit
V	Improbable; impossible

Note: Frequencies determined specifically for the MTU, based on equipment life.

Table C.4–3. Risk Rank Matrix

Risk Rank Matrix					
Consequence Category	Frequency Category				
	I	II	III	IV	V
A	1	1	1	2	3
B	1	1	2	3	4
C	1	2	3	4	4
D	2	3	4	4	4

Table C.4–4. Risk Decision Criteria

Risk Decision Criteria	
Risk Number	Accepted Action
1	Unacceptable Risk – Must be mitigated to risk number 3 or lower
2	Undesirable Risk – Should be reduced to risk rank 3 or lower with cost enhancements
3	Acceptable With Controls – Should evaluate cost effective enhancements
4	Acceptable As Is – No action necessary

Scenario 1—Natural Phenomenon (Figure C.4–1)

Failures due to a natural phenomenon were limited to initiation by earthquake. High wind, flooding, temperature extremes, and others were not considered because it is assumed that the MTU will be housed in a RCRA-permitted building which would be designed for these considerations. Tornados and cyclones are not expected at the sites this MTU is serving.

Scenario 2—Ethanol Fire (Figures C.4–2 and C.4–3)

Major Ethanol Fire (Figure C.4–2)

A major ethanol fire could result from a loss of containment of the ethanol in conjunction with the presence of oxygen and a spark. Loss of containment could result if the ethanol container were dropped or punctured by maintenance equipment or if it tipped over and hit a sharp corner. The frequency of IV with a consequence of A to the worker and B to the co-located worker give a risk rank of 2.

Minor Ethanol Fire (Figure C.4–3)

A minor ethanol fire could occur if the fittings were improperly installed or were defective, causing a slow leak from the ethanol supply. Minor physical damage to the ethanol container could also produce a small loss of containment of ethanol. Should a spark occur in these conditions, a minor fire involving the ethanol spill could result. A frequency of IV with potential lethal consequences to the worker and potential high exposure to the co-located worker (Consequence Category A and B) results in a risk of 2 or 3.

Scenario 3—Personnel Injury from Steam Release (Figures C.4–4 through C.4–5)

Steam Fatality (Figure C.4–4)

Loss of containment on the 1,200 °F or 250 °F steam due to physical damage to the Econobator or associated piping could result in a steam fatality if personnel were in close contact with the steam. Release of high temperature steam is not visibly recognizable, which presents an additional degree of risk. A release of 1,200 °F steam has a frequency of V (10^{-7}) with consequences to the worker and a co-located worker rated C. The overall risk rank is 4.

Chronic Steam Release (Figure C.4–5)

A slow leak in the steam piping could also present the potential for burns to workers should piping be damaged during operation or maintenance. The frequency rating of IV and consequence ratings of B to the worker and C to the co-located worker result in a risk ranking of 3 and 4.

Scenario 4—Personnel Injury from Exposure (Figures C.4–6 through C.4–8)

Loss of containment for the sulfuric acid or sodium hydroxide could result in exposure to the worker resulting in low to moderate health effects. Should both materials suffer a loss of containment at once and were in close enough proximity to mix, an additional hazard is presented. These three event trees show those accidents and estimate the risks.

Personnel Injury from Exposure from Sulfuric Acid Loss of Containment (Figure C.4–6)

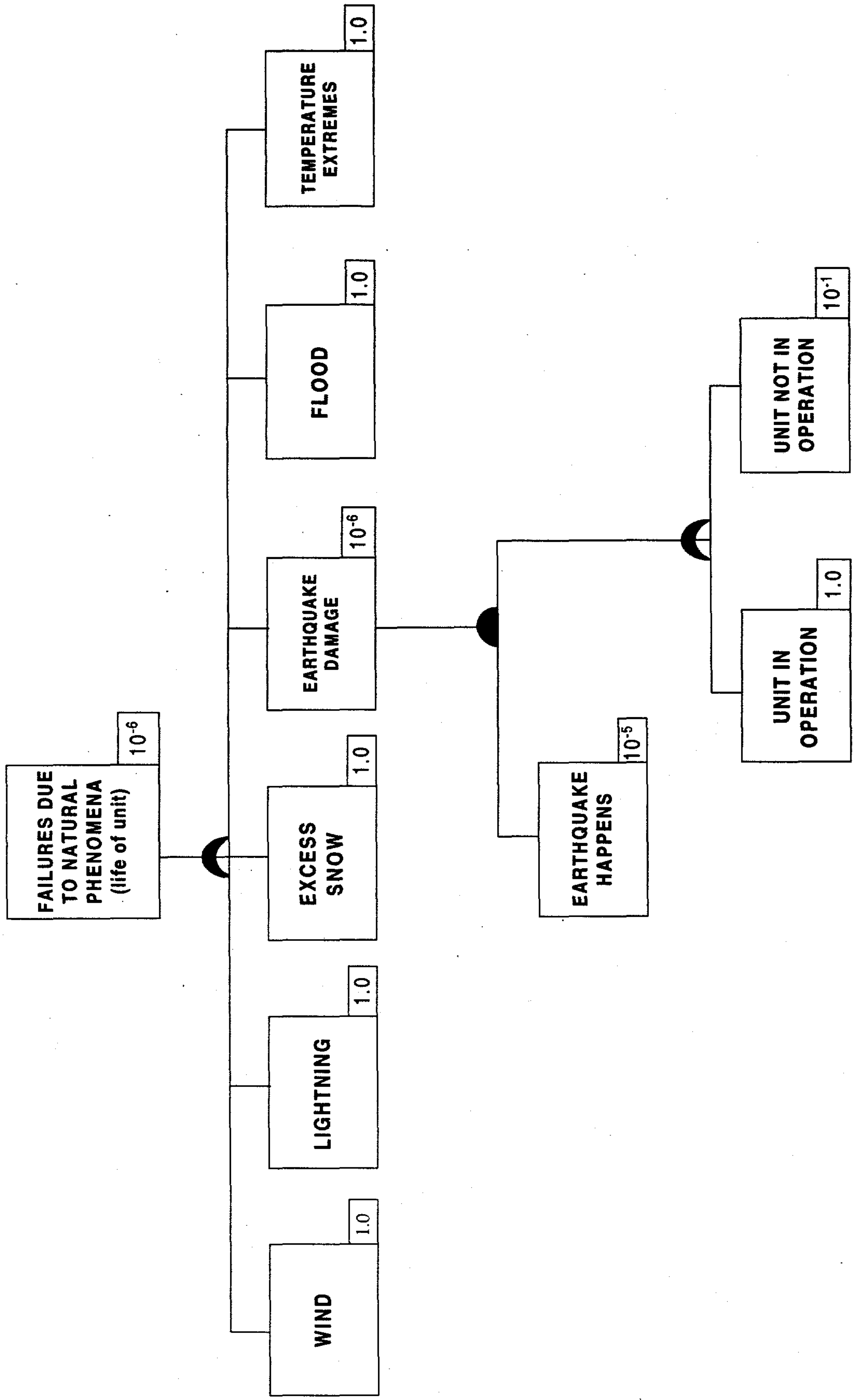
Sulfuric acid loss of containment results in an exposure consequence D to the worker and co-located worker and a frequency of IV. The risk ranking is 4.

Personnel Injury from Exposure from Sodium Hydroxide Loss of Containment (Figure C.4–7)

Sodium hydroxide loss of containment could result in an exposure consequence C to both the worker and co-located worker and a frequency of IV. The risk ranking is 4.

Personnel Injury from Chemical Loss of Containment Reaction (Figure C.4–8)

Concurrent sulfuric acid and sodium hydroxide loss of containment that are in close proximity could cause a chemical reaction producing fumes to expose the worker and co-located worker. The consequence category C to the worker and D to the co-located combined with the frequency of V determines a risk rank of 4.



