Grand Junction Projects Office
Mixed-Waste Treatment Program

**Packed-Bed Reactor/Silent-Discharge
Plasma Design Data Report
Revision 1**

May 1996

MASTER

*U.S. Department of Energy
Grand Junction Projects Office*

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Mixed-Waste Treatment Program**

Packed-Bed Reactor/Silent-Discharge Plasma Design Data Report

Revised
May 1996

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

Prepared by
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Abbreviations, Acronyms, and Initialisms

acfm	actual cubic feet per minute
AL	Albuquerque Operations Office
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
Btu/h	British thermal unit(s) per hour
cm ³ /min	cubic centimeter(s) per minute
CFR	U.S. Code of Federal Regulations
C ₁₄ H ₂₉ Cl	1-chlorotetradecane
C ₂₀ H ₄₂	n-eicosane
CO	carbon monoxide
CO ₂	carbon dioxide
COCl ₂	phosgene
cP	centipoise
CWR	cooling water return
CWS	cooling water supply
DF	(radiological) decontamination factor
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DDR	design data report
EPA	U.S. Environmental Protection Agency
FRP	fiberglass-reinforced plastic
ft	foot (feet)
ft ³	cubic foot (feet)
gal	gallon(s)
gal/d	gallons per day
gal/h	gallons per hour
gal/min	gallons per minute
GJPO	Grand Junction Projects Office
HAZOP	hazards and operability
h/d	hours per day
HCl	hydrogen chloride
HEPA	high-efficiency particulate air
HH	high-high
hp	horsepower
in.	inch(es)
kW	kilowatt
LANL	Los Alamos National Laboratory
lb	pound(s)
lb/ft ³	pounds per cubic foot
lb/h	pounds per hour
LDR	land disposal restriction
LL	low-low
m	meter(s)
m ³	cubic meter(s)

Abbreviations, Acronyms, and Initialisms (continued)

mb	millibar
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mmhos/cm	micro mhos per centimeter
mol/h	mols per hour
mrem/h	milliroentgen(s) per hour
mrem/y	milliroentgen(s) per year
MTU	mobile treatment unit
MWTP	Mixed-Waste Treatment Program
N ₂	nitrogen
NaCl	sodium chloride
NaOH	sodium hydroxide
O ₂	oxygen
OSHA	Occupational Safety and Health Administration
P&ID	process and instrumentation diagram
PBR	packed-bed reactor
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxins
PCDF	polychlorinated dibenzofurans
PLC	programmable logic controller
PM10	particulate material less than 10 microns
POHC	principal organic hazardous constituent
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gauge
PTX	Pantex
RCRA	Resource Conservation and Recovery Act
scfm	standard cubic feet per minute
SDP	silent-discharge plasma
SNL/NM	Sandia National Laboratory/New Mexico
TCE	trichloroethylene
TDH	total developed head
ton/y	ton(s) per year
TSCA	Toxic Substance Control Act
VAC	voltage, alternating current
VE	value engineering
VOC	volatile organic compound
v/v	volume per volume
w/w	weight per weight
WWE	wastewater evaporator

1.0 Introduction

1.1 Project Scope

In 1992, Congress passed the Federal Facility Compliance Act requiring the U.S. Department of Energy (DOE) to treat and dispose of its mixed waste in accordance with Resource Conservation and Recovery Act (RCRA) land disposal restrictions (LDRs). The DOE Albuquerque Operations Office (AL) currently does not have adequate systems to treat the mixed wastes generated and stored at the nine DOE-AL sites. In response to the need for mixed-waste treatment capacity, DOE-AL organized a Treatment Selection Team under the 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 Treatment Selection Team, as described in the *AL Mixed-Waste Treatment Plan* (DOE 1994), is to use available off-site commercial treatment facilities for all wastes that can be successfully and cost-effectively treated by such facilities. Where no appropriate commercial treatment facilities exist, mobile treatment units (MTUs) would be developed to treat wastes at the sites where the wastes are generated. Treatment processes used for mixed waste must not only address the hazardous component (i.e., meet LDRs) but also must contain the radioactive component in a form that allows final disposal while protecting workers, the public, and the environment.

The Treatment Selection Team identified the packed-bed reactor/silent-discharge plasma (PBR/SDP) technology as potentially appropriate for treatment of organic and aqueous liquid and slurried mixed-waste streams. Los Alamos National Laboratory (LANL) has conducted a number of pilot tests with both the PBR and the SDP, individually and with the two units together, on a variety of surrogate organic wastes. Information obtained from the LANL pilot tests was used to determine the scope of applicability of the technology, and in the development of this design data report (DDR). Appendix B of this report lists a number of reports that present data and results of the LANL pilot tests.

DOE-AL assigned overall responsibility for development of the PBR/SDP to Sandia National Laboratory/New Mexico (SNL/NM). SNL/NM subsequently delegated responsibility for development of the DDR for the PBR/SDP MTU to the DOE Grand Junction Projects Office (GJPO). The scope of this report is to present basic design data for the PBR/SDP MTU, which will be used to prepare the detailed design of the MTU under a separate project. The PBR/SDP MTU represents a "second generation" of the technology, based on the design and operating parameters demonstrated at LANL, as reviewed and approved during a Value Engineering (VE) session on the PBR/SDP technology (Rust Geotech 1994).

1.2 Description of Technology

The Process Flow Diagram (Figure 1-1) gives a general overview of the major streams in the PBR/SDP process. PBR/SDP technology treats liquid nonaqueous and aqueous mixed-waste streams containing organic compounds and dissolved or suspended solids that may contain heavy metals and radionuclides. The PBR/SDP MTU combines the PBR and SDP technologies developed at LANL into a single, integrated process unit that will destroy hazardous organic compounds at overall destruction efficiencies of 99.9999 percent. The outlet streams from the process include the "blowdown" from the Acid-Gas Scrubber (equipment number S-300) containing sodium halide and sodium hydroxide, and the vent gas and oxidation products.

The mixed-waste feed is atomized and mixed with air (or a mixture of oxygen and inert gas) and enters the top of the PBR (R-100). The PBR consists of a hollow cylinder or pipe that is filled with an inert packing and externally heated. The packing is not catalytic and functions only to promote uniform heating and

distribution of reactants. The temperature of the PBR is maintained between 600 and 1,050 °C by controlling the external heaters and the waste feed and air rates. Based on data from the pilot PBR studies at LANL, at these temperatures, at least 99.99 percent of the organics are oxidized to form carbon dioxide, water vapor, and, when chlorinated compounds are treated, hydrogen chloride (HCl). The organic concentration is kept below the lower explosive limit by addition of excess air, typically over 200 percent of the stoichiometric requirement, so that no flame is produced in the reactor.

The offgas from the PBR, at 600 to 1,050 °C, is cooled to approximately 500 °C by passing it through a short section of packed bed that is unheated and uninsulated. To inhibit formation of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) in the PBR offgas, a quench is provided for rapid cooling of the offgas. However, minimizing quench water usage is desirable because most of the quench water will eventually be withdrawn as scrubber blowdown (see Section 6.1.1), which is a secondary waste from the process. The potential for formation of PCDD and PCDF exists whenever wastes containing organics and chlorine are treated, although yields are several orders of magnitude lower from feed material consisting of aliphatics than from feed consisting of aromatics (Gullett et al. 1994), so the quench will not be used for waste streams that do not contain chlorine. The offgas from the Quench Chamber (E-110) is cooled to 120 °C (the maximum operating temperature of the SDP) in a shell-and-tube heat exchanger and filtered to remove solids and radionuclides before being introduced to the SDP. Use of the uninsulated section of the packed bed and the heat exchanger to remove as much heat as possible reduces quench water requirements, and concomitant generation of secondary waste, by 80 percent compared to quenching alone.

The SDP consists of pairs of electrodes that are shielded from the flowing gas by plates of a dielectric such as glass. Application of an alternating voltage to the electrodes at near-atmospheric pressure produces a potential that generates an instantaneous electric discharge, which in turn ionizes gas molecules (e.g., oxygen) to form free radicals. The unstable free radicals constitute a "cold plasma" that attacks organic molecules, producing carbon dioxide and water vapor. The action of the SDP in destroying residual organics increases the overall destruction efficiency of the combined PBR/SDP to 99.9999 percent.

The offgas from the SDP flows to the Acid-Gas Scrubber, a packed countercurrent scrubber in which HCl produced from oxidation of chlorinated organics is neutralized by reaction with a solution of sodium hydroxide forming a sodium chloride salt solution. Sodium hydroxide makeup is added to maintain the solution pH, and the salt solution is blown down as needed to maintain the conductivity of the circulating liquid. The inlet gas to the Scrubber is above the boiling point of water, and the neutralization reaction also generates heat, so the Scrubber will vaporize water under most conditions. When this vaporization occurs, addition of makeup water will be necessary to maintain the required liquid level in the Scrubber.

The LANL PBR/SDP pilot unit was never tested on radioactive or mixed wastes, and partitioning of radionuclides as they pass through the process remains uncertain. Tests of the PBR pilot unit at LANL on surrogate waste streams that produced nonradioactive particulates indicated that over 99 percent of those particulates remained in the packed bed. For this DDR, it is assumed that all radionuclides (except tritium) will stay in the packed bed, which will have to be disposed of as radioactive waste at the end of treatment, or as often as necessary to keep radiation levels from exceeding regulatory limits. To remove any particulates that may pass through the PBR, the design includes a knockout section on the Quench Chamber below the reactor, as well as the PBR Offgas Filter (F-120) and the SDP Inlet HEPA Filters (F-130A and F-130B) upstream of the SDP. Two stages of high efficiency particulate air (HEPA) filtration at this point should effectively remove all radionuclides from the offgas stream. Radionuclides removed at these points will not be mixed waste because 99.99 percent of the hazardous constituents will have been destroyed or converted to nonhazardous compounds in the PBR.

Testing of the PBR pilot unit at LANL on surrogate wastes demonstrated that when gas flow through the packed bed becomes restricted due to buildup of particulates in the packing, "steaming out" the packed bed is an effective means for removing these trapped particulates (LANL 1996a). This process may remove radionuclides as well, although, as mentioned above, this has never been tested. This DDR provides for periodic "steaming out" of the packed bed by feeding water to the PBR. This water will vaporize in the bed and can be recondensed in the PBR Offgas Cooler (E-112). If the resulting condensate is radioactive, it would have to be stored for later concentration using the wastewater evaporator (WWE), a secondary treatment process being developed separately by DOE-AL.

Tritiated organic compounds will be converted to tritiated water in the PBR/SDP MTU. When the Acid-Gas Scrubber is in operation, some of the tritiated water will be collected as scrubber blowdown, while the rest will be vented as vapor through the offgas system to the atmosphere. Treatment of nonhalogenated wastes will produce little or no scrubber blowdown; in fact, the scrubber may not be operated when nonhalogenated wastes are being treated. Thus, essentially all the tritiated water from treatment of such wastes will be vented. However, as much as 85 percent of the total water produced during treatment of highly halogenated wastes, such as polychlorinated biphenyls (PCBs), will be taken out in the Scrubber as blowdown. Scrubber blowdown containing tritiated water will have to be stored for later concentration using the WWE. Site permits will have to be reviewed to confirm that the venting of tritiated water vapor, both during operation of the PBR/SDP MTU and during WWE evaporation of scrubber blowdown, will not exceed discharge permits.

To ensure that equipment is designed for maximum flexibility, three types of waste streams were considered for the design, and the process design of each component is based on the "worst case" for that component. Material balances are provided in Tables 1-1 through 1-3 for the following three design cases.

- Case 1: Treatment of 15 gallons per day (gal/d) of a heavy hydrocarbon oil. Properties of n-eicosane ($C_{20}H_{42}$) were used. Oxidation of a hydrocarbon oil requires the highest amount of oxygen per weight of feed of any feed material, so this case sets the required air rate.
- Case 2: Treatment of 15 gal/d of a chlorinated aromatic. Properties of Arachlor 1242 (a PCB containing approximately 42 percent chlorine) were used as a worst case for chlorine content. This case is the only one in which the Acid-Gas Scrubber is required, so it sets the maximum load for the water quench and the scrubbing system.
- Case 3: Treatment of 75 gal/d of an aqueous stream with total organic concentration at parts-per-million levels. Properties of water were used as a worst case for an aqueous waste. Water has no heat of reaction, and the specified feed rate for this case is five times higher than for the other two cases, so this case establishes the maximum load for the PBR Heaters and the PBR Offgas Cooler.

An air rate of 40 standard cubic feet per minute (scfm) will provide a slightly endothermic system even for Case 1 and will ensure that the system is always operated in a nonexplosive regime. For simplicity, the air rate has been set at 40 scfm for all three cases, as determined at the PBR/SDP VE session. During waste treatment using feeds of varying composition, the air rate can be adjusted to meet the characteristics of the actual waste streams.

Table 1-1. Material Balance Case 1: Heavy Hydrocarbon Oil (C₂₀)

Stream No.	Waste Feed 1	Waste 2	Air 3	PBR Outlet 4	Quench Water 5	Quench Outlet 6	SDP Inlet 7	SDP Outlet 8	Scrubber Off Gas 9	HEPA Inlet 10	Vent to ATM 11	CWS to Cooler 12	CWR from Cooler 13	NaOH Makeup 14	Scrubber Outlet 15	Scrubber Blowdown 16	Scrubber Circulation Liquid 17	Scrubber Makeup Water 18
C ₂₀	4.34	4.34	0	4.34E-04	0	4.34E-04	4.34E-04	4.34E-06	4.34E-06	4.34E-06	0	0	0	0	0	0	0	0
N ₂	0	0	139.89	139.89	0	139.89	139.89	139.89	139.89	139.89	139.89	0	0	0	0	0	0	0
O ₂	0	0	42.48	27.47	0	27.47	27.47	27.47	27.47	27.47	27.47	0	0	0	0	0	0	0
CO ₂	0	0	0	13.53	0	13.53	13.53	13.53	13.53	13.53	13.53	0	0	0	0	0	0	0
H ₂ O	0	0	0	5.82	0	5.82	5.82	5.82	8.32	8.32	8.32	1,667	1,667	0.00	1,110.16	0.00	1,112.66	2.51
HCl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
NaOH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
NaCl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
Total lb/h	4.34	4.34	182.37	186.71	0	186.71	186.71	186.71	189.22	189.22	189.22	1,667	1,667	0	1,110.16	0.00	1,112.66	2.51
Total mol/h	0.015	0.015	6.321	6.483	0	6.483	6.483	6.483	6.622	6.622	6.622	92.533	92.533	0	61.62	0.00	61.76	0.139
Temp (°C)	25	25	25	1050	-	500	120	120.10	90.80	120	120	35.0	46.1	-	90.80	-	90.80	25
Pressure (psia)	11.3	11.3	11.3	10.91	-	10.85	10.79	10.73	10.48	10.48	11.3	60.0	55.0	-	10.73	-	25.00	14.7
Density (lb/ft ³)	52.00	52.00	0.0566	0.0123	-	0.0209	0.0409	0.0407	0.0426	0.0394	0.0425	62.06	61.78	-	69.21	-	69.21	62.25
gal/d	15.00	15.00	-	-	-	-	-	-	-	-	-	4,823	4,844	-	2,879.87	-	2,886.37	7
acfm	-	-	53.69	253.01	-	148.66	76.02	76.46	74.01	79.94	74.16	-	-	-	-	-	-	-

Heat Exchanger Duties:

Rx Heater	12,388 Btu/h	3.6 kW
PBR Offgas Cooler	33,301 Btu/h	
Process Vent Heater	2,451 Btu/h	0.72 kW

Table 1-2. Material Balance Case 2: Chlorinated Aromatic (Arachlor 1242)

Stream No.	Waste Feed 1	Waste 2	Air 3	PBR Outlet 4	Quench Water 5	Quench Outlet 6	SDP Inlet 7	SDP Outlet 8	Scrubber Off Gas 9	HEPA Inlet 10	Vent to ATM 11	CWS to Cooler 12	CWR from Cooler 13	NaOH Makeup 14	Scrubber Outlet 15	Scrubber Blowdown 16	Scrubber Circulation Liquid 17	Scrubber Makeup Water 18
PCB 1242	7.23	7.23	0	7.23E-04	0	7.23E-04	7.23E-04	7.23E-06	7.23E-06	7.23E-06	0.00E+00	0	0	0	0	0	0	0
N ₂	0	0	139.89	139.89	0	139.89	139.89	139.89	139.89	139.89	139.89	0	0	0	0	0	0	0
O ₂	0	0	42.48	30.80	0	30.80	30.80	30.80	30.80	30.80	30.80	0	0	0	0	0	0	0
CO ₂	0	0	0	14.82	0	14.82	14.82	14.82	14.82	14.82	14.82	0	0	0	0	0	0	0
H ₂ O	0	0	0	1.01	17.50	18.51	18.51	18.51	26.26	26.26	26.26	643	643	3.36	888.12	19.67	894.36	22.53
HCl	0	0	0	3.07	0	3.07	3.07	3.07	3.07E-03	3.07E-03	0	0	0	0	0	0	0	0
NaOH	0	0	0	0	0	0	0	0	0	0	0	0	0	3.36	0	0	3.36	0.00
NaCl	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	222.03	4.92	217.11	0.00
Total lb/h	7.23	7.23	182.37	189.60	17.50	207.10	207.10	207.10	211.78	211.78	211.77	643	643	6.73	1,110.16	24.58	1,114.84	22.53
Total mol/h	0.028	0.028	6.321	6.434	0.971	7.405	7.405	7.405	7.751	7.751	7.751	35.668	35.668	0.271	53.098	1.176	53.444	1.251
Temp (°C)	25	25	25	1050	25	250	120	120.07	90.80	120	120	35.0	46.1	25	90.80	90.80	90.80	25
Pressure (psia)	11.3	11.3	11.3	10.91	10.91	10.85	10.79	10.73	10.48	10.48	11.3	60.0	55.0	14.7	10.73	25	25	14.7
Density (lb/ft ³)	86.52	86.52	0.0566	0.0126	62.427	0.0300	0.0398	0.0395	0.0407	0.0377	0.0407	62.06	61.78	95.19	69.21	69.21	69.21	62.25
gal/d	15.00	15.00	-	-	50.32	-	-	-	-	-	-	1,859	1,867	12.7	2,880	64	2,892	65
acfm	-	-	53.69	251.09	-	114.90	86.83	87.33	86.62	93.57	86.80	-	-	-	-	-	-	-

Heat Exchanger Duties:

Rx Heater	27,058 Btu/h	7.9 kW
PBR Offgas Cooler	12,836 Btu/h	
Process Vent Heater	2,839 Btu/h	0.83 kW

Table 1-3. Material Balance Case 3: Aqueous Waste (100% water)

Stream No.	Waste Feed 1	Waste 2	Air 3	PBR Outlet 4	Quench Water 5	Quench Outlet 6	SDP Inlet 7	SDP Outlet 8	Scrubber Off Gas 9	HEPA Inlet 10	Vent to ATM 11	CWS to Cooler 12	CWR from Cooler 13	NaOH Makeup 14	Scrubber Outlet 15	Scrubber Blowdown 16	Scrubber Circulation Liquid 17	Scrubber Makeup Water 18
Water	26.08	26.08	0	2.61E-03	0.00E+00	2.61E-03	2.61E-03	2.61E-05	2.61E-05	2.61E-05	0	0	0	0	0	0	0	0
N ₂	0	0	139.89	139.89	0	139.89	139.89	139.89	139.89	139.89	139.89	0	0	0	0	0	0	0
O ₂	0	0	42.48	42.48	0	42.48	42.48	42.48	42.48	42.48	42.48	0	0	0	0	0	0	0
CO ₂	0	0	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H ₂ O	0	0	0.00	26.08	0	26.08	26.08	26.08	29.09	29.09	29.09	2,006	2,006	0	1,110.16	0.00	1,113.17	3.01
HCl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
NaOH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
NaCl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00	0.00	0
Total lb/h	26.08	26.08	182.37	208.45	0	208.45	208.45	208.45	211.46	211.46	211.46	2,006	2,006	0	1,110.16	0.00	1,113.17	3.01
Total mol/h	1.448	1.448	6.321	7.769	0	7.769	7.769	7.769	7.936	7.936	7.936	111.344	111.344	0	61.624	0	61.791	0.167
Temp (°C)	25	25	25	1050	-	500	120	119.973	90.80	120	120	35.0	46.1	-	90.80	-	90.80	25
Pressure (psia)	11.3	11.3	11.3	10.91	-	10.85	10.79	10.73	10.48	10.48	11.3	60.0	55.0	-	10.73	-	25	14.7
Density (lb/ft ³)	62.43	62.43	0.0566	0.0115	-	0.0195	0.0381	0.0379	0.0397	0.0368	0.0397	62.06	61.78	-	69.21	-	69.21	62.25
gal/d	75.00	75.00	-	-	-	-	-	-	-	-	-	5,803	5,829	-	2,880	-	2,888	9
acfm	-	-	53.69	303.21	-	178.15	91.10	91.60	88.70	95.81	88.88	-	-	-	-	-	-	-

Heat Exchanger Duties:

Rx Heater	140,787 Btu/h	41.3 kW
PBR Offgas Cooler	40,071 Btu/h	
Process Vent Heater	2,955 Btu/h	0.87 kW

Appendix A contains the piping and instrumentation diagrams (P&IDs) for the MTU. The following description highlights the engineering features that make the PBR/SDP system a unique mixed-waste treatment process.

1.2.1 Waste Transfer and Feed System

Waste meeting the acceptance criteria (see Section 4.0) for the PBR/SDP process is received in standard shipping/storage containers (typically 55-gallon [gal] drums). The waste is pumped from the drum using a diaphragm-type Waste Transfer Pump (P-002) through a Strainer (F-004) that removes coarse debris (1/8 inch and larger in size) that would plug the spray nozzles. Material retained in F-004 will be washed and containerized. (Details of the washing and containerizing processes will be established in the detailed design.) After passing through F-004, the waste flows to the Waste Feed Tank (T-010), which is equipped with an Agitator (A-010) for blending compatible waste streams to provide a reasonably uniform feed to the PBR (R-100). The 175-gal working capacity of T-010 is sufficient to hold a 2-day supply of aqueous wastes at the design feed rate of 75 gal/d of aqueous waste, or a 10-day supply of organic wastes at the design feed rate of 15 gal/d of organic waste. Sodium hydroxide and sulfuric acid can be added to T-010 for pH adjustment, and antifoam solution can be added as needed to prevent foaming in the tank. The Waste Feed Pumps (P-020, P-022, and P-024) transfer the waste from T-010 to R-100 at a combined rate of up to 15 gal/d of organic waste, or up to 75 gal/d of aqueous waste.

Some degree of personnel protection will be required for the waste transfer operation during which the waste drum is opened and personnel are potentially exposed to hazardous fumes. In addition, some wastes may require pretreatment of some sort (e.g., addition of solvent to reduce viscosity). The minimal level of waste characterization at this time precludes specification of the level of protection and/or pretreatment required. Protection and pretreatment options will have to be evaluated during the detailed design process. Use of a drum unloading glovebox, similar in concept to that being built for the VAC*TRAX thermal desorption MTU¹, may be the most practical solution for this function.

1.2.2 Packed-Bed Reactor

The PBR (R-100) is the primary reactor for the MTU because it is designed to destroy 99.99 percent of all hazardous organic compounds in the waste feed. This level of destruction has been demonstrated in the LANL surrogate tests on a wide variety of organic compounds.

Waste feed is introduced into R-100 through atomizing nozzles where it is mixed with excess air. The nozzles use a design proven during the LANL pilot tests. Normal operating temperatures will be between 600 and 1,050 °C, depending on the principal organic constituent(s) of the waste being treated. Offgas from R-100 will cool to approximately 500 °C before being introduced into the Quench Chamber (E-110). Offgas from destruction of wastes containing chlorine will be quenched to 250 °C by adding a water spray in E-110. To minimize generation of secondary wastes (see Section 6.1.1), the water spray is not used for other wastes, which will pass directly through E-110 and enter the PBR Offgas Cooler (E-112) at 500 °C. A schematic of the LANL nozzle design is shown in Figure 1-2. The top illustration is the nozzle design used in the LANL pilot PBR. The bottom illustration is an improved design (also by LANL) for enhanced atomization at higher liquid rates. LANL has suggested that the high-flow atomizing design might be better suited for the PBR/SDP MTU.

¹The detailed design for the VAC*TRAX MTU has been developed by DOE-GJPO.

Current LANL
Atomizing Nozzle
Design

High Flow
Atomizing Nozzle

Figure 1-2. LANL Pilot PBR/SDP Unit Nozzle Design Schematic

1.2.3 Emergency Vent System

In the event of a plug in the PBR offgas system, the PBR (R-100) pressure may rise rapidly as feed liquid is vaporized. An interlock will immediately stop feeds and shut off the heaters in the event of high pressure in R-100. However, the pressure will continue to rise for a time while residual liquid is vaporized and superheated by the hot packing. If the pressure continues to rise until it reaches the design pressure of R-100, it will be relieved through the Relief Rupture Disk (PSE 100-10). The gases vented through PSE 100-10 will contain both hazardous organics and radionuclides that must be collected to the extent possible. The emergency vent system is designed to capture these contaminants before they can be released to the atmosphere. Gases relieved through PSE 100-10 flow to the Relief Condenser (E-140) where condensable vapors are removed. The two-phase mixture then flows to the Relief Demister (T-142) where liquid droplets are removed and accumulated. The condensate can be drummed and "recycled" to the PBR. Noncondensable gases flow to the Relief HEPA Filter (F-144), which removes radionuclides, before venting the clean gas stream to the atmosphere. The design parameters for the emergency vent system will be established during detailed design after the design pressure of R-100 is determined.

1.2.4 Silent-Discharge Plasma System

The SDP (R-201, R-202, R-203, and R-204) serves as a second stage of organic destruction that will permit overall destruction efficiencies of 99.9999 percent or higher in the combined PBR/SDP unit. This level of destruction will be necessary to meet Toxic Substances Control Act (TSCA) regulations when TSCA-regulated wastes are treated, and also to meet treatment standards for a few select RCRA-regulated wastes (see Section 5.0). Offgas from the Quench Chamber (E-110) will be cooled to 120 °C (the operating temperature of the SDP) in the PBR Offgas Cooler (E-112) to ensure that the SDP gas inlet temperature is above dewpoint. Coarse particulates such as fly ash will be removed in the PBR Offgas Filter (F-120), and radionuclides will be removed in the SDP Inlet HEPA Filters (F-130A and B). Use of two HEPA filters in series ensures that all radionuclides will be retained in the filter elements.

