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GJPO-MWTP-02

Mixed-Waste Treatment Program

Evaporative Oxidation Treatability Test Report

April 1995

U.S. Department of Energy
Grand Junction Projects Office

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

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

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Acronyms, Initialisms, and Abbreviations

Ag	silver
Al	aluminum
A	americium
As	arsenic
b.p.	boiling point (normal)
Ba	barium
Btu	British thermal unit
CCl_4	carbon tetrachloride
Cd	cadmium
CH_3CL	chloromethane (methyl chloride)
$CHCl_3$	chloroform
Cl^-	chloride ion
cm	centimeters
CO	carbon monoxide
Cr	chromium
CTC	Clemson Technical Center
DCE	dichloroethane
DCM	dichloromethane
DOE	U.S. Department of Energy
DOE–AL	U.S. Department of Energy, Albuquerque Operations Office
DOT	U.S. Department of Transportation
dpm	disintegrations per minute
Fe	iron
g	grams
gal/h	gallons per hour
GJPO	Grand Junction Projects Office
Hg	mercury
IPA	isopropyl alcohol
K	equilibrium constant
kW	kilowatt
LANL	Los Alamos National Laboratory
lb	pounds
lb/ft^3	pounds per cubic foot
lb/h	pounds per hour
LDR	land disposal restriction
µg/L	micrograms per liter (equivalent to parts per billion for aqueous substances)
µg	micrograms
mg/L	milligrams per liter (equivalent to parts per million for aqueous substances)
mg/kg	milligrams per kilogram (ppm)
mL	milliliters
mr	millirems
mrem/h	millirems per hour
MTU	mobile treatment unit
N	normality (concentration)
Na	sodium
$NaHCO_3$	sodium bicarbonate
NaOH	sodium hydroxide
ncpm	net counts per minute

Acronyms, Initialisms, and Abbreviations (continued)

ND	not detected
NH_3	ammonia
NH_4^+	ammonium ion
NO_2	nitrite ion
NO_3	nitrate ion
NO_x	oxides of nitrogen
O_2	oxygen
P&ID	piping and instrumentation diagram
Pb	lead
PC	product condensate
pCi/L	picocuries per liter
PO*WW*ER®	process for oxidation of wastewater with evaporation and reduction
PO_4	phosphate ion
ppb	parts per billion
ppm	parts per million
psi	pounds per square inch
psig	pounds per square inch gauge
Pu	plutonium
Ra	radium
Ra-226	radium isotope with atomic weight of 226
RCRA	Resource Conservation and Recovery Act
s	seconds
SCR	silicon-controlled rectifier
Se	selenium
slpm	standard liters per minute
SNL/NM	Sandia National Laboratories/New Mexico
SO_4	sulfate ion
SVOC	semivolatile organic compound
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leachate Procedure
TDS	total dissolved solids
Th	thorium
Th-230	thorium isotope with atomic weight of 230
TIC	total inorganic carbon
TOC	total organic carbon
TOX	total organic halogens
TSS	total suspended solids
U	uranium
U-234	uranium isotope with atomic weight of 234
U-235	uranium isotope with atomic weight of 235
U-238	uranium isotope with atomic weight of 238
UTS	Universal Treatment Standard
V/V_{mf}	ratio of actual velocity to minimum fluidization velocity
V_{mf}	minimum fluidization velocity
VOC	volatile organic compound

1.0 Introduction

In 1992, Congress passed the Federal Facilities Compliance Act that requires the U.S. Department of Energy (DOE) to treat and dispose of its mixed waste in accordance with the Resource Conservation and Recovery Act (RCRA) land disposal restrictions (LDRs). In response to the need for mixed-waste treatment capacity where available off-site commercial treatment facilities do not exist or cannot be used, the DOE Albuquerque Operations Office (DOE–AL) organized a Treatment Selection Team to match mixed wastes with treatment options and develop a strategy for treatment of its mixed wastes. DOE–AL manages operations at nine sites with mixed-waste inventories.

The Treatment Selection Team determined a need to develop mobile treatment capacity to treat wastes at the sites where the wastes are generated. Treatment processes used for mixed waste not only must 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.

On the basis of recommendations of the Treatment Selection Team, DOE–AL assigned projects to the sites to bring mixed-waste treatment capacity on-line. The three technologies assigned to the DOE Grand Junction Projects Office (GJPO) are evaporative oxidation, thermal desorption, and treated wastewater evaporation. Rust Geotech, the DOE–GJPO prime contractor, was assigned to design and fabricate mobile treatment units (MTUs) for these three technologies and to deliver the MTUs to selected DOE–AL sites.

Development of evaporative oxidation treatment capacity for selected DOE–AL mixed wastes requires several activities:

- Conduct treatability tests to confirm the applicability of this technology for DOE–AL waste streams and to collect design information for an MTU.
- Develop preliminary and detailed designs of an MTU.
- Fabricate an MTU.
- Conduct acceptance testing and startup of an MTU.

To conduct treatability tests at the GJPO, Rust leased a pilot-scale evaporative oxidation unit from the Clemson Technical Center (CTC), Anderson, South Carolina. This pilot-scale unit, developed by Chemical Waste Management, Inc., to treat chemical industry wastewaters, is known by the trade name PO*WW*ER®.

The pilot-scale unit, known as the mini-PO*WW*ER® unit, was shipped from CTC to GJPO and installed in a high-bay room at the site (see Figure 1–1). GJPO conducted a series of treatability tests using the mini-PO*WW*ER unit with samples of mixed wastes from three DOE–AL sites: GJPO, Los Alamos National Laboratory (LANL), and Sandia National Laboratories/New Mexico (SNL/NM).

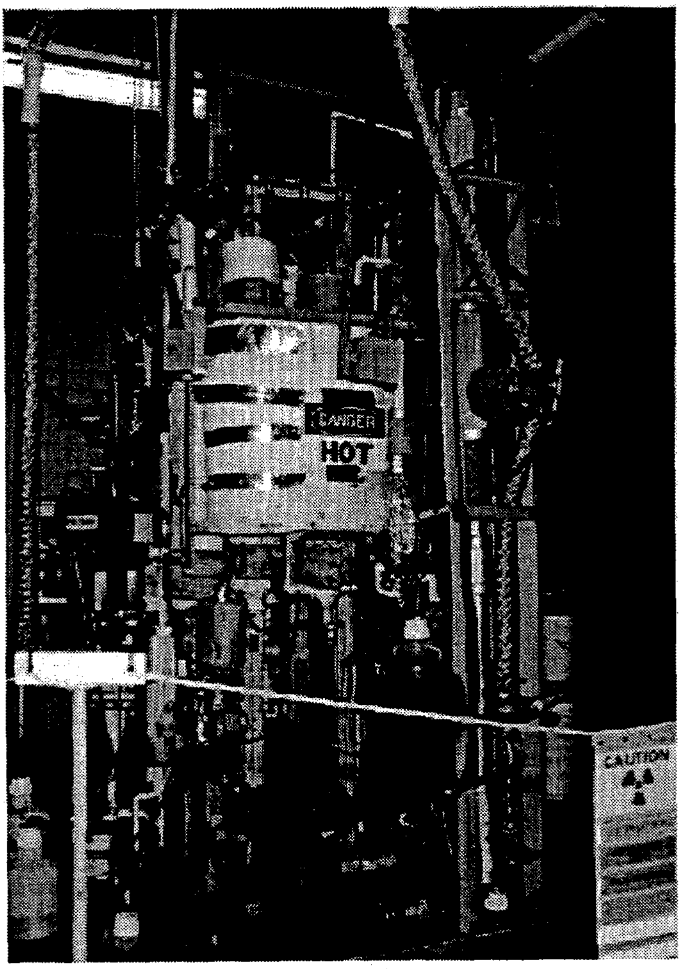

*Figure 1–1. Mini-PO*WW*ER Unit*

The purpose of this report is to document the results and findings of those tests and to determine if the objectives of the tests were met.

1.1 Test Objective

An *Evaporative Oxidation Treatability Test Plan (Treatability Test Plan;* see Appendix A) was prepared that specifies the goals and objectives of the test program. The *Treatability Test Plan* states that "the primary objective of this treatability test is to demonstrate the effectiveness of the PO*WW*ER evaporative-oxidation process on the specific mixed-waste streams . . . effectiveness will be determined by identifying any additional treatment required for ultimate disposal of any process residuals, based on their resulting composition." The *Treatability Test Plan* outlines four key performance parameters that would be evaluated to determine the effectiveness of the PO*WW*ER process. These parameters are:

1. Concentration Factor (*C*): A measure of volume reduction defined to be equal to the volume of feed processed (V_{feed}) divided by the volume of concentrate produced ($V_{concentrate}$).

$$C = V_{feed} / V_{concentrate} \tag{1}$$

2. Oxidation Efficiency (*E*): A measure of effectiveness of the system equal to the difference of the total organic content (TOC_{in}), or specific constituent, at the oxidizer inlet and the total organic, or specific constituent, content (TOC_{out}) at the oxidizer outlet divided by the total inlet organic, or specific constituent, content.

$$E = \frac{TOC_{in} - TOC_{out}}{TOC_{in}} \tag{2}$$

3. Product Condensate Quality: The concentration of contaminants (e.g., radionuclides or RCRA hazardous constituents) in the product condensate.

4. Process Concentrate Quality: The concentration of contaminants in the process concentrate.

The *Treatability Test Plan* further states that "a secondary objective of this treatability test is to obtain any operational data that can be collected by the existing equipment and computer software supplied with the mini-PO*WW*ER unit." To this end, the *Treatability Test Plan* proposes that "the oxidation efficiency will be evaluated at 2-mole-percent excess oxygen concentration and at two different catalyst bed temperatures, 1,000 °F (538 °C) and 1,200 °F (649 °C)."

1.2 Summary of Results

- The PO*WW*ER technology demonstrated the ability to treat mixed-waste samples so that concentrations of all RCRA hazardous organic compounds in the product condensate were below Universal Treatment Standards (UTSs) for wastewaters without further treatment.

- Concentrations of all RCRA hazardous organic compounds in the concentrate (brine) were below UTSs for nonwastewaters. (The brines produced during the GJPO treatability tests did not meet the EPA definition for a nonwastewater because they contained less than 1 percent total dissolved solids. However, the brines that will be produced during waste treatment should contain enough solids to qualify as nonwastewaters. See Section 5.2.4 for additional information.)

- Segregation of radionuclides into the concentrate (brine) was essentially complete. Concentrations of radionuclides in the product condensate and the scrubber liquor were below detection limits in all cases and well below the 400-picocuries-per-liter (pCi/L) threshold standard for radioactive wastewaters.

- Destruction of nonhalogenated organics in the oxidizer ranged from 97.9 percent to more than 99.9995 percent. Feed concentration did not limit destruction efficiency; within the range of wastes tested at GJPO, near-total destruction of volatile organic compounds (VOCs) is possible in the oxidizer regardless of the VOC concentration in the feed. The maximum operating temperature of the catalyst imposes the only limitation on VOC concentration.

- Destruction of halogenated organics was more than 99.9 percent without the addition of hydrogen donor (methanol). Methanol addition improved destruction efficiency to 99.99 percent. For the product condensate to meet LDRs, addition of methanol or other hydrogen donor to halogenated feeds may be required.

- Removal of total organic carbon from brine varied from 99.0 to 99.8 percent, and can be optimized by allowing more time on water feed at the end of a waste run.

- Oxidation of ammonia varied from a low of 86.8 percent (with inadequate oxygen) to as high as 99.99 percent. The rate of ammonia removed from the brine can be controlled by adjusting the pH of the evaporator.

- Optimum destruction of halogenated and nonhalogenated organics and ammonia requires oxidizer-bed temperatures of at least 600 °C, residence times of at least 0.2 seconds, and a minimum of 2 percent oxygen in the off gas.

Table 1–1 summarizes the results of each treatability test run. Two separate series of tests were performed on the LANL New 5, New 6, and L16 waste samples. To minimize confusion between samples, the second test on each waste was designated Prime. Several improvements were made to the Mini-PO*WW*ER unit between the first and second series of tests to permit higher operating temperatures and longer contact times (see Appendix B for details). Consequently, the second test on each waste showed higher destruction efficiencies than the first test on the same waste.

Appendix B gives a detailed summary of waste feed and dilution rates during each test. A detailed history of the feed preparation and each treatability test is given in Appendix C and the full analytical profile for every sample taken during the treatability tests is given in Appendix D.

Table 1–1. Summary of Treatability Test Results

Run Number	Sample	RCRA Code	Waste Composition	RCRA UTS		Feed Concentration[a]	Product Condensate Concentration (ppb)	Brine Concentration (ppm)	Removal from Evaporator	Destruction in Oxidizer	Gross Alpha/Beta Activity (pCi/L)		
				Wastewater (ppb)	Nonwastewater (ppm)						Feed	Product Concentrate	Brine
1	TG1	D018	Benzene	0.140	10	2.4 ppm	<5	<5 ppb	~100%	~100%	56,921	<8.0	22,900
		D019	CCl_4	0.057	6	<2.5 ppm	<5	<5 ppb	-	-			
		D022	$CHCl_3$	46	6	0.16%	<5	<5 ppb	99.9995%	100.00%			
2	New 5	D001	IPA	N/A	N/A	2.19%	ND[b]	1,870[d]	99.1%	100.00%	141,351	<9.0	1,050,000
		D002	pH	N/A	N/A	11.1	-	-	-	-			
		D008	Lead	690	0.37	1.11 ppm	ND[b]	3.0	-	-			
		-	NH_3	N/A	N/A	0.033%	85	765	75.6%	99.97%			
3	New 6	D002	pH	N/A	N/A	9.95	-	-	-	-	12,647	<9.0	154,000
		D009	Hg	150	0.025	<0.4 ppb	-	-	-	-			
		F005	Acetone	0.280	160	1.16 ppm	5.1 ppm[c]	ND[b]	~100%	N/A[c]			
		-	IPA	N/A	N/A	0.96%	191 ppm[d]	4,080[d]	93.5%	97.9%			
		-	NH_3	N/A	N/A	1.12%	1,470 ppm	881	98.8%	86.8%			
4	L17	F002	DCM	89	30	0.18%	150	2.9	99.98%	99.992%	25,460	<10.4	640,000
5	L16	F001	DCM	89	30	1.5%	159 ppm	3.8	99.997%	98.9%	5,400	<21.0	70,000
6	Old New 5	D001	IPA	N/A	N/A	1.13%	147[d]	244[d]	99.79%	99.9987%	49,958	<8.0	305,000
		D002	pH	N/A	N/A	11.1	-	-	-	-			
		D008	Lead	690	0.37	0.98 ppm	ND[b]	0.282	-	-			
		-	NH_3	N/A	N/A	1.46%	728	14.2%	5.9%	99.92%			
7	New 6 Prime	D002	pH	N/A	N/A	9.95	-	-	-	-	11,464	<12.5	44,720
		D009	Hg	150	0.025	<0.4 ppb	ND	ND	-	-			
		F005	Acetone	0.280	160	1.05 ppm	ND	ND	~100%	~100%			
		-	IPA	N/A	N/A	0.87%	<200	ND	~100%	99.998%			
		-	NH_3	N/A	N/A	1.02%	728	1,860	98.4%	99.993%			
8	New 5 Prime	D001	IPA	N/A	N/A	1.57%	<200	870d	99.6%	99.9987%	603,809	<12.3	2,224,000
		D002	pH	N/A	N/A	11.1	-	-	-	-			
		D008	Lead	690	0.37	0.8 ppm	ND	1.45					
		-	NH_3	N/A	N/A	0.024%	135	3,990	6.37%	99.11%			
9	L16 Prime	F001	DCM	89	30	1.5%	47	450 ppb	99.999%	99.9997%	5,400	<12.3	224,000
10	SNL	D001	MeOH	15,600	0.75	3%	<200	255[d]	97.98%	99.9993%	[e]	<12.3	17,690

[a] Feed concentrations have been adjusted for water dilution where applicable.

[b] ND = None detected.

[c] Probably formed from reaction.

[d] Estimated from TOC measurement.

[e] Not taken due to small sample volume.

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2.0 Description of Evaporative Oxidation Unit

Evaporative oxidation technology treats aqueous waste streams containing halogenated and nonhalogenated (VOCs) and semivolatile organic compounds (SVOCs), volatile inorganics, and nonvolatile dissolved or suspended solids (e.g., heavy metals and radionuclides) in a continuous process that combines evaporation and catalytic oxidation. The evaporator concentrates the nonvolatile contaminants into a thick brine, and the catalytic oxidizer (and associated scrubbing system) converts the volatile contaminants into water, inert gases, and salts. Products of the process are a brine, which contains the radionuclides, and a product condensate, which is essentially pure water. Figure 2–1 shows the process flow diagram for the PO*WW*ER unit. Figure 2–2 presents the piping and instrumentation diagram for the mini-PO*WW*ER unit installed and operated at GJPO.

2.1 Evaporator

During operation, the evaporator concentrates an aqueous waste feed stream, boiling off water, VOCs, and SVOCs at near atmospheric pressure. The concentrate (brine) containing radionuclides, heavy metals, nonvolatile organics, and nonvolatile inorganics concentrates in the evaporator and is removed as required.

The evaporator consists of a single-stage, forced-recirculation evaporator with a horizontal two-pass shell-and-tube heat exchanger. Feed is introduced into the circulating liquid mixture, which is pumped through the heat exchanger into the top of the evaporator body. Heat is added to the circulating liquid by condensing low-pressure steam on the shell side of the heat exchanger. This heat brings the liquid to its boiling point, although boiling does not occur in the heat exchanger because of back pressure imposed by liquid head and a throttling valve installed between the exchanger outlet and the evaporator body. Instead, as the liquid enters the evaporator, the pressure drops and a small portion of the liquid flashes to vapor and exits the top of the evaporator body.

Feed to the unit is stored in 25-liter plastic carboys. The feed carboy is placed on a weight load cell that gives continuous measurement of the carboy's weight. Changes in weight of the carboy over time are used to calculate the feed rate. The feed liquid is pumped from the carboy into the evaporator circulating loop by a variable-speed peristaltic feed pump.

Vapors exiting the evaporator may entrain mist particles from the evaporator body. Because these mist particles could contain radionuclides and salts, they must not be allowed to enter the catalytic oxidizer (salts could foul the catalyst surface and the process is designed to retain radionuclides in the evaporator). An entrainment separator, consisting of a mesh pad housed in an oversized piping section installed downstream of the evaporator, traps these mist particles. The entrainment separator is periodically blown down, and the collected liquid is added to the evaporator feed.

As the concentration of nonvolatiles in the brine increases, foaming can become a problem. The mini-PO*WW*ER pilot unit can add an antifoaming agent when high (greater than 65 percent) solids levels are reached. However, the mixed-waste samples evaluated during the tests at the GJPO contained less than 2 percent total solids (see Table 3–2), and the total quantity of each waste tested was insufficient to allow the solids concentration to build to the level where foaming would occur.