C4-1.vsd

Figure C.4–1. Natural Phenomena

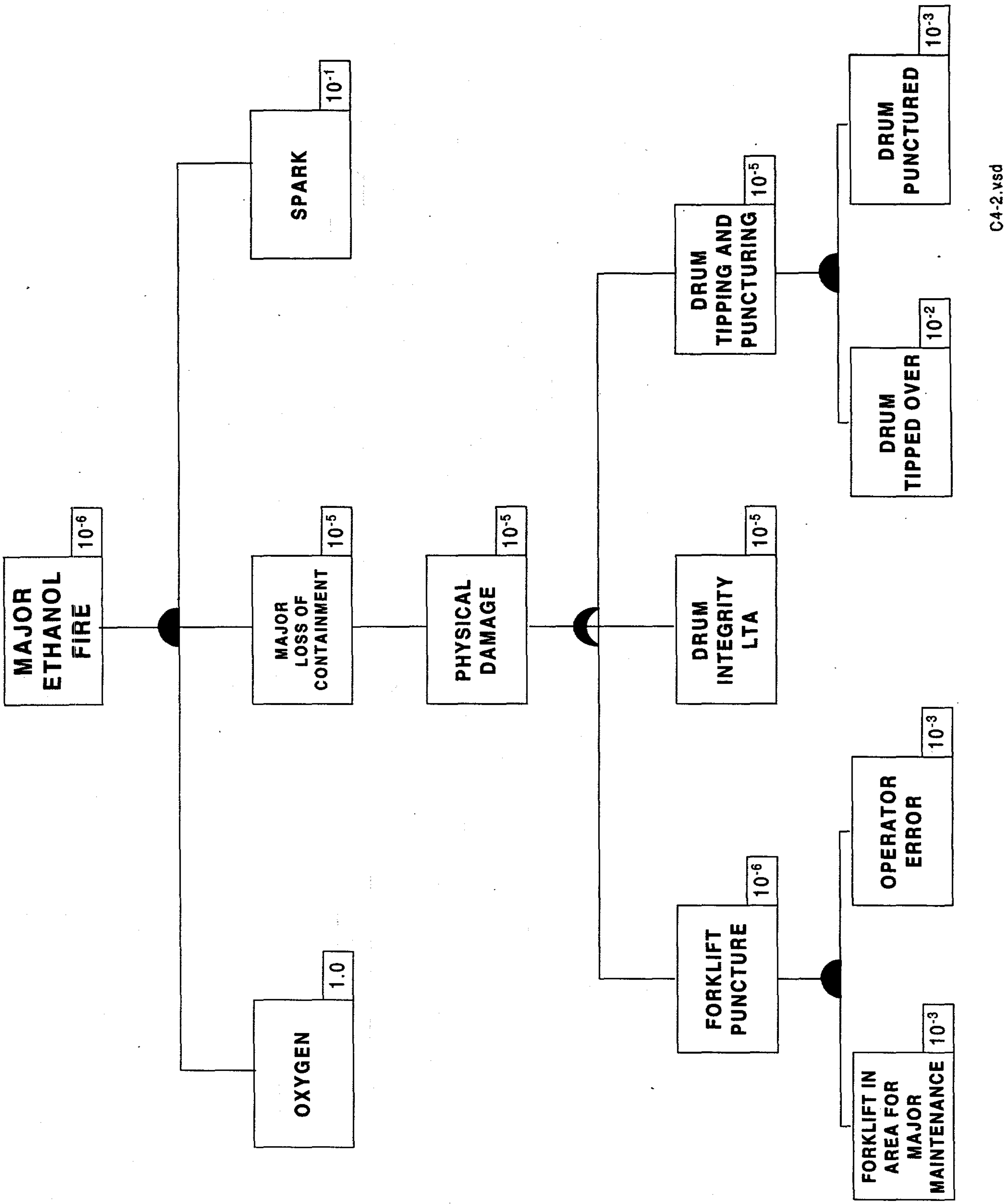


Figure C.4–2. Major Ethanol Fire

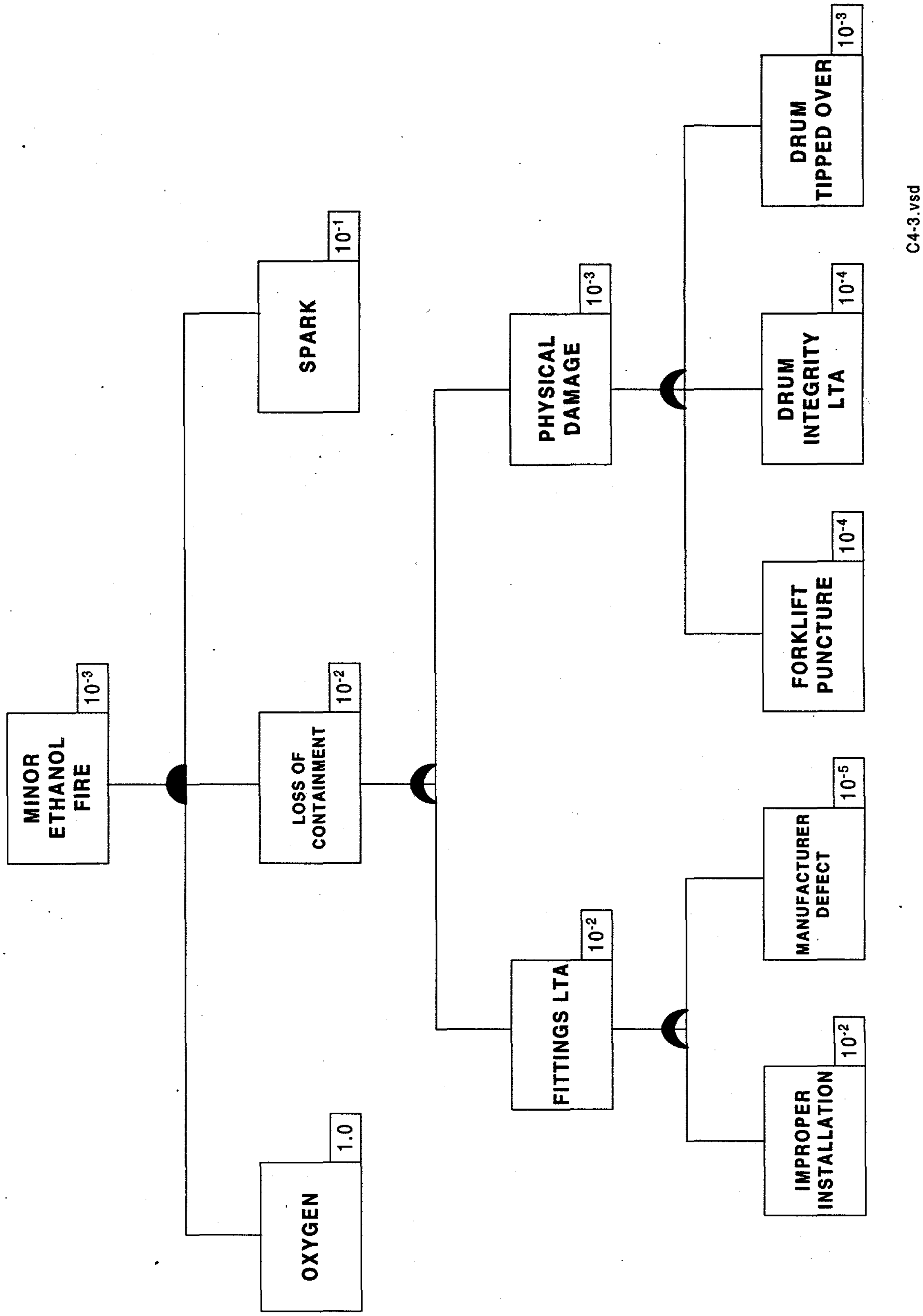


Figure C.4–3. Minor Ethanol Fire