A "stand-alone" PBR is not designed to meet TSCA treatment standards for treatment of PCBs. Also, when wastes containing chlorine are treated, the potential for formation of PCDD/PCDF exists, as detailed in Section 1.2. Particulates collected in filters F-120, F-130A, and F-130B under these conditions may not meet treatment standards. Therefore, a bypass line has been provided so that when wastes containing PCBs or chlorine are being treated, the offgas from the PBR will bypass the filters initially and pass through the SDP directly. After treatment with the SDP is complete, the gas is routed through a second bypass line that passes it through the filters, removing radionuclides and residual particulates before passing on to the Acid-Gas Scrubber (S-300).

The SDP consists of a number of discrete, identical processing units, or cell banks, each containing 20 individual cells that are operated in parallel. The cell bank currently used at LANL is rated at a minimum of 10 scfm, so four cell banks will be required for the 40-scfm design rate determined for the complete SDP module in the MTU. If fewer cell banks are available, the feed rate to the MTU must be reduced proportionately. The design and fabrication of the SDP units will be done by LANL and is not in the scope of this DDR.

1.2.5 Acid-Gas Scrubbing System

When the waste feed contains halogens, the offgas from the PBR/SDP will contain acid halogen gases such as HCl, and also may contain trace amounts of phosgene (COCl_2). The purpose of the scrubbing system is to remove acid gases and particulates and destroy phosgene by reacting these compounds with a

solution of sodium hydroxide and water that absorbs acid gases from the vapor stream and converts them to stable salts before exhausting the treated gas to the atmosphere.

In the Acid-Gas Scrubber (S-300), SDP offgas flows through a packed column where it contacts the sodium hydroxide solution, which is circulated by the Scrubber Pump (P-302). HCl in the gas stream reacts with sodium hydroxide to form sodium chloride salt. Sodium hydroxide makeup is added as required by the Sodium Hydroxide Addition Pump (P-304). The vapor exiting S-300 is exhausted to the atmosphere through the Process Vent Blower (B-320).

1.2.6 Utilities and Chemicals

Utilities for the PBR/SDP MTU include all of the following:

- Cooling water for the PBR Offgas Cooler (E-112) and the Relief Condenser (E-140), supplied by the Cooling Water Cooler (CW-400) in a closed-loop cooling water system.
- Compressed air for the PBR (R-100), the Waste Transfer Pump (P-002), and the Waste Feed Tank Agitator (A-010), supplied by the Air Compressor (AC-420).
- Nitrogen for inerting the vapor space in the Waste Feed Tank and for "sweeping" the pressure relief header, supplied by the Nitrogen Supply System (N-450).
- Process water used as makeup for the Quench Chamber (E-110) and the Acid-Gas Scrubber (S-300), supplied from site potable water systems and pretreated to remove dissolved salts in the Water Softener (W-310).
- Electricity, provided by the sites (480 VAC, 3-phase only), will be stepped down to lower voltage by transformers supplied with the MTU.

Details on expected consumption rates of these utilities are given in Section 2.2.1.

Chemicals for the PBR/SDP MTU include all of the following:

- Sodium hydroxide used in the Acid-Gas Scrubber (S-300) and the Waste Feed Tank (T-010), supplied by the Sodium Hydroxide Addition Pump (P-304) from 55-gal drums of concentrated (50 percent) sodium hydroxide.
- Sulfuric acid used in T-010 supplied by the Sulfuric Acid Addition Pump (P-410) from 5-gal carboys of concentrated (98 percent) sulfuric acid.
- An antifoam agent for the Waste Feed Tank (T-010), supplied by the Antifoam Addition Pump (P-430).

1.3 Permitting, Decontamination, and Transportation

The PBR/SDP pilot unit has successfully passed technical review by the New Mexico Environmental Department, and has been well received in reviews with local public stakeholders. A RCRA research, development, and demonstration (RD&D) permit, the first of its kind in the state of New Mexico, has been granted to the pilot unit for further technology development.

The PBR/SDP MTU is expected to be permitted as a "miscellaneous unit" under Title 40, Part 264 of the U.S. Code of Federal Regulations (40 CFR 264), Subpart X, including the appropriate requirements of Subpart I through O and Subparts AA through CC of Part 264, Part 270, and Part 148. A miscellaneous unit must be located, designed, constructed, operated, maintained, and closed in a manner that will ensure protection of human health and the environment. Permits for miscellaneous units are to contain such terms and provisions as necessary to protect human health and the environment, including, but not limited to, as appropriate, design and operating requirements, detection and monitoring requirements, and requirements for responses to releases of hazardous waste or hazardous constituents from the unit.

The PBR/SDP MTU detailed design will address and demonstrate compliance with the Air Emissions Standards of CFR 264, Subparts AA (Process Vents), BB (Equipment Leaks), and CC (Tanks, Surface Impoundments, and Containers). Since the design goal of the MTU is to reduce organic emissions by 99.99 percent or more, and the only process vent has already passed through the PBR (R-100), the SDP, and the Acid-Gas Scrubber (S-300), compliance with the Air Emissions Standards of Subpart AA should be easily demonstrated. All equipment in the MTU between the inlet to R-100 and the suction of the Process Vent Blower (B-320) normally operates at slightly below ambient pressure but above the threshold for exemption from the requirements of Subpart BB. The requirements of Subpart CC will apply only to the Waste Feed Tank (T-010), which is the only "container" in the MTU having a capacity of greater than 0.1 m³.

At the conclusion of treatment at each site, the PBR/SDP MTU must be decontaminated for transportation to the next site. Prior to transport, all liquids will be drained from the MTU so that it will be considered empty from a RCRA standpoint. Process chemicals such as sodium hydroxide and sulfuric acid will be obtained at each site rather than shipped with the MTU, and all unused chemicals will be added to that site's chemical inventory. It is possible that regulators in the various States where the MTU is targeted for use may have differing opinions regarding the regulatory status of unspent capture media (e.g., HEPA filters or activated carbon). This issue will have to be explored and resolved with the various State regulatory agencies during the permitting process.

Current plans call for the MTU to be shipped as "Radioactive Material—Excepted Package, Limited Quantity of Material." (One possible exception is the PBR itself and its packing, which may have to be removed and disposed of as radioactive waste [see Section 1.2.]). The requirements for shipment under this classification are specified by the U.S. Department of Transportation (DOT) in 49 CFR 173.423. Briefly, the regulations exempt the shipper from shipping documentation, certification, and marking and labeling requirements, other than certain limited and specific requirements called out in the regulation. To qualify for this classification, the internal contamination levels of the MTU must be below specified limits, which implies a knowledge of the type and amount of radioactivity present, as well as a design that provides the ability to assess the internal inventory of radionuclides. In addition, external radiation levels cannot exceed 0.5 millirem per hour (mrem/h) at any point on the surface; removable contamination on the external surface cannot exceed the limits given in 49 CFR 173.443; and the package must not contain more than 15 grams of uranium-235. The MTU must then be packaged in such a way that no radioactive materials will leak during shipment.

Details and information related to the design, construction, operation, and maintenance of the PBR/SDP MTU will be provided to DOE-AL, where the overall permitting effort will be coordinated to ensure reasonable consistency between each of the user sites. It is expected that the DOE-AL centralized permitting organization, in consultation with the States, will address these potential permitting issues and identify any other MTU closure requirements. Any additional requirements or recommendations from the permitting process will be incorporated, where appropriate, into the final MTU design and the technical

information package prepared in support of the permitting process. The user sites will retain ultimate responsibility for negotiating the terms and conditions of the operating permits

1.4 Site Description

The PBR/SDP MTU is scheduled to be delivered to the following sites.

- LANL, Los Alamos, New Mexico.
- SNL/NM, Albuquerque, New Mexico.
- Pantex (PTX), Amarillo, Texas.

The MTU is designed to be housed in climate-controlled environments. However, the barometric pressure will have to be taken into account during design, and the ambient air temperature range will affect the design of any utility equipment that will be placed outdoors. The following are the ambient design conditions for the three designated sites.

LANL

- Elevation: 7,300 feet (ft) (2,225 meters [m])
- Average barometric pressure: 779 millibar (mb) (11.3 pounds per square inch absolute [psia])
- Seismic zone: 2B
- Reasonable maximum temperature: 88 °F

SNL/NM

- Elevation: 4,958 ft (1,511 m)
- Average barometric pressure: 827 mb (12.0 psia)
- Seismic zone: 2B
- Reasonable maximum temperature: 98 °F

PTX

- Elevation: 3,600 ft (1,097 m)
- Average barometric pressure: 889 mb (12.9 psia)
- Seismic zone: 1
- Reasonable maximum temperature: 101 °F

1.5 Waste Stream Description

The waste streams described in the following paragraphs are being considered for treatment by the PBR/SDP MTU as of July 13, 1995. In all cases, the PBR/SDP technology will remove a corrosivity characteristic by neutralization, and will remove other hazardous characteristics by destruction of the hazardous organic compound(s). Radionuclides will concentrate in the packed bed, except for tritium, which will pass directly through the unit. Treatment time estimates are based on a feed rate of 15 gal/d (no aqueous wastes are included in the current inventory of wastes being considered for PBR/SDP treatment) with operation on a 24-hour basis, 7 days a week, and with an on-stream reliability factor of 75 percent.

1.5.1 Los Alamos National Laboratory — LA-W 907

LA-W 907 (formerly LANL-TG 18) is halogenated organic liquids, consisting primarily of spent solvents, laboratory chemicals, and bulk organics. The waste stream has designated RCRA waste codes D001, D002, D003, D007, D009, D018, D019, D022, D028, D029, D035, D043, F001, F002, F003, F005, U077, U080, U226, U227, U228, and U236. Suspected radionuclides are plutonium and uranium.

The current inventory of this waste stream, including an estimated 5-year generation of the waste, is 16.58 cubic meters (m^3)(4,380 gal). Total treatment time for this quantity of waste, including the 5-year generation, is estimated at 389 days.

1.5.2 Los Alamos National Laboratory — LA-W 908

LA-W 908 (formerly LANL-TG 19) is nonhalogenated organic liquids, consisting primarily of spent solvents, laboratory chemicals, and bulk organics. The waste stream has designated RCRA waste codes D001, D002, D003, D004, D007, D008, D009, D011, D018, D038, D040, F002, F003, F004, F005, U002, U019, U169, U188, U220, and U246. Suspected radionuclides are plutonium and uranium.

The current inventory of this waste stream, including an estimated 5-year generation of the waste, is 14.34 m^3 (3,789 gal). Total treatment time for this quantity of waste, including the 5-year generation, is estimated at 337 days.

1.5.3 Sandia National Laboratory/New Mexico — SNL/NM-TG 11

SNL/NM-TG 11 is uncategorized organic liquids including vacuum pump oils, mixed nonhalogenated solvents, and a grinding sludge that contains trichloroethylene (TCE). The waste stream has designated RCRA waste codes D001, D006, D008, F002, F003, and F005. Suspected radionuclides are tritium and cesium-137.

The current inventory of this waste stream is 2.7 m^3 (713 gal). Total treatment time for this quantity of waste is estimated at 63 days.

1.5.4 Pantex Facility — PTX-TG 1.1

PTX-TG 1.1 is uncategorized paint wastes from stripping and repainting parts in PTX Building 12-41. The waste stream consists primarily of epoxy paints, polyurethane enamels, out-of-date paints and solvents, and may include free water. The waste stream has designated RCRA waste codes D001, D006, D007, D008, and D009. Suspected radionuclides are tritium, thorium, and uranium.

The current inventory of this waste stream, including an estimated 5-year generation of the waste, is 0.74 m³ (196 gal). Total treatment time for this quantity of waste, including the 5-year generation, is estimated at 17 days.

1.5.5 Pantex Facility — PTX-TG 1.2

PTX-TG 1.2 is halogenated organic liquids, consisting primarily of chemicals that have been overpacked in drums, and bulked solvents, including dimethyl sulfoxide, which contains tritium in solution. The waste stream has designated RCRA waste codes D001, D003, F001, F002, F003, F004, and F005A. Suspected radionuclides are tritium and uranium.

The current inventory of this waste stream, including an estimated 5-year generation of the waste, is 2.06 m³ (544 gal). Total treatment time for this quantity of waste, including the 5-year generation, is estimated at 48 days.

1.5.6 Pantex Facility — PTX-TG 1.3

PTX-TG 1.3 is nonhalogenated organic liquids, consisting of mercury-contaminated mineral oil from vacuum pump operation of environmental chambers. The designated RCRA waste code for this waste stream is D009 for mercury. Suspected radionuclides are tritium and possibly thorium and uranium-238.

The current inventory of this waste stream, including an estimated 5-year generation of the waste, is 1.55 m³ (410 gal). Total treatment time for this quantity of waste, including the 5-year generation, is estimated at 36 days.

1.5.7 Pantex Facility — PTX-TG 1.5

PTX-TG 1.5 is scintillation cocktails in glass vials loosely packed in vermiculite. The main component is pseudocumene, with some toluene and xylene in older vials. The waste stream has designated RCRA waste codes D001 and F003. Suspected radionuclides are tritium, thorium, and uranium at very low levels.

The current inventory of this waste stream is 0.72 m³ (190 gal). The analytical method in which the waste was generated is no longer used at Pantex, so the estimated 5-year generation of additional waste is zero. Total treatment time for this quantity of waste is estimated at 17 days.

2.0 Design Basis

The process parameters and assumptions that form the basis for the PBR/SDP design are summarized in Table 2-1. Mechanical design basis parameters for each major equipment item are listed in Table 2-2, and general design and siting criteria are listed in Table 2-3. Whenever possible, experimental data have been used to develop the design basis and are referenced. The PBR/SDP MTU will be designed to meet the waste treatment standards discussed in Section 5.0 of this report.

Table 2-1. Process Design Basis Parameters

Parameter	Value/Units	Comments
PBR Feed Rate	15 gal/d organic 75 gal/d aqueous	Maximum flow rates determined during PBR/SDP VE session.
Air Rate	40 scfm	As required to ensure endothermic operation of PBR for all feeds.
Solids In Feed	Concentration unknown, not to exceed 1/8 in. in size when fed to PBR	Wastes having solids larger than 1/8 in. will not be rejected; to avoid plugging inlet nozzles, a strainer will be provided in feed line.
Waste Transfer Pump (P-002)	15 gal/min nominal capacity	To unload 55-gal drum in 5 minutes or less.
Waste Feed Tank (T-010)	175 gal working capacity	At least a three-drum capacity for optimum mixing.
PBR Temperature	600–1,050 °C normal operating range 1,200 °C equipment design maximum	Use four zones of external electric heat to attain operating temperature based on aqueous waste feed.
PBR Pressure	Atmospheric at inlet	Pressure drop to be determined.
Quench Required?	Only when wastes contain chlorine (to minimize generation of secondary waste)	Formation of dioxins and furans is not significant except when chlorine is present.
Quench Temperature Profile	500 °C inlet 250 °C outlet (normal) 200 °C outlet (design capacity of quench)	Dioxin/furan formation occurs only between 400 and 250 °C (Gullett et al. 1994)
Particulate Removal from PBR Offgas	One micron and larger particles at 99% efficiency	HEPA not required at this point.
SDP Inlet Temperature	120 °C	To ensure that SDP operates above dewpoint of water.
SDP Feed Rate	10 scfm per cell minimum, depending on target compound	Based on size of current SDP cells. Can combine as many cells in parallel as required for total MTU feed rate.
Organic Destruction Efficiency (DRE)	99.99% in PBR 99.9999% in combined PBR/SDP	Confirmed in LANL tests on a wide variety of organics.
Acid-Gas Scrubber (S-300)	Packed column, removes 99.9% of acid gases from vapor stream, circulating sodium hydroxide/sodium chloride solution up to 20 percent, pH = 6–8	Slightly acidic for maximum destruction of COCl_2 with negligible absorption of CO_2 .
MTU Operability	24 h/d	75% stream factor.

Table 2-2. Mechanical Design Basis Parameters

Parameter	Value/Units	Comments
Waste Feed Tank (T-010)	Design pressure: 50 psig at 300 °F	To allow pressure buildup when filling tank while PBR is out of service.
PBR (R-100)	Design pressure: 10 psig/1 psi vacuum at 1,200 °C Packing is 1/2 in. and 3/16 in. alumina balls	Design pressure to be confirmed during detail design Heaters to have internal skin over-temperature protection.
Quench Chamber (E-110)	Design pressure: 10 psig/1 psi vacuum at 1,200 °C	Allow 6-in. section below gas outlet for solids disengagement.
PBR Off-gas Cooler (E-112)	Design pressure: 15 psig (shell and tubes) at 600 °C	Size both for cooling load and condensing load during "steam-out" (see text).
SDP Inlet HEPA Filters (F-130A/B)	Design flow 90 actual ft ³ /min (acfm) at 1 psi vacuum	
SDP (R-201, R-202, R-203, R-204)	Design and fabrication by LANL	Four cell banks each having 10 scfm capability.
Acid-Gas Scrubber (S-300)	Design for 3 psig at 300 °F, pH range 2-12; packing of Intalox saddles or equivalent, include demister section at vapor outlet	Wide pH range for maximum corrosion protection.
Scrubber Pump (P-302)	2 gal/min at 30-ft. TDH, design for pH range 2-12	Wide pH range for maximum corrosion protection.
Process Vent Blower (B-320)	Design flow 90 acfm at 1 psi vacuum	
Relief Condenser (E-140)	Design pressure: 3 psig/1 psi vacuum at 1,200 °C (tubes), 50 psig at 300 °F (shell)	Duty to be determined based on sizing of PSE 100-10.
Relief Demister (T-142) Relief HEPA Filter (F-144)	Design pressure: atm 300 °F	Sizing to be determined

Table 2-3. General Design/Siting Criteria

Parameter	Value/Units	Comments
Normal Atmospheric Pressure	11.3 psia, based on elevation of 7,500 ft (LANL location)	Worst case for sizing thermal and gas processing equipment.
Equipment Materials of Construction	Nickel alloys, chloride resistant stainless steel, fiberglass-reinforced plastic, and polymer-lined steel	For corrosion control over 20-year design life, cost effectiveness, and ease of decontamination.
Structural Supports	Epoxy-coated carbon steel	Ease of decontamination and ability to withstand rigors of transportation, commission, and decommission.
Modular Construction	<p>Maximum of six modules can be located in a radiological controlled area (LANL)</p> <p>Largest module shall not exceed 11.5 ft high, 8 ft wide, and 10 ft long for shipment; can be up to 18 ft high fully assembled</p> <p>Maximum weight of modules required to be hoisted into position: 4,000 lb</p> <p>No limit on maximum weight of modules not requiring hoisting</p>	<p>For use at multiple sites — to be transported on flat-bed trucks.</p> <p>Maximum shipping dimensions specified by DOT for highway transportation.</p> <p>Weight specified by LANL based on capacity of overhead crane.</p>
Piping	Stainless steel, nickel alloys, polymer-lined steel (see P&ID and piping specifications)	Designed and fabricated in accordance with ASME B31.3.
Electrical	<p>Designed for National Electrical Code (NEC) Class 1, Division 2 areas (except any utilities to be sited outdoors)</p> <p>Motors shall be totally enclosed, fan cooled, have a 1.15 service factor or specified for continuous service at 7,500 ft elevation</p>	NEC Class 1, Division 2 not required for outdoor service.
Secondary Containment	Each skid shall be capable of complete containment of 110% of the fluid volume of the largest equipment item on that skid	RCRA regulation.
Instrumentation	<p>Designed for NEC Class 1, Division 2 areas</p> <p>All field instruments on the skid-mounted equipment will be wired to a local junction box; cabling will be used from the junction boxes to the central control panel for ease of system setup</p>	<p>Programmable logic controllers (PLC).</p> <p>Capability for operation from a central control panel with local start/stop switches for the equipment.</p>
General	40 CFR 264 requirements will be addressed in detailed design.	

2.1 Process Parameters

On the basis of the waste volumes described in Section 1.4 of this report, the PBR/SDP MTU will be designed around an organic feed rate of 15 gal/d and an aqueous solution feed rate of 75 gal/d. The air-flow rate will be 40 scfm for both waste feed rates. The MTU design will be based on the material balances presented in Tables 1-1 through 1-3.

2.2 Process/Mechanical Design Parameters

2.2.1 Equipment

Table 2-4 lists the equipment required for the PBR/SDP MTU. The P&IDs are presented in Appendix A.

Table 2-4. Equipment List

P&ID No.	Tag No.	Description
E03456	P-002	Waste Transfer Pump
E03456	F-004	Strainer
E03456	A-010	Waste Feed Tank Agitator
E03456	T-010	Waste Feed Tank
E03457	P-020	Waste Feed Pump
E03457	P-022	Waste Feed Pump
E03457	P-024	Waste Feed Pump
E03457	R-100	Packed-Bed Reactor
E03457	H-102	Packed-Bed Reactor Heater
E03457	H-104	Packed-Bed Reactor Heater
E03457	H-106	Packed-Bed Reactor Heater
E03457	H-108	Packed-Bed Reactor Heater
E03457	E-110	Quench Chamber
E03457	E-112	PBR Offgas Cooler
E03488	F-120	PBR Offgas Filter
E03488	F-130A	SDP Inlet HEPA Filter
E03488	F-130B	SDP Inlet HEPA Filter
E03489	E-140	Relief Condenser
E03489	T-142	Relief Demister
E03489	F-144	Relief HEPA Filter
E03488	R-201	Silent-Discharge Plasma Cell Bank No. 1
E03488	R-202	Silent-Discharge Plasma Cell Bank No. 2

Table 2-4 (continued). Equipment List

P&ID No.	Tag No.	Description
E03488	R-203	Silent-Discharge Plasma Cell Bank No. 3
E03488	R-204	Silent-Discharge Plasma Cell Bank No. 4
E03458	S-300	Acid-Gas Scrubber
E03458	P-302	Scrubber Pump
E03458	F-306	Scrubber Filter
E03459	P-304	Sodium Hydroxide Addition Pump
E03458	W-310	Water Softener
E03489	B-320	Process Vent Blower
E03459	CW-400	Cooling Water Cooler
E03459	P-402	Cooling Water Pump
E03459	P-410	Sulfuric Acid Addition Pump
E03459	AC-420	Air Compressor
E03459	P-430	Antifoam Addition Pump
E03459	N-450	Nitrogen Supply System

Waste Transfer Pump (P-002)

P-002 is an air- or nitrogen-operated double-diaphragm pump with a discharge pulsation dampener. P-002 will have a capacity of at least 11 gal/min, allowing it to empty a 55-gal drum of mixed waste in 5 minutes or less. P-002 has a suction lift of at least 10 ft with an expected downstream pressure drop of 25 psi. The inlet dip tube will be inserted into the drum for pumping.

The temperature of the liquid waste feed is nominally 75 °F. Density will vary from 50 to 90 pounds per cubic foot (lb/ft³), and viscosity will typically range from about 0.5 to 10 centipoise (cP), although it may be much higher. The pH range is not known at this time, but may be expected to range from 1 to 14. Coarse solids are expected to be minimal. Materials of construction for P-002 will be determined in the detailed design. Teflon is the most likely material.

Strainer (F-004)

F-004 is a Y-type strainer with a filter assembly equipped for ease of replacement during operation. The required mesh size is 7 mesh (0.111 in.) or finer, which will remove particles larger than 1/8 in. in size that could plug the atomizing nozzles. F-004 can be periodically blown down as necessary to remove retained particulates. (Details of the washing and containerizing processes will be established in the detailed design.) The pressure drop across the filter will be limited to 5 psi (clean) at the maximum flow of the Waste Transfer Pump (P-002).

Materials of construction for F-004 will be determined in the detailed design. Type 316 stainless steel is the most likely material to provide the corrosion resistance necessary to process chlorinated organics and wastes within a large pH range.

Waste Feed Tank (T-010)

T-010 is used for mixing the feed liquid, to keep solids from setting out, and to achieve a more uniform composition for the reactor feed. T-010 has a nominal capacity of 175 gal, sufficient to hold a 2-day supply of aqueous waste feed or a 10-day supply of organic waste feed. Total volume includes American Society of Mechanical Engineers (ASME) flanged and dished heads on the top and bottom of the tank. Mixing action is provided by the air-driven Waste Feed Tank Agitator (A-010).

Design temperature and pressure for T-010 is 300 °F and 50 pounds per square inch gauge (psig). T-010 will be designed and constructed in accordance with the *ASME Boiler and Pressure Vessel Code*, Section VIII, "Rules for Construction of Pressure Vessels" (ASME 1992), and will be ASME code stamped.

Materials of construction for T-010 will be determined during the detailed design. Teflon-lined carbon steel, Acetal (Delrin), PPS (Ryton), Kel-F, or 316L stainless steel have been identified as possible materials for corrosion protection. All welds will be, at a minimum, spot radiographed. For ease of radiological decontamination, the internal surfaces of T-010 will have a Roughness Height Index Value 4 surface finish, as outlined in American National Standards Institute (ANSI) ANSI/ASME B46.1.

Level instrumentation on T-010 will not allow a drum of waste to be added to the tank unless the liquid level is at least 55 gal below the maximum operating volume. The pH of the tank contents will be measured by the T-010 pH Meter (AE 010-6). When a pH less than 2 or greater than 12 is detected, an alarm will sound and the operator can manually adjust the pH by adding either sodium hydroxide or sulfuric acid, as required.

Waste Feed Tank Agitator (A-010)

A-010 is the agitator for the Waste Feed Tank. The agitator uses an air-driven motor to avoid a potential explosion hazard. The primary function of A-010 is to keep fine solids (which may contain high concentrations of radionuclides) in suspension, so it will be designed to "swipe" the bottom of T-010 to break up accumulations of solids. A secondary function of A-010 is to provide mixing of the liquids to reduce variations in feed quality caused by nonhomogeneity of the liquids. Some of the waste streams will contain two or more immiscible layers that cannot be homogenized except by emulsification. Emulsification is not desired in T-010 because emulsions can have unpredictable physical properties (for example, dramatic increases in viscosity), which could plug downstream piping and equipment and/or make accurate flow measurement difficult or impossible. Therefore, A-010 will not be designed to emulsify.

Materials of construction for A-010 will be determined at the detailed design phase. Teflon-lined carbon steel or 316L stainless steel are the most likely materials. For ease of radiological decontamination, the impeller and shaft will have a Roughness Height Index Value 4 surface finish, as defined in ANSI/ASME B46.1.