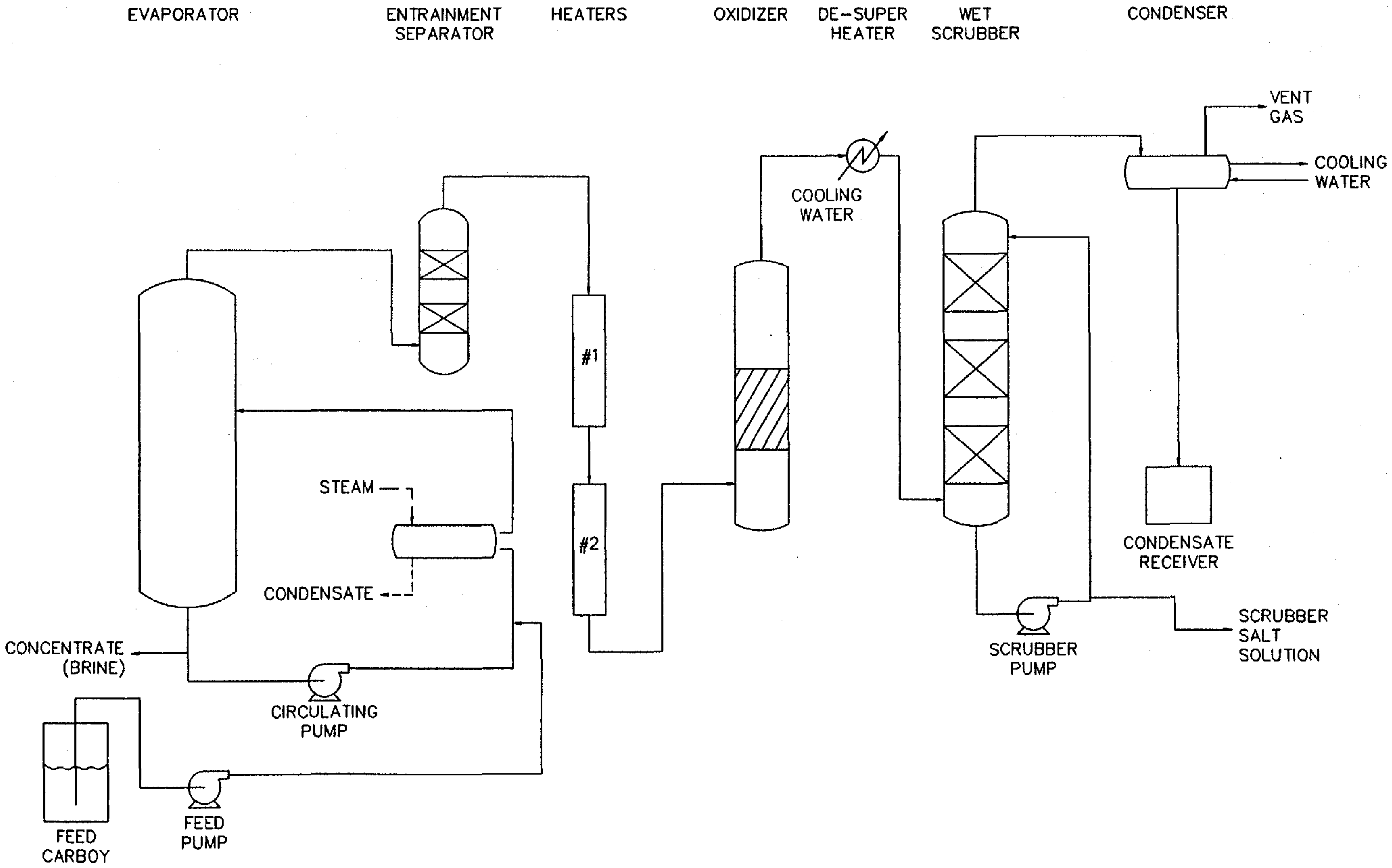


FIGURE: E0293300

Figure 2–1. Evaporative-Oxidation Process Flow Diagram

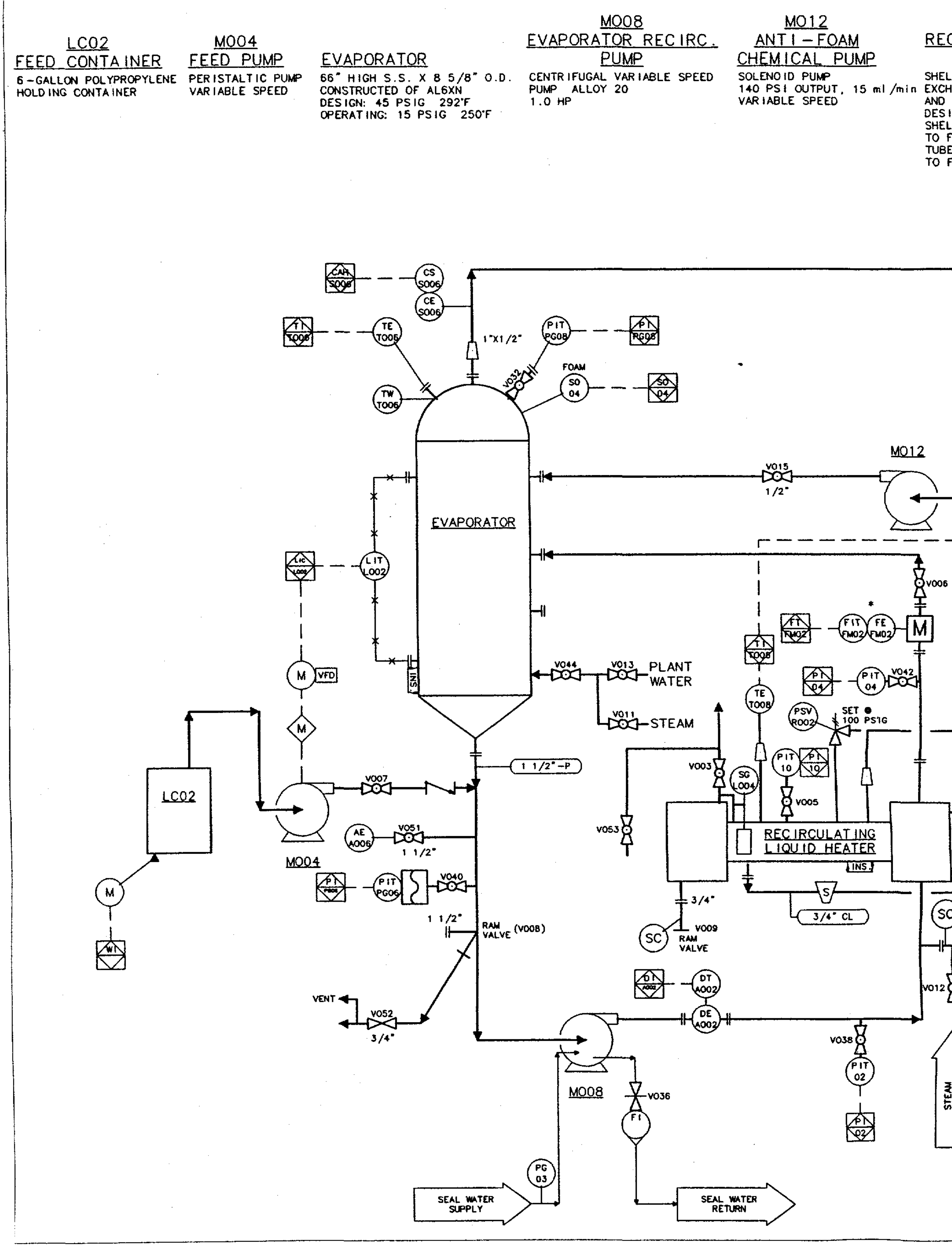
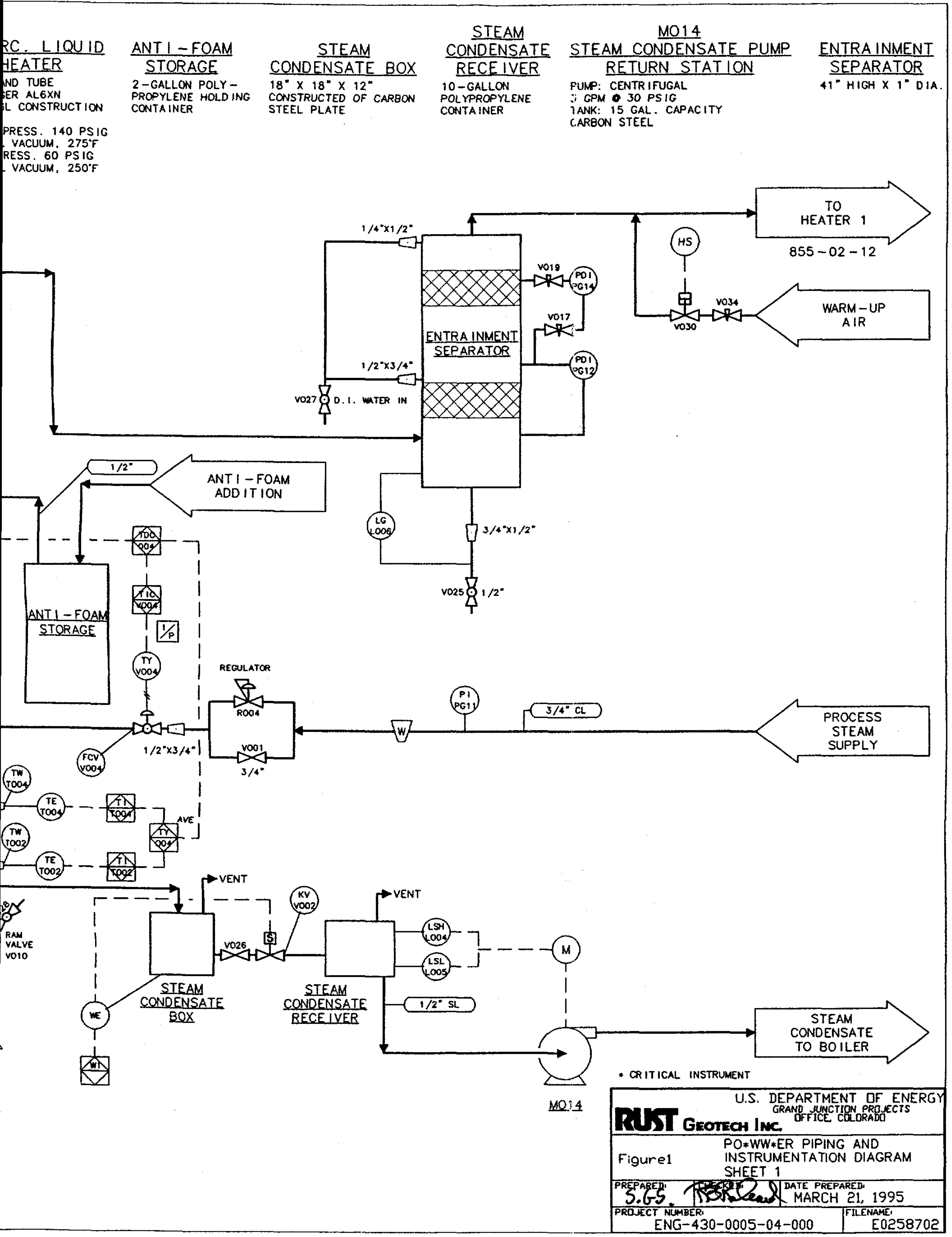


Figure 2–2. PO*WW*ER Pi



g and Instrumentation Diagram

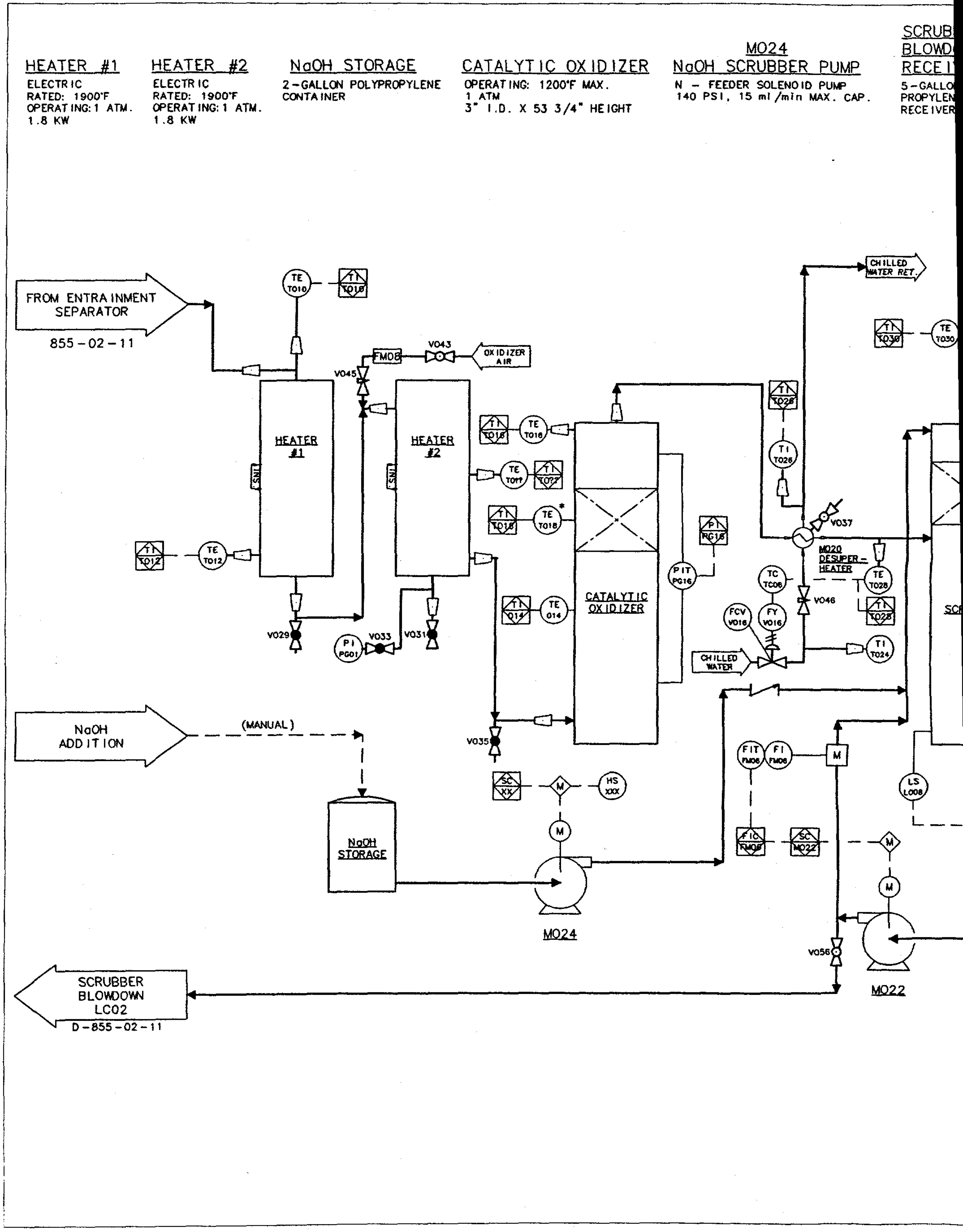
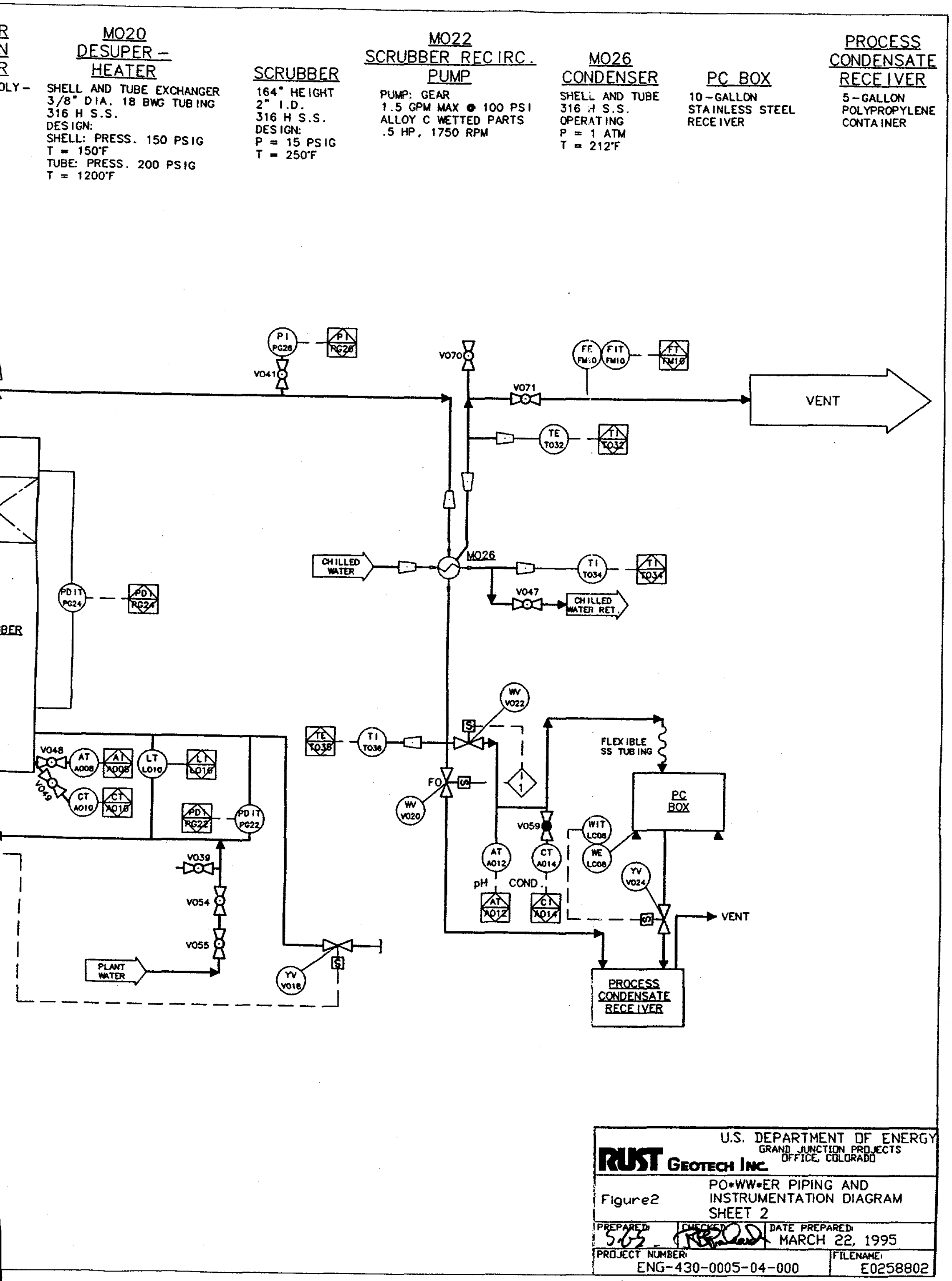


*Figure 2–2 (continued). PO*WW*E*



Piping and Instrumentation Diagram

2.2 Catalytic Oxidizer

Vapor stream from the evaporator is superheated to a temperature of 500 to 600 °C in a series of two electric heaters. Air to provide oxygen for the oxidation reactions is added as the vapor stream enters the second heater. The heaters are controlled by an SCR temperature controller that measures the temperature at the inlet to the oxidizer bed and regulates the output of the heaters to maintain this temperature at the specified setpoint. The heated vapor-air stream then enters the catalytic oxidizer.

The oxidizer contains a proprietary, nonprecious metal catalyst developed by ARI, Inc. (ARI), of Schaumberg, Illinois. In the catalyst bed, volatile organics and inorganics are oxidized to form carbon dioxide, water, and (when chlorinated organics are present in the feed) hydrogen chloride gas. The oxidizer is designed to be operated under conditions of incipient fluidization. Because the maximum operating temperature of the catalyst material was 700 °C and almost all of the oxidation reactions are strongly exothermic, the concentration of organic reactants in the feed had to be limited to about 5 percent total organic to keep the final oxidizer temperature below the maximum limit.

2.3 Scrubbing System

After oxidation, the hot gases exit the oxidizer bed and pass through a desuperheater, a small water-cooled spiral heat exchanger designed to remove some of the heat of reaction and to limit the cooling load on the downstream equipment. (The desuperheater was installed during the test work at GJPO. However, heat losses to ambient air from the off-gas piping gave more than adequate desuperheating during the initial demonstration run with water, so the cooling water to the desuperheater was blocked off for all treatability tests.)

Upon exiting the desuperheater the gases enter the scrubber, a packed tower that uses a circulating solution of sodium hydroxide to neutralize acidic gases formed during the oxidation of halogenated compounds. Flow in the scrubber is countercurrent—the hot gases enter near the bottom of the column and exit at the top, just above the point where the circulating liquid is introduced. The bottom section of the scrubber serves as a holding tank for the scrubber circulating liquid. The pH of the scrubber liquid is maintained in the range of 8 to 10 by the addition of 10N sodium hydroxide, as required.

Acid gases are converted to salt in the scrubber and remain in the liquid. As the concentration of salts increases, the neutralizing capability of the liquid drops because of the buffering action. The conductivity of the circulating solution is monitored to determine when the salt concentration has reached the level where "blowing down" the scrubber is necessary. In practice, a significant amount of water condensed in the scrubber, and blowdown was always based on maintaining the liquid level in the scrubber rather than on controlling conductivity. Scrubber blowdown is returned to the evaporator before waste treatment is concluded to minimize the number of byproduct streams.

2.4 Condenser

Treated vapors exit the scrubber as saturated water vapor and enter a shell-and-tube condenser. Water is condensed in the shell side of the condenser and noncondensable gases are vented from the condenser to the building's ventilation system. The condensed water (hereafter termed "product condensate") is collected in a receiver tank placed on a weight load cell that gives continuous measurement of the condensate weight.

2.5 Control System

A microcomputer using FIXDMACS software (Intellution, Inc.) runs the automatic control system for the mini-PO*WW*ER unit. As designed, the control system has four primary operating loops:

1. Feed rate is controlled by adjusting the speed of the feed pump to maintain the evaporator level.

2. Steam rate to the heat exchanger is controlled by adjusting the position of the steam control valve to maintain the temperature differential across the heat exchanger. Temperature differential is computed by subtracting the average temperature on the process side, calculated as the numeric mean of the heat exchanger inlet and outlet temperatures, from the steam temperature.

3. Output of the electric heaters is adjusted to maintain the oxidizer-bed inlet temperature. (This adjustment is handled by a local silicon-controlled rectifier (SCR) controller, not by the microcomputer.) Both heaters are operated from a common control signal, so the percentage output to both heaters is always equal.

4. Scrubber pH is maintained by adding caustic batch-wise, as required.

Direct measurements are not taken of the feed rate to the unit, the steam rate to the heat exchanger, or the product condensate rate. The feed vessel (25-liter plastic carboys were used at GJPO) and the steam and product condensate receivers are placed on load cells, and the feed rate and condensate rate are calculated by the computer using the difference in weights over time intervals.

3.0 Wastes Tested

Evaporative oxidation technology is applicable to aqueous waste streams containing organic contaminants and dissolved or suspended solids. Table 3–1 lists DOE–AL mixed-waste streams from GJPO, LANL, and SNL/NM that were identified as suitable for treatment with evaporative oxidation technology. These waste streams were tested in the mini-PO*WW*ER unit at GJPO.

Table 3–1. Waste Streams Tested With Evaporative Oxidation Technology at GJPO

Site	Stream	RCRA Hazardous Waste Code[a]	Hazardous Constituent	Concentration[b]	Principal Radionuclide	Activity (pCi/L)[b]
GJPO	TG1	D018 D019 D022	Benzene CCl_4 Chloroform	3.5 ppm < 2.5 ppm 0.16%	Ra-226 Th-230 U-234 U-238	96 1350 13,500 11,700
LANL	New 5	D001 D002 D008	Isopropyl pH Lead	3.7% 11.1 1680 ppm	U-234 U-235 U-238	77,452 9,799 560,317
LANL	New 6	D002 D009	pH Mercury	9.95 < 0.4 ppb	U-234 U-235 U-238	242 42 668
LANL	L16	F001	Methylene Chloride	1.5%	Am Pu	343 1418
LANL	L17	F002	Methylene Chloride	0.24%	Am Pu	2216 3344
SNL/NM	Grind Sludge	D001 D002	Methanol Perchloric Acid	3.8% 0.4%	Depleted Uranium	N/A

[a] Hazardous Waste Codes are assigned to waste streams by the generator. Individual samples may not contain all hazardous components of the total stream.

[b] Concentrations are as reported by the GJPO Analytical Laboratory.

When the GJPO TG1 drum was opened, about 2 gallons of aqueous liquid was observed on top of a drum full of compacted sludge (see Section 4.1, "Feed Preparation"). Because the mini-PO*WW*ER unit is not designed to treat sludge, the liquid portion of the waste stream was decanted into a separate container for treatability testing with the mini-PO*WW*ER unit, and the solids were resealed in the drum. The solids waste will be tested later with thermal desorption technology.

In addition to the hazardous components, the waste samples tested at GJPO contained both dissolved and suspended solids, and other chemical species that could be treated by the technology. Table 3–2 presents the concentrations of these other constituents in the waste samples fed to the mini-PO*WW*ER unit during GJPO treatability tests; a dash indicates that the sample was not tested for a particular analyte.