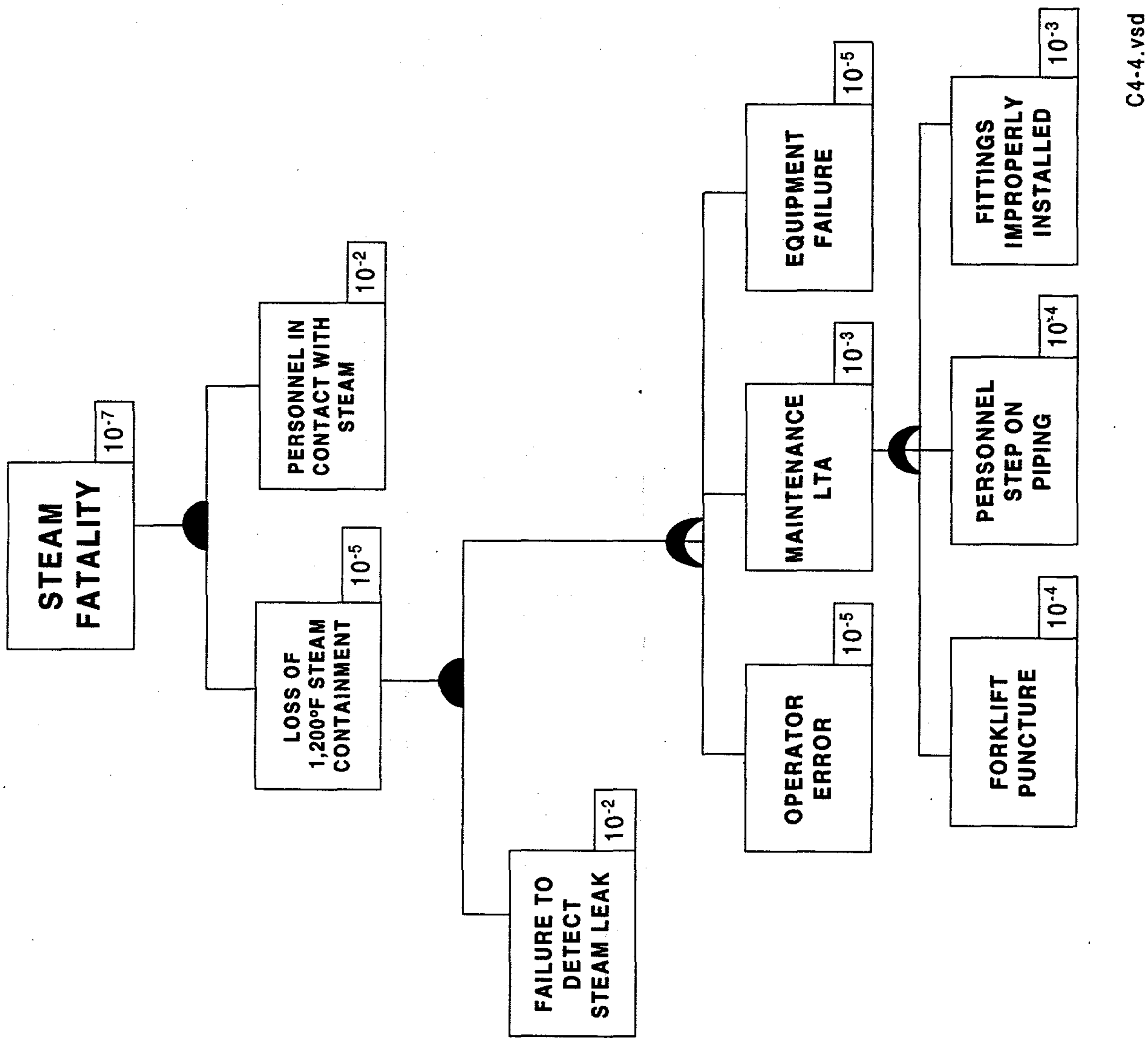


Figure C.4–4. Steam Fatality

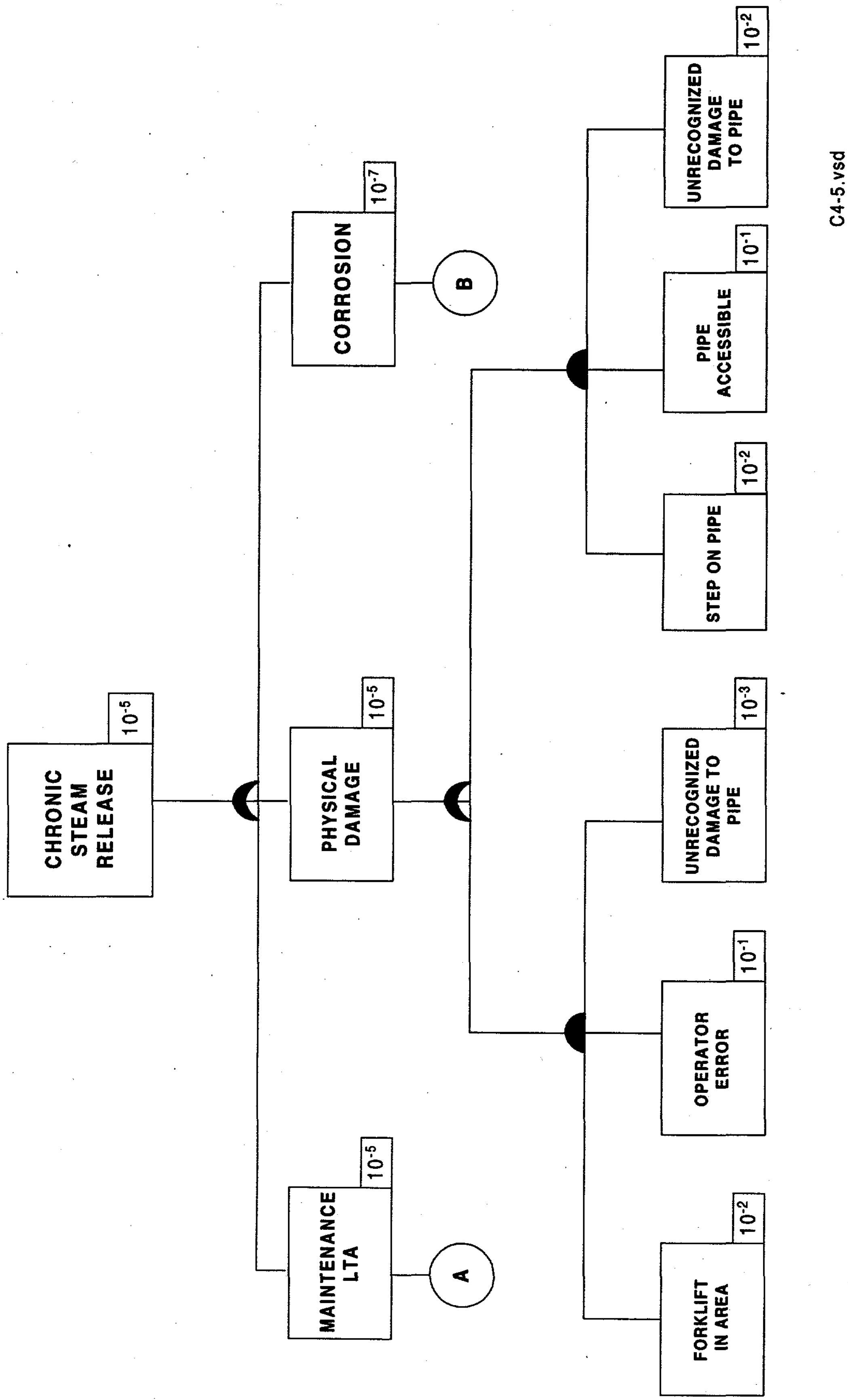


Figure C.4–5. Chronic Steam Release

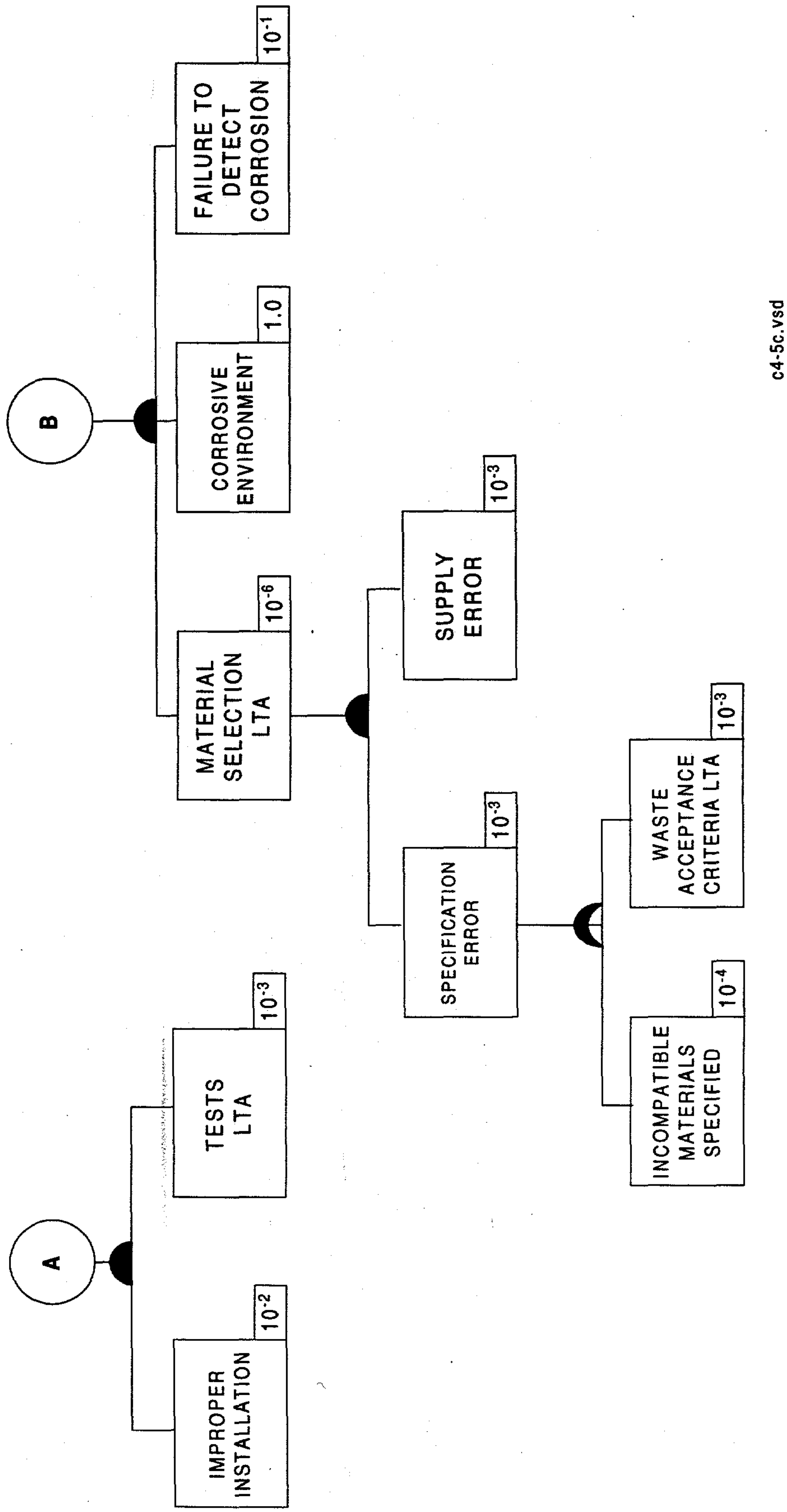