Waste Feed Pumps (P-020, P-022, P-024)

P-020, P-022, and P-024 will be variable-speed gear pumps, equipped with electric motors and installed in parallel to feed the PBR (R-100). Each pump will be designed to deliver up to 25 gal/d (65.7 cubic centimeters per minute [cm^3/min]) of aqueous waste or 5 gal/d (13.1 cm^3/min) of organic waste at 25 psig. R-100 is not designed to handle a pulsating flow, so it is important that the pumps deliver a steady flow at a steady pressure.

The temperature of the waste feed is nominally 75 °F. Density will vary from 50 to 90 lb/ft³, viscosity will typically range from approximately 0.5 to 10 cP, and the pH range is 2 to 12. Coarse solids will not exceed 1/8 in. in size and are expected to be minimal. Materials of construction for the pumps will be determined during the detailed design.

Packed-Bed Reactor (R-100)

Normal operating conditions for R-100 will be between 600 °C and 1,050 °C, depending on the waste to be treated, and about 0.4 psi vacuum. R-100 consists of an 8-in.-diameter vertical section of pipe, containing a 4-foot-long section externally jacketed with electric heaters and packed with aluminum oxide balls and/or cylinders. The pipe is made of Haynes HR 160, a high-temperature alloy having great resistance to corrosion from chloride attack. The packing balls are 3/16 in. in diameter in the bottom foot of packing and 1/2 in. in diameter for the rest of the heated length. Pilot PBR tests at LANL have demonstrated that using a section of smaller packing size at the bottom of the bed is more effective at retaining particulates in the bed than using a larger diameter packing throughout the entire bed length.

The waste feed is introduced through three nozzles located at the top of the bed. The incoming liquid feed is atomized with air to form a fine mist that is sprayed onto the top of the bed. The waste flows downward through the packing, where oxidation of organics takes place. The design will include a support grid for the packing, which will be constructed from the same materials as the reactor walls.

The electric PBR (Heaters H-102, H-104, H-106, and H-108) are numbered top to bottom, with an independent temperature control for each heater. The heaters are sized to heat 75 gal/d of water and 40 scfm of air from ambient temperature (25 °C) to 1,200 °C. The temperature measurements are made using a bundle of thermocouples inserted through the top of the bed inside a single tube, fabricated from Haynes 214 alloy or equivalent. The thermocouples will be arranged so that at least one thermocouple terminates approximately in the center of each zone. During normal operation with organic feeds, all four zones will be controlled at or near the same temperature. Aqueous feeds, which require more heat input from the external heaters, will exhibit a temperature profile that increases towards the bottom of the bed.

The outlet gases from R-100 pass through a short section of packed bed that is unheated and uninsulated, reducing the gas temperature from 1,050 °C to about 500 °C before being introduced into the Quench Chamber (E-110). The length of uninsulated bed required to obtain the desired temperature drop may vary from one waste to another, or with different waste feed rates. Therefore, R-100 will be designed to be moved vertically up or down as much as 6 in. within the heaters.

Nearly all of the radionuclides are expected to concentrate in R-100 (see Section 1.2). Because removal of radiologically contaminated packing poses health and safety concerns, R-100 will be flanged to facilitate removal of the entire bed and reactor shell for disposal as radioactive waste. An alternate method, which should be included in the final PBR design, is to remove only the contaminated packing. This alternative will require removal of the bed support grid and dust controls to minimize fugitive dust emissions. The complete MTU package will include at least one spare packed pipe for replacement of a contaminated PBR.

R-100 is designed to operate at 1,200 °C and 10 psig or 1 psi vacuum. At a minimum, R-100 will be designed and constructed in accordance with the *ASME Boiler and Pressure Vessel Code*, Section VIII, "Rules for Construction of Pressure Vessels" (ASME 1992). Welds made in the fabrication of R-100 will be 100 percent radiographed.

Quench Chamber (E-110)

E-110 will ensure rapid cooling of offgas from oxidation of wastes containing chlorine, which could form PCDD/PCDF if allowed to cool gradually. The temperature window for formation of PCDD/PCDF is between approximately 400 and 250 °C. The offgas will be at approximately 500 °C when it enters E-110. The cooling medium for E-110 is water, which is sprayed directly into the chamber in an ultrafine mist and allowed to vaporize on contact with the hot gas. The flow rate of the water is controlled by the E-110 Outlet Temperature Indicator/Controller (TIC 110-2) on the Quench Chamber outlet, which maintains the temperature at a normal setpoint of 250 °C.

E-110 consists of a section of 3-in. pipe fabricated from Haynes HR-160, a high-temperature alloy having great resistance to corrosion from chloride. Design conditions for E-110 are 600° C and 3 psig. Hot gas enters at the top of the chamber through a 2-in. flange. The spray nozzle is mounted on a 1/4-in. bulkhead tubing fitting. The maximum water-flow rate for E-110 is 160 cm³/min, based on cooling the offgas products from oxidation of 15 gal/d of Arachlor 1242 (design Case 2) from 500 °C to 200 °C. The quenched gas exits through a 2-in. side nozzle mounted 6 in. above the bottom of the chamber and goes to the PBR Offgas Cooler (E-112). The bottom section of E-110 has a small knockout section for removal of heavy particulates.

At a minimum, E-110 will be designed and constructed in accordance with *ASME Boiler and Pressure Vessel Code*, Section VIII, "Rules for Construction of Pressure Vessels" (ASME 1992). Expansion and contraction of E-110 will be addressed in the detailed design. Welds made while fabricating E-110 will be 100 percent radiographed.

PBR Offgas Cooler (E-112)

E-112 is a shell-and-tube heat exchanger designed to cool the offgas to 120 °C before introducing it into the SDP. The inlet temperature will be either 250 or 500 °C, depending on whether or not the quench is used. The cooling medium for E-112 is cooled water from the Cooling Water Cooler (CW-400), at a nominal inlet temperature of 95 °F. The design duty for the cooler should be based on the worst of two scenarios:

- Normal operation. The design case is 40,017 British thermal units per hour (Btu/h), based on cooling the offgas from treatment of 75 gal/d of vaporized aqueous (100 percent water) waste and 40 scfm of air from 500 to 120 °C.
- "Steaming out" the PBR to remove particulates. The design case is 12,960 Btu/h, based on condensing 3.3 pounds per hour (lb/h) or 9.5 gal/d of water from 10 scfm of air entering at 500 °C and condensing at an ambient pressure of 11.3 psia saturated, equivalent to 199 °F or 93 °C.

The design conditions for E-112 are 5 psig and full vacuum at 1,200 °F (649 °C). The material of construction will be Hastalloy C-22 or C-276.

PBR Offgas Filter (F-120)

F-120 removes residual particulates, such as fly ash and metallic flakes, from the PBR offgas stream. F-120 functions as a "coarse" filter to minimize plugging of the SDP Inlet HEPA Filters (F-130A and B) located immediately downstream. F-120 will be designed to remove 1-micron particles at an efficiency of 99 percent. Because the particulates may include radionuclides, the filter will be designed so that the entire bag can be removed and disposed as radioactive waste. Materials of construction for the bag filter

housing will be stainless steel, and design conditions will be 3 psig and full vacuum at 300 °F. The filter element will be constructed from Gore-Tex or similar material.

SDP Inlet HEPA Filters (F-130A and F-130B)

F-130A and B remove radionuclides and other fine particulates from the PBR offgas stream so that they will not be carried into downstream process equipment. The two HEPA filters, each with a radiological decontamination factor (DF) of 3333 (removal of 99.97 percent of all particles 0.3 microns and larger) are installed in series, to give an overall DF of 1.1×10^7 (3333 squared). F-130A and B will be designed so that the entire filter element can be removed and disposed as radioactive or mixed waste. The HEPA filter element will be made from pleated fiberglass, and the filter housing will be stainless steel. Design conditions will be 3 psig and full vacuum at 300 °F.

Relief Condenser (E-140)

E-140 is a single-pass, horizontally mounted shell-and-tube condenser provided to condense vapors generated during an overpressure of the PBR (R-100) and relieved through the Relief Rupture Disk (PSE 100-10). The design duty for E-140 will be determined during the detailed design after PSE 100-10 has been sized. The vapors are on the tube side of the condenser. The cooling medium for E-140 is water from the Cooling Water Cooler (CW-400), at a nominal inlet temperature of 95 °F and a temperature rise of 20 °F.

The design conditions for E-140 are 5 psig and full vacuum at 1,200 °F (649 °C) for the tube side, and 300 °F and 50 psig for the shell. Because E-140 is intended for extremely infrequent operation, it will be considered sacrificial, in that the materials of construction will not be selected to withstand continuous operation at PBR offgas temperatures. (The need for a spare condenser will be evaluated during detailed design.) Materials of construction will be 316 stainless-steel for the tubes and heads, and carbon-steel for the shell. E-140 will be designed and constructed in accordance with *ASME Boiler and Pressure Vessel Code*, Section VIII, "Rules for Construction of Pressure Vessels" (ASME 1992), and ASME code stamped. Tube-side welds will be spot radiographed.

Relief Demister (T-142)

T-142 contains a mesh-type demister to coalesce the fine liquid droplets condensed in the Relief Condenser (E-140) into larger drops that can be collected and drained. T-142 will be sized for the maximum vapor flow rate through the Relief Rupture Disk (PSE 100-10), and will have a liquid holding capacity sufficient to contain the total calculated volume of the worst-case release. Liquid collected in T-142 will be drained after an overpressure incident is over. Both the tank and the demister will be fabricated from 316 stainless steel. The design conditions are 5 psig and full vacuum at 300 °F.

Relief HEPA Filter (F-144)

F-144 removes radionuclides and other particulates from the emergency relief line. F-144 will be designed so that the entire filter element can be removed and disposed as radioactive or mixed waste. The HEPA filter element will be made from pleated fiberglass, and the filter housing will be stainless steel. Design conditions will be 3 psig and full vacuum at 300 °F.

Silent-Discharge Plasma (R-201, R-202, R-203, and R-204)

The SDP will be built in four sections or cell banks, each with a capacity of at least 10 scfm. Design and fabrication of the SDP will be handled by LANL and is outside the scope of this DDR.

Acid-Gas Scrubber (S-300)

The cooled gases enter the bottom of S-300 and flow upward through the packing material while a circulating sodium hydroxide solution flows counter-currently downward to neutralize the acid gases formed during the oxidation of halogenated compounds. The packing in the column provides vapor-liquid contact area for the neutralization reactions. The bottom section of S-300 serves as a liquid holding tank and provides liquid head for the Scrubber Pump (P-302), which recirculates the sodium hydroxide solution to the top of S-300.

The process design requirements for S-300 are based on Case 2 material balance (see Table 1-2), for 99.9 percent removal of hydrogen chloride from a gas stream having a total flow rate of 207.1 lb/h or 87.3 actual cubic feet per minute (acfm), and containing 3.07 lb/h of hydrogen chloride. The inside diameter of S-300 is estimated at 8 in., and the flow rate of the circulating sodium hydroxide solution will be approximately 2 gal/min. S-300 must be designed so that the pressure drop will not exceed 0.5 in. of water per foot of packing. The estimated packed height of S-300 is 6 ft. The design pressure for S-300 is 3 psig at 300 °F.

Materials of construction for S-300 will be fiberglass-reinforced plastic (FRP), Teflon, or comparable temperature- and corrosion-resistant plastic. The materials should be suitable for extended service in a pH range of 2 to 12. The design will allow for dismantling S-300 for internal inspection and radiological surveys.

As acid gases are converted to salt, the salt concentration in the recirculating liquid increases. As the salt concentration increases, the acid-gas scrubbing efficiency decreases and the potential for scaling increases, necessitating "blowdown" of the scrubber liquid. Increasing salt concentration will cause an increase in conductivity of the salt solution, as measured by the S-300 Conductivity Meter (AE 302-2) and the S-300 Conductivity Transmitter (AT 302-2). When the conductivity reaches the specified maximum, the S-300 Conductivity Indicator/ Controller (AIC 302-2) will cause the S-300 Blowdown Valve (EV 302-2) to open, and the blowdown liquid will be sent to a drum. (Ventilation will be provided so that steam from the drum does not pose a safety hazard.) The weight of the drum is continuously measured by the Scrubber Blowdown Drum Weight Cell (WE 302-6), and an alarm will sound on the control panel when the drum is approximately 90 percent full. This alarm also will trigger an interlock that closes EV 302-2. EV 302-2 will remain closed until the operator resets it by removing the full drum, replacing it with an empty one, and entering "Reset" on the control panel.

Blowdown of S-300 also will be required if the scrubber liquid level is high. In this case, EV 302-2 will open, allowing liquid to flow to the blowdown drum. (However, the interlock that closes EV 302-2 on high blowdown drum level will not allow EV 302-2 to open until the interlock is cleared by removal of the full drum and replacement with an empty drum.) More typically, the scrubber liquid level will slowly drop during normal operation due to vaporization of water by the hot inlet gases and the heat of reaction of the neutralization. A low liquid level will open the S-300 Process Water Supply Shutoff Valve (EV 300-4), bringing the scrubber liquid level back to setpoint.

The pH of the scrubber liquid is maintained at the desired value by adding 50 percent weight per weight (w/w) sodium hydroxide. The pH is measured by the S-300 pH Meter (AE 300-6) and the S-300 pH

Transmitter (AT 300-6), and sodium hydroxide solution is added by the Sodium Hydroxide Addition Pump (P-304).

Scrubber Pump (P-302)

P-302 circulates the sodium hydroxide solution through the Acid-Gas Scrubber (S-300). P-302 is a centrifugal pump with a closed impeller, sized for a flow rate of 2 gal/min (the design liquid rate for S-300) at 40 ft total delivered head. The temperature of the circulating sodium hydroxide solution is 215 °F (maximum), density is 56 to 65 lb/ft³, and viscosity is 0.6 to 1.1 cP. The pH range will normally be maintained between 6 and 8. However, the pump must be designed for a pH range of 2 to 12. Because the sodium hydroxide/salt solution is expected to be corrosive, all wetted parts of P-302 will be Teflon-lined. The pump will be equipped with an electric motor in accordance with Section 2.3 of this report.

Sodium Hydroxide Addition Pump (P-304)

P-304 is a positive-displacement metering pump that supplies 50-percent sodium hydroxide solution to the Acid-Gas Scrubber (S-300). The sodium hydroxide solution (specific gravity of 1.525) is stored in a 55-gal drum. Sodium hydroxide solution is automatically provided to S-300 on low pH as detected by the S-300 pH Indicator/Controller (AIC 300-6). The design flow rate of the pump is 41 cm³/min or 15.5 gal/d of sodium hydroxide solution. Material of construction for all wetted parts is 316 stainless steel.

Because a waste feed may occasionally be received with a pH of less than 2, a sodium hydroxide line also is provided to the Waste Feed Tank (T-010), which has continuous pH monitoring by the T-010 pH Indicator (AI 010-6). Because sodium hydroxide addition to the Waste Feed Tank is not expected to be required frequently, there is no automatic control for the addition, which will be initiated and terminated manually by starting and stopping the pump.

Scrubber Filter (F-306)

F-306 is a basket-type filter installed in the circulating scrubber liquid line to remove metal hydroxides, salt precipitates, and other coarse and potentially plugging solids from the liquid. It is designed to remove 99 percent of all solids 10 microns and larger from a salt-water (pH 4 to 8) solution at a temperature of up to 215 °F.

Water Softener (W-310)

W-310 is designed to remove dissolved salts and metals from process water (potable city water) before it is added to the Quench Chamber (E-110) and the Acid-Gas Scrubber (S-300) to minimize buildup of precipitates in those locations. The maximum combined water rate for the two services is 43.4 lb/h or 0.087 gal/min.

Process Vent Blower (B-320)

B-320 provides the motive force for the gas stream flowing through the PBR/SDP MTU, ensuring that the PBR and the SDP are always operated under a slight negative pressure. B-320 will be sized to deliver 50 scfm at a temperature of 120 °C and a draft of 0.5 psig.

Cooling Water Cooler (CW-400)

CW-400 is a closed-loop, nonevaporative fin-fan cooler that provides the cooling water for the PBR Offgas Cooler (E-112) and the Relief Condenser (E-140). E-140 is only used in emergency situations, during which the PBR feed will be shut off by interlocks. Therefore, the design duty for CW-400 is 40,017 Btu/h, at an inlet temperature of 115 °F and outlet temperature of 95 °F, based on the maximum duty of E-112.

Sulfuric Acid Addition Pump (P-410)

P-410 is a positive-displacement metering pump that supplies concentrated (98 percent w/w) sulfuric acid to the Waste Feed Tank (T-010). The acid solution (specific gravity of 1.84) is stored in a 5-gal carboy. P-410 is identical to the Sodium Hydroxide Addition Pump (P-304), with a design flow rate of 41 cm³/min or 15.5 gal/d. Material of construction for all wetted parts is 316 stainless steel. Sulfuric acid is supplied to the Waste Feed Tank (T-010) when a pH greater than 12 is detected by the T-010 pH Indicator (AI 010-6). Because sulfuric acid addition to the Waste Feed Tank is not expected to be required frequently, there is no automatic control for the acid addition, which will be initiated and terminated manually by starting and stopping the pump.

Air Compressor (AC-420)

AC-420 supplies oxidation air to the PBR (R-100), and compressed air to power the Waste Transfer Pump (P-002) and the Waste Feed Tank Agitator (A-010). The required capacity is 50 acfm at 60 psig minimum supply pressure. Because oil carryover from the air compressor is a potential source of contamination in R-100, AC-420 must be of a dry, oilless design, or must be provided with general-purpose and coalescing filters, oil separators, and bleed ports to ensure that no oil can be entrained in the compressed air.

Antifoam Addition Pump (P-430)

P-430 is a positive-displacement metering pump that supplies antifoam solution to the Waste Feed Tank (T-010). The antifoam solution is stored in a 5-gal carboy, and is automatically provided to T-010 when a high foam level is detected by the T-010 Foam Sensor/Controller (AIC 010-11). The design flow rate of P-430 is 50 cm³/min. Material of construction for all wetted parts is 316 stainless steel.

Nitrogen Supply System (N-450)

N-450 supplies nitrogen to maintain the pressure pad on the Waste Feed Tank (T-010), and the nitrogen "sweep" on the pressure-relief header (see Figures A-2 and A-7 and Appendix C, HAZOP Action Item No. 103). The nitrogen will be stored in standard gas cylinders installed in parallel. The design flow requirement for the system is 2 scfm. The Nitrogen Supply Header Pressure Regulator (PCV 450-1) sets the pressure of the nitrogen supply header from N-450.

2.2.2 Utility Requirements

Electricity

Each site will be expected to provide a single 480-volt, three-phase, 60-hertz electrical supply connection. The PBR/SDP MTU will be equipped with transformers for reducing voltage from this supply to the required voltage for each service on the skid. The preliminary single-line electrical diagram for the MTU,

showing estimated electrical requirements and usage for each service, is presented in Figure A-8 of Appendix A. Electrical requirements are summarized in Table 2-5.

Table 2-5. Electrical Requirements for PBR/SDP MTU

480 VAC Motors		
Tag No.	Description	hp
AC-420	Air Compressor	25
B-320	Process Vent Blower	3
CW-400	Cooling Water Cooler	2
P-302	Scrubber Pump	1
P-402	Cooling Water Pump	0.5
120 VAC Motors		
Tag No.	Description	hp
P-020	Waste Feed Pump No. 1	0.17
P-022	Waste Feed Pump No. 2	0.17
P-024	Waste Feed Pump No. 3	0.17
P-304	Sodium Hydroxide Addition Pump	0.17
P-410	Sulfuric Acid Addition Pump	0.17
P-430	Antifoam Addition Pump	0.17
240/480 VAC Heaters		
Tag No.	Description	kW
H-102	Packed-Bed Reactor Heater No. 1	20
H-104	Packed-Bed Reactor Heater No. 2	20
H-106	Packed-Bed Reactor Heater No. 3	20
H-108	Packed-Bed Reactor Heater No. 4	20
R-201	Silent-Discharge Plasma Cell Bank No. 1	20
R-202	Silent-Discharge Plasma Cell Bank No. 2	20
R-203	Silent-Discharge Plasma Cell Bank No. 3	20
R-204	Silent-Discharge Plasma Cell Bank No. 4	20

Key:

hp = horsepower
 kW = kilowatts
 VAC = voltage, alternating current

Air

An Air Compressor (AC-420) will be installed as part of the PBR/SDP MTU. The estimated maximum air requirements for the PBR/SDP MTU are listed in Table 2-6. The air requirements for P-002 and A-010 will be confirmed during the detailed design.

Table 2-6. Estimated Air Requirements for PBR/SDP MTU

Service	Air Flow (scfm)
Packed-Bed Reactor (R-100)	40
Waste Transfer Pump (P-002)	5
Waste Feed Tank Agitator (A-010)	8

Process Water

Process water is used as the makeup water to the Quench Chamber (E-110) and to the Acid-Gas Scrubber (S-300). Maximum flows for these two services are 20.9 lb/h (60.0 gal/d) and 22.5 lb/h (65 gal/d), respectively. Because both of these maximums occur during treatment of high-chloride waste, the maximum instantaneous consumption of process water is 43.4 lb/h. Process water will be supplied by the sites. A Water Softener (W-310) will be supplied on the process water supply to both E-110 and S-300 to minimize scaling from salts and other dissolved solids.

Cooling Water

Cooling water is required on a continuous basis by the PBR Offgas Cooler (E-112). The maximum cooling water flow rate is 2,005 lb/h (4 gal/min), based on a duty of 40,071 Btu/h and a temperature rise of 20 °F. Cooling water also is continuously circulated through the Relief Condenser (E-140), but it will have no duty except when a release occurs from the Waste Feed Tank (T-010) or the PBR (R-100), which is not anticipated in the lifetime of the MTU. Cooling water for E-112 and E-140 is supplied by the Cooling Water Pump (P-402) from the Cooling Water Cooler (CW-400), a closed-loop, air-cooled water cooler with a required duty of 40,017 Btu/h designed to supply cooling water at a nominal temperature of 95 °F.

Nitrogen

Nitrogen is used to maintain the pressure pad on the Waste Feed Tank (T-010), and the nitrogen "sweep" on the pressure-relief header. The nitrogen will be supplied from the Nitrogen Supply System (N-450), which consists of standard gas cylinders installed in parallel. The design flow requirement for the system is 2 scfm.

Chemicals

The chemicals required for the PBR/SDP MTU are sodium hydroxide, sulfuric acid, and antifoam. Sodium hydroxide will be supplied as a 50-percent solution in 55-gal drums. Sulfuric acid, which will be required in much smaller amounts, will be supplied as a 98-percent solution in 5-gal carboys. Antifoam will also be supplied in 5-gal carboys. Chemicals will be ordered after the MTU arrives at each site, and unused chemicals will remain the property of the site at the conclusion of treatment.

The maximum consumption rate of sodium hydroxide is 3.36 lb/h of pure NaOH, or 6.72 lb/h of 50-percent sodium hydroxide solution. The sodium hydroxide solution will only be required for treatment of halogenated wastes (plus an unknown, but probably very small, amount for any pH adjustment of the feed). Of the seven waste streams currently slated for treatment with PBR/SDP, the following three contain halogenated compounds.

- LA-W 907: Halogenated organic liquids. Total current inventory and estimated 5-year generation is 16.58 m³ (4,381 gal).
- PTX-TG 1.2: Halogenated organic liquids. Total current inventory and estimated 5-year generation is 2.06 m³ (544 gal).
- SNL/NM-TG 11: Uncategorized organic liquids. Total current inventory and estimated 5-year generation is 2.7 m³ (713 gal). Only the grinding sludge portion of this waste is expected to contain halogens.

The halogen concentration in these wastes is not known at this time, so it is not possible to estimate the total sodium hydroxide required. At the maximum rate of consumption, based on treatment of a waste containing 42 percent chloride, a 55-gal drum of sodium hydroxide would last 103 hours of continuous operation. Sodium hydroxide is readily available in most locations, so it would not be necessary to keep more than about two drums of sodium hydroxide on hand at any time.

Sulfuric acid consumption is unknown, but expected to be minimal. The acid will only be used for pH adjustment of the feed and the pH adjustment requirements cannot be calculated at this time because the current pH and buffering properties of the waste streams have not yet been determined. Antifoam usage also is unknown and cannot be determined because the foaming properties of the waste streams have not yet been determined.

2.2.3 Piping/Vessel Specifications

All pressure vessels, associated piping, and piping systems will be designed and fabricated in accordance with ANSI/ASME B31.3, "Chemical Plant and Petroleum Refinery Piping," and ASME Boiler and Pressure Vessel Code, Section VIII, "Rules for Construction of Pressure Vessels" (ASME 1992).

Materials of construction for the major sections of piping of the PBR/SDP MTU are listed as the Pipe Specification on Figure A-1. The pipe specification is the second element in the line numbers shown on the P&IDs (Figures A-2 through A-7). The detailed Pipe Specifications will be developed during the detailed design. Table 2-7 lists the materials of construction corresponding to each pipe specification.

Table 2-7. Piping Materials and Design Requirements for PBR/SDP MTU

Specification Number	Size	Material of Construction	Design Pressure/Temperature (psi/°F)
2.6A	1 in. and larger	High alloy, Haynes HR-160 or equal	15/2,200
2.6B	1 in. and larger	316L Stainless Steel Pipe	50/600
2.6C	3/4 in. and smaller	304 Stainless Steel Tubing	150/300
2.6D	3/4 in. and smaller	Type L Copper Tubing	75/70

Table 2-8 lists all the lines shown on the P&IDs (Figures A-2 through A-7). This line list can be used to cross-reference the stream sheets in Appendix D.