Table 3–2. Concentrations of Other Constituents in GJPO Treatability Test Feed Samples

Waste	Composition					
	TDS (ppm)	TSS (ppm)	TOC (ppm)	IPA (mg/L)	CH_3Cl (mg/L)	NH_3 (mg/L)
L16	16,600	429	1,390	-	15,000	-
L17	17,500	402	340	-	1,800	-
Old New 5	89,800	24	22,900	37,500	<1	-
New 5	-	-	21,400	33,000	-	499
New 6	-	-	40,900	43,000	-	50,500
TG1	49,700	5,530	1,360	-	73	-

4.0 Summary of GJPO Test Runs

GJPO received the first samples of feed in August 1994, and the mini-PO*WW*ER unit at the end of the same month. Feed preparation of the LANL and GJPO samples began during the latter part of August, and treatability tests began during the latter part of September.

4.1 Feed Preparation

The PO*WW*ER process is designed to treat aqueous organic liquid streams and can accept a variety of feeds, including those containing suspended solids, dissolved salts, and metals. The PO*WW*ER process cannot handle solid materials or liquids containing large solid particles. Further, the materials used in construction of the mini-PO*WW*ER unit limit the acceptable pH range of the feed, and the concentration of organics in the feed is limited by the need to keep the catalyst temperature below its 704 °C maximum operating limit.

The *Treatability Test Plan* (see Appendix A) specifies a feed preparation process consisting of several discrete steps intended to ensure that the actual feed to the unit is appropriate in terms of solids, pH, and organic concentration:

1. Adjustment of pH to between 6 and 8.

2. Debris screening and washing to remove coarse solids.

3. Dilution with water to reduce total organic carbon content.

4. Augmentation of total solids content by addition of benign inorganic salts.

5. Methanol addition for halide scavenging.

The first samples of LANL and GJPO wastes were screened by agitating the liquids in the original drums and pumping the liquid through a 0.25-inch screen (see Figure 4–1), and were found to contain essentially no coarse solids. The samples were then adjusted for pH, as necessary, by addition of sodium hydroxide and/or sulfuric acid (see Figure 4–2). Water was added to the individual feed carboys as they were prepared, although the basis for water addition was revised from the arbitrary guideline of 5-percent total organic concentration given in the *Treatability Test Plan* to a calculated, waste-specific target to achieve a specified exotherm in the oxidizer bed. Methanol was also added to individual carboys of the halogenated waste feeds. The plan to augment solids concentration by addition of benign salts was dropped from the project after consultation with the designer of the mini-PO*WW*ER unit. (See Appendix B for additional information.)

Because the original samples of the LANL New 5 and New 6 samples contained large amounts of ammonia and buffering salts, the project team requested additional samples of these waste streams to test the ability of the treatment unit to destroy ammonia without neutralization. These additional samples were pH-adjusted to between 4 and 10, the pH range required by the metallurgy of the evaporator system, rather than to the more stringent requirements given in the *Treatability Test Plan.* These samples were used in the GJPO treatability tests. The earlier samples, now referred to as "Old New 5," "Old New 5X (see Page B-3 of Appendix B)," and "Old New 6," were not used in the treatability tests, except that part of the Old New 5 sample was used to evaluate the performance of the evaporator at high solids loadings.

Figure 4–1. Screening Waste Samples

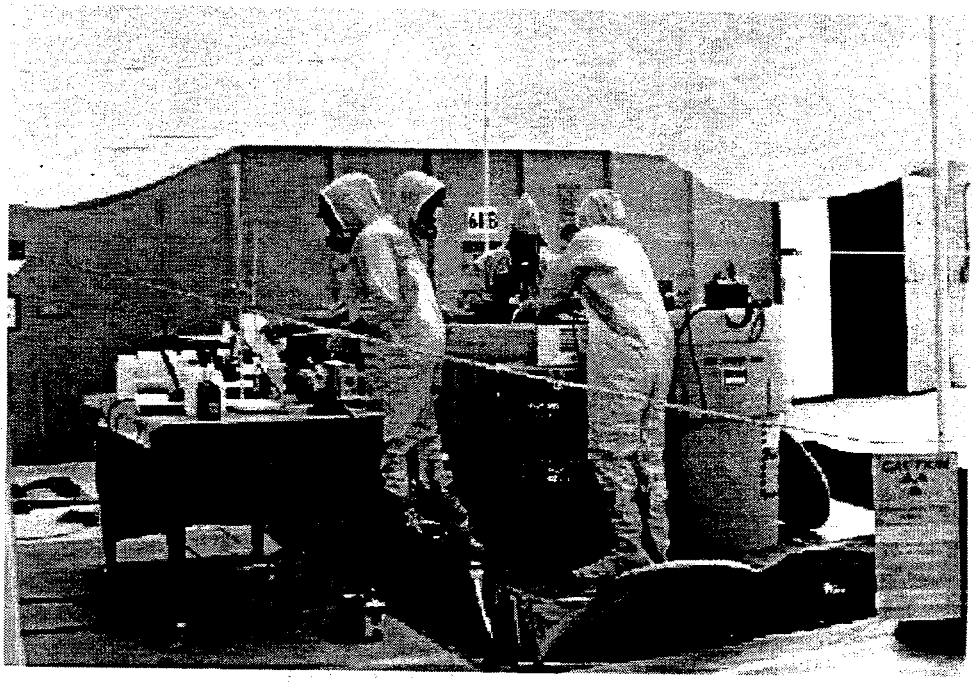


Figure 4–2. Feed Preparation

The last waste stream tested at GJPO was a small sample from SNL/NM. This sample was not subjected to a full analysis because the sampling would have used up nearly all of the sample that was available. The run plan for this sample was prepared with the recipe for its generation that was provided by SNL/NM. The only feed preparation of this sample was neutralization.

Appendix B presents details of the feed preparation activities and discussions that resulted in deviations from the *Treatability Test Plan.*

4.2 PO*WW*ER Unit Operation

A summary of operating data for all GJPO treatability tests is given in Table 4–1. This Table shows total run time for waste feed, average feed rate (including dilution water where applicable), average oxidizer bed temperature, and calculated excess oxygen in the vent gas.

Table 4–1. Average Operating Conditions for GJPO Treatability Tests

Run Number	Sample	Run Time (h)	Feed Rate (lb/h)	Bed Temperature (°C)	Excess O_2 (mole %)
1	TG1	3.78	10.6	509	20.9
2	New 5	30.38	12.5	513	5.4
3	New 6	25.53	10.3	563	-1.2
4	L17	25.77	12.0	515	20.6
5	L16	32.92	11.6	[a]	[a]
6	Old New 5	33.48	12.4	[b]	[b]
7	New 6 Prime	37.4	12.5	621	15.6
8	New 5 Prime	45.67	12.2	630	5.4
9	L16 Prime	8.02	12.4	591	15.5
10	SNL	1.30	12.9	643	4.6

[a] Operation was erratic and average values are not significant.
[b] Computer failure resulted in loss of part of the operating data.

The initial operation of the mini-PO*WW*ER unit at GJPO was a demonstration run to verify the functioning of all pieces of the unit and to gain operating experience. The demonstration run consisted of initial operation on water only, followed by tests with a series of "surrogate" waste streams to demonstrate the destruction efficiency of the catalyst on feeds with known composition. Solutions of isopropyl alcohol (IPA), dichloromethane (DCM, also known as methylene chloride), and ammonium hydroxide were used for these tests, since these were the major contaminants in the LANL waste streams. The oxidation efficiency of organics and ammonia observed during this run was nearly 99.99 percent.

The first portion of the demonstration run used a 2-percent concentration of IPA. This concentration was calculated based on discussions with Brian Eichlin, the designer of the mini-PO*WW*ER unit, who recommended that the feeds be diluted as required to obtain a temperature rise across the oxidizer bed, due to heat of reaction, of not more than 500 °F. For solutions of IPA in water, the calculated concentration required to achieve this temperature rise is 2 percent by weight. (See Appendix B for additional information.) The actual oxidizer bed temperature rise observed during the test using 2-percent IPA was about 250 °F, or half of the calculated value, probably due to heat losses in the unit. Samples containing high levels of organics could thus be fed at relatively low dilutions without exceeding the maximum temperature of the catalyst. However, testing waste samples containing predominantly halogenated organics (which have much lower heats of reaction) at 1,200 °F, as specified in the *Treatability Test Plan*, would be very difficult, since the oxidizer heaters had been proven to be incapable of heating the oxidizer bed to this level without the additional heat provided by heat of reaction.

Run 1, the first treatability test to immediately follow the successful conclusion of the demonstration run, used the TG1 sample from GJPO. The volume of sample was only 27.5 pounds, which was sufficient for a run time of 3 hours 47 minutes. To control the bed temperature, the sample was diluted using about 0.46 parts water (volume) per part waste (0.46:1 dilution).

Run 2 used the New 5 waste sample from LANL. To evaluate operation of the evaporative oxidation unit at high pH, this sample, which had a pH of 11.1, was fed to the unit with no pH adjustment or other feed preparation, other than screening to remove large solids. An initial attempt to feed this sample without dilution, as per the run plan for that sample, resulted in a rapid rise in oxidizer bed temperature to above the action limit of 650 °C. During the remainder of the test, the sample was fed at a 0.5:1 (water/waste) dilution. With this dilution, the bed temperature averaged 513 °C and the air flow rate was adjusted to yield an average of 5.4 mole percent oxygen in the offgas.

Run 3 used the New 6 waste sample from LANL. As with the New 5 sample, New 6 was fed with no pH adjustment. The run plan called for using a dilution of 1:1. As soon as waste feed began, the bed temperature quickly rose above the action limit of 650 °C. For the remainder of the run, the dilution was changed to 6:1. Using this dilution, the oxidizer bed temperature averaged 563 °C during the run. The reason for the very high exotherm was traced to an analytical error in the ammonia concentration, which was originally reported at 1/50 of the actual concentration. Because the air-flow rate was based on the erroneous ammonia concentration, it was set too low for complete oxidation of the organic contaminated and ammonia in the sample during this test.

Run 4 used the L17 waste sample from LANL. This sample contained 0.24 percent DCM, so it was the first halogenated sample (other than the surrogate from the demonstration run) to be tested at GJPO. This sample had been pH-adjusted during feed preparation. Due to the low concentration and low exotherm of the organic contaminant, dilution was not required for this sample, and the average oxidizer bed temperature of 515 °C during this test is indicative of the maximum bed temperature obtainable from the mini-PO*WW*ER unit using only the heaters.

Run 5 used the L16 waste sample from LANL, which was similar to the L17 waste except that the concentration of DCM was 1.5 percent. As with L17, this waste was fed with no dilution. During this test, mechanical reliability of the mini-POWW*ER unit became a serious problem; the run was punctuated with numerous operating and equipment problems, including a failure of one of the heater elements and a broken coupling on the evaporator circulating pump. Because the operation was so erratic, steady-state conditions were seldom obtained during this run.

Run 6 was a demonstration of operation at high evaporator solids concentration, using the LANL Old New 5 waste. The TDS concentration of this sample was 89,800 milligrams per liter (mg/L), almost all of which was salts resulting from acid added for pH adjustment during feed preparation (see Appendix B). The target solids concentration of 40 percent in the evaporator was achieved after 33.5 hours of waste feed. Water dilution during this run was the subject of much experimentation; the average overall dilution was 0.71:1, although no dilution at all was used during the last 8.5 hours of the test. Operation of the pilot unit was stable during this test, no foaming was observed, and the high solids concentration had no detectable effect on oxidizer performance.

Demonstration of the oxidation efficiency of the unit at high temperatures with all waste samples, as specified in the *Treatability Test Plan*, had not been possible to this point in the treatability test because of high heat losses in the mini-PO*WW*ER unit. However, the oxidation efficiencies from the first series of tests indicated that the PO*WW*ER technology might be capable of producing a condensate water that meets RCRA wastewater LDRs if the pilot unit could be operated under steady-state conditions of high oxidizer temperature and contact time. Following the solids-concentration demonstration, the unit was shut down for preventive maintenance. During this shutdown, the heat tape on the bed inlet line was upgraded to permit higher bed temperatures, and the depth of the catalyst bed was doubled to increase contact time.

After restart, the project team conducted a second series of treatability tests on the LANL waste samples. This series of tests included reprocessing the product condensate during the first series of tests, and recycling brine and scrubber samples from the earlier tests to minimize the number of test residuals. Data and residuals from this second series of tests are designated as New 6 prime, New 5 prime, L16 prime, and L17 prime to differentiate them from samples and residuals from the earlier series of tests; a final consolidation of residuals from the New 5 and New 5 prime runs was designated as New 5 double-prime.

Run 7 was the second test of the LANL New 6 waste sample. The run plan called for beginning the operation at a dilution of 4:1, with a goal of gradually reducing the dilution to 2:1. However, the bed temperature averaged 621 °C at 4:1 dilution, so no attempt was made to operate at 2:1. For most of Run 7, product condensate from Run 3 was used as dilution water. However, at 4:1 dilution, the Run 3 product condensate was depleted in about 29 hours, so tap water was used for dilution during the last 8 hours of the run.

Run 8 used remaining New 5 waste sample, with product condensate from Run 2 as dilution water. The waste was fed at a 1:1 dilution and the bed temperature averaged 630 °C. During Run 2, which used the same waste at the same dilution, the bed temperature averaged 513°C. The higher bed temperature in Run 8 clearly shows that the equipment modifications made during the maintenance shutdown to obtain higher bed temperatures was successful.

Run 9 used the remaining L16 waste, followed by reprocessing of L16 product condensate produced during Run 5. During part of this run, methanol was added to the L16 waste feed at a ratio which would give a chloride-to-hydrogen ratio of 4:1, as specified in the *Treatability Test Plan.* While the methanol was being added, the heater output was reduced to compensate for the additional exotherm of the methanol so that the bed temperature would be the same as when methanol was not being added. After Run 9 was completed, operation of the unit was continued to reprocess product condensate from Runs 5 and 4, as well as other residual liquids from other runs. No number was assigned to this series of operations since, as with the demonstration run, it did not constitute a true treatability test.

The last evaporative oxidation treatability test performed at GJPO was Run 10, which used a small waste sample of grinding sludge from SNL/NM. The recipe for this waste supplied by SNL/NM indicated that it contained about 2 percent of a true semivolatile, butyl cellosolve (b.p. 171 °C); it also contained 3.8 percent methanol and 0.4 percent perchloric acid. During operation, the bed temperature rose much more quickly than had been calculated based on the methanol content alone. This indicated that the waste sample contained a significant content of other volatile organics, since butyl cellosolve would not vaporize rapidly enough to contribute significantly to the exotherm. After water was fed to the unit for 4 hours at the end of the run to strip residual organics, the TOC content of the final brine was very low. Subsequent calculations showed that 4 hours was enough time to remove butyl cellosolve from the brine to the level indicated by the TOC results. It appears likely that the perchloric acid had "digested" the butyl cellosolve to produce more volatile decomposition products.

Operational reliability during the second series of tests (Runs 7 through 10) was 100 percent. Samples of product condensate and process concentrate (evaporator brine) from these tests were within LDRs for wastewaters and nonwastewaters, respectively, showing that the evaporative oxidation technology used in PO*WW*ER can serve as a stand-alone treatment for aqueous mixed wastes.

The mini-PO*WW*ER unit was shut down for final decontamination after Run 10. The project team found high levels of residual radioactivity in the unit, and rinses in solutions of warm nitric acid and sodium bicarbonate failed to remove all radioactive contamination. Section 7.3, "Decontamination of Mini-PO*WW*ER Unit," explains the decontamination process for the unit.

Appendix B presents the history of all the runs and the lessons learned. Appendix C contains summaries of rate and quantity data for all waste tests, with dates and times for all waste additions, waste and dilution quantities and rates, and summary data for all wastes and tests.

5.0 Discussion of Test Results

5.1 Operating Data

Table 5–1 gives hourly averages of operating data for the 1-hour periods immediately prior to collection of VOC samples, which were used throughout the treatability tests for measurement of oxidizer-bed performance. Table 5–2 gives performance measures calculated from the data given in Table 5–1; these calculated parameters are:

- Calculated bed temperature, from a heat balance between the inlet and outlet gases including heats of reaction. (Assumes all reactions go to completion.) The calculated bed temperature can be compared with the measured (actual) bed temperature to give an indication of heat losses in the system.
- Excess O_2, mole %, the oxygen concentration of the vent gas (condenser offgas). This is calculated by determining the theoretical oxygen requirement for the oxidation reactions (from the heat-balance calculation above), converting this value to an equivalent stoichoimeteric air flow, and comparing this air rate with the measured vent flow rate to determine the amount of unburned oxygen.
- V/V_{mf}, the ratio of actual superficial velocity in the oxidizer bed to the calculated minimum fluidization velocity (see Section 5.3.6, "Effect of Fluidization").
- Residence time, calculated by dividing the actual oxidizer bed height by the actual velocity.

With the exception of the highly exothermic New 6 waste, bed temperatures were uniformly higher in Runs 7 through 10, after the maintenance shutdown and upgrading of the heat tape, than in the earlier runs. Residence times also essentially doubled for these later runs, after the bed height was doubled by addition of catalyst. Excess oxygen was nearer the nominal target of 2 percent, due to greater familiarity with the waste streams and with the unit itself. The V/V_{mf} ratio was at or near 1.0 for almost all runs.

Appendix D presents the results of all chemical and radiological analyses performed on samples taken during the GJPO treatability tests.

5.2 Performance on Test Objectives

According to the *Treatability Test Plan*, ". . . the primary objective of this treatability test is to demonstrate the effectiveness of the PO*WW*ER evaporative-oxidation process on the specific mixed-waste streams. Effectiveness will be determined by identifying any additional treatment required for ultimate disposal of any process residuals, based on their resulting composition."

Of the four key performance parameters given in the *Treatability Test Plan* that would determine the effectiveness of the PO*WW*ER process, the first two, Concentration Factor and Oxidation Efficiency (see Section 1.1, "Test Objective"), are technical yardsticks to demonstrate the relative effectiveness of the technology. For these criteria, there is no fixed standard (e.g., a regulatory requirement) by which success or failure can be measured.

*Table 5–1. Hourly Averages of PO*WW*ER Operating Data*

Run Number	Date	Time	No. 1 Heater Temperature (°C)		Oxidizer Temperature (°C)			Flow Rates (lb/h)[a]			Sheath Temperature (°C)		Evaporator		Steam	Heat Exchanger Temperature (°C)			Vent Air-Flow
			Inlet	Outlet	Inlet	Bed	Outlet	Feed	Steam	PC	No. 1	No. 2	Level	Pressure (psig)[b]	Pressure (psig)[b]	In	Out	Del T	(slpm)[c]
1	10/07/94	18:59	108	451	490	505	379	15.0	21.0	5.5	836	925	15.3	7.6	12.1	109.7	111.6	3.6	25.6
2	10/27/94	10:00	107	362	486	573	413	10.3	18.4	9.0	696	870	15.7	7.1	11.5	108.8	109.9	3.6	23.5
2	10/27/94	12:30	107	351	486	503	453	7.5	18.0	8.1	680	847	15.2	7.1	11.5	109.0	110.4	3.7	23.0
2	10/27/94	20:30	106	369	488	495	477	11.6	22.3	1.2	694	839	14.9	6.7	11.1	108.1	109.5	3.7	23.1
2	10/28/94	04:30	107	353	493	512	503	12.2	20.8	8.2	668	822	15.1	7.4	12.3	109.3	110.9	4.3	20.8
2	10/28/94	13:30	106	349	488	490	490	11.6	21.6	9.6	684	834	14.9	6.8	11.5	108.1	109.4	4.2	25.2
3	11/07/94	21:00	104	392	n/r[d]	624	450	15.3	21.6	-	735	915	15.2	5.6	10.0	106.2	108.3	4.1	18.5
4	11/09/94	09:15	105	414	n/r	513	381	10.0	21.8	9.7	776	950	15.4	6.1	10.9	107.6	109.0	4.2	11.1
4	11/09/94	11:00	106	415	n/r	514	386	13.0	20.2	-	776	950	15.0	6.4	11.1	107.9	109.3	4.4	10.9
4	11/10/94	09:00	106	411	n/r	517	389	13.4	22.5	9.9	774	948	15.2	7.3	12.5	109.7	111.0	4.3	9.9
5	11/10/94	21:20	107	420	n/r	526	402	13.6	22.4	8.2	780	932	14.8	7.7	12.7	109.5	111.5	4.2	24.4
6	11/17/94	06:30	103	428	579	583	452	16.3	-	12.9	760	1000	15.7	4.9	11.7	108.3	110.9	4.1	20.1
7	12/06/94	16:00	102	342	491	620	464	12.8	18.2	6.3	619	752	15.3	4.5	8.0	103.9	105.8	3.6	22.0
7	12/06/94	17:00	104	333	480	585	459	12.0	25.1	11.3	603	741	15.7	5.6	10.4	106.2	108.3	4.8	21.8
7	12/06/94	23:05	103	369	488	600	452	10.8	22.3	6.8	668	795	15.8	5.5	9.2	105.5	107.4	4.2	15.3
7	12/07/94	07:00	103	366	525	635	483	11.5	-	-	683	838	15.8	5.5	9.6	105.8	107.8	4.1	23.1
7	12/07/94	15:35	104	408	525	634	475	13.9	-	-	711	836	15.8	6.0	10.0	106.4	108.2	4.3	21.8
7	12/07/94	23:00	105	408	525	624	475	12.4	22.0	10.8	713	838	16.3	6.0	10.2	106.8	108.6	4.3	21.7
7	12/08/94	02:15	105	422	526	621	469	13.1	22.4	10.0	725	842	16.3	6.0	10.0	106.2	107.9	4.3	25.0
8	12/08/94	22:00	102	447	579	648	465	12.4	18.1	9.2	772	957	16.3	4.4	7.9	104.4	105.7	4.0	16.5
8	12/09/94	06:00	103	303	488	631	484	13.8	19.5	11.3	566	750	16.0	5.0	9.1	105.3	107.2	4.3	16.6
8	12/09/94	14:00	102	409	526	617	473	11.0	19.9	9.0	732	903	16.9	4.3	8.0	104.1	106.1	4.1	15.6
8	12/09/94	21:50	102	405	543	627	472	11.6	20.4	9.3	733	916	17.1	4.3	8.3	104.6	106.5	4.1	15.6
8	12/10/94	06:00	102	415	536	634	475	12.8	20.7	8.1	747	911	16.5	4.3	8.3	104.5	106.2	4.1	15.5
8	12/10/94	12:39	102	413	540	634	477	10.3	19.7	8.9	743	913	16.5	4.3	8.4	104.5	106.4	4.1	16.7
9	12/11/94	14:00	103	417	569	595	446	13.7	19.7	12.0	747	954	14.1	5.1	9.5	104.9	107.2	4.8	5.8
9	12/11/94	17:00	104	354	544	585	464	13.3	20.1	8.5	680	881	16.4	5.7	9.8	106.2	108.1	4.4	8.8
9	12/11/94	19:35	104	374	542	574	451	11.7	20.6	8.0	711	901	15.9	5.9	10.1	106.6	108.5	4.3	9.1
9	12/11/94	22:10	103	496	550	557	396	11.7	20.2	10.5	857	998	16.3	5.2	9.3	105.5	107.7	4.1	9.9
10	12/20/94	13:45	106	412	588	654	478	12.7	24.9	13.9	722	963	13.6	6.6	11.2	107.8	109.5	5.0	18.6