Figure C.4–5 (continued). Chronic Steam Release

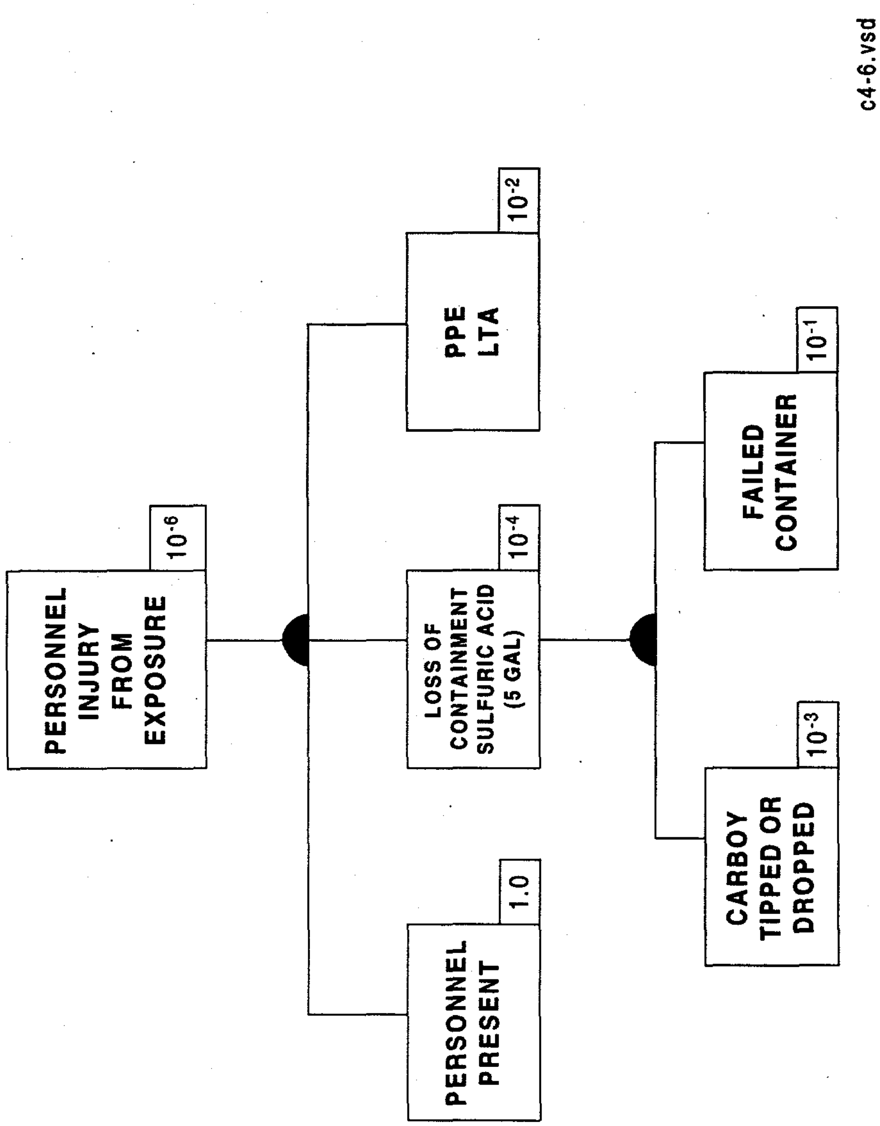


Figure C.4–6. Personnel Injury from Exposure from Sulfuric Acid Loss of Containment