Table 2-8. PBR/SDP MTU Pipe Line List

Size	Line Specification	Number	Service	P&ID
1	2.6B	002-01	Waste from P-002 to F-004	E03456
1	2.6B	002-02	Waste from F-004 to T-010	E03456
1	2.6B	002-03	Waste to Solids Blowdown	E03456
0.5	2.6C	010-01	Waste from T-010 to P-020/2/4	E03456
0.5	2.6C	010-02	T-010 vent to PBR	E03456, E03457

Table 2-8 (continued). PBR/SDP MTU Pipe Line List

Size	Line Specification	Number	Service	P&ID
0.5	2.6C	010-03	Waste to P-020	E03457
0.5	2.6C	010-04	Waste to P-022	E03457
0.5	2.6C	010-05	Waste to P-024	E03457
2	2.6B	010-06	T-010 Pressure Relief to E-140	E03456, E03489
0.5	2.6C	020-01	Waste from P-020 to R-100	E03457
0.5	2.6C	022-01	Waste from P-022 to R-100	E03457
0.5	2.6C	024-01	Waste from P-024 to R-100	E03457
0.75	2.6D	100-01	Air to PBR	E03457
0.5	2.6D	100-02	Air to PBR Nozzle #1	E03457
0.5	2.6D	100-03	Air to PBR Nozzle #2	E03457
0.5	2.6D	100-04	Air to PBR Nozzle #3	E03457
1	2.6A	100-05	PBR Relief to E-140	E03457, E03489
0.25	2.6D	110-01	Quench Water to E-110	E03457, E03458
3	2.6A	110-02	E-110 to E-112	E03457
0.75	2.6D	112-01	CWS to E-112	E03457, E03489
0.75	2.6D	112-02	CWR from E-112	E03457, E03459
2	2.6B	112-03	E-112 to SDP	E03457, E03488
2	2.6B	120-01	F-120 Bypass	E03488
2	2.6B	120-02	F-120/130A/B Bypass	E03488
2	2.6B	120-03	SDP Discharge Return to F-120	E03488
2	2.6B	130-01	F-130A Bypass	E03488
2	2.6B	130-02	F-130A Outlet	E03488
2	2.6B	130-03	F-130B Bypass	E03488
2	2.6B	130-04	F-130B Outlet	E03488
1	2.6B	140-01	E-140 to T-142	E03489
1	2.6B	142-01	T-142 to F-144	E03489
1	2.6B	144-01	F-144 to Vent	E03489
1	2.6B	201-01	R-201 Inlet	E03488
1	2.6B	201-02	R-201 Outlet	E03488
2	2.6B	201-03	SDP Outlet to S-300	E03488, E03458
1	2.6B	202-01	R-202 Inlet	E03488
1	2.6B	202-02	R-202 Outlet	E03488
1	2.6B	203-01	R-203 Inlet	E03488
1	2.6B	203-02	R-203 Outlet	E03488
1	2.6B	204-01	R-204 Inlet	E03488
1	2.6B	204-02	R-204 Outlet	E03488
1.5	2.6B	300-01	S-300 Bypass	E03458
2	2.6B	300-02	S-300 Outlet	E03458, E03489
0.25	2.6D	300-03	Process Water to S-300	E03458
0.5	2.6C	300-04	S-300 to P-302 Circulating Liquid	E03458
0.5	2.6C	302-01	P-302 to S-300 Circulating Liquid	E03458

Table 2-8 (continued). PBR/SDP MTU Line List

Size	Line Specification	Number	Service	P&ID
0.5	2.6C	302-02	S-300 Blowdown	E03458
0.25	2.6C	304-01	Caustic Header	E03459
0.25	2.6C	304-02	Caustic to S-300	E03458, E03459
0.25	2.6C	304-03	Caustic to T-010	E03456, E03459
2	2.6B	320-01	B-320 to Vent	E03489
0.75	2.6D	400-01	CW-400 to P-402	E03459
0.75	2.6D	402-01	CWS to E-140	E03459, E03489
0.25	2.6C	410-01	Sulfuric Acid to T-010	E03456, E03459
0.75	2.6D	420-01	Main Air Header	E03459
0.5	2.6D	420-02	Air to A-010	E03456, E03459
0.375	2.6D	420-03	Air to P-002	E03456, E03459
0.75	2.6D	420-04	Air from AC-420 to PBR	E03457, E03459
0.25	2.6C	430-01	Antifoam to T-010	E03456, E03459
0.5	2.6D	450-01	Nitrogen Supply to T-010	E03456, E03459
0.5	2.6D	450-02	Nitrogen Sweep to Relief Header	E03456, E03459

Corrosion Allowance

The general corrosion allowance will be 1/8 in. for a 20-year design life. Averaging 1/8 in. over 20 years allows 0.00625 in. of corrosion per year (6.25 mil/year or 158.8 micrometers/year).

Corrosion rates for high-temperature nickel-alloy materials of construction in extremely high temperature, high-chloride services are not well defined. Corrosion allowances for equipment in these services (e.g., R-100 and E-110) will be set during the detailed design, in consultation with the alloy manufacturer.

Welds

At a minimum, all pressure vessel welds will be spot radiographed. Specific equipment welds are detailed in Section 2.2.1. All radiological service piping welds and welded fittings will be 100 percent radiographed.

Fittings

All nickel-alloy piping will be lap-joint flanged to eliminate expensive fittings and welding.

Skid Breaks

Where piping extends across skid or shipping break boundaries, flange pairs shall be provided at the skid interface so that the piping can be disconnected and blinded on both skids for transportation.

2.2.4 Process Control

The control logic for the PBR/SDP MTU is shown on the P&IDs (Appendix A). Principal control loops include the following.

- Waste feed rate to the PBR (R-100) will be operator specified using the Total Waste Feed Flow Indicator/ Controller (FIC 010-8). The flow setpoint of FIC 010-8 will be divided by the total number of operating Feed Pumps (P-020, P-022, and P-024), as indicated by the position of the pump run/stop switches. The result is used as the setpoint for the Feed Pump flow controllers (FIC 020/022/024-2), which adjust the rates of the Feed Pumps so that the overall feed rate is maintained and divided equally among the operating feed nozzles.
- Air rate to R-100 will be operator specified using the R-100 Total Air Flow Indicator/Controller (FIC 100-11). The flow setpoint of FIC 100-11 will be divided by the total number of operating feed nozzles, as indicated by the position of the R-100 Nozzle Air Flow Solenoid Valves (EV 100-5, EV 100-6, and EV 100-7). The result is used as the setpoint for the R-100 Nozzle Air Flow Indicator/ Controllers (FIC 100-5, FIC 100-6, and FIC 100-7), which adjust the position of the air flow control valves so that the overall air rate is maintained and divided equally among the operating feed nozzles.
- Temperatures of the zones in R-100 are individually controlled using four heater Temperature Indicator/Controllers (TIC 100-1, TIC 100-2, TIC 100-3, and TIC 100-4). Setpoints for the controllers are set by the operator.
- The maximum temperature in the bed is determined by taking the maximum reading from the four R-100 Temperature Indicator/Controllers (TIC 100-1, TIC 100-2, TIC 100-3, and TIC 100-4) and the three R-100 Midzone Temperature Indicators (TI 100-16, TI 100-17, and TI 100-18). The result of this calculation is stored as the R-100 Maximum Temperature Indicator/Controller (TIC 100-19). If the reading on TIC 100-19 exceeds the high alarm point (normally 1100 °C), the setpoint to the R-100 Total Air Flow Indicator/Controller (FIC 100-11) will be automatically increased.
- Pressure at R-100 inlet (top) is controlled by the R-100 Inlet Pressure Indicator/Controller (PIC 100-8), which will adjust and balance the flow through the SDP cells as needed to maintain the setpoint (see below).
- Water flow to the Quench Chamber (E-110), when needed, will be controlled by the Quench Water Flow Indicator/Controller (FIC 110-1) to maintain the quench outlet temperature setpoint of the E-110 Outlet Temperature Indicator/Controller (TIC 110-2), which will be operator specified.
- Cooling water flow to the PBR Offgas Cooler (E-112) will be controlled by the E-112 Cooling Water Flow Indicator/Controller (FIC 112-1) to maintain the SDP inlet temperature setpoint (normally 120 °C or 248 °F) of the E-112 Outlet Temperature Indicator/Controller (TIC 112-2).
- Feed rates to the SDP cell banks are controlled by the four Inlet Flow Indicators/Controllers (FIC 201-1, FIC 202-1, FIC 203-1, and FIC 204-1). The flow rate to the four banks is totaled and then divided by the number of banks operating to obtain the required setpoint for all four controllers. An additional input comes from the R-100 Inlet Pressure Indicator Controller (PIC 100-8), which will cause the SDP Flow Control Valves (FCV 201-1, FCV 202-1, FCV 203-1, and FCV 204-1) to adjust as needed to compensate for changes in the total feed to R-100. This control loop is disabled when the SDP is not in service. (It may be possible to replace this control system with symmetrical piping without compromising uniform flow distribution. This will be investigated during detailed design.)

- The pH of the circulating solution in the Acid-Gas Scrubber (S-300) is controlled by the S-300 pH Indicator/Controller (AIC 300-6), which will activate the Sodium Hydroxide Addition Pump (P-304) as needed to add sodium hydroxide solution and maintain the specified scrubber pH.
- The salt concentration in S-300 is controlled by the S-300 Conductivity Indicator/Controller (AIC 302-2), which will open the S-300 Blowdown Valve (EV 302-2) as needed to maintain the specified scrubber solution conductivity.
- S-300 is designed to constantly evaporate a small amount of water. The scrubber liquid level is maintained by the S-300 Level Indicator (LI 300-4), which will open the S-300 Process Water Supply Shutoff Valve (EV 300-4) when a low scrubber liquid level is detected, letting in process water to maintain the scrubber level. If S-300 gains rather than loses liquid level (due to system heat losses being much greater than anticipated), LI 300-4 will open EV 302-2 to bring the level back to the setpoint.
- The overall pressure drop across the PBR/SDP MTU is controlled by the MTU Pressure Differential Indicator/Controller (PDIC 100-14), which adjusts the B-320 Inlet Vanes Positioner (ZC 320-2) on the Process Vent Blower (B-320) as needed to maintain the specified setpoint.
- Control of pH in the Waste Feed Tank (T-010) is manual. The pH is monitored by the T-010 pH Indicator (AI 010-6), which will alarm when the pH drops below 3, signaling a need to add sodium hydroxide solution, or above 11, signaling a need to add sulfuric acid.
- Antifoam is added to T-010 automatically when a high foam level is detected by the T-010 Foam Sensor/Controller (AIC 010-11), which will start the Antifoam Addition Pump (P-430) and add antifoam as needed.
- The pressure in T-010 is controlled by the T-010 Pressure Indicator/Controller (PIC 010-2). When liquid waste is added to T-010, PIC 010-2 will open the T-010 Pressure Control Valve (PCV 010-2A), venting the displaced vapors to R-100. During normal operation, the liquid level in T-010 will slowly drop as liquid waste is withdrawn. To maintain the pressure in T-010, PIC 010-2 will open the low pressure T-010 Pressure Control Valve (PCV 010-2B) as needed to allow nitrogen to flow into T-010. When R-100 is out of service (as indicated by a closed R-100 Air Shutoff Valve [EV 100-11]), or either too cold to adequately treat vapors or too hot for vapors to be added safely (as indicated by the R-100 Maximum Temperature Indicator/Controller [TI 100-19]), an interlock will close the T-010 Vent Shutoff Valve (EV 010-9) so that waste tank vapors will not be vented to R-100. To prevent overpressurizing the waste feed tank by addition of waste when the vent line is closed, another interlock will close the air supply line to the Waste Transfer Pump (P-002) on high pressure in the waste tank as indicated by the T-010 Pressure Indicator (PIC 010-2).

Process Control Hardware

Logic control will be handled by an Allen-Bradley programmable logic controller (PLC) with digital data interface. All transducers will either have digital input and output (I/O) capability, or will be converted to digital I/O.

Interlocks

The process control system described above may be thought of as "analog" in the sense that the values of the operating parameters that are monitored by the various control loops vary continuously, and the system

continuously adjusts the controlled parameters to keep the actual values at the desired setpoints. The design of the PBR/SDP MTU control system includes a number of "discrete" points, such as low-flow switches, which generate a digital on/off signal when a discrete setting is reached. Also, the analog measurements can generate discrete alarm signals when the actual value of a measurement deviates unacceptably from the desired value, such as when the actual value is very high, or high-high (HH), compared to its intended value, or when it is very low, or low-low (LL).

Many of these discrete points activate interlocks that take additional discrete actions such as opening or closing valves, or stopping pumps, when a deviation from normal operating conditions would make continuing that operation unsafe or otherwise undesirable. Interlocks also may serve as "permissives" by not permitting operations to be done at inappropriate times. Some interlocks may serve both purposes. An example is Interlock 4, which does not allow EV 010-10, the T-010 vent valve, to open and vent the organic/nitrogen mixture in the head space of T-010 into R-100 if any of three conditions exist:

- The main air flow valve to R-100 (EV 100-11) is closed.
- The temperature in R-100 (TI 100-19) is too low (LL) for efficient oxidation.
- TI 100-19 is too high (HH) to safely allow additional organics to be added.

Under the first condition in this example, Interlock 4 functions as a permissive and under the third condition it is a safety shutdown. Under the second condition, Interlock 4 functions primarily as a permissive because the most likely reason for TI 100-19 to be too low is that R-100 is out of service. However, if the temperature in R-100 should drop below the LL setpoint during operation, the interlock also will serve as a safety shutdown of the T-010 vent line.

Interlocks are indicated on the P&IDs (Appendix A) using diamond symbols. A summary of the interlocks is provided in Table 2-9.

The interlock classification is assigned according to the ranking criteria and guidelines listed in Table 2-10. Note that because the hazard potential of the PBR/SDP process is very low, no interlock classification higher than 4 has been assigned for the PBR/SDP MTU.

Table 2-9. Interlock Description

No.	Initiation	Condition	Output	Action	Interlock Class
1	PI 010-2	HH	HS 002-3	Close EV 002-3	4
2	LI 010-4	HH	HS 002-3	Close EV 002-3	4
	LI 010-7	HH			
3	LI 010-4	LL	HS 010-1	Close EV 010-1	4
	LI 010-7	LL			
4	EV 100-11	Closed	EV 010-10	Close	4
	TI 100-19	HH			
	TI 100-19	LL			

Table 2-9 (continued). Interlock Description

No.	Initiation	Condition	Output	Action	Interlock Class
5	FI 100-11	LL	HS 020-2	Close	4
			IC 100-1	Power Off	
			IC 100-2	Power Off	
			IC 100-3	Power Off	
			IC 100-4	Power Off	
6	PI 100-8	HH	HS 020-2	Close	4
	TI 100-12	HH	EV 010-10	Close	
	TIC 110-2	HH	IC 100-1	Power Off	
	PDI 100-13	HH	IC 100-2	Power Off	
	PSH 010-10	Fail	IC 100-3	Power Off	
	TIC 112-2	HH	IC 100-4	Power Off	
	FSL 140-1	LL			
	Operator Initiation				
7	Operator Initiation		HS 200-2	Bypass	4
	TIC 112-2	HH			
	TIC 112-2	LL			
8	Operator Initiation		HS 300-7	Bypass	4
	LI 300-4	HH			
	YA 302-5	Fail			
	AIC 302-2	HH			
9	FI 302-4	LL	HS 302-5	Stop	4
	LI 300-4	LL	HS 300-7	Bypass	
10	TI 010-3	HH	HS 020-2	Stop	4
	TI 020-3	HH			
	TI 100-19	HH			
	AIC 300-6	LL			
	AIC 302-2	HH			
11	FIC 100-7	LL	HS 020-1	Stop	4
12	FIC 100-8	LL	HS 022-1	Stop	4

Table 2-9 (continued). Interlock Description

No.	Initiation	Condition	Output	Action	Interlock Class
13	FIC 100-9	LL	HS 024-1	Stop	4
14	Operator Initiation		HS 200-2	Bypass	4
			HS 200-3	Bypass	

Key:

HH = high-high

LL = low-low

Table 2-10. Interlock Classifications

Interlock Class	Hazard Description	Level of Protection Required
1	Loss of life or major property damage outside plant boundary.	Hard-wired with redundant instrumentation, diverse types.
2	Loss of life or major property damage within plant boundary.	Hard-wired with redundant instrumentation, may be same type.
3	Property damage or loss of production.	Hard-wired, single instrument.
4	Process desirability.	Software

2.3 Electrical

The electrical service connection to the PBR/SDP MTU will be supplied in accordance with the utility requirements noted in Section 2.2.2 of this report. The electrical classification of the MTU, excluding any utilities which may be sited outdoors, will be National Electrical Code Class 1, Division 2, Group D. All motors will be specified with a 1.15 service factor or for continuous operation at 7,500 ft of elevation. The PBR/SDP Electrical Distribution is presented in Figure A-8.

2.4 Instrument List

Table 2-11 lists the instruments required in the PBR/SDP MTU design. Instruments which interface with the PLC are identified as AI (analog input), AO (analog output), DI (digital input), or DO (digital output). The control logic is presented in the P&IDs (Appendix A).

Table 2-11. Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
PI 002-1	P-002 Discharge Pressure Gauge	0-100 psi					E03456
PCV 002-2	P-002 Air Supply Pressure Regulator	0-60 psig					E03456
PI 002-2	P-002 Air Supply Pressure Gauge	0-100 psi					E03456
EV 002-3	P-002 Air Supply Shutoff Valve				1	1	E03456
HS 002-3	P-002 Air Supply Shutoff Switch				1	1	E03456
EV 010-1	A-010 Air Supply Shutoff Valve				1	1	E03456
HS 010-1	A-010 Air Supply Shutoff Switch				1	1	E03456
PT 010-2	T-010 Pressure Transmitter	0-50 psi	1				E03456
PIC 010-2	T-010 Pressure Indicator/Controller	Split		1			E03456
PCV 010-2A	T-010 Pressure Control Valve (High Pressure)	2 scfm					E03456
PCV 010-2	T-010 Pressure Control Valve (Low Pressure)						E03456
TE 010-3	T-010 Temperature Element	0-100 °C					E03456
TT 010-3	T-010 Temperature Transmitter		1				E03456
TI 010-3	T-010 Temperature Indicator			1			E03456
LE 010-4	T-010 Level Element	0-60 in.					E03456
LT 010-4	T-010 Level Transmitter		1				E03456
LI 010-4	T-010 Level Indicator			1			E03456
PSE 010-5	T-010 Relief Rupture Disk	45 psig					E03456
PI 010-5	T-010 Relief Tell-Tale Gauge	0-50 psi					E03456
PSV 010-5	T-010 Relief Valve	50 psig					E03456
AE 010-6	T-010 pH Meter	pH 1-14					E03456
AT 010-6	T-010 pH Transmitter		1				E03456
AI 010-6	T-010 pH Indicator			1			E03456
LE 010-7	T-010 Level Element	0-60 in.					E03456
LT 010-7	T-010 Level Transmitter		1				E03456
LI 010-7	T-010 Level Indicator			1			E03456
FE 010-8	Total Waste Feed Flow Meter	0-75 gal/d					E03456
FT 010-8	Total Waste Feed Flow Transmitter		1				E03456
FIC 010-8	Total Waste Feed Flow Controller			1			E03456
EV 010-10	T-010 Vent Shutoff Valve				1	1	E03456
AE 010-11	T-010 Foam Sensor Element	Conductivity	1				E03456
AT 010-11	T-010 Foam Sensor Transmitter			1			E03456
AIC 010-11	T-010 Foam Sensor Indicator/Controller						E03456

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
LG 010-12	T-010 Sight Glass						E03456
HS 020-1	P-020 Start/Stop Switch				1	1	E03457
YL 020-1	P-020 Run Indication				1	1	E03457
YA 020-1	P-020 Fail Indication				1	1	E03457
HS 020-3	P-020/022/024 Start/Stop Switch				1	1	E03457
FE 020-2	P-020 Flow Element	0-25 gal/d	1				E03457
FT 020-2	P-020 Flow Transmitter			1			E03457
FI 020-2	P-020 Flow Indicator						E03457
HS 022-1	P-022 Start/Stop Switch				1	1	E03457
YL 022-1	P-022 Run Indication				1	1	E03457
YA 022-1	P-022 Fail Indication				1	1	E03457
FE 022-2	P-022 Flow Element	0-25 gal/d	1				E03457
FT 022-2	P-022 Flow Transmitter			1			E03457
FI 022-2	P-022 Flow Indicator						E03457
HS 024-1	P-024 Start/Stop Switch				1	1	E03457
YL 024-1	P-024 Run Indication				1	1	E03457
YA 024-1	P-024 Fail Indication				1	1	E03457
FE 024-2	P-024 Flow Element	0-25 gal/d	1				E03457
FT 024-2	P-024 Flow Transmitter			1			E03457
FI 024-2	P-024 Flow Indicator						E03457
IC 100-1	R-100 Zone 1 Heater Controller	0-20 kW		1			E03457
TE 100-1	R-100 Zone 1 Temperature Element	0-1,200 °C	1				E03457
TIC 100-1	R-100 Zone 1 Temperature Indicator/Controller			1			E03457
IC 100-2	R-100 Zone 2 Heater Controller	0-20 kW		1			E03457
TE 100-2	R-100 Zone 2 Temperature Element	0-1,200 °C	1				E03457
TIC 100-2	R-100 Zone 2 Temperature Indicator/Controller			1			E03457
IC 100-3	R-100 Zone 3 Heater Controller	0-20 kW		1			E03457
TE 100-3	R-100 Zone 3 Temperature Element	0-1,200 °C	1				E03457
TIC 100-3	R-100 Zone 3 Temperature Indicator/Controller			1			E03457
IC 100-4	R-100 Zone 4 Heater Controller	0-20 kW		1			E03457
TE 100-4	R-100 Zone 4 Temperature Element	0-1,200 °C	1				E03457
TIC 100-4	R-100 Zone 4 Temperature Indicator/Controller			1			E03457
FE 100-5	R-100 Air Flow Element No. 1	0-20 scfm	1				E03457
FT 100-5	R-100 Nozzle Air Flow Transmitter No. 1			1			E03457

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
FIC 100-5	R-100 Nozzle Air Flow Indicator/Controller No. 1						E03457
FE 100-6	R-100 Nozzle Air Flow Element No. 2	0-20 scfm	1				E03457
FT 100-6	R-100 Nozzle Air Flow Transmitter No. 2			1			E03457
FIC 100-6	R-100 Nozzle Air Flow Indicator/Controller No. 2						E03457
FE 100-7	R-100 Nozzle Air Flow Element No. 3	0-20 scfm	1				E03457
FT 100-7	R-100 Nozzle Air Flow Transmitter No. 3			1			E03457
FIC 100-7	R-100 Nozzle Air Flow Indicator/Controller No. 3	0-20 scfm					E03457
PT 100-8	R-100 Inlet Pressure Transmitter		1				E03457
PIC 100-8	R-100 Inlet Pressure Indicator/Controller	0-50 in. water vacuum		1			E03457
PSE 100-10	R-100 Relief Rupture Disk	3 psig					E03457
PSH 100-10	R-100 Relief Rupture Disk Burst Indicator				1		E03457
EV 100-11	R-100 Air Shutoff Valve				1	1	E03457
FE 100-11	R-100 Total Air Flow Element	0-50 scfm	1				E03457
FT 100-11	R-100 Total Air Flow Transmitter			1			E03457
FI C100-11	R-100 Total Air Flow Indicator/Controller						E03457
TE 100-12	R-100 Outlet Temperature Element	0-1,200 °C	1				E03457
TI 100-12	R-100 Outlet Temperature Indicator			1			E03457
PDT 100-13	R-100 Pressure Differential Transmitter		1				E03457
PDI 100-13	R-100 Pressure Differential Indicator	0-50 in. water		1			E03457
PI 100-14	R-100 Outlet Pressure Gauge	0-50 in. water vacuum					E03457
PT 100-15	R-100 Air Supply Pressure Transmitter		1				E03457
PI 100-15	R-100 Air Supply Pressure Indicator	0-20 psi		1			E03457
TE 100-16	R-100 Midzone Temperature Element No. 1	0-1,200 °C	1				E03457
TI 100-16	R-100 Midzone Temperature Indicator No. 1			1			E03457
TE 100-17	R-100 Midzone Temperature Element No. 2	0-1,200 °C	1				E03457
TI 100-17	R-100 Midzone Temperature Indicator No. 2			1			E03457
TE 100-18	R-100 Midzone Temperature Element No. 3	0-1,200 °C	1				E03457
TI 100-18	R-100 Midzone Temperature Indicator No. 3			1			E03457
TIC 100-19	R-100 Maximum Temperature Indicator/Controller	0-1,200 °C		1			E03457
FE 110-1	Quench Water Flow Meter	0-25 lb/h					E03457
FT 110-1	Quench Water Flow Transmitter		1				E03457
FIC 110-1	Quench Water Flow Indicator/Controller			1			E03457

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
TE 110-2	E-110 Outlet Temperature Element	0-600 °C	1				E03457
TIC 110-2	E-110 Outlet Temperature Indicator/Controller			1			E03457
EV 110-3	Quench Water Flow Shutoff Valve				1	1	E03457
FE 112-1	E-112 Cooling Water Flow Meter	0-25 lb/h					E03457
FT 112-1	E-112 Cooling Water Flow Transmitter		1				E03457
FIC 112-1	E-112 Cooling Water Flow Indicator/Controller			1			E03457
TE 130-3	E-112 Outlet Temperature Element	0-200 °C	1				E03457
TIC 130-3	E-112 Outlet Temperature Indicator/Controller			1			E03457
PI 112-3	E-112 Outlet Pressure Indicator	0-100 in. water vacuum		1			E03457
PSV 112-4	E-112 Cooling Water Relief Valve	50 psig					E03457
AE 112-5	E-112 Outlet CO/CO ₂ Analyzer Element	0-5% (v/v)	1				E03457
AT 112-5	E-112 Outlet CO/CO ₂ Analyzer Transmitter			1			E03457
AI 112-5	E-112 Outlet CO/CO ₂ Analyzer Indicator						E03457
PDT 120-1	F-120 Pressure Differential Transmitter	0-10 in. water	1				E03488
PDI 120-1	F-120 Pressure Differential Indicator			1			E03488
PDI 130-1	F-130A Local Pressure Differential Indicator	0-10 in. water					E03488
PDI 130-2	F-130B Local Pressure Differential Indicator	0-10 in. water					E03488
HS 200-2	SDP Bypass Hand Switch				1	1	E03488
HS 200-3	SDP/Filter Inversion Hand Switch				1	1	E03488
FE 201-1	R-201 Inlet Flow Meter	0-20 scfm					E03488
FT 201-1	R-201 Inlet Flow Transmitter		1				E03488
FIC 201-1	R-201 Inlet Flow Indicator/Controller			1			E03488
FE 202-1	R-202 Inlet Flow Meter	0-20 scfm					E03488
FT 202-1	R-202 Inlet Flow Transmitter		1				E03488
FIC 202-1	R-202 Inlet Flow Indicator/Controller			1			E03488
FE 203-1	R-203 Inlet Flow Meter	0-20 scfm					E03488
FT 203-1	R-203 Inlet Flow Transmitter		1				E03488
FIC 203-1	R-203 Inlet Flow Indicator/Controller			1			E03488
FE 204-1	R-204 Inlet Flow Meter	0-20 scfm					E03488
FT 204-1	R-204 Inlet Flow Transmitter		1				E03488
FIC 204-1	R-204 Inlet Flow Indicator/Controller			1			E03488
TE 201-2	SDP Outlet Piping Temperature Element	0-300 °F	1				E03458