[a] lb/h = pounds per hour

[b] psig = pounds per square inch guage

[c] slpm = standard liter per minute

[d] n/r = not recorded

*Table 5–2. Mini-PO*WW*ER Unit Operating Data*[a]

Run Number	Date	Time	Waste	Feed (lb/h)	Vent Air (slpm)	Bed Temperature (°C)		Excess O_2 (%)	V/V_{mf}	Residence Time(s)
						Actual	Calculated			
1	10/07/94	18:59	TG1	15.0	25.6	505	492	20.9	1.10	0.11
2	10/27/94	10:00	New 5	10.3	23.5	573	758	8.7	0.95	0.13
2	10/27/94	12:30	New 5	7.5	23.0	503	752	11.9	0.65	0.19
2	10/27/94	20:30	New 5	11.6	23.1	495	762	6.9	0.95	0.13
2	10/28/94	04:30	New 5	12.2	20.8	512	767	4.6	1.01	0.12
2	10/28/94	12:30	New 5	11.6	25.2	490	760	8.1	0.95	0.13
3	11/07/94	21:00	New 6	15.3	18.5	624	905	-36.2	1.70	0.07
4	11/09/94	09:15	L17	10.0	11.1	513	524	20.7	0.72	0.16
4	11/09/94	11:00	L17	13.0	10.9	514	523	20.5	0.93	0.13
4	11/10/94	09:00	L17	13.4	9.9	517	523	20.5	0.96	0.12
5	11/10/94	21:20	L16	13.6	24.4	526	556	19.2	1.04	0.12
6	11/17/94	06:30	Old New 5	16.3	20.1	583	804	-8.1	1.52	0.08
7	12/06/94	16:00	New 6	12.8	22.0	620	667	4.9	1.23	0.20
7	12/06/94	17:00	New 6	12.0	21.8	585	656	5.8	1.11	0.22
7	12/06/94	23:05	New 6	10.8	15.3	600	665	1.5	1.00	0.24
7	12/07/94	07:00	New 6	11.5	23.1	635	698	7.2	1.14	0.22
7	12/07/94	15:35	New 6	13.9	21.8	634	700	3.4	1.35	0.18
7	12/07/94	23:00	New 6	12.4	21.7	624	699	5.2	1.20	0.20
7	12/08/94	02:15	New 6	13.1	25.0	621	699	6.5	1.27	0.19
8	12/08/94	22:00	New 5	12.4	16.5	648	788	5.2	1.18	0.21
8	12/09/94	06:00	New 5	13.8	16.6	631	704	3.5	1.28	0.19
8	12/09/94	14:00	New 5	11.0	15.6	617	738	6.2	1.01	0.24
8	12/09/94	21:50	New 5	11.6	15.6	627	754	5.4	1.08	0.23
8	12/10/94	06:00	New 5	12.8	15.5	634	748	3.7	1.19	0.21
8	12/10/94	12:39	New 5	10.3	16.7	634	750	8	0.98	0.25
9	12/11/94	14:00	L16	13.7	5.8	595	608	13.5	1.08	0.22
9	12/11/94	17:00	L16	13.3	8.8	585	659	6.3	1.08	0.22
9	12/11/94	19:35	L16	11.7	9.1	574	657	8.5	0.94	0.26
9	12/11/94	22:10	L16	11.7	9.9	557	588	17.3	0.89	0.27
10	12/20/94	13:45	SNL	12.7	18.6	654	898	0.8	1.27	0.19

[a] Calculated bed temperature is based on reaction exotherm.

Key:

Excess O_2 = mole percent oxygen in vent gas (calculated).

lb/h = pounds per hour.

Residence time(s) = bed residence time based on bed depth and superficial velocity.

slpm = standard liter per minute.

V/V_{mf} = ratio of actual bed velocity to calculated minimum fluidization velocity.

The last two performance parameters, Product Condensate Quality and Process Concentrate Quality, are "pass-fail" criteria. For the treatability tests to be deemed successful, both product condensate quality and process concentrate quality would have to be demonstrated as conforming to RCRA requirements. Laboratory analysis of final condensate and brine samples showed conclusively that the GJPO treatability tests were successful from this standpoint; the condensate and brine samples satisfied RCRA UTSs for disposal of wastewaters and nonwastewaters, respectively, without the need for further treatment.

This section summarizes the performance of the mini-PO*WW*ER unit in the GJPO treatability tests by evaluating the results on the basis of each of the four parameters in the *Treatability Test Plan.*

5.2.1 Concentration Factor

The size of the mini-PO*WW*ER evaporator system limited the maximum concentration that could be achieved for each waste stream. The treatability test samples received at GJPO were contained in single 55-gallon drums, while the evaporator system is normally operated at a volume of approximately 5 gallons and cannot be operated below about 3.3 gallons. Therefore, the best concentration factor that could be achieved in the GJPO treatability tests with the minimum volume of the system was 16.7 (55 gallons of sample divided by 3.3 gallons of final brine). Table 5–3 presents the calculated concentration factors for the GJPO tests, based on the weight of sample tested.

Table 5–3. Concentration Factors for GJPO Tests

Run No.	Sample	Sample Weight (lb)	Brine Weight (lb)	Concentration Factor
2, 8	New 5	516	31	16.5
3, 7	New 6	153	42	3.7
4	L17	310	42	7.4
5, 9	L16	482	31	15.4
6	Old New 5	242	42	5.8
10	SNL	17	42	0.4

In actual treatment operation, a full-size evaporator will have the capability to concentrate waste to at least 40 percent total solids during long runs. Operation at up to 40-percent solids concentration was demonstrated during the Run 6, the test of the Old New 5 waste. During this test, a portion of the Old New 5 waste sample, which had a dissolved-solids concentration of 89.8 grams per liter (g/L) due to addition of salts during feed preparation, was fed to the unit in a deliberate attempt to concentrate to 40-percent solids. The primary constituent of the dissolved solids was ammonium sulfate; the specific gravity of a 40-percent solution of ammonium sulfate is 1.23. Therefore, feed was continued until the densitometer in the circulating solution indicated a specific gravity of 1.23. During the later part of the concentration run on November 18, the data in Table 5–4 were obtained:

Table 5–4. Specific Gravity of LANL Old New 5 Sample

Time	Total Hours Feed	Specific Gravity	Cumulative Waste Fed (lb)
12:08	26.8	1.1667	158.3
13:25	28.1	1.178	171.0
13:45	28.4	1.18	175.3
14:28	29.1	1.1877	184.7
15:30	30.2	1.1951	198.5
16:00	30.7	1.1999	205.1
18:53	33.5	1.23	241.5

These data are essentially linear ($R^2 = 0.996$), showing a direct and constant increase in specific gravity as more feed was added at a constant rate. No operational problems were noted as the solids concentration increased. Foaming in the evaporator, a major concern at high solids levels, was minimal and required no corrective action (e.g, antifoam agent was not used). Slight fouling of the heat exchanger was suggested by an increase in the heat-exchanger temperature differential from about 4.0 at the beginning of the run to as high as 5.3 near the end. The increase in temperature differential was not a problem and did not affect the operation of the unit.

Although the LANL wastes were not analyzed for dissolved solids in "as-received" condition, data from the feed preparation samples indicate that this solids measure would be low in the original waste samples (see Section 4.1, "Feed Preparation"). Suspended solids values for the LANL wastes ranged from 0.002 to 0.043 percent. The total mass of solids in each waste stream can be calculated with the values for TDS calculated from feed preparation data and the estimated total weights of the LANL waste streams. Then, assuming a solids concentration of 40 percent in the final concentrate, the theoretical final volume of concentrate that will be generated during alternate waste treatment at LANL can be determined. These calculated volumes are presented in Table 5–5.

Table 5–5. Estimated Final Volumes of Concentrates at LANL

Sample	TDS (%)	TSS (%)	Estimated Weight at LANL (lb)	Estimated Total Solids (lb)	Final Volume (gal)
L16	1.66	0.043	33,044	562	137
L17	1.17	0.040	27,316	331	81
New 6	0	0.020	15,641	3.2	0.77
New 5	0	0.002	30,400	0.7	0.18

The evaporative oxidation MTU will be about 15 times as large as the mini-PO*WW*ER unit, so its evaporator system volume will be roughly 50 gallons. Thus, the concentrates made from treating the New 5 and New 6 wastes will probably not reach 40-percent solids even after all the waste is treated.

The L16 and L17 wastes will produce concentrates with at least 40-percent solids, but the GJPO treatability tests show that this will pose no problem.

5.2.2 Oxidation Efficiency

The oxidation efficiency of the mini-PO*WW*ER unit can be calculated using TOC analyses of feed and composite product condensate samples. The results of these calculations are presented in Table 5–6.

The samples in Table 5–6 are listed in the order they were tested. Two general conclusions can be drawn from these results:

1. The performance of the unit was uniformly better during the second test of each waste sample than during the first tests of the same waste. This improvement was likely due to the addition of heat tape and bed catalyst between the first and second series of tests (see Section 4.2, "PO*WW*ER Unit Operations"), and improved operation because the operating personnel were more familiar with the mini-PO*WW*ER unit.

*Table 5–6. Oxidation Efficiency of Mini-PO*WW*ER Unit for Composite Samples*

Run No.	Sample	Feed Rate (lb/h)	Oxidizer Temperature (°C)	Excess O_2 (mole %)	Residence Time (s)	TOC (µg/L)		Oxidation Efficiency (%)
						Feed	Product Condensate	
3	New 6	10.3	563	1.2	0.07	40,900,000	182,000	99.555
4	L17	12.0	515	20.6	0.16	340,000	840	99.75
5	L16	11.6	[a]	[a]	0.12	1,390,000	72,100	94.81
7	New 6 Prime	12.5	621	15.6	0.20	40,900,000	<200	99.9995+
8	New 5 Prime	12.2	630	5.4	0.19	21,400,000	230	99.999
9	L16 Prime	12.4	591	15.5	0.24	1,390,000	1,300	99.906

[a] Operation was erratic and average values are not significant.

2. Oxidation efficiencies were better for samples containing higher feed concentrations of VOCs. The data in Table 5-6 suggest that, within the range of wastes tested at GJPO, near-total destruction of VOCs is possible in the oxidizer regardless of the VOC concentration in the feed. Thus, if the product concentration is fixed in the range of 200 parts per billion (ppb) for any feed, the overall efficiency will be higher if the feed concentration is higher.

The data in Table 5–6 were calculated from composite samples, which include all the condensate formed during a run. Table 5–7 presents oxidation efficiencies for performance samples (grab rather than composite condensate samples).

Table 5–7. Oxidation Efficiencies for Performance Samples

Run No.	Sample	Feed Rate (lb/h)	Oxidizer Temperature (°C)	Excess O_2 (mole %)	Residence Time (s)	TOC (µg/L)		Oxidation Efficiency (%)
						Feed	Product Condensate	
1	TG1	15.0	505	20.9	0.11	1,360,000	870 220	99.936 99.984
2	New 5	11.6 12.2	495 512	6.9 4.6	0.13 0.12	21,400,000	3,640 <560	99.983 99.997+
7	New 6 Prime	11.0	617	6.2	0.24	40,900,000	580	99.999
10	SNL	12.7	654	0.8	0.19	12,100,000	<200	99.998+

Comparison of New 6 and New 6 Prime results shows the improvement in performance during the second series of tests. These data indicate that the PO*WW*ER evaporative oxidation technology is capable of achieving oxidation efficiencies as high as 99.999 percent when the bed temperature is near or above 600 °C, residence times are 0.2 seconds or higher, and fluidization velocity and adequate oxygen flow are maintained.

5.2.3 Product Condensate Quality

Table 5–8 shows final VOC analyses of the product-condensate composite samples from the GJPO treatability tests. Concentrations of VOCs (as shown in Table 5–8) in the samples were below the RCRA UTS for wastewaters. Radionuclide levels in the same composite samples (see Table 5–9), as measured by gross alpha and beta activity, were well below the activity limit of 400 pCi/L combined alpha and beta that would qualify the liquid as a radioactive waste.

On the basis of the VOC and radionuclide analyses, the product condensates produced from treatment of the LANL waste streams would be expected to meet LDRs for wastewater disposal. Thus, the product condensate quality criterion for success of the treatability tests was met.

Table 5–8. TCLP VOC Analysis of Product Condensates

		Analyte Concentration (μg/L)					
Run No.	Sample	TOC	DCM	Acetone	Benzene	CCl_4	$CHCl_3$
	RCRA UTS	--	--	280	140	57	46
6	Old New 5	ND[a]	38	94	ND	ND	ND
7	New 6 Prime	ND	<25	<50	<25	<25	<25
8	New 5 Prime	200	<5	<20	<5	<5	<5
8	New 5 Prime	230	ND	ND	ND	ND	ND
9	L16 Prime	1300	35	<100	<25	<25	<25
9.1	L17 Prime	<50	<25	<25	<25	ND	<25
10	SNL	ND	<25	<100	<25	<25	<25

[a] ND = not detected.

Table 5–9. Gross Radiation in Product Condensate Composite Samples

Run No.	Sample	Gross Activity Level (pCi/l)	
		Alpha	Beta
6	Old New 5	<2	<6
7	New 6 Prime	<5.4	<7.1
8	New 5 Prime	<5.1	<7.2
8	New 5 Prime	<5.1	<7.2
9	L16 Prime	<5.1	<7.2
9.1	L17 Prime	<5.3	<7.1
10	SNL	<5.1	<7.2

5.2.4 Process Concentrate (brine) Quality

The final brine to be produced by the MTU during actual waste treatment will have total solids concentrations in the order of 40 to 50 percent. As such, the brine will probably be classified as a nonwastewater under RCRA rules and will have to meet the RCRA UTS for nonwastewaters. This outcome is desirable because the UTSs for nonwastewaters are higher than the corresponding standards for wastewaters, as shown in Table 5–10.

Table 5–10. Comparison of Wastewater and Nonwastewater UTSs

Compound	Universal Treatment Standard (mg/kg)	
	Wastewater	**Nonwastewater**
Acetone	0.28	160
Benzene	0.14	10
Carbon tetrachloride	0.057	6.0
Chloroform	0.046	6.0
1,1,1-Trichloroethane	0.054	6.0
1,1,2-Trichloroethane	0.054	6.0

To qualify as a nonwastewater, a waste stream must have a suspended-solids concentration greater than 1 percent. The brines produced during the GJPO treatability tests did not have such high concentrations because of the relatively small concentration factors achieved during the tests (see Section 5.1.1, "Concentration Factor"). However, the percent of total suspended solids (TSS) in the final brine that will be produced at LANL can be estimated by using the amount of waste tested at GJPO and the percent TSS in the brine produced at GJPO, and "ratioing" this value to the estimated inventory of each waste stream at LANL, as given in the *Project Implementation Plan for Evaporative Oxidation* (U.S. Department of Energy 1994). Table 5–11 presents the results of these calculations.

Table 5–11. Estimated Final Percent TSS for LANL Treatment Concentrates

Sample	Sample Weight (lb)	Brine TSS (%)	Estimated Weight at LANL (lb)	Estimated LANL TSS (%)
New 5	516	0.074	30,400	4.3
New 6	153	0.018	15,641	1.9
L17	310	0.055	33,044	5.9
L16	482	0.231	27,316	13.2

The estimated solids concentrations for the LANL wastes are all greater than 1 percent. It is then reasonable to evaluate the concentration of contaminants in the process concentrate from the GJPO treatability tests using the RCRA nonwastewater standards. As presented in Table 5–12, the concentration of the tested RCRA VOC compounds in the brine samples from the GJPO tests were all below the RCRA nonwastewater UTSs.

Table 5–12. VOC Test Results of Brine (concentrate) Samples

Run No.	Analyte Sample	Concentration (mg/kg)				
		DCM	Acetone	Benzene	CCl_4	$CHCl_3$
	RCRA UTS	--	160	10	6	6
6	Old New 5	ND	0.19	ND	ND	ND
7	New 6 Prime	<0.1	<0.4	<0.1	<0.1	<0.1
8	New 5 Prime	<0.25	<1	<0.25	<0.25	<0.25
8	New 5 Prime	ND	<1	<0.25	<0.25	<0.25
9	L16 Prime	0.16	<1	<0.25	0.25	<0.25
9.1	L17 Prime	0.079	<0.05	<0.05	<0.05	<0.05
10	SNL	<0.1	<0.4	<0.1	<0.1	<0.1

On the basis of VOC analyses, the brines produced from treatment of all tested waste streams would be expected to meet UTSs for nonwastewater disposal. Therefore, the concentrate quality criterion for success of the treatability tests was met.

5.2.4.1 Volatile Organic Separation in Evaporator

The PO*WW*ER process is designed to separate volatile organics from the brine concentrate for destruction in the oxidizer. The performance of the evaporator in separating organics can be demonstrated with TOC data from the tests on the LANL New 5 and New 6 waste samples, as shown in Table 5–13.

Table 5–13. LANL New 5 and New 6 TOC Data

Sample		Mass (lb)	TOC	
			Product Condensate (µg/L)	Total (g)
New 5	Waste	516	21,400,000	5,011
	Brine	41	564,000	10.67
	Removal = 99.79%			
New 6	Waste	153	40,900,000	2,840
	Brine		1,570,000	29.71
	Removal = 98.95%			

The difference between the removal efficiency for the two waste streams is probably due to the higher concentration of organics in the New 6 waste sample. During sustained operation of the mini-PO*WW*ER unit, the concentration of organics in the evaporator will reach a steady-state value that is dependent on the nature of the compounds involved and their concentrations in the feed. After waste feed stops and water feed begins, the organic concentration in the evaporator drops as residual organics are stripped out, until a new, final equilibrium concentration is reached.

Both of these brine samples were taken about 12 hours after waste feed had stopped. The two feed streams contained similar organic compounds, although concentrations in New 6 were roughly double those of New 5. It appears likely that the final TOC concentration in the New 6 brine is higher than that in the New 5 brine primarily because the initial concentration in the New 6 feed was higher.

Evidence for the time dependency of organic removal from brine comes from a series of brine samples taken at the end of the run on the SNL/NM waste feed. While the primary volatile organic constituent of the New 5 and New 6 wastes was isopropyl alcohol (boiling point [b.p.] = 82.3 °C), the primary volatile organic constituent of the SNL/NM waste was methanol (b.p. = 64.7 °C). Therefore, the TOC of the SNL/NM waste might be expected to decline more rapidly. The first SNL/NM brine sample was taken at 1345, just as the last of the waste sample was consumed. The second brine sample was taken at 1545, 2 hours after the feed was switched to water; and the third sample was taken at 1800, four hours after the end of waste feed. Results of the analyses for these samples, presented in Table 5–14, show the efficiency with which the organic was removed.

Table 5–14. Brine Analysis Results for SNL/NM Waste

Time	Time After End of feed (h)	TOC (µg/L)
1345	0	1,790,000
1545	2	266,000
1800	4.25	103,000

The last of these brine samples almost certainly did not represent an equilibrium organic concentration. However, the concentration was approaching an equilibrium value because the drop in organic concentration between the second and third samples was much smaller than the drop between the first and second samples.

The TOC of the SNL/NM waste was not measured directly but, on the basis of process knowledge of the waste stream, is estimated at 12,100,000 micrograms per liter (µg/L). The final TOC value represents a removal efficiency from the brine of 99.15 percent over a period of 4 hours. In terms of time and removal efficiency, this falls neatly between the New 5 and New 6 samples.

5.2.4.2 Radionuclide Concentration in Evaporator

The PO*WW*ER process is designed to separate radionuclides from volatile organics. Above a total concentration of 400 pCi/L combined gross alpha and beta, a liquid can be considered as radioactive waste. Therefore, one criterion for success of the treatability tests would be that concentrations of radionuclides in the scrubber and product condensate liquids would not exceed 400 pCi/L.

Gross alpha and beta concentrations in the mixed-waste feed samples varied significantly. Most of the total radiation was concentrated in the New 5 waste, as shown in Table 5–15.

Table 5–15. Radiation Concentration in GJPO Treatability Samples

Waste	Gross α and β (pCi/L)
L16	5,400
L17	25,460
New 5	1,270,000
New 6	56,800
TG1	83,000

The detection limits for radioactive contamination in the product condensate were generally below 10 pCi/L. Because none of the product condensate samples exceeded these detection limits (see Section 5.1.3, "Product Condensate Quality"), the product condensate would not be considered radioactive waste.

All of the reported radiological levels for the scrubber liquor samples were below the contamination threshold of 400 pCi/L. Detection limits for radioactive contamination in the scrubber liquor were generally less than 50 pCi/L. The highest contamination level reported for any scrubber sample was a combined 83 pCi/L for a scrubber rinse taken during Run 7, the New 6 prime test. However, the reported detection limits for individual samples of scrubber water taken during Runs 5, 7, and 9 (one sample from each run) were as high as 1,550 pCi/L. On the basis of the results of the other samples, there is no reason to expect that the radiological contaminant levels in these samples were high. Nonetheless, it could not definitely be established that these samples met radiological contamination criteria because the detection limits were so high.