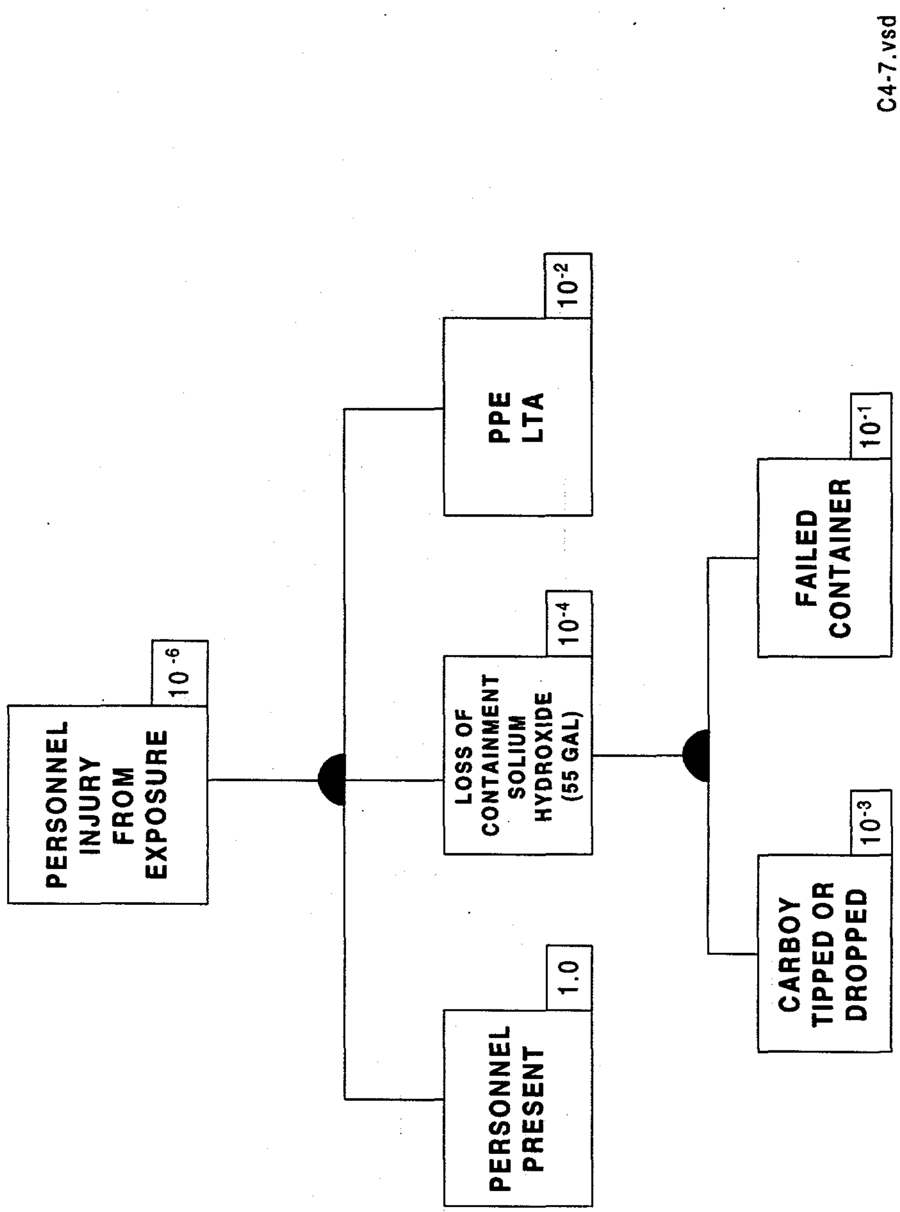


Figure C.4–7. Personnel Injury from Exposure from Sodium Hydroxide Loss of Containment

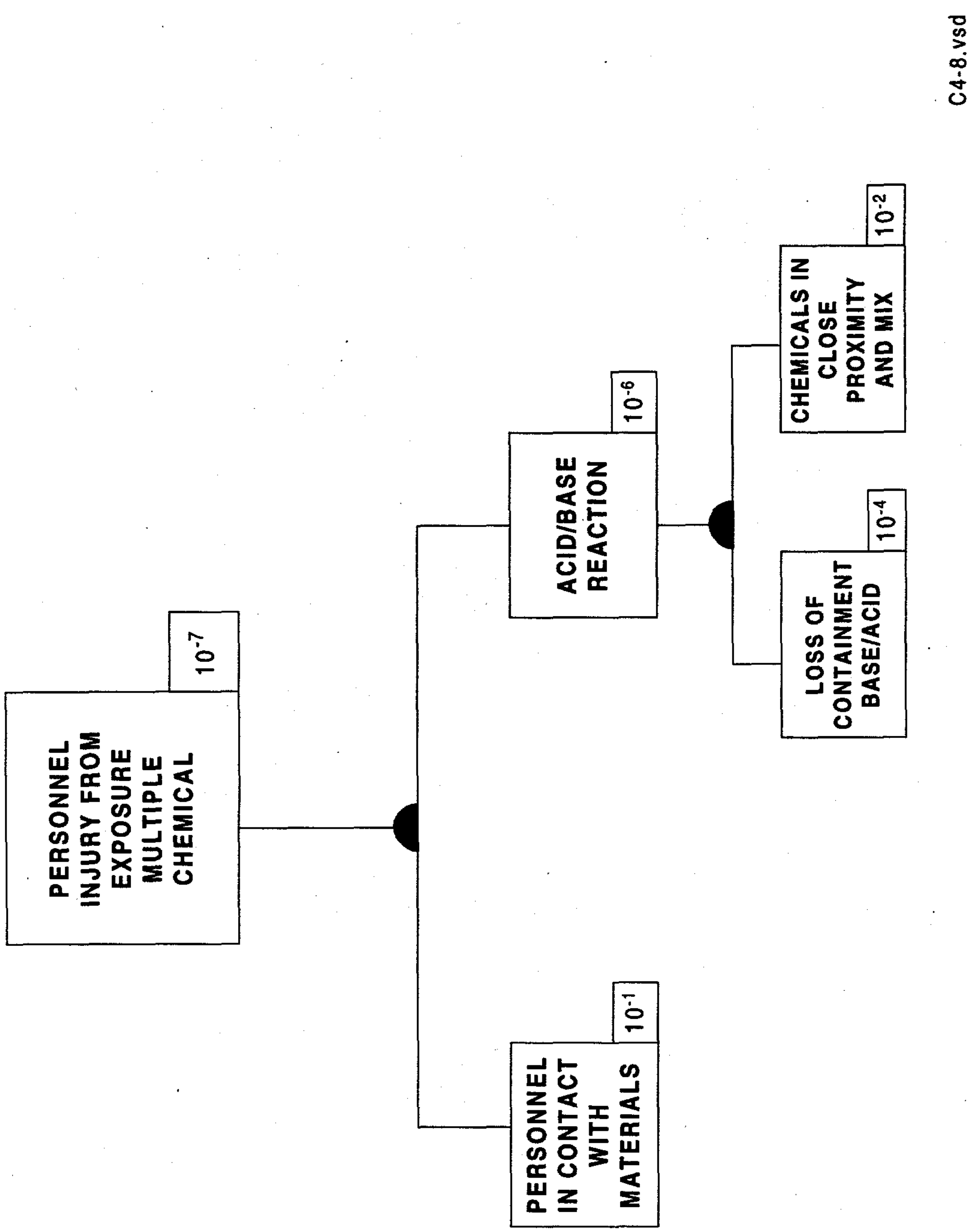


Figure C.4–8. Personnel Injury from Chemical Loss of Containment and Reaction

C.5 Unmitigated Accident Consequences

The results of the unmitigated accidents are discussed in this section. The computational methods, models, and assumptions are also presented. Input data for the calculations is provided for each model and computational method.