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
TIC 201-2	SDP Outlet Piping Temperature Indicator/Controller			1			E03458
IC201-2	SDP Outlet Piping Heat Tracing Power Controller						E03458
PDT 300-1	S-300 Pressure Differential Transmitter		1				E03458
PDI 300-1	S-300 Pressure Differential Indicator	0-10 in. water		1			E03458
TE 300-2	S-300 Outlet Temperature Element	0-200 °C	1				E03458
TI 300-2	S-300 Outlet Temperature Indicator			1			E03458
PT 300-3	S-300 Outlet Pressure Element		1				E03458
PI 300-3	S-300 Outlet Pressure Indicator	0-100 in. water vacuum		1			E03458
EV 300-4	S-300 Process Water Supply Shutoff Valve				1	1	E03458
LT 300-4	S-300 Level Transmitter		1				E03458
LI 300-4	S-300 Level Indicator			1			E03458
LG 300-5	S-300 Level Sight Glass	0-24 in.					E03458
AE 300-6	S-300 pH Meter	pH 1-14					E03458
AT 300-6	S-300 pH Transmitter		1				E03458
AIC 300-6	S-300 pH Indicator/Controller			1			E03458
HS 300-7	Scrubber Bypass Hand Switch				1	1	E03458
PSV 300-9	S-300 Relief Valve	3 psig					E03458
AE 300-10	Vent Gas CO/CO ₂ Analyzer		1				E03458
AT 300-10	Vent Gas CO/CO ₂ Transmitter			1			E03458
AI 300-10	Vent Gas CO/CO ₂ Indicator						E03458
PI 302-1	P-302 Discharge Pressure Gauge	0-30 psig					E03458
AE 302-2	S-300 Conductivity Meter	0-300 mmhos/cm					E03458
AT 302-2	S-300 Conductivity Transmitter		1				E03458
AIC 302-2	S-300 Conductivity Indicator/Controller			1			E03458
EV 302-2	S-300 Blowdown Valve				1	1	E03458
HS 302-2	EV 302-2 Cutout Hand Switch				1	1	E03458
FE 302-4	P-302 Circulation Flow Meter	0-4 gal/min					E03458
FT 302-4	P-302 Circulation Flow Transmitter		1				E03458
FI 302-4	P-302 Circulation Flow Indicator			1			E03458
HS 302-5	P-302 Start/Stop Switch				1	1	E03458
YL 302-5	P-302 Run Indicator				1	1	E03458

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
YA 302-5	P-302 Fail Indicator				1	1	E03458
WE 302-6	Scrubber Blowdown Drum Weight Cell	0-600 lb					E03458
WT 302-6	Scrubber Blowdown Drum Weight Transmitter		1				E03458
WI 302-6	Scrubber Blowdown Drum Weight Indicator			1			E03458
PDI 306-1	F-306 Differential Pressure	0-5 psi					E03458
PDIC 100-14	MTU Pressure Differential Indicator/Controller	0-100 in. water		1			E03489
FSL 140-1	E-140 Cooling Water Low-Flow Switch					1	E03489
PSV 140-2	E-140 Cooling Water Relief Valve	50 psig					E03489
PT 140-3	Relief Header Pressure Transmitter	0-10 psig	1				E03489
PI 140-3	Relief Header Pressure Indicator			1			E03489
PDI 144-1	F-144 Pressure Differential Indicator	0-10 in. water	1	1			E03489
PT 300-8	B-320 Suction Pressure Transmitter	0-100 in. water vacuum	1				E03489
PI 300-8	B-320 Suction Pressure Indicator			1			E03489
HS 320-1	B-320 Start/Stop Switch				1	1	E03489
YL 320-1	B-320 Run Indicator				1	1	E03489
YA 320-1	B-320 Fail Indicator				1	1	E03489
ZC 320-2	B-320 Inlet Vane Positioner						E03489
AE 320-3	Process Vent VOC Meter						E03489
AIT 320-3	Process Vent VOC Indicator/Transmitter		1				E03489
AI 320-3	Process Vent VOC Indicator			1			E03489
EV 320-4	Process Vent VOC Shutoff Valve				1	1	E03489
HS 304-1	P-304 Start/Stop Switch				1	1	E03459
YL 304-1	P-304 Run Indicator				1	1	E03459
YA 304-1	P-304 Fail Indicator				1	1	E03459
WE 304-2	Sodium Hydroxide Drum Weight Cell	0-1,000 lb					E03459
WT 304-2	Sodium Hydroxide Drum Weight Transmitter		1				E03459
WI 304-2	Sodium Hydroxide Drum Weight Indicator			1			E03459
HS 402-1	P-402 Start/Stop Switch				1	1	E03459
YL 402-1	P-402 Run Indicator				1	1	E03459
YA 402-1	P-402 Fail Indicator				1	1	E03459
HS 410-1	P-410 Start/Stop Switch				1	1	E03459
YL 410-1	P-410 Run Indicator				1	1	E03459
YA 410-1	P-410 Fail Indicator				1	1	E03459

Table 2-11 (continued). Instrument List

Tag No.	Description	Range	AI	AO	DI	DO	Drawing No.
HS 430-1	P-430 Start/Stop Switch				1	1	E03459
YL 430-1	P-430 Run Indicator				1	1	E03459
YA 430-1	P-430 Fall Indicator				1	1	E03459
PCV 450-1	Nitrogen Supply Header Pressure Regulator	0-20 psig					E03459
PSV 450-2	Nitrogen Supply Header Relief Valve	20 psig					E03459
Total			49	56	40	43	

Key:

AI = analog input
 AO = analog output
 DI = digital input
 DO = digital output

2.5 Modular Design

Skids for modular transport of the PBR/SDP MTU will be restricted to 8 ft wide x 10 ft long x 11.5 ft high. When fully assembled, the maximum height of the MTU must not exceed 18 ft. Each skid will be required to fit on a standard "low boy" truck bed without requiring special height or width clearance restrictions.

Each skid will consist of process equipment mounted on a painted, carbon-steel, skid-mounted frame that will conform to DOT regulations for the transportation of mobile chemical equipment. The skid-mounted frames will be designed for all operating and seismic loads in accordance with the American Institute of Steel Construction (AISC) "Specifications for Structural Steel Buildings, Allowable Stress Design and Plastic Design," (AISC 1989). Seismic loading will be evaluated using the static force procedure. Temporary loading conditions due to commissioning, decommissioning, and transport will be considered. Although lifting the skids with cranes is not anticipated, each skid will be equipped with "pick-points" for lifting if necessary.

Radiological Shipment

The PBR/SDP MTU will be designed with the goal of being transported and labeled as "Radioactive Material, Excepted Package — Limited Quantity (of material)" as defined in 49 CFR 173.443. The DOT requirements for shipping the PBR/SDP MTU in this manner are

- The unit must be RCRA empty (less than 3 percent full of liquid).
- The unit must have less than 0.5 mrem/h exposure on the external surface.
- The removable contamination on the external surfaces must be less than those levels specified in 49 CFR 173.443.
- The unit must contain less than 15 grams of uranium-235.
- The unit must be secured during shipment so that no leakage can occur.

The surface contamination inside the PBR/SDP MTU is not regulated if being shipped "limited quantity." However, the materials of construction for the MTU will be chosen so that the MTU is easily decontaminated. Construction will include equipping the tanks with portals, manholes, etc., to allow access for internal inspection and radiological surveys. In addition, all wetted surface materials upstream of the SDP Inlet HEPA Filters (F-130A and F-130B) will be polished to a Roughness Height Index Value of 4 as outlined in ANSI/ASME B46.1.

3.0 Feed Preparation Requirements

The preliminary hazards and operability (HAZOP) analysis of the PBR/SDP MTU (see Section 7.9 and Appendix C) identified the waste transfer operation as potentially the most troublesome area, because of possible personnel exposure issues and because of the unpredictability of the wastes, which may contain multiple immiscible layers, high concentrations of solids, tars and other gummy, high-viscosity materials, or all of the above at once. At this time, waste characterization is incomplete, making determination of the level of protection and/or pretreatment required during operation of the PBR/SDP MTU problematic. Protection and pretreatment options will have to be evaluated during the detailed design process. Use of a drum unloading glovebox, similar in concept to that being built for the VAC*TRAX thermal desorption MTU may be the most practical solution for this function.

In general, the PBR/SDP MTU can accept liquid feed streams of virtually any composition, from 100 percent hydrocarbon oils to 100 percent water. The MTU also can accept slurries containing fine solids, provided that the particle size is less than 1/8 in. Wastes slated for treatment in the PBR/SDP MTU will be filtered as they are unloaded from the waste drums to remove coarse solids by passing the waste feed through the Strainer (F-004). This Y-type strainer assembly with a 1/8-in. (maximum) screen will remove solids that might otherwise plug the spray nozzles.

Feeds with a pH of less than 3 or greater than 11 potentially can damage the metallurgy of the PBR (R-100). Therefore, the pH of the waste feed will be adjusted in the Waste Feed Tank (T-010) by adding sodium hydroxide or sulfuric acid when appropriate. Because pH adjustment is not expected to be a routine operation, addition of sulfuric acid or sodium hydroxide will be initiated and terminated manually by starting and stopping the appropriate pump.

Because the primary function of the PBR/SDP MTU is treatment of organic mixed wastes, it is possible that some wastes slated for treatment with this technology may include tarry or gummy liquids of high viscosity. Such liquids will not atomize in the spray nozzles and, thus, would not be suitable for treatment with the present PBR technology. In the absence of detailed information about the wastes, no explicit provision has been made in the DDR for pretreatment of high-viscosity liquids. These liquids potentially could be treated by mixing them with a low-viscosity solvent and pumping the resultant mixture into the Waste Feed Tank (T-010). Provisions for such an operation have not been included in this DDR, but may be addressed during the detailed design process as part of the greater feed preparation issue discussed above.

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4.0 Waste Acceptance Criteria

The PBR/SDP MTU will be designed for treatment of liquid mixed organic and aqueous waste streams containing RCRA hazardous compounds. PBR/SDP technology has also been demonstrated on surrogates for waste streams containing TSCA wastes (e.g., PCBs), although no such wastes are presently slated for treatment with the MTU.

PBR/SDP is a robust and "forgiving" technology that can successfully treat a wide variety of liquid organic and aqueous waste streams. However, wastes exhibiting certain characteristics, as detailed below, are not appropriate for treatment with PBR/SDP technology. Wastes that will be excluded are those exhibiting any of the following properties or characteristics.

- **Reactivity:** The waste must not contain pyrophorics or explosives (40 CFR 261).
- **Criticality:** Radionuclide content shall be verified to limit the total radionuclide inventory within the PBR/SDP system to no more than one-tenth the critical mass.
- **Pathogenic waste or etiological agents.** (Wastes with these characteristics should not be part of mixed-waste inventory.)

Other waste characteristics, while not necessarily sufficient to disqualify a waste stream from treatment with PBR/SDP, can cause operability problems in the MTU. The remainder of this section deals with waste characteristics in these "gray areas" that may or may not cause specific wastes to be excluded from treatment with PBR/SDP.

Gaseous materials: PBR/SDP technology is capable of destroying gas-phase organics. However, because the PBR technology has only been demonstrated on liquids, the design presented in this DDR does not have the capability for opening gas cylinders and metering the gas flow into the PBR. Such capability may be retrofitted to the MTU after it is operational, but is outside the scope of this DDR.

Slurries: The PBR/SDP technology has demonstrated the ability to treat slurries containing plastics and other organic solids (LANL 1994), provided that the particle size does not exceed 1/8 in. Larger particles will be removed in the Strainer (F-004). However, the solids-holding capacity of F-004 is limited and it should not be expected to remove large quantities of solids. Streams containing large amounts of coarse solids should be prescreened by the sites or treated with other technologies.

Mercury: Four of the six waste streams currently slated for PBR/SDP treatment, including both LANL wastes and two of the four PTX wastes, contain mercury (RCRA waste code D009). D009 is the only RCRA waste code assigned to PTX TG 1.3, a relatively small waste stream containing only 1.23 m³ or 325 gal. The pilot PBR/SDP unit has never been tested on mercury and the disposition of mercury in the process is uncertain. Vapor-phase mercury would condense in the offgas stream and would presumably deposit on equipment surfaces. Mercury oxides could conceivably pass through the PBR (R-100) and SDP and would precipitate in the Acid-Gas Scrubber (S-300), if it is being used, or in the offgas piping.

Compatibility: The Waste Feed Tank (T-010) has a working capacity of about 175 gal, or about three full 55-gal drums. To avoid operational problems and potential releases, it is important to avoid mixing incompatible wastes (e.g., water-reactive wastes with aqueous wastes) in T-010. The waste characterization process should include this consideration.

Tritium: As detailed in Section 1.2, tritium will be converted into tritiated water in the PBR/SDP MTU. This conversion does not pose a problem for the technology; but, because most of the tritium will ultimately be vented to the atmosphere in the form of tritiated water, site permits need to address tritium emissions.

High-Viscosity Liquids: High-viscosity liquids have the potential to plug the atomizing nozzles or atomize poorly and unevenly into the bed (Section 3.0.). The design of the atomizing nozzles will include guidance as to the maximum viscosity that can be atomized. High-viscosity liquids would not necessarily be excluded from treatment with PBR/SDP if they can be pretreated (e.g., mixed with a solvent) to reduce the viscosity. However, such pretreatment would represent a process in itself and is outside the scope of this DDR, so no provisions for it have been made in the design.

5.0 Treatment Standards

The goal of treatment of hazardous waste is to meet the specific treatment standards for the waste and thus allow final disposal of the waste and/or any treatment residuals. Treatment standards for hazardous wastes are specific requirements that must be met before a hazardous waste may be land disposed (40 CFR 268 Subpart D). The specific treatment requirements for a given waste are dependent on the nature of the waste and its RCRA hazardous-waste code. Specific treatment standards for RCRA hazardous wastes are identified as either numerical concentration limits for specific hazardous constituents or treatment with specific treatment technologies (40 CFR 268.40).

Treatment standards apply to the hazardous waste itself and to any solid or liquid residuals that result from treatment. With the PBR/SDP technology, the waste itself is consumed in the treatment. The residuals to which numerical waste treatment standards would apply are the scrubber blowdown liquid and the activated carbon. If these residuals do not meet the treatment standards, they would have to be further treated to meet the treatment standards before they could be land disposed.

Table 5-1 is a list of the numerical treatment standards for the RCRA hazardous-waste codes identified in the seven waste streams currently slated for treatment with PBR/SDP (Section 1.4). The numerical standards differ depending on whether the residual is classified as a wastewater or a nonwastewater. To qualify as a wastewater, the residual must be a liquid containing less than 1 percent total organic carbon and less than 1 percent total suspended solids. On this basis, considering the high destruction efficiency of the PBR/SDP MTU, the fact that the SDP offgas is filtered upstream of the Acid-Gas Scrubber (S-300) to remove particulates, and that S-300 is designed to blow down before precipitation takes place, the scrubber blowdown from the PBR/SDP MTU would be expected to be classified as a RCRA wastewater, and would have to conform to the generally more stringent wastewater standards. The spent activated carbon, a solid, would be considered a nonwastewater. For RCRA waste codes D001 through D003, the treatment standard is deactivation (i.e., chemical removal of the hazardous characteristics, such as neutralization to remove the D002 corrosivity characteristic) with removal of underlying constituents. For Trypan Blue (RCRA waste code U236) and cyanogen bromide (RCRA waste code U246), the treatment standard is incineration.

Table 5-1. RCRA Hazardous-Waste Treatment Standards

RCRA Waste Code	Constituent	Wastewater Treatment Standard (mg/L)	Nonwastewater Treatment Standard (mg/kg)
D001	ignitability	Deactivation	Deactivation
D002	corrosivity	Deactivation	Deactivation
D003	reactivity	Deactivation	Deactivation
D004	arsenic	5	5
D006	cadmium	1	1
D007	chromium	5	5
D008	lead	5	5
D009	mercury	0.2	^a
D011	silver	5	5
D018	benzene	0.14	10
D019	carbon tetrachloride	0.057	6

Table 5-1 (continued). RCRA Hazardous-Waste Treatment Standards

RCRA Waste Code	Constituent	Wastewater Treatment Standard (mg/L)	Nonwastewater Treatment Standard (mg/kg)
D022	chloroform	0.046	6
D028	1,2-dichloroethane	0.21	6
D029	1,1-dichloroethylene	0.025	6
D035	methyl ethyl ketone	0.28	36
D038	pyridine	0.014	16
D040	trichloroethylene	0.054	6
D043	vinyl chloride	0.27	6
F001	acetone	0.28	160
F002	benzene	0.14	10
F003	n-butyl alcohol	5.6	2.6
F004	carbon disulfide	3.8	4.8 ^b
F005	carbon tetrachloride	0.057	6
	chlorobenzene	0.057	6
	o-cresol	0.11	5.6
	m-cresol	0.77	5.6
	p-cresol	0.77	5.6
	cresol - mixed	0.88	11.2
	cyclohexanone	0.36	0.75 ^b
	o-dichlorobenzene	0.088	6
	ethyl acetate	0.34	33
	ethyl benzene	0.057	10
	ethyl ether	0.12	160
	isobutyl alcohol	5.6	170
	methanol	5.6	0.75 ^b
	methylene chloride	0.089	30
	methyl ethyl ketone	0.28	36
	methyl isobutyl ketone	0.14	33
	nitrobenzene	0.068	14
	pyridine	0.014	16
	tetrachloroethylene	0.056	6
	toluene	0.08	10
	1,1,1-trichloroethane	0.054	6
	1,1,2-trichloroethane	0.054	6
	1,1,2-trichloro 1,2,2-trifluoroethane	0.057	30
	trichloroethylene	0.054	6
	trichloromonofluoromethane	0.02	30
	xylene	0.32	30
	2-nitropropane	Incineration	Incineration
	2-ethoxyethanol	Incineration	Incineration
U002	acetone	0.28	160
U019	benzene	0.14	10
U077	1,2-dichloroethane	0.21	6

Table 5-1 (continued). RCRA Hazardous-Waste Treatment Standards

RCRA Waste Code	Constituent	Wastewater Treatment Standard (mg/L)	Nonwastewater Treatment Standard (mg/kg)
U080	methylene chloride	0.089	30
U169	nitrobenzene	0.068	14
U188	phenol	0.039	6.2
U220	toluene	0.08	10
U226	1,1,1-trichloroethane	0.054	6
U227	1,1,2-trichloroethane	0.054	6
U228	trichloroethylene	0.054	6
U236	Trypan Blue	Incineration	Incineration
U246	cyanogen bromide	Incineration	Incineration

*See RCRA regulations (40 CFR 268.40) for mercury treatment standards.

^bUnits are mg/L toxicity characteristic leachate process.

In those cases where the treatment standard for a particular hazardous constituent is incineration, the performance requirement for the treatment is based on destruction efficiency of the hazardous constituent. A destruction efficiency of either 99.99 percent or 99.9999 percent of the principal organic hazardous constituents (POHCs) is required by 40 CFR 264.343. The higher destruction efficiency, 99.9999 percent, is required for RCRA waste codes F020, F021, F022, F023, F026, and F027. None of the mixed-waste streams currently scheduled for PBR/SDP treatment carries any of these RCRA waste codes.

According to 40 CFR 264.342, the POHCs of interest for a particular site will be specified in the facility's permit. The RCRA regulations are unclear as to whether the specified POHCs must include only those constituents that do not have numerical treatment standards (e.g., Trypan Blue), or if all the hazardous constituents of the waste could be potentially POHCs even if they normally have numerical treatment standards. Interpretations to date suggest that if "incineration" and "nonincineration" wastes are mixed in a single stream, the most stringent treatment standard will apply, so that constituents with numerical treatment standards also may be designated as a POHC and the treatment standard will be the more stringent of either the numerical or the 99.99 percent destruction efficiency.

40 CFR 268.42(b) provides for using an "alternate treatment method" that can achieve "equivalent performance" to the specified technology, which in this case is incineration. Once it is decided to "operate in accordance with incineration standards," none of the numerical treatment standards of any constituent in the waste would be applicable, and the 99.99 percent standard would be applied across the board. Acceptance testing of the PBR/SDP MTU will have to show that the technology can qualify as an "alternate treatment method" to incineration under this definition.

Treatment of PCBs is regulated by TSCA instead of RCRA and the standards are based on incineration. 40 CFR 761.70 contains several criteria for incineration of PCBs. However, the U.S. Environmental Protection Agency (EPA) allows use of other technologies as long as the destruction efficiency of the PCBs is at least 99.9999 percent, which is one of the criteria for incineration of nonliquid PCB wastes specified by 40 CFR 761.70. The destruction efficiency of the PBR/SDP MTU is designed to be at least 99.9999 percent, which will be confirmed during acceptance testing.

The largest "product" stream from treatment of most wastes in the PBR/SDP MTU is the Acid-Gas Scrubber (S-300) offgas stream, which is vented to the atmosphere. Gas-phase emissions are covered by the air-discharge permits of the individual sites, which limit total tons of emissions, rather than by concentration-based treatment standards. Potential environmental impacts of gas-phase emissions are discussed in Section 6.0.

6.0 Environmental Impacts

6.1 Byproducts

The PBR/SDP process produces two byproduct streams in normal operation.

- Scrubber blowdown (Stream 16 on the material balances, Tables 1-1 through 1-3), a salt-water solution that is normally produced only when treating wastes containing halogens.
- Scrubber offgas (Stream 11 on the material balances), which is vented to the atmosphere.

The high destruction efficiency of the PBR/SDP MTU virtually ensures that releases of RCRA and TSCA compounds to the air from the offgas vent will be below regulatory limits. The Process Vent VOC Indicator (AI 320-3) in the offgas stream will provide on-line confirmation of volatile organic compound (VOC) concentrations. Radionuclides should be contained within the PBR (R-100) and the immediate downstream equipment by the use of the two SDP Inlet HEPA Filters (F-130A and F-130B) and should not be released to either of the byproduct streams.

6.1.1 Scrubber Blowdown

When nonhalogenated wastes are treated, there is no need to operate the Acid-Gas Scrubber (S-300) and, therefore, no liquid residual waste stream need be produced. During treatment of halogenated wastes, however, S-300 must be operated. Depending on the halogen concentration in the feed organics, the amount of scrubber blowdown can be significant. Table 6-1 shows the amount of scrubber blowdown produced, in units of pounds of blowdown per pound of organic feed, during treatment of a number of chlorinated organics, based on removal of a 20-percent solution of sodium chloride from S-300. Myristyl chloride is the common name for 1-chlorotetradecane ($C_{14}H_{29}Cl$), a chlorinated aliphatic containing 15 percent chlorine by weight. Arachlor is a trade name for PCBs. The last two digits of the Arachlor number give the chlorine content by weight (e.g., Arachlor 1242 contains approximately 42 percent chlorine).

Depending on the chlorine content of the waste, the volume of scrubber blowdown produced from treatment of halogenated wastes can be quite high. For example, one of the most common halogenated solvents to be treated by PBR/SDP is TCE and, as shown in Table 6-1, treatment of TCE will produce over 7 lb of scrubber blowdown for every pound of TCE treated. It is anticipated that all scrubber blowdown will be retained at the site for later volume reduction using the WWE. Even with the action of the WWE taking the residual waste from an initial concentration of 20 percent sodium chloride to a final concentration of 50 percent, the volume of byproduct produced from treatment of highly chlorinated wastes such as TCE still will be significant. However, because the concentration of hazardous constituents in the scrubber blowdown is expected to be well below RCRA standards and radionuclide concentrations are expected to be very low, scrubber blowdown should be disposable as a solidified salt solution, rather than as a hazardous or mixed waste.

Tritium in the mixed-waste streams to be treated by PBR/SDP will be bound up either as tritiated water or as tritiated organic molecules, which will be converted into tritiated water in the PBR/SDP at very high yields and will thereafter behave like regular water. During treatment of nonhalogenated wastes, all water produced from waste treatment will be vented to the atmosphere as vapor.

Table 6-1. Scrubber Blowdown from Treatment of Halogenated Organics

Compound	Blowdown (lb per lb waste)
Myristyl chloride	1.25
Arachlor 1242	3.40
Arachlor 1248	4.00
Arachlor 1254	4.47
Arachlor 1260	5.07
1,1,2-trichloroethane	6.56
Methylene chloride	6.87
Trichloroethylene	7.27
Chloroform	8.01

When the Acid-Gas Scrubber (S-300) is used, a portion of the water will leave the process as scrubber blowdown and the rest will leave with the vent gases. The split of water between scrubber blowdown and vent gas is a function of the concentration of halogen in the waste. Table 6-2 shows the percentage of the total water produced during waste treatment that leaves the process as scrubber blowdown during treatment of various chlorinated organic compounds (the balance is vented as process vapor). Tritium will exist as tritiated water, so the split of tritium between scrubber blowdown and vent gas should be the same as for other forms of water.

Table 6-2. Percentage of Total Water Removed in Scrubber Blowdown

Compound	Water in Blowdown (%)
Myristyl chloride	34.8
Arachlor 1242	42.8
Arachlor 1248	47.0
Arachlor 1254	50.7
Arachlor 1260	55.3
1,1,2-trichloroethane	76.4
Methylene chloride	76.3
Trichloroethylene	83.2
Chloroform	83.6%

A review of tritium capture requirements (DOE 1995) shows that tritium capture is not needed for the waste streams designated for the PBR/SDP MTU.

The "fate" of radionuclides other than tritium is not known at this point, since no mixed-waste streams have ever been tested in the pilot PBR/SDP units. This DDR assumes that most of the radionuclides will be retained on the packing in the PBR (R-100) and will have to be removed periodically. Two mechanisms have been provided for removal of radionuclides from the bed.

- The "steaming out" process, described in Section 1.2, has been proven to be effective at removing numerous contaminants from the bed. Whether this process will also remove radionuclides remains to be seen. If the process is effective at doing so, the radionuclides would be withdrawn with the condensate at this point.
- If "steaming out" is not effective at removing all radionuclides, the remainder will have to be removed by dumping the bed. The design of R-100 provides for dumping the bed either by unloading the contaminated packing, or by sealing up and removing R-100 entirely, including the alloy shell. In either case, the bed would then be suitable for disposal as radioactive (or potentially mixed if RCRA heavy metals are present) waste using the macroencapsulation process being developed by the DOE-AL Mixed-Waste Treatment Program.

Radionuclides not retained on the packing will be removed in the SDP Inlet HEPA Filters (F-130A and F-130B).