5.2.4.3 Heavy Metals Concentration in Evaporator

The *Treatability Test Plan* anticipated that "evaporator concentrate may be retained for waste stabilization studies." Stabilization would be necessary if the concentration of any regulated metal constituent was above RCRA treatment standards for hazardous waste. All final brine samples were subjected to TCLP metals analyses to determine if stabilization would be required. Results of these analyses (see Appendix D) show that all brine samples were at or below RCRA treatment standards in the liquid state; therefore, further stabilization was not necessary.

The TCLP extract results from two of the LANL waste streams do not support the hazardous waste classification assigned to the waste streams. One of the waste streams, LANL New 5, was given the hazardous waste classifications D001, D002, and D008. Waste streams with the D008 classification have lead concentrations in the TCLP extract in excess of 5.0 mg/L. TCLP analyses were not performed on the feed material for this waste steam, but TCLP analyses were conducted on samples from the evaporator concentrate. The level of lead present in the evaporator concentrate was 0.57 mg/L, less than the 5.0 mg/L required to be classified as D008. Either the waste stream was incorrectly classified as D008 or the sample of LANL New 5 sent to GJPO is not representative of the entire waste stream.

Similar results were found for the waste stream LANL New 6. This waste stream was given the hazardous waste classifications of F005, D002, and D009. Waste streams with the D009 classification have mercury concentrations in the TCLP extract in excess of 2.0 mg/L. TCLP analyses were not performed on the feed material for this waste steam, but TCLP analyses were conducted on samples from the evaporator concentrate. The presence of mercury in the evaporator concentrate was not detected; therefore, the concentration of mercury in this sample is less than the 2.0 mg/L required to be classified as D009. The presence of mercury was not detected in samples of condensate or scrubber liquid from New 6. Either the waste stream was incorrectly classified as D009 or the sample of LANL New 6 sent to GJPO is not representative of the entire waste stream.

5.3 Oxidizer Performance

The GJPO tests were intended primarily to prove treatability of DOE–AL mixed wastes and to demonstrate the applicability of the technology to these waste types. The test work was not intended as a research project that would determine kinetic rate expressions for the oxidation reactions. In general, the performance of the oxidizer bed was as expected and results were more dependent on operating conditions than on catalyst characteristics.

The PO*WW*ER technology has been proven in other applications, and its general behavior is well known (e.g., reaction conversion is improved at higher temperatures). Therefore, although the GJPO treatability tests will not add significantly to the body of "first principle" data on the catalyst performance, the tests do confirm that the catalyst performed as designed. On the basis of a relatively limited number of data points, it is possible to draw a few general conclusions about the basic chemistry of the PO*WW*ER process when applied to DOE–AL mixed wastes.

5.3.1 Effect of Temperature

The *Treatability Test Plan* states that "The oxidation efficiency will be evaluated at . . . two different catalyst bed temperatures, 1,000 °F (538 °C) and 1,200 °F (649 °C)." In practice, for reasons noted elsewhere in this report, steady-state operation at different bed temperatures proved to be difficult. Therefore, no formal effort was made to evaluate the oxidation efficiency of the unit at different temperatures.

However, it is possible to extract limited information on temperature sensitivity from the sets of data collected during the tests. In general, the tests performed during the second series were at higher temperatures than those performed during the first series. The clearest demonstration of the beneficial effect of increased temperature comes from comparing two sets of data collected during treatability tests on the LANL L16 waste sample. Table 5–16 presents the results for the destruction of DCM in the L16 waste sample.

Data in Table 5–16 substantiate that destruction of organics in the oxidizer bed improves at increased temperature. The fluidization behavior of both samples is comparable and the oxygen concentration is at least as favorable for the earlier sample as for the later one. Only the temperature is more favorable for the later sample and, thus, the improvement in DCM destruction is almost certainly due to the increased temperature.

Table 5–16. Destruction of Dichloromethane in L16 Waste Sample

Date	Time	Bed Temperature (°C)	Excess O_2 (%)	V/V_{mf}[a]	DCM Concentration in Condensate (μg/L)
11/10	2120	526	19.2	1.04	> 3,000
12/11	1400	595	13.5	1.08	287

[a] Ratio of actual bed velocity to calculated minimum fluidization velocity.

5.3.2 Effect of Residence Time

Data from earlier users of the PO*WW*ER technology showed that the residence time needed to effect destruction of a wide range of volatile organics in the catalyst bed was about 0.1 second(s). During the initial series of tests at GJPO, the catalyst bed was charged to a depth of 8 inches, which was sufficient to give contact times in the 0.1-second range. Results of the first series of tests were encouraging in terms of destruction efficiency; Brian Eichlin (Rust Environment and Infrastructure), the designer of the mini-PO*WW*ER unit, indicated that destruction efficiency of 99.9 percent, which was achieved or bettered in several of the first tests, represented exceptional performance. However, the results for some of the first series of tests were disappointing because many of the condensate samples did not meet RCRA UTSs for wastewater.

During the shutdown between the first and second series of treatability tests, the depth of the catalyst bed was doubled by adding catalyst. This effectively doubled the residence time in the bed, as shown by the residence times given in Table 5–2. At the same time, the heating capability of the unit was upgraded, making higher-temperature operation possible. In general, the tests performed during the second series gave better results than those performed during the first series. However, the fact that the tests from the second series were uniformly performed at higher temperatures ***and*** at higher contact times makes it difficult to sort out the relative effect of the two changes.

The GJPO treatability tests do clearly show that, when operated at temperatures of 620-640 °C and contact times of about 0.2 seconds, the PO*WW*ER evaporative oxidation technology is capable of treating DOE–AL mixed wastes and producing residuals that meet RCRA UTSs. The evaporative oxidation MTU should be designed to provide a contact time of at least 0.2 seconds.

5.3.3 Effect of Oxygen

The *Treatability Test Plan* provides that ". . .the oxidation efficiency will be evaluated at 2 mole percent excess oxygen concentration . . ." Discussions with the CTC chemist who prepared the original *Treatability Test Plan* proposal established that "mole percent excess oxygen," as used by CTC, is not a stoichiometric excess; instead, it refers to the concentration of oxygen in the vent gas.

Control of oxygen concentration proved to be difficult for at least four reasons:

1. The mini-PO*WW*ER unit did not provide any means to measure oxygen concentration.
2. The required airflow rate to obtain the target oxygen concentration would change as the waste feed rate changed. However, waste feed rate was not directly measured, and there was no means

in the control system for the two flow rates to "communicate" so that airflow could be automatically adjusted when the feed rate changed.

3. Two flow meters were provided for measuring airflow. One was a rotameter on the oxidizer air inlet line. This meter had a maximum flow of 13 standard liters per minute (slpm), while, in many cases, the desired airflow rate was higher than 13 slpm. The second meter was the vent-gas-flow meter. Theoretically, the readings of these two meters should have been nearly identical. In practice, the vent-gas flowmeter reading was 20 to 25 percent lower than the air rotameter. To be safe, airflow rates were generally set to give the desired airflow rate as measured by the vent-gas flowmeter.

4. The difference between the stoichiometric airflow rate and the airflow rate that would give 2-percent excess oxygen was often as little as 5 percent. This was within the observed variability of the airflow meter.

Table 5–2 shows the excess airflow for each run based on measurements by the vent-gas flowmeter. In many cases, particularly during the second series of tests on LANL New 5 and New 6 wastes, the airflow rate is acceptably close to 2-percent excess. Data in Table 5–2 for November 7, 1994, during Run 3 (the first test of the New 6 waste sample), are particularly interesting in this regard because an oxygen deficiency is clearly indicated. The airflow rate used during the early portion of this test, when the sample was taken, was about 18 slpm; the required oxidizer airflow for this sample would have been about 50 slpm. The airflow rate was specified too low during the early portion of this test because an analytical error on the feed sample severely underestimated the concentration of ammonia. The laboratory originally reported the ammonia concentration as about 0.1 percent, but later (after the operating group questioned the analysis on the basis of the smell of the feed and unusually high exotherm in the unit) corrected the concentration to the actual value of 5.05 percent. This almost quadrupled the oxygen requirement.

The product condensate sample taken during Run 3, when the oxidizer air rate was below the stoichiometric requirement, showed an acetone concentration of more than 5,100 micrograms per liter (μg/L), which exceeded the RCRA UTS for that compound. This was the only significant acetone concentration reported in a product condensate sample from any of the GJPO tests. The concentration of acetone in the New 6 feed was about 160,000 μg/L. After correcting for dilution of the waste sample, the oxidation efficiency of acetone during this run was 85.7 percent. Oxidation of ammonia during Run 3 was 86.7 percent (see Section 5.3.5, "Treatment of Ammoniated Wastes"), which is comparable to the oxidation of acetone, and overall TOC oxidation during this run was 99.555 percent. The temperature of the bed at the time this sample was taken was 624 °C.

When the first condensate sample was taken during Run 7, the second test of the New 6 waste, the bed temperature was 600 °C, which was slightly lower than the bed temperature during Run 3. However, the oxygen content in the vent gas was 1.5 percent excess. The condensate samples taken during Run 7 showed no detectable acetone, oxidation of ammonia was 99.99 percent, and overall TOC oxidation was over 99.9995 percent.

These data show that maintenance of adequate oxygen flow is demonstrably important. The evaporative oxidation MTU should be designed to ensure that at least a 2-percent excess of oxygen is available at all times.

5.3.4 Effect of Methanol Addition

The original draft of the *Treatability Test Plan*, as supplied by Clemson Technology Center, included a requirement that the ratio of hydrogen to halide ions in the organic portion of the feed to the PO*WW*ER unit should be at least 4:1. The hydrogen was needed by the catalyst as a halide scavenger. If the hydrogen-to-halide ratio was less than 4:1, it should be adjusted to obtain this ratio by adding methanol during feed preparation.

This recommendation was based on the original catalyst development work by ARI, which determined that the catalyst life was adversely affected by the presence of halogens in the feed. ARI recommended addition of a halide scavenger for feeds containing high halide concentrations. The test work that led to this recommendation was done with nonaqueous systems, and methane was used as the halide scavenger. The best results in the ARI work were obtained using steam injection to supplement methane addition. ARI could not be certain whether additional hydrogen ions would be required for halide scavenging in aqueous feeds that already contain hydrogen-to-halide ratios far greater than 4:1 when the hydrogen in the water is counted.

One of the goals of the GJPO treatability tests was to determine if addition of methanol had a detectable effect on catalyst performance. Because the waste streams that contained significant concentrations of halides (L16 and L17) contained no other organics and because the exotherm for the halogenated organics was low, addition of methanol also would cause a significant rise in temperature compared to the feed without methanol addition. To compensate for this effect, it would be necessary to reduce heater output while methanol was being added.

The project team decided to perform a test to evaluate the effectiveness of methanol addition. The L16 waste stream was the most appropriate sample for this test because of its high concentration of halogenated organics (1.5-percent DCM) with no significant concentration of other organics.

During the second series of tests of the L16 waste, the first carboys of waste were fed with no water dilution or addition of methanol. These two carboys of waste required almost 4 hours to feed, more than sufficient time for the unit to achieve steady state. A performance sample of the product condensate from this run was taken at 1400 on December 11, 3 hours after feed of the L16 waste began.

Two additional carboys of waste were then fed, after being "spiked" with a methanol concentration of 10.5 ml per liter of waste. The addition of methanol gave a H:Cl ratio of 4:1 as specified in the *Treatability Test Plan*. Feed rates were kept essentially constant during this period, and the bed temperature was kept as constant as possible. A performance sample of product condensate from this test run was taken at 1700, slightly more than 2 hours after feeding of the "spiked" waste began.

Analytical results for these samples, shown in Table 5–17, indicate that some of the DCM in the feed redistributed in the oxidizer to form other halogenated organics, such as trichloroethylene (TCE) and dichloroethane (DCE), but the concentrations of these byproducts were small. The destruction efficiency shown in Table 5–17 is the difference between the concentration of DCM in the feed and the concentration of all chlorinated species in the product condensate. Residence times and ratios of actual velocity to minimum fluidization velocity (V/V_{mf}) for both samples were comparable at 0.22 and 1.09 seconds, respectively.

Table 5–17. Effect of Methanol Addition on Dichloromethane Destruction

Sample Time	Methanol Added	Feed Rate (lb/h)	Air Rate (slpm)	Bed Temp (°C)	Impurity Concentration (µg/L) in Condensate				Excess O_2 (mole %)	Halogen Destruction (%)
					DCM	TCE	DCE	Others		
1400	No	13.7	5.8	595	287	142.5	145	51.5	13.5	99.91
1700	Yes	13.3	8.8	585	52.5	13.5	N/D	N/D	6.3	99.99

The increase in destruction of chloride species realized by addition of methanol was small but significant. The product condensate sample obtained at 1400 without methanol addition did not meet UTSs because even the low levels of DCM, TCE, and DCE in that sample (about 600 ppb total) exceeded the UTSs for those contaminants. The destruction efficiency of the unit improved by only 0.08 percent when methanol was added, but the concentrations of all contaminants in the sample taken after methanol addition were below UTS requirements. Thus, addition of methanol, or other hydrogen donor species, may be essential for the MTU to produce a condensate that does not need secondary treatment.

5.3.5 Treatment of Ammoniated Wastes

The LANL New 5 and New 6 wastes both contained significant levels of ammonia, so the performance of the unit in treating ammoniated wastes was of interest. Ammonia is not a RCRA-regulated compound, and the PO*WW*ER technology was not specifically designed for oxidation of ammonia. However, the basic oxidation chemistry should be amenable to ammonia oxidation. Brian Eichlin indicated that ammoniated wastes had been tested in the mini-PO*WW*ER unit in the past with some success, although the oxidation of ammonia was not as complete as that of organics.

Results of the GJPO treatability tests on the samples containing ammonia indicate:

1. The PO*WW*ER oxidizer appears to be capable of oxidizing ammonia to NO_x at efficiencies as high as 99.99 percent, provided that bed temperature is adequate (minimum 500 °C, greater than 600 °C preferred) and that sufficient oxidizing air is present.

2. The rate at which ammonia is stripped from the brine and fed to the oxidizer can be controlled by controlling the pH of the brine. When acidic conditions ($pH < 6$) are maintained in the evaporator, the evaporator will retain ammonia. Alkaline conditions ($pH > 9$) in the evaporator will cause ammonia to be stripped out essentially as fast as it is fed.

The first ammoniated waste to be treated was the New 5 sample, which contained only about 0.05-weight-percent ammonia and 0.31-percent nitrate. Brine analyses from both tests of this waste (New 5 and New 5 Prime) indicated that most of the ammonia and nitrate in the feed was concentrating in the brine. The same result was found during the solids concentration test of the Old New 5 waste, which contained 2.5-percent ammonia. Tables 5–18 and 5–19 show how the actual concentration of ammonia and nitrate in the brine increased over time during the New 5 and Old New 5 tests. The calculated concentrations of ammonia and nitrate shown are the total fed to the unit before the sample was taken, based on the feed rate and analyses. This calculated concentration would equal the brine concentration if all of the ammonia and/or nitrate was retained in the brine.

Table 5–18. Ammonia Concentrations in New 5 Brine Samples

Waste	Date	Time	NH_3/NH_4 in Brine (µg/L)		pH
			Actual	**Calculated**	
New 5	10/27	2030	765,000	1,240,918	4.7
New 5	10/28	0430	1,380,000	2,045,090	4.4
New 5	10/28	1330	2,100,000	2,971,187	4.2
Old New 5	Composite		14,200,000	14,478,417	5.8
New 5 Prime	Composite		25,400,000	19,630,514	4.4

Table 5–19. NO_3 Concentrations in New 5 Brine Samples

Waste[a]	Date	Time	Nitrate in Brine (µg/L)	
			Actual	**Calculated**
New 5	10/27	2030	6,240,000	7,733,981
New 5	10/28	0430	10,500,000	12,745,949
New 5	10/28	1330	16,200,000	18,517,820
New 5 Prime	Composite		3,990,000	3,166,212

[a] The Old New 5 waste residuals were not analyzed for NO_3.

The New 5 Prime results appear to indicate that the unit actually produced ammonia and NO_3 during the run because the reported concentrations were higher than the calculations indicate would be possible. These anomalous concentrations are probably due to residual ammonia and NO_3 left in the evaporator after the "hot turnaround" at the end of the New 6 Prime test, which directly preceded the New 5 Prime test.

The high retention of NH_3 in the brine during the New 5 and Old New 5 runs is due to the pH of the brine. The ammonia analysis method used by the GJPO Analytical Laboratory actually reports total NH_3 and NH_4^+ without distinction between species. The equilibrium distribution between NH_3 and NH_4^+, which determines how much of the total will be retained in the evaporator ($NH_{3,}$, a gas, will flash off to the oxidizer, while the NH_4^+ ion will remain chemically bound in the concentrate), is pH dependent:

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^- \qquad K = 1.75 \times 10^{-5} \tag{3}$$

Because pH = – log [H^+], the ratio of NH_4^+ to NH_3 is an inverse logarithmic function of pH. Based on the above equilibrium distribution, at a moderately basic condition (pH = 10), the NH_4^+/NH_3 ratio is 0.175:1, and the ammonia will be flashed off as the gas. When the brine is moderately acidic (pH = 4), the NH_4^{+}/NH_3 ratio is 175,000:1, so ammonia would exist as the ion almost exclusively and would be retained in the brine. The average pH of the brine in the New 5, New 5 Prime, and Old New 5 runs were all moderately acidic (4 < pH < 6). In this pH range, the NH_4^+ to NH_3 ratio is very high, and almost all ammonia in the feed would be retained in the brine.

The LANL New 6 samples, however, show a different pattern. The ammonia level in the New 6 feed was more than 100 times higher than the concentration in New 5, and the pH during the New 6 run was much higher, averaging more than 8. In this pH range, the ratio of NH_4^+ to NH_3 is still about 12 to 15. However, as NH_3 is formed, it will flash off to the oxidizer and new NH_3 will continuously be formed to maintain the equilibrium. Over time, the brine would tend to give up ammonia much more readily under these conditions. When waste feed is stopped, the brine will be stripped of its remaining NH_3. Results for the New 6 and New 6 Prime brine samples shown in Table 5–20 were both taken more than 4 hours after the feed was switched from waste to water. The brine concentration shows the effect of the NH_3 stripping.

Table 5-20. Ammonia Stripping in New 6 Brine

Waste	Location	Date	Time	Concentration (μg/L)	
				NO_3	NH_3
New 6	Feed	11/01	1330	2,090,000	50,500,000
	Brine	11/09	0030		881,000
New 6 Prime	Brine	12/08	1400	6,330,000	1,860,000

The efficiency of oxidation of ammonia can be estimated from the final GJPO composite samples by comparing the concentration of ammonia in the feed stream with that in the final product condensate, correcting for the dilution used during operation and the ammonia concentration in the brine. Only the New 6, New 6 Prime, and Old New 5 tests have the required data for this analysis. Table 5–21 presents the composite ammonia concentrations reported for feed, brine, and product condensate for these tests.

Table 5–21. Ammonia Concentrations in Composite Samples

Stream	Brine pH	NH_3 Concentration (μg/L)		Product Condensate Composite
		Feed	Brine	
New 6	7.9	50,500,000	881,000	1,470,000
New 6 Prime	7.6	50,500,000	1,860,000	728
Old New 5	5.4	25,000,000	142,00,000	728

The amounts of ammonia in the evaporator feed, in the brine, and in the product condensate can be determined by using the actual quantities of waste and dilution (presented in Appendix A). The oxidation efficiency (shown in Table 5–22) is calculated by comparing the total ammonia in the product condensate with the total available ammonia, determined by subtracting the ammonia in the brine from the total in the feed. This analysis assumes that ammonia is not lost from the product condensate, which is reasonable if the pH is less than about 9. Grab samples of product condensate taken during the runs and tested for pH indicated slight acidity, which would be expected if the condensate contains trace amounts of NO_x.

Table 5–22. Ammonia Oxidation Efficiency

Total NH_3 in waste Stream (mg)				
Stream	**Feed**	**Brine**	**Product Condensate Composite**	**Oxidation Efficiency (%)**
New 6	1,329,288	16,673	174,791	86.7
New 6 Prime	2,154,364	35,201	155	99.99
Old New 5	2,745,713	2,687,350	137	99.8

The oxidation efficiency of the unit for New 6 waste during the first test is poor compared with the efficiency for the same waste during the second test (New 6 Prime). Temperatures in the two run series were comparable. However, as noted in Section 5.2.3, "Effect of Oxygen," the operation of the unit during part of the first New 6 test series was oxygen deficient. Operation during the New 6 Prime series, on the other hand, averaged 2- to 7-percent excess oxygen, and contact times were twice as high during the second series. The improvement in oxidation efficiency in the second test is almost certainly due to a combination of these factors.

Grab samples taken during the first New 5 test series, shown in Table 5–23, indicate a spike in ammonia concentration in the condensate early in the run.

Table 5–23. LANL New 5 Scrubber and Condensate Grab Samples

Stream	Location	Date	Time	Concentration (µg/L)	
				NO_2	NH_3
New 5	Scrubber	10/27	2030	426	10,800
	Condensate	10/27	2030	785	110
New 5	Scrubber	10/28	0430	10,100	112
	Condensate	10/28	0430	324	59
New 5	Scrubber	10/28	1330	15,700	34
	Condensate	10/28	1330	306	19

The feed of LANL New 5 waste in the first test series began at 0725, so by the time the 2030 sample was taken, the unit had been operating on waste feed for more than 13 hours. During most of that time, however, the bed temperature was below 500 °C. This information seems to indicate that a large concentration of ammonia got past the oxidizer sometime before 2030, presumably during a period of low bed temperature, and was subsequently stripped out after the bed temperature increased and NH_3 carryover declined. The increase of NO_2, a product of ammonia oxidation, in the scrubber liquor during this period appears to substantiate this hypothesis.