C.5.1 Results By DBA

The summary of the unmitigated accident consequences is provided in Table C.5.3–1. This table also provides a comparison to the evaluation criteria. *Guidance for the Preparation of MWT Process Hazards Analysis* (DOE 1995b) states to "compare the calculated exposure of the maximum exposed off-site individual against the evaluation guidelines presented in Appendix A (draft) to DOE–STD–3009 . . ." However, Appendix A to DOE–STD–3009–94 was never published by DOE. Guidance was obtained from Vince Wahler of the DOE–AL Nuclear Safety Division regarding the evaluation criteria. DOE–AL indicated that the criteria of interest in the unpublished document was that equipment which mitigates a off-site dose at the site boundary to a member of the public in excess of 25 rem committed effective dose equivalent (CEDE) should be designated safety classification equipment. For chemicals, if the Emergency Response Planning Guidelines (ERPG) III level is not exceeded the site is a low hazard. For chemicals without ERPGs, a similar criterion may be used such as the facility is a low hazard if the immediately dangerous to life and health (IDLH) concentration is not exceeded. These criteria are for classifying equipment, and are not valid as risk acceptance guidelines.

Table C.5.3–1 shows the unmitigated accident consequences for each source term scenario of the fire/explosion DBA based on the evaluation basis site characteristic from Appendix A. As can be seen, the site boundary committed effective dose equivalent to a member of the public never exceeds the guideline value of 25 rem. The doses are several orders of magnitude below the guideline. The hazardous chemical concentrations at the site boundary are all less than the IDLH values, and are several orders of magnitude less than the guideline.

Additional consequences are given in Tables C.5.3–2 through C.5.3–4 for various distances from the PO*WW*ER MTU. These tables are provided for the sites where the nearest onsite worker and the offsite member of the public may differ in distance to those specified in Appendix A.

C.5.2 Source-Term Analysis

The materials at risk (MAR) described in Appendix B was used in the unmitigated accident analyses. To maximize the potential consequences of the analysis, the fire DBA assumes that the contents of the ethanol container are spilled, and an explosion/fire ensues. It was assumed that 50 percent of the ethanol was consumed in the fire, and 50 percent released to the atmosphere. The fire would likely consume the majority of the ethanol, thus releasing non-hazardous degradation products. The contents of the waste feed tank (i.e., 1,035 kg) and the contents of the evaporator (i.e., 625 kg) were assumed to be released during the event. The "worst case" MAR for the evaporator of 100 nCi/g was assumed to be concentrated by a factor of 10, while the "likely worst case" and "likely low activity/hazardous component" MARs were assumed to be concentrated by a factor of 100 at the time of the DBA.

One hundred percent of the radiological activity was assumed to be released in the fire with the respirable fraction of 0.05 percent taken from the HOTSPOT computer model (Homann 1994). The hazardous components of the source term (i.e., methylene chloride, isopropyl alcohol, and ammonia) were assumed to be fully released into the atmosphere and unaffected by the fire. This allowed for a conservative estimate of the airborne concentration of the hazardous materials.

*Table C.5.3–1. Unmitigated Consequences for the PO*WW*ER Unit Fire DBAs*

Fire DBA Event	Contaminant	MTU Worker	On-Site Nearest Worker (0.3 km)	Site Boundary (2.8 km)	Guideline[a]
Worst Case	plutonium	109 rem	2.4×10^{-3} rem 2.4 mrem	0.046 mrem	25 rem
	uranium	26 rem	8.7×10^{-4} mrem	0.015 mrem	25 rem
	ammonia	> IDLH	110 ppm	0.36 ppm	300 ppm IDLH
	isopropyl alcohol	> IDLH	29 ppm	0.094 ppm	2,000 ppm IDLH
	methylene chloride	> IDLH	5.5 ppm	0.018 ppm	2,300 ppm IDLH
	ethyl alcohol	> IDLH	47 ppm	0.15	3,300 ppm IDLH
Likely Worst Case	plutonium	3.6×10^{-2} rem	7.0×10^{-7} rem	1.3×10^{-5} mrem	25 rem
	uranium	1.4 rem	4.3×10^{-5} rem	8.1×10^{-4} mrem	25 rem
	ammonia	> IDLH	55 ppm	0.18 ppm	300 ppm IDLH
	isopropyl alcohol	> IDLH	15 ppm	0.051 ppm	2,000 ppm IDLH
	methylene chloride	> IDLH	5.5 ppm	0.018 ppm	2,300 ppm IDLH
	ethyl alcohol	> IDLH	47 ppm	0.15 ppm	3,300 ppm IDLH
Likely Low-Activity, Low-Hazardous Concentration	plutonium	2.6×10^{-2} rem	1.4×10^{-6} rem	2.7×10^{-5} mrem	25 rem
	uranium	0.73 rem	2.1×10^{-5} rem	4.0×10^{-4} mrem	25 rem
	ammonia	> IDLH	31 ppm	0.10 ppm	300 ppm IDLH
	isopropyl alcohol	> IDLH	15 ppm	0.051 ppm	200 ppm IDLH
	methylene chloride	> IDLH	5.5 ppm	0.018 ppm	2,300 ppm IDLH
	ethyl alcohol	> IDLH	47 ppm	0.15 ppm	3,300 ppm IDLH

[a] *Guidance for the Preparation of MWT Process Hazards Analysis* references Appendix A of DOE–STD–3009–94, which was never published. Vince Wahler of DOE–AL Nuclear Safety Division indicated that the criteria of interest in the unpublished document was that equipment that mitigates a site boundary dose to a member of the public in excess of 25 rem committed effective dose equivalent should be designated safety classification equipment. For chemicals, if the Emergency Response Planning Guideline (ERPG) Level III is not exceed the site is a low hazard. For chemicals without ERPGs, a similar criteria may be used such as a facility is low hazard if the IDLH concentration is not exceeded at the site boundary.

Key: DBA = design basis accident
IDLH = immediately dangerous to life or health
km = kilometer(s)
mrem = milliroentgen(s)
MTU = mobile treatment unit
ppm = parts per million
rem = roentgen(s)

Table C.5.3–2. Unmitigated Accident Consequences for "Worst Case" Source-Term Scenario

Distance (km) from MTU	Plutonium (mrem)	Uranium (mrem)	Ammonia (ppm)	Isopropyl Alcohol (ppm)	Methylene Chloride (ppm)	Ethyl Alcohol (ppm)
0.1	7.6	2.8	7.6	2.0	0.39	3.3
0.2	4.2	1.5	110	30	5.8	49
0.5	2.4	0.87	58	15	3.0	22
1.0	0.31	0.11	13	3.5	0.67	5.7
2.0	0.085	0.031	1.1	0.29	0.055	0.47
5.0	0.016	0.0057	0.048	0.013	0.0024	0.20
10.0	0.0046	0.0017	0.0035	9.3×10^{-4}	1.8×10^{-4}	0.0015
20.0	0.0014	0.0005	4.9×10^{-4}	1.3×10^{-4}	2.5×10^{-5}	2.1×10^{-4}

Key: km = kilometer(s)
ppm = parts per million
mrem = milliroentgen(s)
MTU = mobile treatment unit

Table C.5.3–3. Unmitigated Accident Consequences for "Likely Worst Case" Source-Term Scenario