6.1.2 Vent Emissions

The chief pollutant of concern in the vent stream is carbon monoxide (CO). Table 6-3 gives the estimated pounds of CO that will be produced from treatment of each of the waste streams currently slated for PBR/SDP treatment. The waste quantity used for the calculations includes both the current inventory and the estimated 5-year generation. The calculation of CO that will be produced is based on the following assumptions.

- The specific gravity of halogenated wastes is 1.4, while the specific gravity of nonhalogenated wastes is 0.8.
- Halogenated wastes contain 80 percent carbon by weight, while nonhalogenated wastes contain 90 percent carbon.
- 99.9999 percent of the carbon in the waste is converted to carbon dioxide and the balance is converted to CO.

A review of 40 CFR 52 reveals that LANL and SNL/NM are located within Federal Guideline Attainment Areas for all pollutants of concern. The emissions limit for prevention of significant deterioration of air quality for CO, as described in 40 CFR 52.21, is 100 tons per year (ton/yr) of CO. The estimated amount of CO that would be generated while treating the LANL waste streams is 0.22 lb, while treatment of the SNL/NM waste stream should generate about one-tenth of this amount. These CO quantities represent much less than 0.001 percent of a permitted CO source. Therefore, emissions control of the PBR/SDP MTU for control of CO at these locations is not required.

Table 6-3. Carbon Monoxide Emissions from Operation of PBR/SDP MTU

Waste Stream	Quantity (m ³ waste)	Quantity (lb waste)	Total CO Produced (lb)
LA-W 907	16.58	51,148	0.095
LA-W 908	14.34	25,279	0.053
Total LANL			0.148
PTX-TG 1.1	0.74	1,305	0.002
PTX-TG 1.2	2.06	6,355	0.012
PTX-TG 1.3	1.55	2,732	0.006
PTX-TG 1.5	0.72	1,269	0.003
Total PTX			0.023
SNL/NM-TG 11	2.7	8,329	0.015
Total SNL/NM			0.015

The area surrounding PTX is in a Federal Guideline Attainment Area for CO. The estimated amount of CO that would be generated while treating PTX waste streams is 0.045 lb, or about 0.00002 percent of the emissions limit. It is unclear whether or not PTX is within the attainment levels for particulate material less than 10 microns. The presence of the HEPA filter in the offgas line will limit particulate emissions to no more than 0.03 percent of particulates with a particle size of 0.3 microns or greater. Control of criteria pollutants from treatment of wastes with the PBR/SDP MTU at PTX therefore does not seem warranted.

6.2 National Emission Standards for Hazardous Air Pollutants

Because the mixed-waste feeds slated for treatment with the PBR/SDP MTU contain radionuclides, 40 CFR 61 Subchapter C, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon From Department of Energy Facilities," was reviewed. This statute states that, "Emissions of radionuclides to the ambient air from DOE facilities shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 mrem/yr." To determine compliance, the facility must implement EPA-approved monitoring and test procedures and computer modeling. The PBR/SDP MTU will not include ventilation emission monitoring for radionuclides because the SDP Inlet HEPA Filters (F-130A and F-130B) will remove all radionuclides that are not trapped in the bed packing. It is assumed that the DOE facilities will monitor, test, and model emissions for radionuclides in accordance with 40 CFR 61.93.

7.0 Health and Safety

When possible, engineering controls will be implemented to eliminate the need for special health and safety requirements. Multiple safety interlocks will be designed into the system to prevent unsafe conditions during operation of the unit. When necessary for specific tasks, appropriate personal protective equipment (PPE) will be specified.

7.1 Ventilation

Operation of the MTU poses three primary ventilation hazards.

- Normal operation generates scrubber offgas, a high-temperature (120 °C nominal) vapor stream. This stream should contain air, carbon dioxide, and water vapor; concentrations of organics should be extremely low.
- During waste transfer from drums to the Waste Feed Tank (T-010), the drums of hazardous liquid are open and venting hazardous vapors.
- The Acid-Gas Scrubber (S-300) is blown down into an open drum. The hot salt solution will vent steam when it is exposed to the atmosphere.

The detailed design must address provisions for waste unloading, for containing chemical emissions, and for ventilation of the PBR/SDP MTU in a safe and controlled manner.

7.2 Radioactive Hazards

The suspected radioactive constituents of the waste streams to be treated with PBR/SDP MTU are uranium, plutonium, thorium, tritium, and cesium-137. Total quantities of radioactive material are unknown. It is expected that most of the radionuclides (with the exception of tritium) will be collected in the packed bed and that the packed bed will have to be cleaned before criticality limits are approached. If the bed packing is dumped from the bed (rather than the entire bed being removed and encapsulated), radioactive emission controls will be in effect during the work. The same will apply to any work on piping and equipment upstream of, and including, the SDP Inlet HEPA Filters (F-130A and F-130B).

Based on a preliminary discussion with Tom McLaughlin (LANL 1996b), the criticality specialist at LANL, criticality is not expected to be an issue with the PBR/SDP MTU. The waste to be treated with PBR/SDP is low-level by definition, so the level of radiological contamination in each drum will be well below the threshold of 200 grams of plutonium or uranium-235 at which criticality could become a concern. (Tritium and cesium do not pose a criticality concern at any concentration.) The final resolution of criticality issues should be confirmed during the detailed design process. Analysis of radiological concentrations in the waste drums will be required before treatment can begin.

7.3 Chemical Hazards

The wastes currently selected for treatment may contain acids, caustics, and heavy metals, including lead and mercury. They may also contain chlorinated and nonchlorinated solvents, including chloroform, methylene chloride, carbon tetrachloride, and benzene and other aromatics. (See the listing of possible hazardous constituents in Section 5.) Dedicated eyewash stations and safety showers will be placed within

the distances required by the Occupational Safety and Health Administration (OSHA). Personnel exposure issues during waste transfer will be addressed during detailed design (see Section 3.0).

7.4 Burn Hazards

All hot surfaces will be insulated, as required by OSHA, to be no higher than 120 °F on the exterior surface. The exception is the section of pipe between the PBR (R-100) and the Quench Chamber (E-110), which is uninsulated to reduce the requirement for quench water. Exterior burn protection will be provided for this section of piping.

7.5 Fire Hazards

A portable fire extinguishing system will be installed on each skid.

7.6 Electrical Hazards

All skid-mounted electrical components shall be installed in accordance with the applicable provisions of OSHA requirements contained in 29 CFR 1910, Subpart S, and the National Electrical Code to minimize personnel exposure to hazards.

7.7 Spill Containment Concerns

Each skid will be equipped with secondary containment for spill control in the form of a "sump" built into the bottom of each skid. The skid will have grating in the floor to allow liquids to fall through the bottom of the skid into the sump. The capacity of the sump on each skid will be equal to at least 110 percent of the total quantity of liquid in the largest vessel on that skid. For example, the feed preparation skid sump will be able to contain 193 gal, 110 percent of the 175-gal working volume of the feed tank, including all of the associated piping.

7.8 Air Monitoring

Continuous air monitors for organics and radioactive material will be used to alert workers of inadvertent releases. Operating personnel will be trained in the use of these monitors, or trained personnel will be provided for routine sampling and for such special sampling as may be deemed appropriate.

7.9 HAZOP and Process Hazards Analysis

The MTU will be designed to provide adequate protection for the health and safety of operators, collocated workers, and the public. Safety analysis of the MTU design will include two stages of review.

- A HAZOP analysis to determine risk factors and consequences related to the normal operation of the MTU, to determine causes of deviations from normal operation, identify the consequences of such deviations, and quantify the hazards so that mitigation can be done.
- A process hazards analysis (PHA) to determine the hazard classification of the MTU, quantify the materials at risk, and determine the maximum credible release scenario(s). The PHA uses the results of the HAZOP analysis, and the mitigation performed as a result of the HAZOP, as the basis for risk evaluation.

Both of these analyses impact the MTU design, so both must be complete before the detailed MTU design can be completed.

A preliminary HAZOP analysis of the PBR portion of the MTU was performed during the preparation of this DDR. A report on the results of that analysis is presented in Appendix C. (The preliminary HAZOP did not cover the SDP unit, which is outside the scope of this DDR. A separate HAZOP must be performed on the SDP design.) The preliminary PBR HAZOP identified 148 "action items," design and/or procedural modifications that would mitigate potential hazard scenarios. Eighty-eight of the action items identified during the preliminary PBR HAZOP are addressed in this DDR. The remainder cannot be resolved at this stage, and must be addressed during the detailed design or during preparation of the standard operating procedures. Appendix C also lists all HAZOP action items that remain to be addressed.

The PHA will be performed prior to completion of the detailed design, and the final PHA report will be issued at the same time as the detailed design package.

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Appendix A

PBR/SDP

Process and Instrumentation Diagrams and Electrical Distribution

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Figure A-1. PBR/SDP P&ID Drawing

TYPICAL INSTRUMENT LINE IDENTIFICATION

- DIRECT CONNECTION TO PROCESS
 PNEUMATIC SYMBOL
 ELECTRIC SIGNAL
 CAPILLARY (FLUID FILLED)
 SOFTWARE LINK OR DATA LINK

SYMBOL DENOTES SIGNAL TRANSFER TYPE (DISTRIBUTED CONTROL SYSTEM)

SYMBOL DENOTES SIGNAL TRANSFER TYPE (PROGRAMMABLE LOGIC CONTROLLER)

ANALOG INPUT

ANALOG OUTPUT

DIGITAL INPUT

DIGITAL OUTPUT

PULSE INPUT

PULSE OUTPUT

RTD INPUT

THERMOCOUPLE INPUT

2 LETTER DESIGNATIONS APPLY TO PROGRAMMABLE LOGIC CONTROLLERS. I.E.

TRANSDUCER DESIGNATIONS

I/P - CURRENT-TO-PNEUMATIC
 P/I - PNEUMATIC-TO-CURRENT
 E/P - VOLTAGE-TO-PNEUMATIC
 E/I - VOLTAGE-TO-CURRENT
 I/I - CURRENT-TO-CURRENT

** TYPES OF POWER SUPPLY

AS - AIR SUPPLY
 IA - INSTRUMENT AIR
 PA - PLANT AIR
 ES - ELECTRIC SUPPLY
 GS - GAS SUPPLY
 HS - HYDRAULIC SUPPLY
 NS - NITROGEN SUPPLY
 SS - STEAM SUPPLY
 WS - WATER SUPPLY

PROCESS FLOW STREAM IDENTIFIERS

AA - BB - CCC - DD
 AA = PIPE SIZE
 BB = PIPE SPEC.
 CCC = ASSOCIATED EQUIPMENT NO.
 DD = UNIQUE LINE NO.

BB PIPE SPECIFICATION NO.

2.6A = NICKEL ALLOY PIPE
 2.6B = 316 SS PIPE
 2.6C = 304 SS TUBING
 2.6D = COPPER TUBING

VALVE IDENTIFICATION:

1. TYPE OF VALVE

B - BALL
 C - CHECK
 E - PRESSURE REDUCING
 F - BUTTERFLY
 G - GATE
 H - PINCH
 L - GLOBE
 R - RELIEF
 S - SOLENOID
 T - CONTROL

2. MATERIAL OF CONSTRUCTION OF BODY

0 - BRONZE
 1 - CAST IRON/DUCTILE IRON
 2 - ALUMINUM
 4 - CARBON STEEL
 5 - ZINC
 7 - STAINLESS STEEL
 9 - BRASS

3. PRESSURE RATING

1 - 150
 2 - 300
 3 - >300

4. END CONNECTION

A - FLANGED
 B - MECHANICAL JOINT
 C - SOCKET WELD
 D - THREADED
 F - WAFER
 H - SWEAT

5. VARIATION IN STYLE, TRIM, ACCESSORIES, ETC.

6. VALVE NUMBER: SEQUENTIAL NUMBER FOR THE VALVE GROUP

EXAMPLE:
 G 4 1 A A - 001
 (C.1) (C.2) (C.3) (C.4) (C.5) (C.6)

NOTES:

- ANALYTICAL INSTRUMENTS ARE USED FOR THE FOLLOWING SERVICES: CONDUCTIVITY, pH, CO₂, VOC, LEL, FOAM, ETC.
- WHERE APPLICABLE, ALL SYMBOLS SHOWN MAY BE USED AS LOCAL INDICATORS, TRANSMITTERS, SWITCHES, AND/OR CONTROLLERS.

TEMPERATURE

TYPICAL INTERLOCK SYMBOLS

LEVEL

VALVES (SELF-CONTAINED REGULATING)

ACTUATOR ACTIONS

FO = FAIL OPEN
 FC = FAIL CLOSED
 LO = LOCK OPEN
 LC = LOCK CLOSED

SPECIAL

VALVES/ACTUATORS

PRESSURE RELIEF OR SAFETY VALVE

GRAND JUNCTION PROJECTS OFFICE, COLORADO
 U.S. DEPARTMENT OF ENERGY
 MIXED-WASTE TREATMENT PROGRAM
 PACKED-BED REACTOR/SILENT-DISCHARGE PLASMA
 P&ID DRAWING SYMBOLOGY
 ENG-43D-0007-02-000
 E03557AB-R00-Y02-D+

DESIGN DEVELOPMENT
 RUST Geotech
 2002 4/19

2 9

Symboology (Drawing E03557)

Figure A-2. PBR/SDP P&ID Fee

System (Drawing E03456)

Figure A-3. PBR/SDP P&ID Package

Bed Reactor (Drawing E03457)

Figure A-4. PBR/SDP P&ID Silent-Di

Figure A-5. PBR/SDP P&ID Acid-1

s Scrubber (Drawing E03458)

Figure A-6. PBR/SDP P&ID Off-Gas

Handling System (Drawing E03489)

Figure A-7. PBR/SDP P&ID Utility/CI

Figure A-8. PBR/SDP Electrical

LEGEND

- _____ ELECTRICAL FEEDER WIRING AT 480 OR 240VAC
 _____ ELECTRICAL CONTROL WIRING AT 120VAC NOMINAL
 _____ COMBINATION FUSIBLE ELECTRICAL DISCONNECT SWITCH
 _____ MAGNETIC MOTOR STARTER WITH MANUAL OPERATORS
 _____ FUSIBLE ELECTRICAL DISCONNECT SWITCH

NO. DATE		REVISION		DATE		REVISION		DATE		REVISION	
<p align="center">GRAND CENTRAL DESIGN OF REACTOR</p>											
<p align="center">U.S. DEPARTMENT OF ENERGY NUCLEAR ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATIVE OFFICE WASHINGTON, D.C.</p>											
PROJECT NO.		PROJECT NAME		PROJECT NO.		PROJECT NAME		PROJECT NO.		PROJECT NAME	
100-430-0007-42-000		PACKED BED REACTOR		100-430-0007-42-000		PACKED BED REACTOR		100-430-0007-42-000		PACKED BED REACTOR	
SUBJECT		SUBJECT		SUBJECT		SUBJECT		SUBJECT		SUBJECT	
ELECTRICAL DISTRIBUTION		ELECTRICAL DISTRIBUTION		ELECTRICAL DISTRIBUTION		ELECTRICAL DISTRIBUTION		ELECTRICAL DISTRIBUTION		ELECTRICAL DISTRIBUTION	
DRAWN BY		DRAWN BY		DRAWN BY		DRAWN BY		DRAWN BY		DRAWN BY	
J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.	
CHECKED BY		CHECKED BY		CHECKED BY		CHECKED BY		CHECKED BY		CHECKED BY	
J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.	
APPROVED BY		APPROVED BY		APPROVED BY		APPROVED BY		APPROVED BY		APPROVED BY	
J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.		J. H. H. H.	
DATE		DATE		DATE		DATE		DATE		DATE	
10/1/54		10/1/54		10/1/54		10/1/54		10/1/54		10/1/54	

Distribution (Drawing E03460)

Appendix B

PBR/SDP Technology Development Reports

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PBR/SDP Technology Development Reports

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Appendix C

Resolution of PBR HAZOP
Action Items

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Resolution of PBR HAZOP Action Items

This Appendix summarizes the actions identified during the preliminary packed-bed reactor (PBR) hazards and operations (HAZOP) analysis held on February 26–28, 1996. This preliminary HAZOP did not cover the silent-discharge plasma (SDP) unit, which is outside the scope of this design data report (DDR). The detailed results of the preliminary PBR HAZOP will be published separately. This Appendix documents changes made to the design as a result of the preliminary PBR HAZOP and the actions that remain to be addressed during the detailed design of the PBR/SDP mobile treatment unit (MTU) and the preparation of the operating procedures.

The HAZOP 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, and the review is conducted one node at a time. 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 that 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 the deviation (e.g., a plugged line for low/no flow). The causes are ranked according to their expected frequency, as defined in Table C-1. (Because of the nature of the MTU and the waste streams that it treats, and the short expected lifetime of the MTU compared with a normal production facility, the standard frequency definitions have been modified to suit the program realities.)
2. The consequences, in terms of safety, environmental contamination, financial loss, and general (miscellaneous) consequences if the deviation occurs. The consequences are quantified according to the criteria given in Table C-2.
3. Existing safeguards in the current design that 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 matrix is given in Table C-3. The risk factors are then evaluated using the risk decision criteria in Table C-4 to determine whether the design must be modified to provide additional mitigation.

Table C-1. Frequency Categories

Frequency Rating	Definition
I	Likely during normal operation
II	Once per waste stream
III	Once per site
IV	Once in the life of the MTU
V	Not expected in the lifetime of the MTU

Table C-2. Consequence Categories

	Safety	Environment	Financial	General
A — High	Loss of worker life or significant public exposure	Significant off-site contamination.	Significant Costs	Extended production shutdown
B — Moderate	Severe worker injury with disability, or moderate public exposure	Significant off-site contamination	Moderate Costs	Short-term production shutdown
C — Low	Severe worker injury without disability, or minor public exposure	Moderate off-site contamination	Low Costs	Loss of production efficiency
D — Negligible	Minor worker injury, or public exposure with no health effects	Negligible on-site contamination	Negligible costs	Minor production delay for repair

Table C-3. Risk 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	2	4	4	4

Table C-4. 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 Number 3 or lower with cost enhancements.
3	Acceptable With Control — Should evaluate cost effective enhancements.
4	Acceptable As Is — No action necessary.

As the preliminary PBR HAZOP progressed, deviations and causes were identified, the consequences determined, and existing safeguards noted. The residual risk for each deviation was quantified as a risk number from Table C-3, and the criteria in Table C-4 were used to determine whether additional mitigative action will be required. Suggestions for possible additional mitigation are noted as "action items," which will be addressed after the PBR HAZOP review is complete.

Table C-5 lists the total 148 action items identified during the preliminary PBR HAZOP. The actions are organized by Action Item Number and go as high as 152. A peculiarity in the HAZOP software used caused four items to be listed and numbered although no action item was identified and no safety consequence given; these were dropped from the list, but the remaining items were not renumbered. All of the action items were addressed and a recommendation for appropriate action was made.

1. Seventy-two items either were completed by accepting the HAZOP recommendation, or became moot when an alternative recommendation was accepted instead. The resolution has been added to the process and instrumentation diagrams (P&IDs) and/or the text of the DDR as appropriate.
2. Sixteen items were reviewed with a recommendation that no action be taken. These included six items for which the hazard rating did not justify the expense of the proposed change (this applies only to items with a hazard rating of 3 or 4).
3. Forty-four items will be addressed during the detailed design. This includes 19 items relating to drum unloading, feed preparation, and waste transfer operations, which were major areas of concern during HAZOP. The DDR suggests that the detailed design may consider use of a glovebox similar to the feed preparation glovebox being incorporated into the design of the VAC*TRAX thermal desorption MTU.
4. Sixteen items will be addressed when the standard operating procedures (SOPs) are prepared.

Table C-5 is organized with the 72 action items completed with an action taken listed first (this is why the list begins with item number 13), followed by the 16 items for which no action was taken, the 44 items that will be addressed during detailed design, and finally the 16 items that will be addressed when the SOPs are prepared. The following information is given in the action item list.

Item Number: Sequential, 1 through 152 (Numbers 38, 71, 123, and 132 were dropped).

Node: The description of the node (e.g., Waste Drum Feed Line) is given first, followed by the node number and deviation number in parentheses (e.g., Node 1.6 is Node 1, Deviation 6); a complete listing of all nodes will be given in the complete HAZOP report.

Deviation: The description of the deviation.

Risk Level: The quantified risk level, from the risk matrix in Table C-3, as determined by the HAZOP analysis for each of the four categories (safety, environmental, financial, or general) in which a risk was identified for the specific deviation.

Action Item: A description of the recommended action from the HAZOP analysis.

Resolution: The action taken to incorporate the HAZOP recommendation into the design.

The information in Table C-5 does not include the deviation causes identified during the HAZOP, or the expected frequency; this information will be available in the detailed HAZOP report. The risk level is given, along with the category(ies) to which it applies. For example, for the first item in Table C-5, Number 13:

The Node and Deviation was 1.6, high concentration of contaminants in the transfer line from the Waste Feed Drum to the Waste Feed Tank. The risk level was 3 for Safety, for which mitigation is recommended if cost effective. The recommended mitigation action was to avoid traps and pockets in the piping, which is simple and virtually cost-free to implement, so the recommendation was accepted and a note to avoid traps and pockets in that line was added to the P&ID (Note 4 on drawing E03456).

Table C-5. Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot

Item Number: 13
Node: Waste Drum Feed Line (1.6)
Deviation: High concentration of contaminants
Risk Level: 3—Safety
Action Item: Piping design should minimize traps and low points.
Resolution: Added note to this effect to the P&ID.

Item Number: No. 17
Node: Waste Drum Feed Line (1.8)
Deviation: Shutdown
Risk Level: 4—Safety, Environmental, General
Action Item: Consider blowing out feed line
Resolution: Added air connection and Note 5 to P&ID for blowing out line.

Item Number: 22
Node: Sulfuric Acid Supply (2.5)
Deviation: Shutdown
Risk Level: 4—General
Action Item: Consider providing a means to flush out the line.
Resolution: Block and drain valves added to P&ID. Simplest method to flush line is to disconnect the acid drum and hook up water in its place.

Item Number: 24
Node: Waste Feed Tank (4.1)
Deviation: High level
Risk Level: 2—Environmental
Action Item: Consider making the two level probes of different types.
Resolution: Note to this effect added to P&ID.

Item Number: 25
Node: Waste Feed Tank (4.1)
Deviation: High level
Risk Level: 2—Environmental
Action Item: Consider adding a sight glass.
Resolution: Added LG 010-12.

Item Number: 26
Node: Waste Feed Tank (4.2)
Deviation: Low level
Risk Level: 3—General
Action Item: Consider impeller design to work/wipe bottom of tank.
Resolution: Revised representation on P&ID and added requirement for wiping bottom of tank to description in DDR.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 28
Node: Waste Feed Tank (4.2)
Deviation: Low level
Risk Level: 3—General
Action Item: Consider continuous circulation of liquids in tank.
Resolution: Revised agitator design (see No. 26) will handle this.

Item Number: 29
Node: Waste Feed Tank (4.9)
Deviation: Foam
Risk Level: 1—General
Action Item: Consider adding antifoam.
Resolution: Added P-430 and antifoam carboy and piping.

Item Number: 30
Node: Waste Feed Tank (4.9)
Deviation: Foam
Risk Level: 1—General
Action Item: Consider adding a foam sensor
Resolution: Added AIC 010-11.

Item Number: 36
Node: Waste Feed Tank (4.3)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: Consider interlocking TI 010-3 with all feeds.
Resolution: Added to Interlock 10.

Item Number: 37
Node: Waste Feed Tank (4.3)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: Consider inerting the tank.
Resolution: PIC 010-2 and Nitrogen Addition System N-450 added.

Item Number: 39
Node: Waste Feed Tank (4.5)
Deviation: Low pressure
Risk Level: 2—General
Action Item: Consider adding inerts.
Resolution: Done; see #37.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 40
Node: Waste Feed Tank (4.8)
Deviation: Shutdown
Risk Level: 3—Financial
Action Item: Consider adding inspection ports on top of tank.
Resolution: Added ports to P&ID.

Item Number: 41
Node: Waste Feed Tank (4.8)
Deviation: Shutdown
Risk Level: 3—Financial
Action Item: Add flush connections at the bottom of tank.
Resolution: Added to P&ID

Item Number: 42
Node: Waste Feed Tank (4.11)
Deviation: Inability to sample tank.
Risk Level: 3—Financial
Action Item: Consider adding sample ports to tank.
Resolution: Sample ports added.

Item Number: 43
Node: Waste Feed Tank Vent (5.2)
Deviation: Low/no flow
Risk Level: 4—General
Action Item: Reroute vent line to top of reactor.
Resolution: Vent line moved.

Item Number: 44
Node: Waste Feed Tank Vent (5.2)
Deviation: Low/no flow
Risk Level: 4—General
Action Item: Revisit pressure control scheme.
Resolution: Added PIC 010-2.

Item Number: 45
Node: Waste Feed Tank Vent (5.3)
Deviation: Reverse flow
Risk Level: 2—Safety
Action Item: Review inerting tank.
Resolution: Done; see #37.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 46
Node: Waste Feed to PBR (6.1)
Deviation: High flow
Risk Level: 4—Safety
Action Item: Consider tying bed temperature to air flow controller.
Resolution: Added RSP link from TIC 100-19 to FIC 100-5/6/7.

Item Number: 47
Node: Waste Feed to PBR (6.2)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider pressure gauge on each line.
Resolution: Moot since each line will have flow measurement (see #49).

Item Number: 48
Node: Waste Feed to PBR (6.2)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider supplying same power to each pump (manual operation).
Resolution: Moot since each line will have flow measurement (see #49).

Item Number: 49
Node: Waste Feed to PBR (6.2)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider flow measurement for each nozzle feed line.
Resolution: Added FI 020-3 and FI 022/024-2 on individual lines.

Item Number: 52
Node: Waste Feed to PBR (6.4)
Deviation: High pressure
Risk Level: 2—Safety
Action Item: Consider using larger line.
Resolution: Increased line size to ½".

Item Number: 53
Node: Waste Feed to PBR (6.4)
Deviation: High pressure
Risk Level: 2—Safety
Action Item: Consider facilitating line clean-up.
Resolution: Added block and drain valves for each feed line.

*Table C-5 (continued). Resolution of PBR HAZOP Action Items***Complete Items — Action Taken or Moot (continued)**

Item Number: 54
Node: Waste Feed to PBR (6.4)
Deviation: High pressure
Risk Level: 2—Safety
Action Item: Piping design should minimize or eliminate pockets.
Resolution: Note to this effect added to P&ID.

Item Number: 57
Node: Waste Feed to PBR (6.7)
Deviation: Shutdown
Risk Level: 4—Safety
Action Item: Piping design should minimize elbows and traps.
Resolution: Note 4 added to P&ID.