5.3.6 Effect of Fluidization

The PO*WW*ER process is designed to be operated at incipient fluidization (i.e., at or close to the calculated minimum fluidization velocity). This was confirmed in discussions with both Brian Eichlin and Myron Reicher of ARI. Operating under fluidized conditions confers several advantages:

1. Gas-solids contact is optimized because the fluidized bed will not "channel" and permit gas to bypass the bed particles.

2. Temperature distribution across the bed is uniform, avoiding hot spots where catalysts could be damaged, and cold zones where the bed would be less reactive.

3. Optimum surface activity is maintained because the motion of the particles against one another provides a mild erosive action that keeps potentially fouling impurities from building up on the particle surfaces.

The designers determined fluidization velocities using the Wen and Yu (1966) correlation,

$$R_e = [(33.7)^2 + 0.0408N_{GA}]^{1/2} - 33.7 \tag{4}$$

where the Galileo number, N_{GA}, is

$$N_{GA} = \frac{gD_p^3\rho_f(\rho_p - \rho_f)}{\mu_f^2}. \tag{5}$$

D_p is the particle diameter, ρ_f and ρ_p are the densities of the fluid and the particle, respectively, and μ_f is the fluid viscosity. The minimum fluidization velocity V_{mf} is then calculated from the expression for the particle Reynolds number, R_e,

$$R_e = \frac{D_p V_{mf} \rho_f}{\mu_f}. \tag{6}$$

The Wen and Yu equation is not generally considered to be the best standard correlation for predicting fluidization velocities because it covers only a narrow range of values of mean bed voidage (ε_{mf}). However, for spherical particles of nearly uniform size such as the catalyst used in the PO*WW*ER process, the Wen and Yu correlation gives satisfactory agreement with measured values of V_{mf}.

According to ARI, the catalyst particles used in PO*WW*ER have an average diameter of 1/8 inch, and a density of 96 pounds per cubic foot (lb/ft³). The V_{mf} values shown in Table 5–2 (in ratio form) were calculated by using the Wen and Yu correlation with the ARI values for particle diameter and density. The calculated minimum fluidization velocity for the catalyst particles in the evaporative oxidation process is about 5.5 feet per second (ft/s), which corresponds to an aqueous waste-feed rate of about 12 lb/h, with an air flow rate of 10-12 slpm. This is about equal to the feed rate used during most of the GJPO test runs; therefore, the mini-PO*WW*ER unit bed was generally operated in a condition of incipient fluidization.

The importance of fluidization to the operation of the unit was graphically demonstrated during a period when the bed was ***not*** operated in a condition of incipient fluidization. This occurred during Run 2, the first LANL New 5. Figure 5–1 presents the temperature profile of the unit during the period from 0900–1200. Note that while the sheath temperatures and the oxidizer inlet temperature were measurably stable during this period, the oxidizer bed temperature became very erratic shortly before 1030.

Operating data for this run, summarized in Table 5–2, shows that the oxidizer was operating in incipient fluidization mode ($V/V_{mf} \sim 0.95$) at 1000. By 1230, V/V_{mf} had dropped to 0.65, and the bed was no longer fluidized. This drop in V/V_{mf} was due to a drop in the feed rate from more than 10 lb/h to about 7.5 lb/h, which occurred at around 1020 when the operators began having trouble controlling the feed rate.

This period of erratic feed rate coincides with the point on Figure 5–1 when the bed temperature abruptly went from relatively stable to wildly erratic. By the time the feed rate recovered and the bed temperature was stabilized, the bed temperature had fallen below 500 °C. Samples taken during this period show poor oxidizer performance by the MTU (see Section 5.2.5, "Treatment of Ammoniated Wastes").

The abrupt shift in bed temperature behavior is probably due to loss of fluidization in the bed. When the bed is not fluidized, flow and temperature distribution are not uniform and temperature measurement at any given location becomes unreliable. This behavior clearly shows the importance of maintaining fluidized conditions from oxidizer operation; it also confirms the sound judgment of the operating team in maintaining flow rates in the fluidized regime during the GJPO test work.

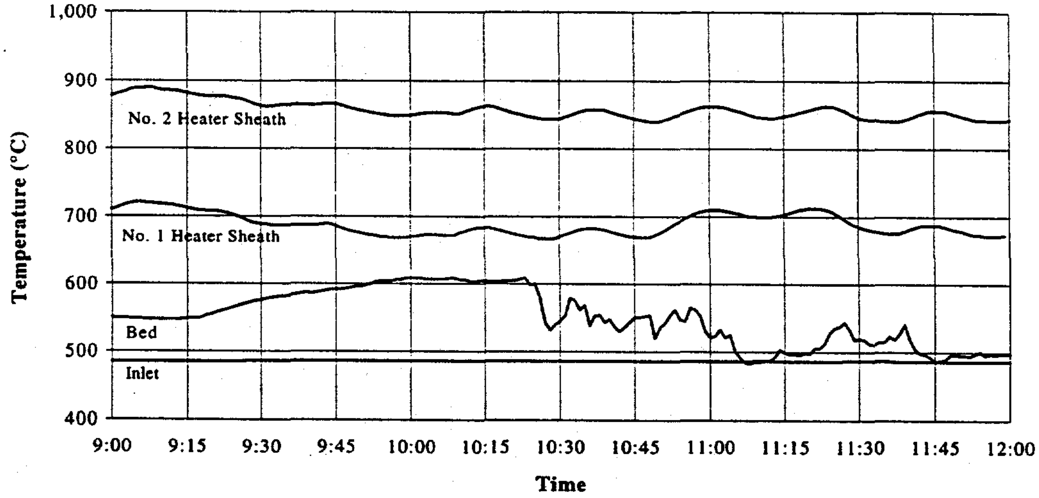


Figure 5–1. Oxidizer Temperatures for New 5 Run October 27, 1994

6.0 Design Considerations for Mobile Treatment Unit

6.1 Heater Temperature Control

During the demonstration run with IPA and water feed, the temperature rise in the oxidizer bed (the difference between the inlet temperature and the bed temperature) was only about half the value calculated from the reaction exotherm. Brian Eichlin pointed out that an increase in bed temperature causes some heat to be radiated to the bed inlet, which causes the inlet temperature to rise. This rise in inlet temperature signals the heater controller to reduce the heater output, indicated by a drop in the heater sheath temperatures. So the control system tends to be self-compensating to a certain extent.

One drawback of this self-compensating feature became apparent during the first treatibility test. When a feed containing one or more exothermic constituents is introduced into the oxidizer bed, the bed temperature will begin to rise to a new equilibrium value. Because the reaction exotherm must heat up not only the gas itself, but also the catalyst bed and the body of the oxidizer, the temperature will not reach the new equilibrium instantly, but will increase at a finite rate, which is rapid initially and then diminishes as equilibrium is approached.

Once the bed temperature exceeds the inlet temperature, some of the heat from the bed will be radiated back to the inlet. The heater controller will sense the rising inlet temperature and will reduce the heater output. This action reduces the total heat input into the system and shifts the final equilibrium temperature downward. However, because the bed temperature is still increasing and is still hotter than the inlet temperature, the heater controller will continue to reduce the heater output.

Eventually, the bed temperature will reach a maximum value and then it will begin to drop because of the continuing reduction in heater output. But as long as the bed is still hotter than the inlet, the heater output will continue to drop, and the bed temperature will continue to fall. Eventually, the bed temperature will drop below the inlet temperature. If, in the process, the bed temperature also falls below the activation temperature for the catalyst, the reaction will stop.

On two occasions, engineers operating the unit reported that, with both the heater output and the evaporator steam rate operated in manual, a reduction in the heater output produced a rise in bed temperature, rather than a drop as expected. This appears to indicate that oxidation was taking place in the heaters. Reducing the heater temperature would reduce the rate of oxidation in the heaters. The organic concentration in the material going into the oxidizer would then be higher, which would result in a higher bed temperature because of increased exotherm.

Review of operating data showed that the magnitude of this effect was difficult to quantify because of the complex interplay between different operating parameters that ultimately determine the oxidizer bed temperature. However, the design of the MTU can be configured to ensure that this undesirable effect does not recur in waste treatment by adding the oxidizer air downstream of the heaters.

It should be noted that feed rate as measured and reported here reflects the rate at which waste feed is added to the ***evaporator***. The rate at which waste is fed to the ***oxidizer***, on the other hand, is set ***not*** by the feed rate to the unit but by the boilup rate in the heat exchanger. The composition of the waste entering the oxidizer is set by a combination of both of these factors:

- Feed rate sets total rate of makeup to evaporator.

- Steam (boilup) rate sets total rate of vapor leaving evaporator (water plus volatiles).

The organics in the waste samples were almost all volatiles that would vaporize preferentially to water and boil off as quickly as they were fed. Increasing the feed rate to the evaporator, while holding the steam rate to the heat exchanger constant, results in a vapor flow to the oxidizer that contains a higher proportion of volatile organics than the original feed, as shown by the following hypothetical example.

Stream composition	5% methanol, 95% water
Initial feed rate	10 lb/h
=	0.5 lb/h methanol, 9.5 lb/h water
Latent heat	960 Btu/lb (water) 465 Btu/lb (methanol)
Total heat required	(9.5 lb/h water)(960 Btu/lb) + (0.5 lb/h methanol)(465 Btu/lb)
=	9,352 Btu/h

Increase feed rate to 15 lb/h while maintaining heat input of 9,352 Btu/h

Total methanol	0.75 lb/h (5% of 15 lb/h)

Methanol is completely vaporized (since it is more volatile than water)

Heat required	(0.75 lb/h methanol)(465 Btu/lb)
=	349 Btu/h to vaporize methanol

Heat available to vaporize water

=	9,352 Btu/h – 349 Btu/h
=	9,003 Btu/h
Water vaporized	(9,003 Btu/h)/(960 Btu/lb)
=	9.38 lb/h water vaporized
Vapor composition	7.4% methanol, 92.6% water

Since the vapor going to the oxidizer contains proportionately more reactant (methanol) and less diluent (water), the oxidizer bed temperature will increase.

Increasing the boilup rate at constant feed rate has the opposite effect. The amount of volatiles being boiled up does not change if the feed rate does not change; they cannot be boiled off faster than they are fed into the system. The increase in heat duty then will go entirely to boiling off water. The result is a leaner feed mixture and less exotherm (proportionately; the heat of reaction does not change, but there are more pounds of inert water to absorb it) in the oxidizer, which would be expected to result in a lower bed temperature. In this case, however, increasing boilup gives more efficient heat transfer in the heaters. This action tends to cancel out the reduction in exotherm, and the final effect on bed temperature will depend on which effect is dominant for a particular combination of conditions.

6.2 Control Mode

During the last series of tests beginning with Run 7, the mini-PO*WW*ER unit was operated with almost all control loops in manual mode. The oxidizer heaters were set on manual to eliminate self-compensation. The speed of the feed pump was adjusted, as required, to maintain the desired evaporator level. The steam rate to the heat exchanger was set on manual to maintain a constant boilup and a constant vapor rate through the heaters and the oxidizer bed. Only the scrubber pH control was retained from the original design of the automatic control system. Section 2.5, "Control System," discusses the design control system for the mini-PO*WW*ER unit. Section 6.1, "Heater Temperature Control," discusses some of the problems encountered with the heater control system.

Typically, the boilup rate was set to maintain a feed rate between 1 and 1.5 gal/h, which normally required a valve opening of about 25 percent. Adjusting the feed rate proved to be less disruptive to the overall operation than changing the steam rate because the steam-control valve was so oversized that fine adjustments to the steam flow were not possible. Therefore, the preferred control mode was to maintain a constant steam flow rate and adjust the feed pump speed until a constant evaporator level was achieved.

Another key operating parameter that was never part of the automatic control system, but which is nevertheless vital for the proper operation of the unit, is the oxidizer airflow rate. In the mini-PO*WW*ER unit, airflow rate was set manually by adjusting a rotameter setting. The desired air-makeup rate was specified in the individual waste-specific run plan to give a comfortable excess of oxygen at the highest flow rate. A second air measurement, the vent air, is a flowmeter installed on the vent gas downstream of the vent condenser.

Theoretically, the oxidizer air rate and the vent-gas rate would be almost identical because the vent gas is measured downstream of the chilled-water condenser that removes nearly all of the water, and the oxygen consumed in the reaction would be replaced by carbon dioxide. However, the two meters typically differed by 20 to 25 percent, with the vent-gas meter giving the lower reading. To be conservative (also because the oxidizer air rotameter had a maximum reading of 13 slpm, which was lower than the required rate for some runs), airflow rates were typically set to obtain the desired flow reading on the vent-gas flowmeter. However, setting these rates was a manual operation with no possibility for automatic control.

Another process variable is the water dilution required to control reaction exotherm. During the treatability tests, dilution was controlled by adding water to individual feed carboys in a trial-and-error process.

Obviously, this all-manual control system is not desirable for the mobile treatment unit. The final design of the mobile treatment unit should incorporate the following control logic:

- Evaporator feed rate is operator specified. This feed rate is the key operating parameter for the unit.

- Boilup rate is controlled by adjusting the steam rate to the evaporator, to maintain a constant level in the evaporator body.

- Heater output is controlled to maintain a constant bed (not inlet) temperature.

- Dilution water rate is controlled by measuring the flow rates of waste and dilution water and adjusting the ratio of the two to maintain a constant exotherm, measured as the difference between the inlet and bed temperatures.

- Oxidizer air rate is controlled to maintain a constant oxygen content in the process vent gas. (This control would require installation of an on-line oxygen analyzer.)

The unit would be started up filled with water, and the initial feed also would be 100-percent water at the specified feed rate. The heaters would have sufficient capacity to bring the bed to the maximum operating temperature of 650 °C with water. (This capacity would be a design requirement for the unit because some waste streams contain almost no heat of reaction.) Once the bed temperature is established, introduction of waste would begin by putting the ratio controller on automatic at a low value and gradually increasing the ratio until either the feed is at 100-percent waste or the temperature rise across the bed is at the maximum value. Oxidizer air would increase automatically as needed to maintain the specified excess oxygen.

6.3 Heaters and Oxidizer

The electric heaters in the mini-PO*WW*ER unit have a combined heat duty of 3.6 kilowatts (kW), which is approximately 4 times the heat load actually required to heat the vapor stream to the maximum operating temperature of 650 °C. Despite this apparent oversizing, the maximum bed temperature that could be achieved in the early phase of operation was about 520 °C. Part of this disparity was due to the series arrangement of the heaters that limited the output of the first heater to the same percentage output as the second heater. This arrangement is inefficient and should not be part of the MTU design.

The preliminary design developed by ARI and Rust for a large-scale PO*WW*ER waste-treatment unit provided for an economizer section. This design, similar in concept to the arrangement that is commonly used on industrial boilers, incorporates a heat exchanger that uses the oxidizer output gas to heat the vapor inlet into the oxidizer. Although this design poses challenges in metallurgy and thermal stresses, it is a worthwhile innovation to conserve and optimize energy, and should be considered for the mixed-waste MTU.

6.4 Radiological Decontamination of Mini-PO*WW*ER Unit

The mini-PO*WW*ER unit was designed to treat industrial and municipal wastes containing organic contaminants in water matrices. The unit was not designed specifically to treat mixed wastes, and radiological decontamination was not a consideration in the design of the evaporator. The mini-PO*WW*ER unit uses a forced-circulation evaporator design containing numerous piping and tubing connections for instruments, and the heat-exchanger design incorporates "dead spots" where solids can drop out and accumulate. Samples of rinse water taken at the beginning of the demonstration run were below detection limits for radioactivity, indicating that the mini-PO*WW*ER unit was radiologically clean when it arrived at GJPO. However, the unit did not arrive chemically clean, and contained numerous deposits of nonreactive solids that could act as "sponges" for radioactivity.

Table 6–1 shows the total amount of each radionuclide fed to the unit during the GJPO treatability tests, the levels of radioactivity in each sample, and the total radioactivity fed to the unit. Table 6–2 gives a breakdown of the total radionuclides fed during the test by isotopes, showing that 99.8 percent of the total mass of radionuclides was uranium-238, of which almost 95 percent was contributed by the New 5 and Old New 5 feeds. (These tables omit the SNL/NM sample, which was not analyzed for radioactivity.) Table 6–3 shows the radioactivity levels in all test residual streams (brines and evaporator rinses), except those that were fed back to the unit during the last phase of the tests, and the total amount of radioactivity removed from the unit in residual streams. Comparison of this total with the total in the feeds given in Table 6–1 shows that over 70 percent of the radioactivity that was fed to the mini-PO*WW*ER unit during the treatability tests was still in the unit at the conclusion of the tests:

Total combined alpha/beta activity in feeds:	316,770,982	pCi
Total combined alpha/beta activity in residuals:	90,987,362	pCi
Percent of total feed activity removed in residuals:	28.7	%

Table 6–1. Radioactivity in Feed Samples

Sample	Sample Quantites		Radioactivity (pCi/L)		Total Activity (pCi)	
	lb	**liters**	**alpha**	**beta**	**alpha**	**beta**
L16	482	219	2,200	3,200	481,548	700,434
L17	310	141	25,000	460	3,521,775	64,801
Old New 5	242	110	63,000	22,600	6,905,711	2,477,287
TG1	27	12	59,000	24,000	736,008	299,393
New 6	153	69	3,800	53,000	263,982	3,681,847
New 5	516	234	480,000	490,000	112,493,177	185,145,021
				Total Activity	124,402,200	192,368,782
				Total Combined alpha/beta	316,770,982	

Table 6–2. Total Radionuclides in Treatability Test Feeds (total grams)

Sample	U-238	U-235	U-234	Th-230	Ra-226	Am-241	Pu-238	Pu-239	Pu-240
L16						2.19E-08	1.15E-08	1.82E-06	4.97E-07
L17						9.10E-08	1.67E-08	2.98E-06	8.13E-07
Old New 5	3.60	6.70E-03	2.19E-05						
TG1	0.44	3.12E-03	2.70E-05	3.16E-14	1.21E-09				
New 6	0.63	1.25E-03	4.96E-06						
New 5	14.97	2.79E-02	9.13E-05						
Total	19.63	3.89E-02	1.45E-04	3.16E-14	1.21E-09				

This data indicated the need for additional decontamination beyond simply rinsing with water. Visual examination of the outside of the sight glass confirmed the likelihood of residual radioactive contamination because the lower section of the sight glass was coated with radioactive residue, primarily from the LANL New 5 waste that originally was yellowish in color but now was a dirty brown. During the treatability tests, this yellowish radioactive residue was found to be soluble in concentrated nitric acid. This finding suggested that it might be possible to decontaminate the unit by rinsing the evaporator with nitric acid. However, the concentration of nitric acid in the evaporator had to be low enough to keep the final pH of the solution above 2 so that the residual would not be characteristic for corrosivity and classified as a mixed waste.

The acid rinse was performed on December 29, 1994. The unit was charged with water, and sufficient 1N nitric acid was added to give a final pH of 2.15. The mixture was then heated to 50 °C and circulated for 30 minutes. During this time, it was noted that the brownish coating on the evaporator sight glass was significantly reduced, although it was not completely eliminated. The acid was then drained. The evaporator was refilled with water, which was heated to 80 °C, circulated for

Table 6–3. Radioactivity in Test Residuals

Stream	Sample	Sample Volume (gal)	Radioactivity (pCi/L)		Total Activity (pCi)	
			alpha	beta	alpha	beta
TG1	brine	5	8,400	8,300	158,970	157,078
TG1	brine rinse	5	1,060	280	20,061	5,299
New 5	evap. rinse	7.5	159,000	219,000	4,513,613	6,216,863
New 5	evap. rinse	5	35,300	33,500	668,053	633,988
New 6	evap. rinse	5	41,000	59,000	775,925	1,116,575
New 6	evap. rinse	5	22,000	26,900	416,350	509,083
L17	brine	5	350,000	290,000	6,623,750	5,488,250
L17	brine solids	5	66,000	115,000	1,249,050	2,176,375
L17	evap. rinse	5	34,000	56,000	643,450	1,059,800
L17	evap. rinse	5	4,600	9,600	87,055	181,680
Old New 5	brine	5	90,000	215,000	1,703,250	4,068,875
Old New 5	evap. rinse	5	24,000	41,000	454,200	775,925
Old New 5	evap. rinse	5	11,500	19,600	217,638	370,930
New 6 Prime	brine	5	35,400	9,320	669,945	176,381
New 5 Prime	evap. rinse	5	348,000	246,900	6,585,900	4,672,583
New 5 Prime	evap. rinse	5	267,000	207,800	5,052,975	3,932,615
L16 Prime	brine	5	75,500	148,500	1,428,838	2,810,363
L17 Prime	evap. rinse	5	23,000	34,600	435,275	654,805
L17 Prime	evap. rinse	5	16,800	42,300	317,940	800,528
New 5 Prime Prime	brine	5	637,000	275,000	12,055,225	5,204,375
New 5 Prime Prime	evap. rinse	5	106,800	80,200	2,021,190	1,517,785
New 5 Prime Prime	evap. rinse	5	52,100	36,900	985,993	698,333
SNL	brine	2.5	6,370	11,320	60,276	107,116
SNL	evap. rinse	4	6,740	5,570	102,044	84,330
SNL	evap. rinse	5	5,420	9,400	102,574	177,895
				Total Activity	47,349,536	43,597,825
				Total Combined alpha/beta	90,947,362	

30 minutes, and then drained. The evaporator was then refilled with water a second time and circulated without heating for 15 minutes. Samples of the brine from the acid rinse and of both the first and final water rinses were tested for gross alpha and beta levels. Results of these analyses, presented in Table 6–4, showed that the acid rinse and subsequent water rinses removed only about 1.4 percent of the total estimated amount of gross alpha and beta activity left in the evaporator after the end of the treatibility tests.