Distance (km) from MTU	Plutonium (mrem)	Uranium (mrem)	Ammonia (ppm)	Isopropyl Alcohol (ppm)	Methylene Chloride (ppm)	Ethyl Alcohol (ppm)
0.1	0.0022	0.13	3.8	1.1	0.39	3.3
0.2	0.0012	0.074	57	16	5.8	49
0.5	7.0×10^{-4}	0.019	29	8.3	3.0	25
1.0	9.0×10^{-5}	0.0055	6.7	1.9	0.67	5.7
2.0	2.5×10^{-5}	0.0015	0.55	0.15	0.055	0.47
5.0	4.6×10^{-6}	2.8×10^{-4}	0.024	0.0067	0.0024	0.021
10.0	1.3×10^{-6}	8.2×10^{-5}	0.0018	5.0×10^{-4}	1.8×10^{-4}	.00015
20.0	4.1×10^{-7}	2.5×10^{-5}	2.5×10^{-4}	7.0×10^{-5}	2.5×10^{-5}	2.1×10^{-4}

Key: km = kilometer(s)
ppm = parts per million
mrem = milliroentgen(s)
MTU = mobile treatment unit

Table C.5.3–4. Unmitigated Accident Consequences for "Likely Low-Hazard Case" Source-Term Scenario

Distance (km) from MTU	Plutonium (mrem)	Uranium (mrem)	Ammonia (ppm)	Isopropyl Alcohol (ppm)	Methylene Chloride (ppm)	Ethyl Alcohol (ppm)
0.1	0.0045	0.067	2.1	1.1	0.39	3.3
0.2	0.0025	0.037	32	16	5.8	49
0.5	0.00063	0.0093	16	8.3	3.0	25
1.0	0.00018	0.0027	3.7	1.9	0.67	5.7
2.0	5.1×10^{-5}	0.00075	0.31	0.15	0.055	0.47
5.0	9.4×10^{-6}	0.00014	0.013	0.0067	0.0024	0.021
10.0	2.7×10^{-6}	4.0×10^{-5}	9.9×10^{-4}	5.0×10^{-4}	1.8×10^{-4}	0.0015
20.0	8.4×10^{-7}	1.2×10^{-5}	1.4×10^{-4}	7.0×10^{-5}	2.5×10^{-5}	2.1×10^{-4}

Key: km = kilometer(s)
ppm = parts per million
mrem = milliroentgen(s)
MTU = mobile treatment unit

The respirable fraction of each component of the source term was assumed to be released into the room for the worker exposure. In addition, the respirable fraction was also assumed to be available to the onsite worker and the public. This allowed for a conservative, generic analysis which avoids the uncertainty of leak-path factors for releases from the facility.

C.5.3 Description of Calculational Methods

Three calculation methods were used in the assessment of onsite and off-site radiological doses and chemical concentrations. The worker located in the building housing the PO*WW*ER MTU was assessed using simple hand calculation methods. The nearest onsite worker and off-site member of the public were assessed using the computer models EPIcode (Homann 1988) and HOTSPOT (Homann 1994).

PO*WW*ER Unit Worker Model

This assessment consisted of simplified calculations for the determination of the contaminant concentrations in the air of the room housing the PO*WW*ER MTU. The material at risk was adjusted for each DBA according to the fraction that was considered respirable. To be consistent with the HOTSPOT computer code used for offsite analyses, the respirable fraction for plutonium and uranium of 0.05 percent was assumed for the fire DBA. The ethanol, which created the fire, was assumed to be 50 percent consumed by the fire with the other 50 percent being released into the room.

The respirable fraction was assumed to be released instantaneously into a room assumed to be the equivalent to that required to house the PO*WW*ER MTU footprint (i.e., 880 m^3). The worker then was assumed to reside in the room for 30 minutes, considered a reasonable time for rescue of the worker by onsite personnel.

The following equation was used to calculate the CEDE from inhalation of radionuclides by the worker:

$$D = C_a * B_r * E_t * DCF$$

where: D = committed effective dose equivalent (rem)
C_a = radionuclide air concentration (μCi/m^3)
B_r = worker breathing rate (m^3/h)
E_t = exposure time (h)
DCF = dose conversion factor for inhalation (rem/μCi)

The concentration of the hazardous chemicals in the atmosphere of the room were determined as follows:

$$C_h = \frac{S_h}{A_r \rho_a}$$

where: C_h = air concentration of hazardous component (ppm)
S_h = source term of hazardous component (mg)
A_r = volume of the room (m^3)
ρ_a = density of air (kg/m^3)

The input assumption for the PO*WW*ER worker parameters are given in Table C.5.3–5.

On-Site Worker and Off-Site Public Radiological Dispersion Model

The HOTSPOT computer code (Homann 1994) was used for the calculation of radiological doses for the nearest on-site worker and the off-site public. HOTSPOT uses the well-established Gaussian plume model, widely used for safety-analysis planning of a radionuclide release. The dosimetric methods of the International Commission on Radiological Protection (ICRP) Publication 30 are used in the HOTSPOT program. The HOTSPOT dose values are due solely to the inhalation of released material during passage of the plume. The ground-shine dose is not included because the committed effective dose equivalent (per hour of time in the contaminated area) due to ground shine is typically several orders of magnitude less than the committed effective dose equivalent due to plume passage. For alpha-emitting radionuclides (i.e., plutonium and uranium) the hourly ground-shine component is at least 7 orders of magnitude less than the inhalation component.

The Gaussian model has been used and accepted by the Environmental Protection Agency. The adequacy of the this model for making initial dispersion estimates or worst-case safety analyses has been tested and verified for many years.

HOTSPOT requires the input of the release height. The fire/explosion DBA would generate heat thus creating a buoyant plume rise in the ambient air. The determination of the plume rise was determined using HOTSPOT using a heat of combustion value of 6620 cal/g for ethanol, and assuming that the liquid pooled to a 1 cm depth on the floor. This resulted in a released radius of 1.82 m and a burn duration of 2 to 10 minutes. For purposes of conservatism, the burn duration was chosen as 2 minutes to completely consume 50 percent of the ethanol. These assumptions resulted in a HOTSPOT calculated plume rise of 69 meters. For purposes of conservatism, half of this value was assumed (i.e., 35 meters). The meteorological parameters were also maximized as stability category A and a 1-meter-per-second (m/s) wind speed assumed to be in the direction of the off-site public during the duration of the event. A stability category A is unstable and creates the condition where the elevated plume is brought to the ground. The input parameter values used in HOTSPOT are given in Table C.5.3–5.

On-Site Worker and Off-Site Public Hazardous Air Concentration Model

EPIcode (Homann 1988) was used for the calculation of the hazardous air concentrations for the nearest on-site worker and the off-site public. EPIcode uses the well-established Gaussian plume model, which is widely used for safety analysis planning of a chemical release. The EPIcode library contains information on over 600 toxic substances listed in the Threshold Limit Values and Biological Exposure Indices published by the American Governmental Conference of Governmental Industrial Hygienist.

For the fire/explosion DBA, EPIcode requires the estimation of the duration of the event, and the radius of the release. The values determined using HOTSPOT for the plume rise were used with a 2-minute release duration and a 1.82-meter radius of release. The larger the values for duration and radius of release the lower the predicted doses.

EPIcode requires the input of the release height. Once again, the release height determined by HOTSPOT was used assuming half of the calculated value for conservatism. The meteorological parameters were also maximized as stability category A and a 1-m/s wind speed assumed to be in the direction of the offsite public during the duration of the event.

The input parameter values used in EPIcode are given in Table C.5.3–5.