Item Number: 59
Node: Air Feed to PBR (7.1)
Deviation: High flow
Risk Level: 2—General
Action Item: Consider flow controls for individual nozzles.
Resolution: Added individual controllers FIC 100-5/6/7 for air flow.

Item Number: 60
Node: Air Feed to PBR (7.1)
Deviation: High flow
Risk Level: 2—General
Action Item: Consider limiting the capacity of the air compressor.
Resolution: Moot; see #59.

Item Number: 61
Node: Air Feed to PBR (7.3)
Deviation: Misdirected flow
Risk Level: 3—General
Action Item: Software link to prevent waste flow to a nozzle that has no air flow.
Resolution: Added interlocks 11-13 to stop waste feed to individual nozzles on LL air flow to that nozzle.

Item Number: 62
Node: Air Feed to PBR (7.4)
Deviation: Low pressure
Risk Level: 3—General
Action Item: Run air supply on high pressure header.
Resolution: Low pressure header eliminated so all air users are on high pressure.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 63
Node: Air Feed to PBR (7.4)
Deviation: Low pressure
Risk Level: 3—General
Action Item: Minimum line size of ½ inch.
Resolution: Line size changed to ½" on P&ID.

Item Number: 64
Node: Air Feed to PBR (7.5)
Deviation: High concentration of contaminants
Risk Level: 1—Safety
Action Item: Specify oil less compressor or filters and separators.
Resolution: Specified oil-free compressor on P&ID and in description in DDR.

Item Number: 65
Node: Air Feed to PBR (7.5)
Deviation: High concentration of contaminants
Risk Level: 1—Safety
Action Item: Interlock waste tank vent with PBR temperature.
Resolution: Interlock added to close vent valve on low bed temperature (TI 100-19).

Item Number: 66
Node: Air Feed to PBR (7.6)
Deviation: Shutdown
Risk Level: 3—Environmental
Action Item: Add CO₂ monitor between E-112 and SDP.
Resolution: Added CO₂ monitor AI 112-5.

Item Number: 68
Node: Air Feed to PBR (7.5)
Deviation: High concentration of contaminants
Risk Level: 1—Safety
Action Item: Consider installing bleed to check for oil in line.
Resolution: Moot since oil-free compressor will be used (see #64).

Item Number: 69
Node: Packed Bed Reactor (8.1)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: Consider adding more thermocouples.
Resolution: Added midzone thermocouples TI 100-16/17/18.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 70
Node: Packed Bed Reactor (8.1)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: High temperature fuel shutoff.
Resolution: Added TI 100-19 to Interlock 11.

Item Number: 74
Node: Packed Bed Reactor (8.1)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: Consider extending packed bed below heating zone.
Resolution: Added to P&ID.

Item Number: 77
Node: Packed Bed Reactor (8.10)
Deviation: Shutdown
Risk Level: 2—Environmental
Action Item: Add CO2 monitor to determine when residual organics in bed have been consumed.
Resolution: Done; see item #66.

Item Number: 79
Node: PBR Discharge to Quench Chamber (9.1)
Deviation: High temperature
Risk Level: 3—Environmental
Action Item: Consider making Node 9 an integral part of the PBR.
Resolution: Modified P&ID and description in DDR so that "uninsulated pipe" is the bottom section of the packed bed:

Item Number: 81
Node : PBR Discharge to Quench Chamber (9.2)
Deviation: Low temperature
Risk Level: 3—Environmental
Action Item: Consider coupling heat exchanger directly to PBR (as per Mound experimental configuration #3).
Resolution: Quench needed per VE session; configuration #3 not tested on PCB surrogates so no data on the effectiveness of this arrangement in suppressing PCDD/PCDF formation exists.

Item Number: 82
Node: PBR Discharge to Quench Chamber (9.3)
Deviation: High concentration of contaminants
Risk Level: 2—Safety
Action Item: MOC must be appropriate for high chloride environment.
Resolution: Moot (see item #79)

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 88
Node: PBR Offgas Cooler (12.1)
Deviation: High temperature
Risk Level: 3—Environmental
Action Item: Consider activating Interlock 7 on TIC 112-2.
Resolution: Done.

Item Number: 92
Node: SDP (13.2)
Deviation: High temperature
Risk Level: 4—Financial
Action Item: Consider bypassing SDP (Interlock 7) on high inlet temperature.
Resolution: Added TIC 112-2 HH to Interlock 7.

Item Number: 93
Node: SDP (13.3)
Deviation: Low temperature
Risk Level: 4—Financial
Action Item: Consider bypassing SDP (Interlock 7) on low inlet temperature.
Resolution: Added TIC 112-2 LL to Interlock 7.

Item Number: 103
Node: Waste Feed Tank Relief Line (25.1)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Consider nitrogen sweep on relief header
Resolution: Added line ½"-2.6D-450-02 for this purpose.

Item Number: 104
Node: Waste Feed Tank Relief Line (25.1)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Consider high-pressure alarm on relief header.
Resolution: Added PI 140-3 and HH on relief header.

Item Number: 107
Node: PBR Relief Line (23.2)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Add nitrogen sweep in the line.
Resolution: Done (see #103).

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 111
Node: Scrubber Inlet (15.1)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider eliminating valves in this line.
Resolution: No block valves in line after HEPA filter moved and carbon canister deleted.

Item Number: 112
Node: Scrubber Inlet (15.1)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider installing PSE on F-220 (changed to F-120) bypass.
Resolution: Bypass valve changed to PSE 120-2.

Item Number: 115
Node: Scrubber Inlet (15.4)
Deviation: Low temperature
Risk Level: 2—Financial
Action Item: Consider using heat tracing.
Resolution: Added heat tracing and TIC/IC 201-2.

Item Number: 118
Node: Acid-Gas Scrubber (17.5)
Deviation: High pressure
Risk Level: 4—Environmental
Action Item: Consider pressure relief on S-300
Resolution: Added PSV 300-9; setpoint will have to be confirmed during detailed design.

Item Number: 121
Node: Acid-Gas Scrubber (17.7)
Deviation: High concentration of contaminants
Risk Level: 3—General
Action Item: Consider filter for removal of metal hydrides.
Resolution: Added Scrubber Filter F-306.

Item Number: 122
Node: Acid-Gas Scrubber (17.8)
Deviation: Startup
Risk Level: 3—General
Action Item: Consider heat tracing inlet lines.
Resolution: Done; see item #115.

*Table C-5 (continued). Resolution of PBR HAZOP Action Items***Complete Items — Action Taken or Moot (continued)**

Item Number: 124
Node: SDP (13.6)
Deviation: High concentration of contaminants
Risk Level: 2—General
Action Item: Consider moving F-220 upstream of SDP.
Resolution: Filter moved and retagged as F-120.

Item Number: 125
Node: Acid-Gas Scrubber (17.7)
Deviation: High concentration of contaminants
Risk Level: 3—General
Action Item: Consider using softened water for makeup.
Resolution: Added scrubber water as inlet to water softener W-310.

Item Number: 127
Node: Acid-Gas Scrubber Pump (18.6)
Deviation: Shutdown
Risk Level: 3—General
Action Item: Consider drain valve for scrubber.
Resolution: Added drain to P&ID.

Item Number: 128
Node: Acid-Gas Scrubber Pump (18.6)
Deviation: Shutdown
Risk Level: 3—General
Action Item: Consider block valve upstream of AE 302-2.
Resolution: Block valves added upstream and downstream of filter F-306 which is upstream of AE 302-2.

Item Number: 129
Node: NaOH Feed to Scrubber (19.1)
Deviation: High flow
Risk Level: 4—Environmental
Action Item: Consider moving pH probe to circulating line if filter is installed.
Resolution: Filter has been added and probe has been moved.

Item Number: 130
Node: NaOH Feed to Scrubber (19.2)
Deviation: Low/no flow
Risk Level: 4—Environmental, General
Action Item: Consider moving caustic addition above normal liquid level.
Resolution: Line moved on P&ID.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 132
Node: NaOH Feed to Scrubber (19.3)
Deviation: Reverse flow
Risk Level: 1—Environmental
Action Item: Consider moving caustic addition above normal liquid level.
Resolution: See #130.

Item Number: 134
Node: NaOH Feed to Scrubber (19.7)
Deviation: Shutdown
Risk Level: 3—Safety
Action Item: Consider ways to flush lines and pump at end of run.
Resolution: Block and drain valves added to P&ID. Simplest method to flush line is to disconnect the caustic drum and hook up water in its place.

Item Number: 135
Node: Process Water to Scrubber (20.3)
Deviation: High concentration of contaminants
Risk Level: 2—General
Action Item: Consider using softened water.
Resolution: Scrubber makeup water will be treated with water softener W-310.

Item Number: 136
Node: Scrubber Blowdown Line (21.3)
Deviation: Misdirected flow
Risk Level: 4—Environmental, General
Action Item: Consider not allowing blowdown when load cell indicates drum is full.
Resolution: Added LL in WI 302-6 for cutout of HS 302-2 to disable blowdown.

Item Number: 139
Node: Scrubber Blowdown Line (21.6)
Deviation: High concentration of contaminants
Risk Level: 3—Environmental
Action Item: Consider installation of HEPA upstream of scrubber.
Resolution: Added F-130A/B.

Item Number: 142
Node: Scrubber to Vent Heater (22.2)
Deviation: High temperature
Risk Level: 3—Safety
4—Environmental
Action Item: Consider eliminating carbon canister C-324.
Resolution: Carbon canister eliminated.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — Action Taken or Moot (continued)

Item Number: 143
Node: Scrubber to Vent Heater (22.4)
Deviation: Low pressure
Risk Level: 4—General
Action Item: Confirm vacuum rating of C-324 and F-322 is higher than deadhead suction of blower.
Resolution: Moot; eliminated carbon drum and moved HEPA filter.

Item Number: 144
Node: Scrubber to Vent Heater (22.4)
Deviation: Low pressure
Risk Level: 4—General
Action Item: Consider vacuum break system.
Resolution: Moot (see item #143).

Item Number: 145
Node: Scrubber to Vent Heater (22.6)
Deviation: Maintenance/sampling
Risk Level: 2—General
Action Item: Consider moving HEPA upstream of SDP.
Resolution: Added F-130A/B.

Item Number: 146
Node: Scrubber to Vent Heater (22.6)
Deviation: Maintenance/sampling
Risk Level: 2—General
Action Item: Make provisions for canister changeout without shutdown
Resolution: Moot (see #142).

Item Number: 147
Node: Relief Condenser/Demister (24.4)
Deviation: High concentration of contaminants
Risk Level: 4—Safety
Action Item: Consider sloping piping to drain away from relief devices.
Resolution: Added notes on line slope to P&ID.

Item Number: 151
Node: Caustic to Waste Feed Tank (3.5)
Deviation: Shutdown
Risk Level: 3—Safety
Action Item: Consider providing a means to flush out the line.
Resolution: Block and drain valves added to P&ID. Simplest method to flush line is to disconnect the caustic drum and hook up water in its place.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — No Action Taken

Item Number:	10
Node:	Waste Drum Feed Line (1.2)
Deviation:	Reverse flow
Risk Level:	2—Safety, Environmental
Action Item:	Consider whether drum containment needs to hold entire volume of T-010.
Resolution:	Not needed. The siphon break in T-010 and the block valves in the transfer line will provide adequate protection.
Item Number:	11
Node:	Waste Drum Feed Line (1.3)
Deviation:	Misdirected flow
Risk Level:	3—Safety, Environmental
Action Item:	Consider directing blowdown to waste drum when drum is not in use.
Resolution:	Does not make sense. The drum will not normally be in place except when it is needed.
Item Number:	19
Node:	Sulfuric Acid Supply (2.1)
Deviation:	Low/no flow
Risk Level:	4—General
Action Item:	Consider using larger feed line
Resolution:	Not desirable. Increasing the line size would increase the total inventory of acid in the system.
Item Number:	21
Node:	Sulfuric Acid Supply (2.4)
Deviation:	Loss of containment
Risk Level:	3—Safety
Action Item:	Consider using an organic acid instead of sulfuric
Resolution:	No change. Use of sulfuric will minimize secondary wastes because it can be added in more concentrated form than other acids and has higher activity. The acid addition is expected to be minimal in any case.
Item Number:	27
Node:	Waste Feed Tank (4.2)
Deviation:	Low level
Risk Level:	3—General
Action Item:	Consider high-energy mixing system
Resolution:	Not desirable due to emulsification concerns.
Item Number:	56
Node:	Waste Feed to PBR (6.7)
Deviation:	Shutdown
Risk Level:	4—Safety
Action Item:	Consider adding solvent flush system.
Resolution:	Not justified at this risk level.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — No Action Taken (continued)

Item Number: 58
Node: Waste Feed to PBR (6.7)
Deviation: Shutdown
Risk Level: 4—Safety
Action Item: Consider using translucent tubing.
Resolution: Not justified at this risk level, possibly ineffective or counterproductive since plastic may cloud or degrade.

Item Number: 83
Node: Quench Chamber (11.2)
Deviation: High temperature
Risk Level: 3—Environmental, Financial
Action Item: Consider redundant temperature measurement.
Resolution: Not justified at this risk level.

Item Number: 89
Node: PBR Offgas Cooler (12.2)
Deviation: Low temperature
Risk Level: 4—Financial
Action Item: Consider heat trace on line.
Resolution: Not required. TE 112-2 will be located as close as possible to the SDP to give the most accurate control of the SDP inlet temperature.

Item Number: 94
Node: SDP Bypass (13.3)
Deviation: Low temperature
Risk Level: 4—Financial
Action Item: Consider installation of condensate trap.
Resolution: Not justified at this risk level.

Item Number: 113
Node: Scrubber Inlet (15.4)
Deviation: Low temperature
Risk Level: 2—Financial
Action Item: Consider using plastics (at least for filter)
Resolution: Not desirable; #115 (heat tracing) will eliminate condensation.

Item Number: 114
Node: Scrubber Inlet (15.4)
Deviation: Low temperature
Risk Level: 2—Financial
Action Item: Consider making line out of Hastalloy.
Resolution: Not justified; #115 (heat tracing) will eliminate condensation.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Complete Items — No Action Taken (continued)

Item Number: 131
Node: NaOH Feed to Scrubber (19.2)
Deviation: Low/no flow
Risk Level: 1—Environmental
Action Item: Consider low flow switch in series with P-304 motor starter.
Resolution: Not required; reverse flow unlikely since NaOH will enter above scrubber liquid level (see #130).

Item Number: 133
Node: NaOH Feed to Scrubber (19.5)
Deviation: Loss of containment
Risk Level: 4—Safety
Action Item: Consider using 20% caustic.
Resolution: Not required at this risk level (general level 4); use of 50% will minimize generation of secondary waste.

Item Number: 140
Node: Scrubber Blowdown Line (21.6)
Deviation: Loss of containment
Risk Level: 4—Environmental
Action Item: Consider method to determine when drum is full.
Resolution: Load cell will be adequate; filter will minimize chance of deviation in specific gravity due to solids in liquid.

Item Number: 148
Node: Caustic to Waste Feed Tank (3.1)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Consider using larger caustic line.
Resolution: Not justified; larger line would increase volume of caustic in system and increase risk if containment is lost.

Detail Design Items

Item Number: 1
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Consider coarse strainer in waste drum.
Comment: This item, and the following four items, have been deferred for detail design when the unloading requirements (e.g. glovebox) will be examined. (See #6.)

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 2
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Consider blowback system for coarse strainer.
Comment: See #1.

Item Number: 3
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Define blowback for F-004.
Comment: See #1.

Item Number: 4
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Consider waste feed drum mixer.
Comment: See #1.

Item Number: 5
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Consider installation of F-004B.
Comment: See #1.

Item Number: 6
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Consider whether drum unloading will be glovebox operation.
Comment: This possibility is discussed in the DDR.

Item Number: 7
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Determine viscosity limit of pump.
Comment: After pump data is available.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 8
Node: Waste Drum Feed Line (1.1)
Deviation: Low/no flow
Risk Level: 4—Safety, General
Action Item: Determine maximum particle size of pump
Comment: After pump data is available.

Item Number: 12
Node: Waste Drum Feed Line (1.6)
Deviation: High concentration of contaminants
Risk Level: 4—Safety, Environmental
Action Item: Consider sampling drums prior to acceptance.
Comment: See #1 and #100.

Item Number: 14
Node: Waste Drum Feed Line (1.6)
Deviation: High concentration of contaminants
Risk Level: 4—Safety, Environmental
Action Item: Consider using a plastic system and a metal system for unloading.
Comment: Deferred until more information on waste is available.

Item Number: 18
Node: Waste Drum Feed Line (1.9)
Deviation: Maintenance/sampling
Risk Level: 4—Safety, General
Action Item: Consider how sampling will be done.
Comment: See #1.

Item Number: 23
Node: Sulfuric Acid Supply (2.6)
Deviation: Maintenance/sampling
Risk Level: 3—Safety, General
Action Item: Evaluate servicing requirements of the pump.
Comment: After pump data is available.

Item Number: 31
Node: Waste Feed Tank (4.10)
Deviation: High viscosity
Risk Level: 4—General
Action Item: Define viscosity limit
Comment: After detailed information on agitator and feed pumps is available.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 32
Node: Waste Feed Tank (4.10)
Deviation: High viscosity
Risk Level: 4—General
Action Item: Waste Acceptance Criteria to set upper limit.
Comment: See #31.

Item Number: 33
Node: Waste Feed Tank (4.10)
Deviation: High viscosity
Risk Level: 4—General
Action Item: Consider solvent addition to waste feed tank.
Comment: See #1; solvent addition would be part of the overall feed preparation and pretreatment process.

Item Number: 34
Node: Waste Feed Tank (4.10)
Deviation: High viscosity
Risk Level: 4—General
Action Item: Make drum mixer same type as tank agitator.
Comment: Detail design to evaluate drum mixer requirements (see #4).

Item Number: 35
Node: Waste Feed Tank (4.10)
Deviation: High viscosity
Risk Level: 4—General
Action Item: Make waste transfer pump equal to the viscosity limit of the waste.
Comment: After feed preparation/pretreatment is resolved; see #1.

Item Number: 50
Node: Waste Feed to PBR (6.2)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider putting in a finer strainer (F-004).
Comment: Deferred as part of feed preparation/pretreatment; see #1.

Item Number: 51
Node: Waste Feed to PBR (6.4)
Deviation: High pressure
Risk Level: 2—Safety
Action Item: Pump selection — pump shutoff or internal relief pressure must be lower than line pressure.
Comment: Address during pump selection process.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 72
Node: Packed Bed Reactor (8.7)
Deviation: High pressure
Risk Level: 4—Environmental
Action Item: Consider increasing PBR design pressure.
Comment: Preliminary calculations indicate that a maximum pressure rating of 10 psig can be obtained with a wall thickness of ½". The P&ID and description in the DDR have been changed to show a pressure rating of 10 psig, but detailed design should obtain more information on maximum allowable stress for HR-160 at 2200 °F to confirm that this design rating is possible.

Item Number: 73
Node: Packed Bed Reactor (8.3)
Deviation: High temperature
Risk Level: 3—Safety
Action Item: Consider adding a fan for top of reactor.
Comment: Concern is high temperature on the exterior of the reactor.

Item Number: 75
Node: Packed Bed Reactor (8.8)
Deviation: High concentration of contaminants
Risk Level: 3—Safety
4—Environmental, Financial
Action Item: Analyze waste drum contents for radionuclides.
Comment: Deferred as part of feed preparation/pretreatment (see #1); added suggestion to DDR.

Item Number: 76
Node: Packed Bed Reactor (8.8)
Deviation: High concentration of contaminants
Risk Level: 3—Safety
4—Environmental, Financial
Action Item: Initial review by Health Physicist (HP).
Comment: HP will review final design package.

Item Number: 80
Node: PBR Discharge to Quench Chamber (9.2)
Deviation: Low temperature
Risk Level: 3—Environmental
Action Item: Design to allow bed height adjustment during setup.
Comment: The need is mentioned in the DDR for incorporation in the final design.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 84
Node: Quench Chamber (11.5)
Deviation: High concentration of contaminants
Risk Level: 3—Financial, General
4—Safety
Action Item: Better define the compounds and their impact.
Comment: Deferred as part of feed preparation/pretreatment; see #1.

Item Number: 90
Node: PBR Offgas Cooler (12.3)
Deviation: Tube leak or rupture.
Risk Level: 4—Financial
Action Item: Put E-112 in a low spot
Comment: May not be desirable but will be evaluated during detailed design..

Item Number: 91
Node: PBR Offgas Cooler (12.3)
Deviation: Tube leak or rupture.
Risk Level: 4—Financial
Action Item: Consider some way to detect pinhole leaks.

Item Number: 96
Node: Waste Feed Drum (26.1)
Deviation: High pressure
Risk Level: 3—Safety
Action Item: Detail design to address this issue.
Comment: Part of feed preparation/pretreatment; see #1.

Item Number: 97
Node: Waste Feed Drum (26.2)
Deviation: High concentration of contaminants
Risk Level: 3—General
4—Safety, Environmental
Action Item: Consider addition of solvent to drum.
Comment: See #1; solvent addition would be part of the overall feed preparation and pretreatment process.

Item Number: 98
Node: Waste Feed Drum (26.2)
Deviation: High concentration of contaminants
Risk Level: 3—General
4—Safety, Environmental
Action Item: Consider opening and sampling drum under containment.
Comment: Part of feed preparation/pretreatment; see #1.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 99
Node: Waste Feed Drum (26.4)
Deviation: Maintenance/sampling
Risk Level: 2—Safety
Action Item: Consider use of mobile laboratory.
Comment: Part of feed preparation/pretreatment; see #1.

Item Number: 100
Node: Waste Feed Drum (26.4)
Deviation: Maintenance/sampling
Risk Level: 2—Safety
Action Item: Consider whether sites will be required to characterize wastes.
Comment: Discussed in DDR but will be part of overall feed preparation/pretreatment; see #1.

Item Number: 101
Node: Waste Feed Tank Relief Line (25.2)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Confirm that the MOC of relief devices are adequate.
Comment: Pipe spec is a good general MOC guideline, although sometimes relief devices may have to be better material than the piping because of their stagnant installation and critical availability requirement.

Item Number: 102
Node: Waste Feed Tank Relief Line (25.2)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Confirm that the rupture disk has vacuum support.
Comment: Add to specification of PSE.

Item Number: 106
Node: PBR Relief Line (23.1)
Deviation: High flow
Risk Level: 4—Environmental
Action Item: Consider making rupture disk out of Tantalum.
Comment: Tantalum is ideal MOC for chloride resistance; see #101.

Item Number: 108
Node: PBR Relief Line (23.2)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: MOC of rupture disk.
Comment: See #106.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 109
Node: PBR Relief Line (23.3)
Deviation: Reverse flow
Risk Level: 4—Safety
Action Item: PSE 100-10 should have vacuum support.
Comment: Add to specification of PSE.

Item Number: 116
Node: Acid-Gas Scrubber (17.1)
Deviation: High flow
Risk Level: 4—Environmental, General
Action Item: Confirm capacity of AC-420 is less than flooding velocity in scrubber.
Comment: Resolve when detailed data is available.

Item Number: 117
Node: Acid-Gas Scrubber (17.5)
Deviation: High pressure
Risk Level: 4—Environmental, General
Action Item: Consider increasing pressure rating of S-300.
Comment: Review with scrubber vendors to see what design pressure is practical.

Item Number: 119
Node: Acid-Gas Scrubber (17.5)
Deviation: High pressure
Risk Level: 4—Environmental, General
Action Item: Consider vacuum relief on S-300.
Comment: If required.

Item Number: 120
Node: Acid-Gas Scrubber (17.6)
Deviation: Low pressure
Risk Level: 4—Environmental, General
Action Item: Confirm vacuum rating of S-300 is greater than maximum suction of B-320.
Comment: After info on blower and scrubber available; addition of vacuum breaker (see #119) may be required if satisfactory resolution of this item is not possible.

Item Number: 126
Node: Acid-Gas Scrubber Pump (18.5)
Deviation: Startup
Risk Level: 4—General
Action Item: Determine initial scrubber liquid level required for pump operation.
Comment: Need pump NPSH requirement and liquid holdup in packing.

Table C-5 (continued). Resolution of PBR HAZOP Action Items

Detail Design Items (continued)

Item Number: 141
Node: Scrubber Blowdown Line (21.6)
Deviation: High concentration of contaminants
Risk Level: 3—General
Action Item: Evaluate sampling for rad and metals.

Item Number: 152
Node: Caustic to Waste Feed Tank (3.6)
Deviation: Maintenance/sampling
Risk Level: 3—Safety
Action Item: Evaluate servicing requirements of pump.
Comment: After pump info is available.

SOP Items

Item Number: 9
Node: Waste Drum Feed Line (1.2)
Deviation: Reverse flow
Risk Level: 2—Safety, Environmental
Action Item: SOPs specify one valve to be closed until pump starts.

Item Number: 15
Node: Waste Drum Feed Line (1.7)
Deviation: Loss of containment
Risk Level: 4—Safety, Environmental
Action Item: Requirement to pressure-test line after maintenance.

Item Number: 16
Node: Waste Drum Feed Line (1.7)
Deviation: Loss of containment
Risk Level: 4—Safety, Environmental
Action Item: Evaluate PPE requirements.
Comment: Will be part of overall feed preparation/pretreatment; see #1.

Item Number: 20
Node: Sulfuric Acid Supply Line (2.4)
Deviation: Loss of containment
Risk Level: 3—Safety
Action Item: Consider hooking up acid only when needed (do not leave it hooked up when not in use).

Table C-5 (continued). Resolution of PBR HAZOP Action Items

SOP Items (continued)

Item Number: 55
Node: Waste Feed to PBR (6.2)
Deviation: Low/no flow
Risk Level: 4—Safety
Action Item: Consider using single nozzle for high-energy (exothermic) wastes
Comment: This would apply if such wastes were to be fed at a rate less than 15 gal/d so that atomization might not be adequate if the flow is split among all three nozzles; the control system is designed to allow this (see #49 and #59).

Item Number: 67
Node: Air Feed to PBR (7.6)
Deviation: Shutdown
Risk Level: 3—Environmental
Action Item: SOP to provide for gradual reduction of air flow when PBR is being shut down.

Item Number: 78
Node: Packed Bed Reactor (8.10)
Deviation: Shutdown
Risk Level: 2—Environmental
Action Item: SOPs to specify feeding air until CO₂ goes to acceptable minimum.
Comment: CO₂ analyzer has been added; "acceptable minimum" needs to be defined.