Table 6–4. Radioactivity Removed in Acid Rinse

Stream	Sample	Sample Volume (gal)	Radioactivity (pCi/L)		Total Activity (pCi)	
			alpha	beta	alpha	beta
Acid	brine	5	77,000	80,000	1,457,225	1,514,000
Rinse	first water	5	1,900	3,200	35,958	60,560
Rinse	second water	5	1,350	1,520	25,549	28,766
				Total Activity	1,518,731	1,603,326
				Total Combined alpha/beta		3,122,057

After the results of the acid rinse were reviewed, a second rinse using sodium carbonate or sodium bicarbonate was suggested. Uranium solids have a high solubility in both of these bases, and the rates of dissolution are acceptable. A mixture of sodium carbonate and sodium bicarbonate is generally used to optimize the rate of attack. However, for the GJPO work, pure sodium bicarbonate was the preferred base because of its ready availability and ease of handling. Information from *The Extractive Metallurgy of Uranium* (Merritt 1971) indicated that a 0.36 M solution of sodium bicarbonate would result in a dissolution rate of 10 milligrams per liter per minute. On the basis of the activity of the feed, this concentration would give a solution time of about 6 minutes.

The bicarbonate rinse was performed on January 7, 1995. The evaporator was charged with water to a level of about 11 inches, equivalent to a volume of 3 to 4 gallons. Then a solution of 1 pound of $NaHCO_3$ in 1 gallon of water was added. The solution was heated to 75–80 °C and circulated for 90 minutes. The evaporator was then drained and refilled with water, which was circulated without heat for 1 hour. Radioactivity levels in the bicarbonate rinse solution and the water rinse showed that the bicarbonate solution was significantly more effective at removing the contamination than the acid solution. As shown in Table 6–5, analysis of the residuals showed that the bicarbonate rinse was more effective in removing contamination from the evaporator. However, based on the radiation balances indicated in Tables 6–1 and 6–3, only 3.5 percent of the estimated total contamination in the unit was removed with the bicarbonate rinse.

After the results of the bicarbonate rinse samples were received, the evaporator, heat exchanger, and circulating piping were disassembled and surveyed for radiological contamination. Within the evaporator and the circulating piping, levels of contamination were typically 2,500–4,000 ncpm (167,500 to 268,000 disintegrations per minute per 100 square meters [dpm/100 cm^2]) and dosages were no higher than 0.2 millirem per hour (mrem/h) at 12 inches. Inside the heat exchanger head, however, samples showed contamination as high as 80,000 ncpm or 5.36 million dpm/100 cm^2, and a dose rate of 5 mrem/h on contact. Because the dosage was less than 0.5 mrem/h at 12 inches with the

Table 6–5. Radioactivity Removed in Bicarbonate Rinse

Stream	Sample	Sample Volume (gal)	Radioactivity (pCi/L)		Total Activity (pCi)	
			alpha	beta	alpha	beta
Bicarbonate	brine	5	210,000	140,000	3,974,250	2,649,500
Rinse	water	5	21,000	37,000	397,425	700,225
				Total Activity	4,371,675	3,349,725
				Total Combined alpha/beta		7,721,400

head of the heat exchanger in place, the unit did not have to be classified as a radiation area and could be shipped as long as the head remained installed.

The U.S. Department of Transportation (DOT) has advised the Mixed-Waste Treatment Program that the MTU should be transported as radioactive material, excepted package, limited quantity of material. Internal contamination is not a consideration for the limited-quantity shipping classification. However, it would be necessary to show that the MTU contains less than 15 grams of uranium-235. The LANL waste streams may contain nearly 67 grams of uranium-235; Table 6–6 gives the total quantity of uranium-235 in the LANL waste streams calculated from estimated quantities of each waste and laboratory analyses of the waste samples tested at GJPO.

Table 6–6. Estimated Quantity of U-235 in LANL Wastes

Waste	Alpha (pCi/L)	U-235 (pCi/L)	Total Waste (lb)	Total U-235 (g)
New 5	480,000	9799	30,400	62.59
L17	25,000	510[a]	33,044	3.54
L16	2,200	45[a]	27,316	0.26
New 6	3,800	78[a]	15,641	0.25

[a] Estimate is based on gross alpha activity.

For the MTU to qualify as a limited quantity, it would be necessary to demonstrate that at least 78 percent of the total uranium-235 in the feed had been removed either with brines or by final decontamination of the unit. Experience with the mini-PO*WW*ER unit at GJPO suggests that this level of decontamination may not be easy to achieve with this evaporator design. The design of the MTU can and should incorporate features such as flush-mounted instrumentation to minimize traps where radiological contamination can accumulate. However, from the standpoint of decontamination, a forced-circulation evaporator is not the optimum design for this service, and the design process for the MTU should consider alternatives that will not compromise the overall mission of the program.

6.5 Ammonia and NO_x Removal

The evaporative oxidation process was successful in oxidizing ammonia. Products of the oxidation reaction are oxides of nitrogen (NO_x), which are regulated air pollutants, and their discharge into the atmosphere must be controlled and minimized. Two alternatives have been suggested for controlling and minimizing NO_x formation:

1. The evaporator could be operated in an acidic mode (a pH of approximately 4). Under these conditions, the ammonia would be retained in the concentrate as NH_4^+ rather than flashing off as NH_3 gas. (See Section 5.3.5, "Treatment of Ammoniated Wastes.")

2. Reduction of NO_x to nitrogen and oxygen is mature technology and packaged units are available for this purpose. The MTU could be equipped with secondary treatment capability to treat the NO_x as it is formed.

Option 1, retaining the ammonia in the brine, is not practical because of the large concentration of ammonia in the LANL wastes, which causes a number of process and design complications:

- The inventory of New 6 waste at LANL is estimated at 7.1 cubic meters (m^3) or 1,875 gallons, and this waste contains 5.05-percent ammonia. When neutralized with sulfuric acid and concentrated to 40-percent solids, the volume of final brine produced from treatment of the New 6 waste is about 750 gallons. This gives a concentration factor of 2.5:1, which is not consistent with the volume-reduction target of evaporative oxidation technology.

- The New 5 and New 6 waste samples were heavily buffered, requiring large amounts of acid for pH adjustment. Based on GJPO experience during feed preparation, acidifying the entire LANL New 5 and New 6 waste streams would require about 500 gallons of concentrated acid. Storing and handling this volume of concentrated acid on a mobile unit at a DOE site would be a major design and safety challenge.

- Neutralization of the New 5 and New 6 wastes generated copious amounts of fumes and gave off sufficient heat of reaction to raise the liquid temperature by 40 °C. Dealing with these problems in the field would require installation of a vent scrubber for the fumes and cooling coils in the feed treatment tank(s). Neither has been contemplated in the MTU design.

Thus, Option 2, fitting NO_x reduction capability to the MTU, appears to be the preferred method for dealing with ammoniated wastes and should be incorporated into the design of the unit. As one possibility, ARI, the makers of the catalyst used in PO*WW*ER, also market an NO_x reduction technology called ECONOX that could easily be fitted to the oxidizer off-gas stream. ARI has indicated that it might be possible to combine the PO*WW*ER and ECONOX catalysts in a single bed, although this would have to be confirmed by bench-scale testing.

Most of the oxides of nitrogen decompose in water to form HNO_3 and HNO_2. If they are not treated until after the off gases have passed through the scrubber, most of the NO_x will be converted in the scrubber to aqueous nitrates and nitrites. Production of nitrogen gas is preferable to production of nitrate and nitrite salts, which would consume caustics while increasing the dissolved-solids concentration of the brine (the salts would be generated in the scrubber, and scrubber liquor will be recycled to the evaporator before the end of treatment). If possible, the NO_x reduction unit should operate directly on the oxidizer off gas rather than downstream of the scrubbing section.

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Appendix A

Evaporative Oxidation Treatability Test Plan

Grand Junction Projects Office
Mixed-Waste Treatment Project

Evaporative-Oxidation Treatability Test Plan

August 1994

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Evaporative-Oxidation Training Matrix

1.0 Introduction

Within the network of facilities operated by the U.S. Department of Energy (DOE), there exists a large volume of wastewater contaminated with both organic chemicals (volatile and semi-volatile) and radioactive materials. When the organic contaminants are regulated by the U.S. Environmental Protection Agency (EPA), under the Resource Conservation and Recovery Act (RCRA), this wastewater is classified as mixed waste. Adequate treatment and disposal capacity currently does not exist for the wastes that are generated and stored at the nine sites overseen by the DOE Albuquerque Operations Office (AL). If the organic chemicals can be eliminated from the waste (e.g., by evaporation and vapor-phase catalytic oxidation) then the residuals (i.e., condensate and concentrate) would be acceptable for recycling and disposal, provided that the materials are either de-listed or meet the applicable RCRA land disposal restriction (LDR) treatment standards.

This treatability test plan describes the protocols required to perform a pilot demonstration of the PO*WW*ER process on selected mixed waste. The PO*WW*ER process is designed to separate volatile and/or semi-volatile organic contaminants from wastewaters. In addition, non-volatile organic and inorganic contaminants are concentrated in an evaporator, providing waste volume reduction with concentration factors ranging from 30:1 to 50:1. By applying this process to mixed wastes, the volatile organic contaminants are destroyed. Radionuclides, heavy metals, and non-volatile organics are concentrated for subsequent treatment to meet LDR treatment standards before disposal. The product condensate is available for recycling or can be vented directly to the air without condensation if recycling is not required.

2.0 Process Overview

2.1 PO*WW*ER Overview

The PO*WW*ER process is a wastewater treatment technology developed by Chemical Waste Management, Inc. (CWM) to treat chemical industry wastewaters. The PO*WW*ER process concept has been developed into a fully integrated pilot plant, the Mini-PO*WW*ER unit.

The PO*WW*ER process combines several standard chemical industry processes. Wastewater is concentrated in an evaporator by vaporizing water, volatile organics, and volatile inorganics. The evaporator concentrate, which will contain radionuclides, heavy metals, and nonvolatile organics/inorganics present in the wastewater, is removed from the system and managed by solidification/stabilization and landfill disposal.

The evaporator design used for a PO*WW*ER process is dependent on the wastewater to be treated and waste reduction requirements. The standard evaporation system used is a single-stage, forced recirculation evaporator with a shell and tube heat exchanger.

The vapor stream from the evaporator is superheated and passed through a catalytic oxidizer. The catalyst, a non-precious metal catalyst resistant to poisoning, is proprietary and patented by CWM. The volatile compounds, including aromatics, chlorinated solvents, ammonia, sulfides, and cyanides, are oxidized to carbon dioxide, water, and trace amounts of acid gasses. Halogenated organics (e.q., methylene chloride, chloroform, carbon tetrachloride, chloroethylenes, freons, etc.), require the addition of methanol (CH_3OH, a hydrogen donor) to the feed, in the ratio of 4 moles hydrogen to: 1 mole X (where X = F, Cl or Br), for the purpose of scavenging halide, as HX, from the catalyst surface.

Acid gases are removed from the vapor stream by a wet scrubbing system, which uses a slightly basic sodium hydroxide scrubbing solution to perform traditional neutralization and mass transfer treatment. The treated vapors are condensed in a condenser or directly vented to the atmosphere if water recycling is not required. The treated water is pure and can be used for a variety of applications, including cooling tower water, boiler water, and process water.

2.2 Mini-PO*WW*ER Overview

The Mini-PO*WW*ER system is used to demonstrate process commercialization potential, using customer supplied waste. Such a commercialization study would include on-line oxidation data and evaporator performance at normal operating concentrate composition. Oxidation data is required to determine the most efficient oxidation temperature and oxygen content for treating the waste stream and to determine if the wastewater causes catalyst poisoning or physical degradation of the catalyst. The evaporator and oxidizer are operated simultaneously. Initially, the evaporator concentrates wastewater (feed) to operating conditions; during the final portion of the operation the concentrate specific gravity is maintained by periodically purging the evaporator system of concentrate.

The only exception is tritium, which should distribute to all these streams as radioactive water. PO*WW*ER is probably not an appropriate technology for waste streams which contain significant concentrations of tritium.

Data quality objectives for accuracy, precision, completeness, representativeness, and bias of analytical data are sufficient, as defined for each analytical method, to satisfy test acceptance criteria. The instrumentation of the mini-PO*WW*ER unit will be checked out and calibrated prior to operation of the unit in accordance with the *Mini-PO*WW*ER Operations Manual.* The instrumentation and the representativeness of the sample points have been proven, for all five objective criteria, in prior treatability studies with mixed waste and will be acceptable for purposes of this test.

3.4 Treatability Test Report

The Treatability Test Report will document the results and findings of the treatability testing and will describe whether the objectives of the testing were met. Results and recommendations pertinent to designing and fabricating the mobile treatment units may be included in the Treatability Test Report. The Treatability Test Report will be submitted to the Program Manager for acceptance.

4.0 Waste Stream Description

In response to the need for mixed waste treatment capacity, DOE-AL organized a Treatment Selection Team to match mixed wastes with treatment options and to develop a strategy for treatment of its mixed wastes. The evaporative oxidation technology is applicable to aqueous waste streams containing organic contaminants and dissolved or suspended solids. The technology was recommended by the Treatment Selection Team as the first choice of treatment options for five different candidate waste streams. The five candidate waste streams are listed and briefly described in Table 4.1. Waste streams and volumes are expected to change; the information presented in Table 4.1 is the best available information at this time.

Table 4.1 Candidate Waste Streams for PO*WW*ER Treatability Testing

Site	Waste Stream	Approximate Quantity	Waste Stream Characteristics	RCRA Waste Codes Radionuclides
GJPO[a]	TG 1	204 Kg	Aqueous liquid; 2 (of 4) drums may contain 10-1800 ppm chloroform ($CHCl_3$), >1 percent sludge; low levels of carbon tetrachloride and benzene	D018, D019, D022 U, ^{226}Ra, ^{230}Th
LANL[b]	New 5	485.6 ft^3 (70 x 55 gal drums)	Aqueous solution containing isopropyl alcohol (5 percent), some ammonia and U-oxide solids	D001, D002, D008 ^{235}U
LANL	New 6	250 ft^3 (34 x 55 gal drums)	Aqueous slurry containing isopropyl alcohol, ammonia and U solids	D002, D009, F005 ^{235}U, ^{238}U
LANL	L 16	529.9 ft^3 (90 x 30 gal & 50 gal drums)	Solvents in bulk form, where the primary material is either an oil or an aqueous liquid containing F002.[c] Hazardous constituents may include 1,1,1-trichloroethane, trichloroethylene, methylene chloride, and chlorofluorocarbons	F001[d], and various radionuclides
LANL	L 17	436.7 ft^3 (139 x 30 gal & 50 gal drums)	Oils or aqueous liquids.[c] Hazardous constituents may include 1,1,1-trichloroethane and trichloroethylene	F002, and various radionuclides

[a] Grand Junction Projects Office

[b] Los Alamos National Lab

[c] Only the aqueous portion of this waste stream will be treated with PO*WW*ER

[d] The generator is attempting to reclassify waste as F002 since the solvents were not used for degreasing F001

Each generator is responsible for selecting a representative sample of each waste stream for this treatability test. It may not be possible for the generators to select a sample that will include all of the characteristics identified in a waste stream; the waste content may vary from drum to drum and the generators may not have the capability, or resources, to bulk their wastes for sampling purposes.

4.1 Grand Junction Project Office - TG 1 (GJPO-TG 1)

The GJPO-TG 1 is an aqueous liquid waste stream generated during site remediation of test mill sumps. The generator expects the waste streams to contain up to 0.2 percent chloroform. The generator suspects it to contain radium-226, thorium-230, and uranium. This waste stream has designated RCRA waste codes of D018, D019, and D022.

The PO*WW*ER process is expected to eliminate the chloroform from this waste, thereby removing the D018, D019, and D022 characteristics. The resulting process concentrate would contain any heavy metals or radionuclides originally present in the waste.

4.2 Los Alamos National Laboratory - New 5 (LANL-New 5)

The LANL-New 5 is an aqueous liquid waste stream containing about 5 percent isopropyl alcohol, ammonia, lead, and uranium oxide solids, including small amounts of uranium-235. This waste stream has designated RCRA waste codes of D001, D002, and D008.

The PO*WW*ER process is expected to eliminate the isopropyl alcohol from the waste, thereby removing the D001 ignitability characteristic. The D002 corrosivity characteristic is expected to be eliminated by the pH adjustment during feed preparation. The resulting process concentrate would contain any lead and uranium originally present in the waste.

4.3 Los Alamos National Laboratory - New 6 (LANL-New 6)

The LANL-New 6 is an aqueous slurry waste stream containing isopropyl, ammonia, volatile and semi-volatile solvents, mercury, and uranium solids. This waste stream has designated RCRA waste codes of D002, D009, and F005.

The D002 corrosivity characteristic is expected to be eliminated by the pH adjustment during feed preparation. The PO*WW*ER process is expected to eliminate the volatile solvents and a portion of the semivolatile solvents from the waste. The uranium solids and a portion of the semi-volatile solvents would remain in the process concentrate. The mercury may partition between the process concentrate, the scrubber liquid, and the product condensate.

4.4 Los Alamos National Laboratory - L 16 (LANL-L 16)

The LANL-L 16 is an aqueous liquid waste stream containing 1,1,1-trichloroethane, trichloroethylene, methylene chloride, chlorofluorocarbons, and possible radionuclides, including americium-241, plutonium-238, and plutonium-239. This waste stream has a designated RCRA waste code of F001.

The PO*WW*ER process is expected to eliminate the organic solvents. The radionuclides, if originally present, would remain in the process concentrate.

4.5 Los Alamos National Laboratory - L 17 (LANL-L 17)

The LANL -L 17 is an aqueous liquid waste stream containing 1,1,1-trichloroethane, trichloroethylene, methylene chloride, sulfuric acid, and possible radionuclides including americium-241, plutonium-238, and plutonium-239. This waste stream has designated RCRA waste codes of D002 and F002.

The D002 corrosivity characteristic is expected to be eliminated by the pH adjustment during feed preparation. The PO*WW*ER process is expected to eliminate the organic solvents. The radionuclides, if present, would remain in the process concentrate.

5.0 Feed Preparation

Preparation of the waste sample prior to treatment in the Mini-PO*WW*ER unit will consist of pH adjustment to between 6 and 8, solids screening and washing, methanol addition for halide scavaging, dilution with water to a total organic carbon (TOC) content of less than 5 percent, and the addition of benign inorganic salts to achieve a total solids content of greater than 8 percent.

The pH adjustment and solids screening and washing will be performed prior to waste characterization sampling and analysis. Methanol addition, dilution, and salts addition will be based on the results of this analysis and will be performed after the analytical results have been obtained.

5.1 Adjustment of pH

As described in Section 7.2, the evaporator pH must be maintained between a pH of 5 and 10. Consequently, pH of the as-received waste must be adjusted to a pH of between 6 and 8. If acidification is required, concentrated (20 percent) sulfuric acid (H_2SO_4) will be used. **(CAUTION: ALWAYS ADD ACID TO WATER, NOT WATER TO ACID).** Concentrated (10 Molar) sodium hydroxide (NaOH) solution will be used for basification.

A small (~250 mL) ***representative*** subsample will be collected and the appropriate amount of acid or base required to achieve neutralization will be determined on this subsample. Any unexpected chemical/physical reactions, aside from the neutralization exotherm, resulting from the neutralization will be determined on this subsample. Recommended neutralization procedures are

1. Using a drum mixer, or drum tumbler, homogenize drum contents, including any settleable solids.
2. Obtain a 250 mL ***representative*** (grab) sample.
3. Determine pH of sample.
4. If the pH is less than 6, adjust pH upward with concentrated (10 Molar) sodium hydroxide solution; if the pH is greater than 8, adjust pH downward with concentrated (20 percent) sulfuric acid.
5. Add either concentrated (20 percent) sulfuric acid or concentrated (10 Molar) sodium hydroxide solution very slowly, in small increments, monitoring the pH and temperature and allowing the pH to stabilize between incremental additions.
6. Note the extent of the neutralization exotherm, any vigorous reactions, gas evolution, color changes, etc.
7. Determine the amount of acid or base required to achieve pH = 7 ± 1.
8. Estimate total volume of drummed wastewater sample; based on amount of acid or base calculated in Step 7 above, estimate the total amount of acid or base required to neutralize the entire drum contents. Assure sufficient drum capacity.

9. Using the drum mixer, homogenize the drum contents and begin the slow, incremental addition of acid or base, monitoring pH and temperature. As in Step 5 above, allow the pH to stabilize between incremental additions.

10. If there is a significant exotherm resulting from the neutralization, the exotherm should be allowed to subside between incremental (acid/base) additions.

11. Add sufficient acid or base to achieve a final constant pH = 7 ± 1.

12. Minimize the potential for generating mixed waste per Procedure 2.11 of the RUST Geotech Inc. (Geotech), *Environmental Protection Manual* (Manual 102) by bringing only the volume of acid required into the Radioactive Materials Management Area (RMMA).

5.2 Debris Screening/Washing

The wastewater sample, GJPO - TG 1, is reported to contain debris and suspended solids. Prior to treatment with the Mini-PO*WW*ER unit, the debris will be removed by screening (10 mesh screen), washed by agitation with water, and screened again (10 mesh screen) to ensure decontamination of the debris. The washing and screening (10 mesh screen) may need to be repeated. All of the wash waters will be combined with the wastewater sample. A screen, with attached feed hopper, built to fit a 55 gallon drum, will be used for this purpose. The recommended debris screening/washing procedures are

1. Transfer the drum contents through the drum-mounted screen (10 mesh screen) into a second drum and allow the debris to drain completely.

2. Transfer the collected debris back into the original drum and add sufficient clean tap water to just cover the debris. Using a drum tumbler, agitate to wash both the debris and the drum.

3. Transfer the debris and rinse water through the drum-mounted screen (10 mesh screen) into the second drum and allow the debris to drain completely.

4. Repeat Steps 2 and 3 for a total of at least 3 rinses or until the debris is fully decontaminated, based on visual examination and radiological frisking of the debris.