Table C.5.3–5. Input Parameter Values Used in The Unmitigated Accident Analyses

Parameter	Value	Application	Comments
Area of the room	880 m^3	MTU worker	MTU footprint
Worker breathing rate	1.2 m^3/h	All Scenarios	HOTSPOT/EPIcode value
Exposure time worker	0.5 h	MTU worker	assumed rescue time
Exposure time offsite	plume passage duration	all except MTU worker	determined by codes
Air density	1.2 kg/m^3	MTU worker	
Release radius	1.82 m	All except MTU worker	conservative value
Release height	35 m	All except MTU worker (determined using HOTSPOT)	conservative value
Release duration	2 minutes	All except MTU worker (determined using HOTSPOT)	conservative value
Stability Class	A	All except MTU worker	conservative value
Wind speed	1 m/s	All except MTU worker	conservative value
Receptor location	plume centerline	All except MTU worker	conservative value
Specific Activity Pu	8.1 x 10^{-2} Ci/g	All Scenarios	weapons-grade plutonium
Specific Activity U	1.55 x 10^{-6} Ci/g	All Scenarios	enriched uranium
Pu Activity	100 nCi/g 3.3 x 10^{-6} μCi/g 2.4 x 10^{-6} μCi/g	Worst Case Likely Worst Case Likely Low Activity Case	8.99 x 10^{-3} kg 2.62 x 10^{-6} kg 1.86 x 10^{-6} kg
U Activity	100 nCi/g 5.6 x 10^{-4} μCi/g 2.8 x 10^{-4} μCi/g	Worst Case Likely Worst Case Likely Low Activity Case	470 kg 23 kg 11.4 kg
Ethanol	164 kg	All Cases (50% burned, 50% release)	27.4 gal burned 27.4 gal release
Methylene chloride	1.3 weight % 1.3 weight % 0.88 weight %	Worst Case Likely Worst Case Likely Low Activity Case	3.55 gal 3.55 gal 2.4 gal
Isopropyl Alcohol	8 weight % 4.3 weight % 4 weight %	Worst Case Likely Worst Case Likely Low Activity Case	21.9 gal 11.8 gal 10.9 gal
Ammonia	10 weight % 5 weight % 2.8 weight %	Worst Case Likely Worst Case Likely Low Activity Case	27.3 gal 13.7 gal 7.66 gal
MAR	1,035 kg 625 kg	Waste Feed Tank Evaporator	See Appendix B

Key:
Ci/g = curies per gram
gal = gallon(s)
h = hour(s)
kg = kilogram
kg/m^3 = kilogram(s) per cubic meter
km = kilometer(s)
m = meter(s)
m^3 = cubic meter(s)
m^3/h = cubic meter(s) per hour
m/s = meter(s) per second
nCi/g = nanocuries per gram
ppm = parts per million
Pu = Plutonium
U = Uranium

Attachment C.5.3–1

Table C.5.3–1. Dose Rate Calculation

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Attachment C.5.3–1. Dose Rate Calculation

To understand the dose conditions that would exist if fission or activation products were introduced into the process vessels, the dose rate was calculated from a 55-gallon drum containing an evaporator concentrate brine solution that includes cobalt-60, a high-energy gamma-emitting radionuclide.

In addition to the 55-gallon drum, the evaporator tank will also contain the brine solution. The conical tank shape makes quantitative dose rate modeling. The program does not explicitly handle this shape so some approximations are necessary and the analysis is done only for the drum. It is likely that the self-shielding from a larger volume of brine will counteract the higher activity in the larger evaporator tank volume and the dose rate from the drum and evaporator are likely to similar.

The following assumptions are made:

The 55-gallon drum is 34 inches tall and 23 inches in diameter with a 1/8-inch thick iron wall. The dose points of interest are 10 cm and 100 cm from the surface of the drum. The brine is a high density aqueous solution with a specific gravity of 1.5 g/cm^3. It was concentrated by a factor of 100 from aqueous feed material containing 100 pCi/g of cobalt-60. The resulting activity concentration in the brine is 10 nCi/cm^3. Cobalt-60 represents a worst likely case radionuclide for both fission and activation products and therefore adds conservatism to this analysis.

The program Microshield 4.0 (Grove Engineering) was used to calculate the dose rates. Figure C.5.3–1 includes the report of the calculations. Table 1 shows the calculated dose rates for the two distances.

Table C.5.3–1. Dose Rate from a 55-gallon Drum Containing Cobalt-60 at 10 nCi/cm^3

Distance from drum surface, cm	Dose Rate, mrem/hr
10	2.7
100	0.61

This screening analysis shows that the dose rate from the drum at one meter distance is half the level that requires posting as a radiation area (5 mrem/hour) if the activity in the feed material is constrained to 100 pCi/g and the concentration ratio in the evaporator is 100 or less. Considering the conservative assumptions regarding the concentration ratio and radionuclides, the dose rate in occupied areas will be acceptable even if all of the activity in the feed material is associated with fission or activation products.

Figure C.5.3–1. Report on Dose Rate Calculation

MicroShield 4.00 - Serial #4.00-00099
Geotech

Page : 1
DOS File: POWBRIN2.MS4
Run Date: May 16, 1996
Run Time: 3:37 p.m. Thursday
Duration: 0:00:06

File Ref: ________
Date: __/__/__ Robert Morris 7/1/96
By: ________
Checked: ________

Case Title: POWWER brine in 55 gallon drum Co-60 at 10 cm

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	39.0	1.0	3.4
Dose point coordinate Y:	100.0	3.0	3.4
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	86.36	2.0	10.0
Cylinder radius:	29.0	0.0	11.4
Shield 1:	0.3175	0.0	.1
Air Gap:	9.6825	0.0	3.8

Source Volume: 228170. cm^3 8.05775 cu ft. 13923.8 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Cylinder	Transition Shield	Air Gap	Immersion Shield
Air			0.00122	0.00122	0.00122
Iron		7.86			
Water	1.5				

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	μCi/cm^3
Co-60	2.2817e-003	1.0000e-002

============================== RESULTS ==============================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6	1.377e+004	1.698e-002	5.496e-002	3.314e-005	1.073e-004
1.0	8.442e+007	2.337e+002	5.849e+002	4.307e-001	1.078e+000
1.5	8.442e+007	4.444e+002	9.397e+002	7.476e-001	1.581e+000
TOTAL:	1.689e+008	6.781e+002	1.525e+003	1.178e+000	2.659e+000

Figure C.5.3–1 (Continued). Report on Dose Rate Calculation

MicroShield 4.00 - Serial #4.00-00099
Geotech

Page : 1
DOS File: POWBRIN4.MS4
Run Date: May 17, 1996
Run Time: 2:08 p.m. Friday
Duration: 0:00:06

File Ref: ________
Date: __/__/__
By: ________
Checked: ________

Robert Morris 7/1/96

Case Title: POWWER brine in 55 gal drum, Co-60, 0.1 uCi/cc at 100 cm

GEOMETRY 7 - Cylinder Volume - Side Shields

	centimeters	feet	and inches
Dose point coordinate X:	129.0	4.0	2.8
Dose point coordinate Y:	100.0	3.0	3.4
Dose point coordinate Z:	0.0	0.0	.0
Cylinder height:	86.36	2.0	10.0
Cylinder radius:	29.0	0.0	11.4
Shield 1:	0.3175	0.0	.1
Air Gap:	99.6825	3.0	3.2

Source Volume: 228170. cm^3 8.05775 cu ft. 13923.8 cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Cylinder	Transition Shield	Air Gap	Immersion Shield
Air			0.00122	0.00122	0.00122
Iron		7.86			
Water	1.5				

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	10
Circumferential	10
Axial (along Z)	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3
Co-60	2.2809e-003	9.9964e-003

============================== RESULTS ==============================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6	1.377e+004	4.090e-003	1.273e-002	7.984e-006	2.485e-005
1.0	8.439e+007	5.554e+001	1.345e+002	1.024e-001	2.480e-001
1.5	8.439e+007	1.045e+002	2.145e+002	1.758e-001	3.609e-001
TOTAL:	1.688e+008	1.601e+002	3.491e+002	2.782e-001	6.089e-001

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