Item Number: 85
Node: Quench Chamber (11.6)
Deviation: Startup
Risk Level: 2—General
Action Item: SOP should provide for gradual introduction of waste feed.

Item Number: 86
Node: Quench Chamber (11.6)
Deviation: Startup
Risk Level: 2—General
Action Item: Verify that the startup procedure is valid.

Item Number: 87
Node: Quench Chamber (11.7)
Deviation: Shutdown
Risk Level: 2—General
Action Item: SOP includes continuing to feed air for some period after stopping waste feed,

Item Number: 95
Node: SDP Bypass (14.1)
Deviation: High flow
Risk Level: 3—Environmental
Action Items: Consider administrative controls on activation of bypass line.

*Table C-5 (continued). Resolution of PBR HAZOP Action Items***SOP Items (continued)**

Item Number: 105
Node: Waste Feed Tank Relief Line (25.2)
Deviation: Low/no flow
Risk Level: 3—Safety
Action Item: Consider testing relief devices each time the MTU is set up at a new site.

Item Number: 110
Node: PBR Relief Line (23.4)
Deviation: High concentration of contaminants
Risk Level: 4—Safety
Action Item: Inspect PSE inlet line each time the MTU is set up at a new site.

Item Number: 137
Node: Scrubber Blowdown Line (21.4)
Deviation: High temperature
Risk Level: 4—Environmental
Action Item: SOPs to specify use of only drums rated for 212 °F or higher.

Item Number: 138
Node: Scrubber Blowdown Line (21.5)
Deviation: Low pressure
Risk Level: 3—Environmental
Action Item: SOPs to specify that drum will be allowed to cool prior to being sealed.

Item Number: 149
Node: Caustic to Waste Feed Tank (3.4)
Deviation: Loss of containment
Risk Level: 3—Safety
Action Item: Consider hooking up caustic only when needed (do not leave it hooked up when not in use).

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Appendix D

Stream Sheets

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Stream Sheets

This Appendix contains stream sheets that give mass and volumetric flow rates, temperatures, and pressures for the PBR/SDP MTU. Data are supplied for all three of the design cases (see Tables 1-1 through 1-3) upon which the design is based. Stream sheets are supplied for all lines shown on the P&IDs (Appendix A) except those that do not normally have flow. Table D-1 lists the lines that normally have a zero flow.

Table D-1. Zero Flow Lines

Line No.	Description
1"-2.6B-002-3	Waste Transfer Blowdown Line
2"-2.6B-016-6	T-010 Pressure Relief Line
1"-2.6A-100-5	R-100 Pressure Relief Line
1"-2.6B-140-1	E-140 Outlet to T-142
1"-2.6B-142-1	T-142 Outlet to F-144
1"-2.6B-144-1	F-144 Outlet to Vent
¼"-2.6C-304-3	Sodium Hydroxide Supply to T-010
¼"-2.6C-410-1	Sulfuric Acid Supply to T-010
¼"-2.6C-430-1	Antifoam Supply to T-010

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Table D-2. Stream Sheets

PROCESS STREAM SHEET	Line No. 1"-2.6B-002-01/02					
	Revision	Approval				
	NOTES: Waste Unloading Line to Waste Feed Tank				PROJECT:	PBR/SDP
					PREPARER:	RR
					DATE:	2/13/96
	Drawing No. E03456					
	System: Waste Feed				Line Size:	1
		CASE NAME				
COMPOSITION	UNITS	Case 1	Case 2	Case 3		
C ₂₀ H ₄₂ Oil	lb/h	6,257	0	0		
PCB 1242	lb/h	0	10,410	0		
Water	lb/h	0	0	7,512		
TOTAL	lb/h	6,257	10,410	7,512		
PROPERTIES						
Temperature	°F	70	70	70		
Pressure	psia	25	25	25		
Density	lb/ft ³	52.00	86.52	62.43		
Molecular Weight	lb/lb-mole	282.55	291.99	18.015		
Viscosity	cP	0.650				
FLOWS						
Mass Flow	lb/h	6,257	10,410	7,512		
Volumetric – Actual (liquid)	gal/min	15.00	15.00	15.00		
Fluid Velocity	ft/s	6.1	6.1	6.1		

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6C-010-01				
	Revision	Approval			
NOTES: Waste Feed Header to PBR				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03456				
	System: Waste Feed			Line Size:	0.5
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
C ₂₀ H ₄₂ Oil	lb/h	4.34	0	0	
PCB 1242	lb/h	0	7.22	0	
Water	lb/h	0	0	26.05	
TOTAL	lb/h	4.34	7.22	26.05	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	25	25	25	
Density	lb/ft ³	52	86.52	62.43	
Molecular Weight	lb/lb-mole	282.55	291.99	18.02	
Viscosity	cP	0.65	0	0	
FLOWS					
Mass Flow	lb/h	4.34	7.22	26.05	
Volumetric – Actual (liquid)	gal/d	15.00	15.00	75.00	
Fluid Velocity	ft/s	0.02	0.02	0.09	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6C-010-02				
	Revision	Approval			
NOTES: Waste Feed Tank Vent Line				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03456, E03457				
	System: Waste Feed Tank			Line Size:	0.5
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Air	lb/h	19.20	19.20	19.20	
TOTAL	lb/h	19.20	19.20	19.20	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	31.3	31.3	31.3	
Density	lb/ft³	0.160	0.160	0.160	
Molecular Weight	lb/lb-mole	29	29	29	
Viscosity	cP	0.018	0.018	0.018	
FLOWS					
Mass Flow	lb/h	19.20	19.20	19.20	
Volumetric – Actual (vapor)	acfm	2.01	2.01	2.01	
Volumetric – Standard	scfm	4.19	4.19	4.19	
Fluid Velocity	ft/s	24.5	24.5	24.5	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6C-010-03/04/05				
	Revision	Approval			
NOTES: Waste Feed to P-020/022/024 Properties are the same for lines 1/2"-2.6C-020/022/024-01				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03457				
	System:	Waste Feed		Line Size:	0.5
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
C ₂₀ H ₄₂ Oil	lb/h	1.45	0	0	
PCB 1242	lb/h	0	2.41	0	
Water	lb/h	0	0	8.68	
TOTAL	lb/h	1.45	2.41	8.68	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	25	25	25	
Density	lb/ft ³	52	86.52	62.43	
Molecular Weight	lb/lb-mole	282.55	291.99	18.02	
Viscosity	cP	0.65	0	0	
FLOWS					
Mass Flow	lb/h	1.45	2.41	8.68	
Volumetric – Actual (liquid)	gal/d	5.00	5.00	25.00	
Fluid Velocity	ft/s	0.01	0.01	0.03	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No.	3/4"-2.6D-100-01			
	Revision	Approval			
NOTES: Atomizing Air to PBR R-100 Same properties apply to line 3/4"-2.6D-420-04				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
		Drawing No. E03457, E03459			
		System:	PBR	Line Size:	0.75
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Air	lb/h	183.35	183.35	183.35	
TOTAL	lb/h	183.35	183.35	183.35	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	71.3	71.3	71.3	
Density	lb/ft³	0.364	0.364	0.364	
Molecular Weight	lb/lb-mole	29	29	29	
Viscosity	cP	0.018	0.018	0.018	
FLOWS					
Mass Flow	lb/h	183.35	183.35	183.35	
Volumetric – Actual (vapor)	acfm	8.40	8.40	8.40	
Volumetric – Standard	scfm	40.00	40.00	40.00	
Fluid Velocity	ft/s	45.7	45.7	45.7	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6D-100-2/3/4				
	Revision	Approval			
NOTES: Atomizing Air to PBR R-100 Nozzles				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
	Drawing No. E03457				
	System: PBR			Line Size:	0.5
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Air	lb/h	61.12	61.12	61.12	
TOTAL	lb/h	61.12	61.12	61.12	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	71.3	71.3	71.3	
Density	lb/ft³	0.364	0.364	0.364	
Molecular Weight	lb/lb-mole	29	29	29	
Viscosity	cP	0.018	0.018	0.018	
FLOWS					
Mass Flow	lb/h	61.12	61.12	61.12	
Volumetric – Actual (vapor)	acfm	2.80	2.80	2.80	
Volumetric – Standard	scfm	13.33	13.33	13.33	
Fluid Velocity	ft/s	34.2	34.2	34.2	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/4"-2.6D-110-1				
	Revision	Approval			
NOTES: Quench Water Supply to E-110				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
	Drawing No. E03457, E03458				
	System: PBR Quench			Line Size:	0.25
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Water	lb/h	0	17.5	0	
TOTAL	lb/h	0	17.5	0	
PROPERTIES					
Temperature	°F	70	70	70	
Pressure	psia	25	25	25	
Density	lb/ft ³	62.43	62.43	62.43	
Molecular Weight	lb/lb-mole	18.015	18.015	18.015	
Viscosity	cP				
FLOWS					
Mass Flow	lb/h	0	17.5	0	
Volumetric – Actual (liquid)	gal/min	0.00	0.035	0.00	
Fluid Velocity	ft/s	0.0	0.2	0.0	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 3"-2.6A-110-2				
	Revision	Approval			
NOTES: Quench Chamber E-110 to PBR Offgas Cooler E-112				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03457				
	System: PBR				Line Size: 3
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Nitrogen	lb/h	139.89	139.89	139.89	
Oxygen	lb/h	27.47	30.8	42.48	
Carbon Dioxide	lb/h	13.53	14.82	0	
Water	lb/h	5.82	18.51	26.08	
Hydrogen Chloride	lb/h		3.07		
TOTAL	lb/h	186.71	207.09	208.45	
PROPERTIES					
Temperature	°F	932	482	932	
Pressure	psia	10.85	10.85	10.85	
Density	lb/ft ³	0.021	0.030	0.019	
Molecular Weight	lb/lb-mole	28.800	27.968	26.831	
Viscosity	cP	0.0341	0.025	0.034	
FLOWS					
Mass Flow	lb/h	186.71	207.09	208.45	
Volumetric – Actual (vapor)	acfm	148.74	114.97	178.25	
Volumetric – Standard	scfm	41.01	46.84	49.15	
Fluid Velocity	ft/s	50.5	39.0	60.5	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 3/4"-2.6D-112-1				
	Revision	Approval			
NOTES: Cooling Water Supply to E-112 Properties are the same for lines 3/4"-2.6D-400-1 3/4"-2.6D-402-1				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
	Drawing No. E03457, E03489				
	System:	PBR Offgas		Line Size:	0.75
	CASE NAME				
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Water	lb/h	1,667	643	2,006	
TOTAL	lb/h	1,667	643	2,006	
PROPERTIES					
Temperature	°F	95	95	95	
Pressure	psia	25	25	25	
Density	lb/ft ³	62.06	62.06	62.06	
Molecular Weight	lb/lb-mole	18.015	18.015	18.015	
Viscosity	cP				
FLOWS					
Mass Flow	lb/h	1,667	643	2,006	
Volumetric – Actual (liquid)	gal/min	3.35	1.292	4.03	
Fluid Velocity	ft/s	2.4	0.9	2.9	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 3/4"-2.6D-112-2				
	Revision	Approval			
NOTES: Cooling Water Return from E-112				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
	Drawing No. E03457, E03459				
	System: PBR Offgas			Line Size:	0.75
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Water	lb/h	1,667	643	2,006	
TOTAL	lb/h	1,667	643	2,006	
PROPERTIES					
Temperature	°F	115	115	115	
Pressure	psia	25	25	25	
Density	lb/ft³	61.78	61.78	61.78	
Molecular Weight	lb/lb-mole	18.015	18.015	18.015	
Viscosity	cP				
FLOWS					
Mass Flow	lb/h	1,667	643	2,006	
Volumetric – Actual (liquid)	gal/min	3.36	1.298	4.05	
Fluid Velocity	ft/s	2.4	0.9	2.9	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 2"-2.6B-112-3				
	Revision	Approval			
NOTES: PBR Offgas Cooler E-112 to SDP Properties are the same for lines: 2"-2.6B-130-02/04 2"-2.6B-120-01 (when in use) 2"-2.6B-130-01/03 (when in use)				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03457, E03488				
	System: PBR			Line Size:	2
	CASE NAME				
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Nitrogen	lb/h	139.89	139.89	139.89	
Oxygen	lb/h	27.47	30.8	42.48	
Carbon Dioxide	lb/h	13.53	14.82	0	
Water	lb/h	5.82	18.51	26.08	
Hydrogen Chloride	lb/h	0	3.07	0	
TOTAL	lb/h	186.71	207.09	208.45	
PROPERTIES					
Temperature	°F	248	248	248	
Pressure	psia	10.79	10.79	10.79	
Density	lb/ft ³	0.041	0.040	0.038	
Molecular Weight	lb/lb-mole	28.800	27.968	26.831	
Viscosity	cP	0.02	0.019	0.020	
FLOWS					
Mass Flow	lb/h	186.71	207.09	208.45	
Volumetric – Actual (vapor)	acfm	76.07	86.89	91.16	
Volumetric – Standard	scfm	41.01	46.84	49.15	
Fluid Velocity	ft/s	58.1	66.4	69.6	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1"-2.6B-201/202/203/204-1				
	Revision	Approval			
NOTES: SDP Cell Inlet Line Properties are the same for outlet 1"-2.6B-201/202/203/204-2				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03488				
	System: SDP			Line Size:	1
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Nitrogen	lb/h	34.97	34.97	34.97	
Oxygen	lb/h	6.87	7.70	10.62	
Carbon Dioxide	lb/h	3.38	3.71	0	
Water	lb/h	1.46	4.63	6.52	
Hydrogen Chloride	lb/h	0	0.77	0	
TOTAL	lb/h	46.68	51.77	52.11	
PROPERTIES					
Temperature	°F	248	248	248	
Pressure	psia	10.79	10.79	10.79	
Density	lb/ft ³	0.041	0.040	0.038	
Molecular Weight	lb/lb-mole	28.800	27.968	26.831	
Viscosity	cP	0.02	0.019	0.020	
FLOWS					
Mass Flow	lb/h	46.68	51.77	52.11	
Volumetric – Actual (vapor)	acfm	19.02	21.72	22.79	
Volumetric – Standard	scfm	10.25	11.71	12.29	
Fluid Velocity	ft/s	58.1	66.4	69.6	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 2"-2.6B-201-3				
	Revision	Approval			
NOTES: SDP to Scrubber Properties are the same for line 1.5"-2.6B-300-01 (when in use)				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03458, E03488				
	System: PBR			Line Size:	2
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
NITROGEN	lb/h	139.89	139.89	139.89	
OXYGEN	lb/h	27.47	30.8	42.48	
CARBON DIOXIDE	lb/h	13.53	14.82	0	
WATER	lb/h	5.82	18.51	26.08	
HYDROGEN CHLORIDE	lb/h	0	3.07	0	
TOTAL	lb/h	186.71	207.09	208.45	
PROPERTIES					
Temperature	°F	248.18	248.13	247.95	
Pressure	psia	10.73	10.73	10.73	
Density	lb/ft³	0.041	0.039	0.038	
Molecular Weight	lb/lb-mole	28.80	27.97	26.83	
Viscosity	cP	0.02	0.0193	0.0199	
FLOWS					
Mass Flow	lb/h	186.71	207.09	208.45	
Volumetric – Actual (vapor)	acfm	76.52	87.39	91.67	
Volumetric – Standard	scfm	41.01	46.84	49.15	
Fluid Velocity	ft/s	58.5	66.8	70.0	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 2"-2.6B-300-2					
	Revision	Approval				
	NOTES: Scrubber S-300 to Blower B-320				PROJECT: PBR/SDP	
					PREPARER: RR	
					DATE: 2/13/96	
					Drawing No. E03458, E03489	
System: PBR				Line Size:	2	
		CASE NAME				
		CASE NAME				
COMPOSITION	UNITS	Case 1	Case 2	Case 3		
NITROGEN	lb/h	139.89	139.89	139.89		
OXYGEN	lb/h	27.47	30.8	42.48		
CARBON DIOXIDE	lb/h	13.53	14.82	0		
WATER	lb/h	8.32	26.26	29.09		
HYDROGEN CHLORIDE	lb/h	0	3.07E-03	0		
TOTAL	lb/h	189.21	211.77	211.46		
PROPERTIES						
Temperature	°F	195.44	195.44	195.44		
Pressure	psia	10.48	10.48	10.48		
Density	lb/ft ³	0.043	0.041	0.040		
Molecular Weight	lb/lb-mole	28.57	27.32	26.65		
Viscosity	cP	0.0187	0.018	0.0187		
FLOWS						
Mass Flow	lb/h	189.21	211.77	211.46		
Volumetric – Actual (vapor)	acfm	74.06	86.69	88.76		
Volumetric – Standard	scfm	41.89	49.03	50.20		
Fluid Velocity	ft/s	56.6	66.2	67.8		

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/4"-2.6D-300-3			
	Revision	Approval		
NOTES: Process Water to Scrubber S-300				PROJECT: PBR/SDP
				PREPARER: RR
				DATE: 3/8/96
	Drawing No. E03458			
	System: Scrubber			Line Size: 0.25
		CASE NAME		
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Water	lb/h	2.51	22.53	3
TOTAL	lb/h	2.51	22.53	3.01
PROPERTIES				
Temperature	°F	77	77	77
Pressure	psia	25	25	25
Density	lb/ft³	62.25	62.25	62.25
Molecular Weight	lb/lb-mole	18.015	18.015	18.015
Viscosity	cP			
FLOWS				
Mass Flow	lb/h	3	22.53	3
Volumetric – Actual (liquid)	gal/min	0.01	0.045	0.01
Fluid Velocity	ft/s	0.0	0.3	0.0

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6C-300-4			
	Revision	Approval		
NOTES: Scrubber Circulating Liquid Properties also apply to line 1/2"-2.6C-302-1			PROJECT:	PBR/SDP
			PREPARER:	RR
			DATE:	3/8/96
	Drawing No. E03458			
	System:	Scrubber	Line Size:	0.5
CASE NAME				
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Water	lb/h	1,112.66	894.36	1,113.17
TOTAL	lb/h	1,112.66	894.36	1,113.17
PROPERTIES				
Temperature	°F	195.44	195.44	195.44
Pressure	psia	25	25	25
Density	lb/ft³	69.21	69.21	69.21
Molecular Weight	lb/lb-mole	20.86	20.86	20.86
Viscosity	cP			
FLOWS				
Mass Flow	lb/h	1,113	894.36	1,113
Volumetric – Actual (liquid)	gal/min	2.00	1.611	2.01
Fluid Velocity	ft/s	3.3	2.6	3.3

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET		Line No. 1/2"-2.6C-302-2			
		Revision	Approval		
NOTES: Scrubber Blowdown				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
		Drawing No. EO3458			
		System: Scrubber			Line Size: 0.5
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Water	lb/h	0	19.67	0	
TOTAL	lb/h	0	19.67	0	
PROPERTIES					
Temperature	°F	195.44	195.44	195.44	
Pressure	psia	25	25	25	
Density	lb/ft ³	69.21	69.21	69.21	
Molecular Weight	lb/lb-mole	20.90	20.90	20.90	
Viscosity	cP				
FLOWS					
Mass Flow	lb/h	0	19.67	0	
Volumetric – Actual (liquid)	gal/min	0.00	0.035	0.00	
Fluid Velocity	ft/s	0.0	0.1	0.0	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET		Line No. 1/4"-2.6C-304-2			
NOTES: Scrubber Caustic Makeup Properties are the same for line 1/4"-2.6C-304-01	Revision	Approval			
				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	3/8/96
	Drawing No. E03458, E03459				
	System:	Scrubber		Line Size:	0.25
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
Sodium Hydroxide (NaOH)	lb/h	0	3.36	0	
Water	lb/h	0	3.36	0	
TOTAL	lb/h	0	6.72	0	
PROPERTIES					
Temperature	°F	77	77	77	
Pressure	psia	25	25	25	
Density	lb/ft ³	95.19	95.19	95.19	
Molecular Weight	lb/lb-mole	24.83	24.83	24.83	
Viscosity	cP				
FLOWS					
Mass Flow	lb/h	0	6.72	0	
Volumetric – Actual (liquid)	gal/min	0.00	0.009	0.00	
Fluid Velocity	ft/s	0.0	0.06	0.0	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 2"-2.6B-320-1				
	Revision	Approval			
NOTES: Proces Vent Blower B-320 to Atm				PROJECT:	PBR/SDP
				PREPARER:	RR
				DATE:	2/13/96
	Drawing No. E03489				
	System:	PBR		Line Size:	2
		CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3	
NITROGEN	lb/h	139.89	139.89	139.89	
OXYGEN	lb/h	27.47	30.80	42.48	
CARBON DIOXIDE	lb/h	13.53	14.82	0.00	
WATER	lb/h	8.32	26.26	29.09	
HYDROGEN CHLORIDE	lb/h	0.00	0.00	0.00	
TOTAL	lb/h	189.21	211.77	211.46	
PROPERTIES					
Temperature	°F	195.44	195.44	195.44	
Pressure	psia	11.3	11.3	11.3	
Density	lb/ft³	0.046	0.044	0.043	
Molecular Weight	lb/lb-mole	28.58	27.32	26.65	
Viscosity	cP	0.02	0.02	0.02	
FLOWS					
Mass Flow	lb/h	189.21	211.77	211.46	
Volumetric – Actual (vapor)	acfm	68.68	80.40	82.32	
Volumetric – Standard	scfm	41.89	49.03	50.20	
Fluid Velocity	ft/s	52.5	61.4	62.9	

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 3/4"-2.6D-420-1			
	Revision	Approval		
NOTES: Compressed Air Supply Header			PROJECT:	PBR/SDP
			PREPARER:	RR
			DATE:	3/8/96
	Drawing No. E03459			
	System: Compressed Air			Line Size: 0.75
		CASE NAME		
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Air	lb/h	288.77	288.77	288.77
TOTAL	lb/h	288.77	288.77	288.77
PROPERTIES				
Temperature	°F	70	70	70
Pressure	psia	71.3	71.3	71.3
Density	lb/ft³	0.364	0.364	0.364
Molecular Weight	lb/lb-mole	29	29	29
Viscosity	cP	0.018	0.018	0.018
FLOWS				
Mass Flow	lb/h	288.77	288.77	288.77
Volumetric – Actual (vapor)	acfm	13.24	13.24	13.24
Volumetric – Standard	scfm	62.99	62.99	62.99
Fluid Velocity	ft/s	71.9	71.9	71.9

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 1/2"-2.6D-420-02			
	Revision	Approval		
NOTES: Air to Agitator A-010			PROJECT:	PBR/SDP
			PREPARER:	RR
			DATE:	3/8/96
	Drawing No. E03456, E03459			
	System: Waste Feed Tank			Line Size: 0.5
		CASE NAME		
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Air	lb/h	68.75	68.75	68.75
TOTAL	lb/h	68.75	68.75	68.75
PROPERTIES				
Temperature	°F	70	70	70
Pressure	psia	71.3	71.3	71.3
Density	lb/ft³	0.364	0.364	0.364
Molecular Weight	lb/lb-mole	29	29	29
Viscosity	cP	0.018	0.018	0.018
FLOWS				
Mass Flow	lb/h	68.75	68.75	68.75
Volumetric – Actual (vapor)	acfm	3.15	3.15	3.15
Volumetric – Standard	scfm	15.00	15.00	15.00
Fluid Velocity	ft/s	38.5	38.5	38.5

Table D-2 (continued). Stream Sheets

PROCESS STREAM SHEET	Line No. 3/8"-2.6D-420-03			
	Revision	Approval		
NOTES: Air to Waste Transfer Pump P-002			PROJECT:	PBR/SDP
			PREPARER:	RR
			DATE:	3/8/96
	Drawing No. E03456, E03459			
	System: Waste Feed Tank			Line Size: 0.375
		CASE NAME		
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Air	lb/h	36.67	36.67	36.67
TOTAL	lb/h	36.67	36.67	36.67
PROPERTIES				
Temperature	°F	70	70	70
Pressure	psia	71.3	71.3	71.3
Density	lb/ft³	0.364	0.364	0.364
Molecular Weight	lb/lb-mole	29	29	29
Viscosity	cP	0.018	0.018	0.018
FLOWS				
Mass Flow	lb/h	36.67	36.67	36.67
Volumetric – Actual (vapor)	acfm	1.68	1.68	1.68
Volumetric – Standard	scfm	8.00	8.00	8.00
Fluid Velocity	ft/s	20.5	20.5	20.5

PROCESS STREAM SHEET	Line No. 1/2"-2.6D-450-1			
	Revision	Approval		
NOTES: Nitrogen Pad to T-010 Based on 15 gal/d for Case 1 and 2 75 gal/d for Case 3			PROJECT: PBR/SDP	
			PREPARER: RR	
			DATE: 3/8/96	
	Drawing No. E03456, E03459			
	System: Nitrogen		Line Size:	0.5
	CASE NAME			
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Nitrogen	lb/h	0.006	0.006	0.030
TOTAL	lb/h	0.006	0.006	0.030
PROPERTIES				
Temperature	°F	70	70	70
Pressure	psia	71.3	71.3	71.3
Density	lb/ft³	0.351	0.351	0.351
Molecular Weight	lb/lb-mole	28.013	28.013	28.013
Viscosity	cP	0.018	0.018	0.018
FLOWS				
Mass Flow	lb/h	0.0060	0.0060	0.0302
Volumetric – Actual (vapor)	acfm	0.0003	0.0003	0.0014
Volumetric – Standard	scfm	0.0014	0.0014	0.0070
Fluid Velocity	ft/s	0.0035	0.0035	0.0175

PROCESS STREAM SHEET NOTES: Nitrogen Sweep to Relief Header Based on 1 scfm	Line No. 1/2"-2.6D-450-2			
	Revision	Approval		
				PROJECT: PBR/SDP
				PREPARER: RR
				DATE: 3/8/96
	Drawing No. E03456, E03459			
	System:	Nitrogen	Line Size:	0.5
		CASE NAME		
COMPOSITION	UNITS	Case 1	Case 2	Case 3
Nitrogen	lb/h	4.345	4.345	4.345
TOTAL	lb/h	4.345	4.345	4.345
PROPERTIES				
Temperature	°F	70	70	70
Pressure	psia	71.3	71.3	71.3
Density	lb/ft³	0.351	0.351	0.351
Molecular Weight	lb/lb-mole	28.013	28.013	28.013
Viscosity	cP	0.018	0.018	0.018
FLOWS				
Mass Flow	lb/h	4.345	4.345	4.345
Volumetric – Actual (vapor)	acfm	0.206	0.206	0.206
Volumetric – Standard	scfm	1	1	1
Fluid Velocity	ft/s	2.520	2.520	2.520

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