5.3 Dilution to Reduce Total Organic Carbon Content

To avoid exceeding the maximum catalyst bed temperature of 1250°F (677°C), the TOC of the feed must be less than or equal to 5 percent (50,000 ppm), including the methanol added for hydrogen halide scavenging. Dilution will be accomplished with tap water. The dilution required to reduce the TOC to less than or equal to 5 percent is defined as follows:

$$C_1 \ V_1 = C_2 \ V_2$$

Where C_1 and C_2 are initial and final concentrations, respectively, and V_1 and V_2 are initial and final volumes, respectively. For example, consider the situation wherein the initial volume (V_1) equals 40 gallons and the initial TOC (C_1) equals 150,000 ppm (15 percent). Dilute to a final volume (V_2) with a final concentration (C_2) of 50,000 ppm (5 percent), as follows:

$$\frac{C_1\ V_1}{C_2} = V_2 = \frac{(150{,}000ppm)\ (40gal)}{(50{,}000ppm)} = V_2 = 120gal$$

Consequently, 80 gallons of tap water would be required to dilute the 40 gallon samples up to 120 gallons with a final TOC of 5 percent.

If the sample initially occupies a single drum, and dilution will increase the sample volume to multiple drums, the final volume should be calculated and the initial sample divided equally into all of the required drums to ensure approximately equal feed concentrations in all drums.

5.4 Augmentation of Total Solids Content

The time required, during Phase II (concentration), to achieve a 50 percent solids level in the evaporator, is directly related to the solids content in the feed. This concentration process can be accelerated by intentionally adding benign inorganic salts. A total solids content of greater than 8 percent would be preferred for feed material. This would reduce the time (Phase II) required to achieve 50 percent solids content to approximately 24 hours and would reduce the total volume of waste feed required for the test. A benign inorganic salt, such as calcium carbonate, will be added to the waste to a final total dissolved solid concentration of greater than 8 percent.

5.5 Methanol Addition

Methanol will be added to the waste feed as required to achieve a 4:1 organic hydrogen to organic halide mole ratio.

6.0 Health and Safety

6.1 Purpose and Scope

The operational tasks associated with the evaporative-oxidation treatability test will be identified and evaluated for health and safety hazards. These operational tasks include the preparation of the test material to be treated, feed preparation, the operation of Mini-PO*WW*ER system, the acquisition of samples that will be analyzed to determine the performance of the system, and the handling of residual products of the process (residuals management).

6.2 Job Safety Analysis

The Job Safety Analysis (JSA) procedure will be the main vehicle to identify and evaluate hazards associated with this project. The JSA procedure is outlined in Procedure 2.2 in Volume 1 of the Geotech *Health and Safety Manual* (Manual 103). A JSA will be developed for each operational task associated with the treatability test.

6.3 Operational Tasks

For each of the following (e.g.: feed preparation; mini-PO*WW*ER system start-up; operation of the Mini-PO*WW*ER system; performance sampling; and shut down and decontamination) operational tasks identified below, the JSA will evaluate the health and safety hazards for the activities required to accomplish each task.

6.3.1 Feed Preparation

Feed preparation includes altering the compositions of the aqueous wastes so they are within the range required by the PO*WW*ER process. This will include: pH adjustment to 6-8; solids screening, to less than 10 mesh; methanol spiking to a 4:1 hydrogen:halide mole ratio; dilution, to less than 5 percent TOC; and calcium carbonate addition, to a total solids content of greater than 8 percent.

6.3.2 Mini-PO*WW*ER System Start-Up (Phase I)

The Mini-PO*WW*ER system will follow the start-up procedure as detailed in Section 4.3 of the *Mini-PO*WW*ER Operations Manual.* The start-up procedure will be performed with tap water as the feed stream instead of aqueous waste. This portion of the test is also referred to as Phase I.

6.3.3 Operation of the Mini-PO*WW*ER System, with Waste Feed (Phase II and Phase III)

Feed to the Mini-PO*WW*ER system will be switched from tap water to prepared aqueous waste. The Mini-PO*WW*ER system will be operated following the procedure detailed in Section 4.2 of the *Mini-PO*WW*ER Operations Manual.* This portion of the test is also referred to as Phase II for the initial approach to operational concentration in the evaporator and Phase III for steady state operation with periodic removal of concentrate.

6.3.4 Performance Sampling

Performance sampling includes all sampling associated with characterization and feed preparation of the waste, operation of the Mini-PO*WW*ER system, and characterization of the process residuals.

6.3.5 Shut Down and Decontamination of the Mini-PO*WW*ER System

At the conclusion of each waste stream test, the Mini-PO*WW*ER system will be shut down and decontaminated following the procedure detailed in Section 4.4 of the *Mini-PO*WW*ER Operations Manual.*

6.4 Chemical Hazard Identification

The aqueous wastes selected for treatability testing may contain acids; caustics; and heavy metals, including lead and mercury; ammonia; and organic constituents, including chloroform, methylene chloride, 1,1,1-trichloroethane, trichloroethylene, carbon tetrachloride, chlorofluorocarbons, isopropyl alcohol, methanol, toluene, xylenes, benzene, and ethylbenzene.

Concentrated sodium hydroxide solution and sulfuric acid may be used for pH adjustment.

The process residuals could also contain any of the material identified above.

6.5 Radiological Hazard Identification

The specific radionuclides ^{226}Ra, ^{230}Th, ^{235}U, and ^{238}U are among the radioactive isotopes suspected to be present in the aqueous waste to be treated. Some waste data will be available for the individual drums of waste to be tested. Feed characterization will better define the identity and activities of the radionuclide constituents of the aqueous waste streams.

The radionuclide constituents are expected to remain either in the waste feed or in the process concentrate during and after each waste stream test. Residual radionuclides could remain in any processing equipment, after each waste stream test. The residual radionuclides should be removed during decontamination of both the Mini-PO*WW*ER system and any equipment used during feed preparation.

Real-time monitoring for radiation exposure will be performed as necessary during all operations.

7.0 Treatability Test Procedures

Each treatability test run consists of three phases: Phase I, start-up; Phase II, concentration to target specific gravity; and Phase III, simultaneous feed and removal of concentrate.

The actual operating procedures are detailed in the *Mini-PO*WW*ER Operations Manual.* All test operations will be conducted within the instructions provided in the Radioactive Materials Management Areas Operating Criteria, Procedure 2.11 of the RUST Geotech Inc. *Environmental Protection Manual* (Manual 102).

7.1 Phase I, Start-Up

The Phase I start-up will be performed using tap water, as described in the *Mini-PO*WW*ER Operations Manual.* The start-up phase ensures the catalyst is at operating temperature prior to initiating feed of actual waste. The Mini-PO*WW*ER unit is allowed to stabilize for 4 hours at an oxidizer inlet temperature of 1000°F (538°C) and a tap water flow rate of 8.5 pounds per hour.

7.2 Phase II, Concentration to Target Specific Gravity

Phase II begins when the feed to the Mini-PO*WW*ER unit is switched from tap water to waste. Phase II is designed to concentrate the waste to the desired solids, target specific gravity, content, monitor operating parameters, assess heat transfer data, optimize performance (i.e., oxidation efficiency), and build an operations database. During this phase, the feed stream is concentrated to the desired solids content of approximately 50 percent (specific gravity 1.4 - 1.5). The duration of Phase II is dependent on the solids content of the feed.

1. Monitor and maintain the following parameters during Phase II:

Evaporator Recirculation Rate	5.5 ft-sec^{-1} ± 0.2
Vapor body level	20 ± 5 inches
Feed flowrate	8.5 lbs-hr^{-1}

2. Additional parameters and procedures which govern operation are contained in "Unit General Operation" of the *Mini-PO*WW*ER Operations Manual.*

3. Closely monitor the system for foaming and entrainment separator differential pressure. If these items occur, refer to Section 4, pages 36 and 37, of the *Mini-PO*WW*ER Operations Manual* for corrective actions.

4. Monitor evaporator pH and maintain between pH 5 and pH 10 by adding aqueous sulfuric acid or sodium hydroxide to the feed.

5. Sample the evaporator concentrate, scrubber discharge, and product condensate every 8 hours. Perform analysis according to Section 8.2.

6. Continue operation with Phase II feed until desired, evaporator concentrate specific gravity is attained.

7.3 Phase III, Simultaneous Feed and Removal of Concentrate

Once the target evaporator concentrate specific gravity has been attained, Phase III commences. Discharge of the product concentrate occurs simultaneously with removal of the product condensate and wastewater feed to the evaporator, maintaining the target specific gravity content. This phase of the test includes the continued determination of oxidizer efficiency provision of scrubber operating experience, demonstration of specified concentrate physical and chemical characteristics, and verification of organics destruction. Phase III will conclude when all prepared feed has been processed. This phase may last from 10 to 72 hours.

- The catalyst bed temperature is maintained at 1000°F (538°C) by adjusting the oxidizer heater controller. Because the catalytic oxidation reactions are exothermic, the oxidizer inlet temperature must be set to somewhat less than the target catalyst bed temperature.

- Perform sampling of the evaporator concentrate, scrubber discharge, product condensate, and system vent as detailed in Section 8. Sampling should be performed according to the *Mini-PO*WW*ER Operations Manual*, Section 4.5.

- When approximately one-half of the waste has been processed, adjust the oxidizer inlet to achieve a catalyst bed temperature of 1200°F (649°C) and continue as before until all waste has been processed or sufficient data has been obtained.

- When all the waste has been processed, the unit should be shut down and decontaminated according to shut down procedures in Section 4.4 of the *Mini-PO*WW*ER Operations Manual.*

8.0 Process Sampling and Analysis

Process sampling and chemical analysis are needed to characterize the waste for feed preparation, process performance monitoring, and process instrument verification.

8.1 Waste Characterization for Feed Preparation

The process feed to the Mini-PO*WW*ER system must contain no more than 5 percent organics, must contain at least a 4:1 ratio of organic hydrogen to organic halide, and must contain at least 8 percent total solids. To make the necessary additions to achieve these requirements, the following laboratory analyses will be performed after the received waste has been pH adjusted and screened for solids:

1. Total Organic Carbon (TOC);
2. Volatile Organic Compounds (VOC);
3. Semi-volatile Organic Compounds (SVOC);
4. Total Organic Halides (TOX);
5. Total Dissolved Solids (TDS); and
6. Total Suspended Solids (TSS).

8.2 Process Performance Monitoring

The composition of the waste feed and process residuals before, during, and after each test run will be documented by sampling and laboratory analysis. The analytical parameters, sampled streams, and sampling schedule is provided in Table 8.1.

For vent gas concentrations and mass balance calculations, the vent gas should be sampled over time with an adsorption tube and using the vent flow totalizer on the Mini-PO*WW*ER unit, the average vent gas VOC or specific constituent concentration can be determined. The *Mini-PO*WW*ER Operations Manual* should be consulted for further information on this procedure.

All sampling activities should be performed according to sampling procedures contained in the *Mini-PO*WW*ER Operations Manual*

Table 8.1 Performance Sampling and Analysis Requirements

	Sampled Once		Sampled Every 8 hours			
Parameter	**Feed**	**Final Concentrate**	**Concentrate**	**Scrubber**	**Condensate**	**Vent***
pH	X	X	X	X	X	
Conductivity	X	X	X	X	X	
VOCs	X	X	X	X	X	X
TCLP VOCs		X				
Semi-VOCs	X	X**	X**	X**	X**	X**
TCLP Semi-VOCs		X				
Metals (As, Ba, Cd, Cr, Pb, Hg, Se, and Ag)	X	X	X	X	X	X
TCLP Metals		X				
Radionuclides	X	X	X	X	X	X
CH_3OH	X			X	X	X
X^- (F^-, Cl^-, Br^-)				X	X	
Free SO_4^{2-}, NO_3^-, CO_3^{2-}, PO_4^{3-}	X					
TOC	X	X	X	X	X	
TOX	X					
CO						X
TSS	X	X	X			
TDS	X	X	X			

* Vent samples should be taken using Sensidyne detector tubes.
** Analyze only if found in feed sample.

8.3 Process Instrument Verification

The Mini-PO*WW*ER system is equipped with pH meters, a densitometer, and a conductivity meter for process control purposes. In order to verify the operation of these instruments, samples will be taken and analyzed every 8 hours by the operators of the Mini-PO*WW*ER system. Instrumentation values and temperatures must be recorded at sample time to compare with analytical values. Table 8.2 contains the analytical parameters and sampled waste streams for process instrument verification.

Table 8.2 Instrumentation Analysis Requirements

Parameter	Evaporator	Scrubber	Product
pH	X	X	X
Conductivity		X	X
Density	X		
Total Solids	X		

9.0 Residuals Management

9.1 Waste Stream Characteristics and Estimated Volumes

The waste streams which are typically generated from treatability testing are

- Product condensate
- Product concentrate (evaporator discharge)
- Scrubber discharge
- System flush water
- Contact waste
- Debris
- Non-debris screened solids
- Empty containers

All of the above waste streams must be collected in appropriate containers and managed appropriately. Appropriate management entails analyzing each waste stream for the RCRA characteristics present prior to treatment. Listed hazardous waste remains listed even upon destruction of the listed constituent. Characteristics (radioactive, hazardous) attributed to the various waste streams assume

- Radioactive contaminants, other than tritium (^3H), are non-volatile and will partition exclusively to the product concentrate.
- Wastes contaminated with ^3H, the ^3H will be distributed (as ^3H_2O) throughout all of the products (i.e., concentrate, condensate, and scrubber discharge).
- Hazardous RCRA organic constituents are volatile and/or semi-volatile and consequently will be destroyed under optimized conditions.
- Hazardous metals, other than mercury, are non-volatile and will partition exclusively to the product concentrate.

9.1.1 Product Condensate

Product condensate is a typically non-hazardous aqueous liquid, primarily distilled water, potentially contaminated with trace quantities of such constituencies as VOCs. However, based on system design and operating experience, contamination of this waste stream is considered unlikely.

9.1.2 Product Concentrate (Evaporator Discharge)

Product concentrate (evaporator discharge) is a typically hazardous (RCRA metals) radioactive aqueous suspension/solution containing 55-65 percent solid constituents. The product concentrate also includes any solids removed during decontamination of the heat exchanger tubes.

9.1.3 Scrubber Discharge

Scrubber discharge is a typically non-hazardous aqueous liquid consisting of less than 1 percent sodium hydroxide and approximately 4 percent sodium chloride .

9.1.4 System Flush and Decontamination Water

System flush and decontamination water will contain diluted amounts of the evaporator concentrate and scrubber water.

9.1.5 Contact Waste

Contact waste is any compactible solid material that has come in contact with the waste sample. This generally includes paper towels, gloves, sample containers, disposable analytical equipment, and other miscellaneous items.

9.1.6 Debris

Debris includes all solid materials, screened from waste stream during feed preparation, that meet EPA debris classification.

9.1.7 Non-debris Screened Solids

Non-debris screened solids (greater than 10 mesh) are solid materials screened from waste stream during feed preparation that do not meet the EPA definition of debris.

9.1.8 Empty Containers

Empty containers include shipping drums, process drums, sampling containers, and process chemical containers.

Table 9.1 provides estimated volumes of the various treatability study residual waste streams which will require management.

9.2 Management of Waste Stream Residuals

To allow for the use of process knowledge on residual waste streams, each waste stream will be analyzed for the RCRA characteristics present in the waste prior to the treatability study. Each waste stream generated by the treatability study will be analyzed to determine effectiveness of the study, to determine if secondary waste streams are radioactive, and to determine which EPA waste codes apply. Due to the "Derived From Rule," waste streams generated from listed hazardous waste remain hazardous waste even though the constituent for which the waste was listed is destroyed or treated to LDR standards. Each waste stream will be scanned or analyzed pursuant to Geotech's *Performance*

Objective for Certification of Non-Radioactive Hazardous Waste (PO) to define radioactive classification.

The requirements specified in Geotech's *Environmental Protection Manual*, Procedure 2.10 *Acceptance Criteria for Characterization, and Transfer of Radioactive, Hazardous, and Mixed Waste (WAC)* will be met for all waste managed at the GJPO.

9.2.1 Product Condensate

Product condensate will be returned to the facility that originally generated the hazardous waste under treatability study sample exclusion, codified in 40 CFR 261.4[e]. This waste will be characterized by Geotech with respect to RCRA constituents, based on EPA protocol and radioactivity, based on release criteria specified in the Geotech *PO*.

Table 9.1 Estimated Volumes of Treatability Study Residual Streams

Waste Stream	Source	Volume	Suspected Health Hazard
Product Condensate	Phase II	75 Gallons	Non-Hazardous*
Product Condensate	Phase III	50 Gallons	Non-Hazardous*
Evaporator Concentrate	Phase III	15 Gallons**	Radioactive, potentially hazardous
Scrubber Discharge	Phase III	25 Gallons	Potentially Radioactive
System Flush Water	System cleanup	25 Gallons	Non-Hazardous
Contact Waste	All	25 Pounds	Non-Hazardous
Debris	Feed Preparation	0-100 Pounds	Non-Hazardous
Screened Solids	Feed Preparation	0-100 Pounds	Potentially Hazardous and Radioactive
Empty Containers	Feed Preparation	5-10 Containers	Non-Hazardous***

* Condensate may contain detectable levels of VOCs greater than LDRs if the oxidizer fails to efficiently remove them from the stream.

** Evaporator concentrate may be retained for waste stabilization studies.

*** Non-Hazardous if triple rinsed, as per 40 CFR 261.7.

9.2.2 Scrubber Discharge

Scrubber discharge will be returned to the facility that originally generated the hazardous waste under treatability study sample exclusion, codified in 40 CFR 261.4[e]. This waste will be characterized by Geotech with respect to RCRA constituents, based on EPA protocol, and radioactivity, based on release criteria specified in the Geotech *PO*.

9.2.3 Product Concentrate

Product concentrate (evaporator discharge) will be returned to the facility that originally generated the hazardous waste under treatability study sample exclusion, codified in 40 CFR 261.4[e]. This waste will be characterized by Geotech with respect to RCRA constituents, based on EPA protocol, radioactivity, and based on release criteria specified in the Geotech *PO*. A portion of the concentrate may be used for stabilization studies prior to being returned to the generator.

9.2.4 Decontamination Water

Decontamination water will be managed by Geotech. The decontamination water is from a RCRA empty, per 40 CFR 261.7, container (i.e., the empty vessel that contained the waste during the treatability study). As such, the decontamination water will not be managed as listed waste. The requirements specified in Geotech's *Environmental Protection Manual*, Procedure 2.10 *WAC*, will be met for this waste stream. A determination of characteristics of hazardous waste will be conducted based upon the characteristics associated with the original, untreated, waste stream. Additionally, a radioactive determination, based on release criteria specified in the Geotech *PO*, will be made to certify the radioactive classification of the waste. Efforts made to maintain the GJPO's conditionally-exempt small quantity generator status will include the goal of limiting the generation of hazardous and mixed waste to less than 5 kilograms per month, and reporting and forecasting the quantity of regulated waste generated to Geotech's Waste Management Subsection. The requirements specified in Geotech's *Environmental Protection Manual*, Procedure 2.10 *WAC* will be met for this waste stream.

9.2.5 Contact Waste

Contact waste will be managed by Geotech. Contact waste has the potential to be radioactive, hazardous, or mixed waste. Contact waste will be segregated based on process knowledge to minimize the quantity of radioactive, hazardous, and mixed waste. Efforts made to maintain the GJPO's conditionally-exempt small quantity generator status will include the goal of limiting the generation of hazardous and mixed waste to less than 5 kilograms per month and reporting and forecasting the quantity of regulated waste generated to Geotech's Waste Management subsection. The requirements specified in Geotech's *WAC* will be met for this waste stream.

Segregation of contact waste will result in several subcategories of this waste stream. The subcategories and the corresponding management techniques are

- Personal Protective Equipment (PPE)

  PPE that has not contacted listed waste will not be managed as listed waste. All PPE, except that which is used in handling waste samples LANL-L 16 and LANL-L 17, will be radiologically surveyed. If found to be radioactive, the PPE will be decontaminated and surveyed again. If still radioactive, it will be managed as radiological waste if it has not contacted a listed waste. If it is still radioactive and also has contacted a listed waste, it will be managed as mixed waste. If it is non-radioactive, but has contacted a listed waste, it will be managed as a listed waste. If it is non-radioactive and has not contacted a listed waste, it will be managed as non-hazardous solid waste.

  PPE used in handling waste samples from LANL-L 16 and LANL-L 17 will be considered radioactive waste if found to be radioactive or not. The suspected radiological constituents in these waste samples may not be detected with the available portable radiological surveying devices.

- Disposable Cleaning Equipment

  Paper towels, absorbent rags, etc., will require the operating engineer to use good professional judgement in making the appropriate segregation decision. Paper materials which have direct contact with samples or waste material will be segregated from paper products that were used to clean or wipe equipment that has not been contaminated with samples or waste.

  Materials that have been contaminated will be scanned for unconditional release. Those wastes that do not meet unconditional release criteria and have contacted a listed waste will be managed as mixed waste. Those wastes meeting unconditional release criteria will be managed as hazardous if they contacted a listed waste. Those wastes meeting unconditional release criteria that contacted a characteristically hazardous waste will be evaluated on an individual basis to determine if they are hazardous.

9.2.6 Debris From Washing

Debris from washing will be returned to the facility that originally generated the hazardous waste under treatability study sample exclusion, per 40 CFR 261.4[e]. When properly decontaminated this waste stream is not regulated under RCRA due to the exclusions provided in the Debris Rule. A radioactive determination, based on release criteria specified in the Geotech *PO*, will be made to certify the radioactive classification of the waste. Debris may contain material less than 60 mm, but material greater than or equal to 60 mm must predominate.

9.2.7 Screened Solids From Feed Preparation

Non-debris screened solids from feed preparation (greater than 10 mesh), will be returned to the facility that originally generated the hazardous waste under treatability study sample exclusion, codified in 40 CFR 261.4[e]. These solids carry the same EPA waste codes as the original wastewater sample; however, they are not amenable to evaporative oxidation. A radioactive determination, based on release criteria specified in the Geotech *PO*, will be made to certify the radioactive classification of the waste.

9.2.8 Empty Containers

Empty containers are not regulated under RCRA if they meet the definition of empty, as codified in 40 CFR 261.7. A radioactive determination, based on release criteria specified in the Geotech *PO*, will be made to certify the radioactive classification of the empty container. Those containers determined to be non-radioactive will be managed by Geotech as solid waste. Those containers that are determined to be radioactive will be returned to the facility that originally generated the waste.

Attachment A

Evaporative-Oxidation Training Matrix

Evaporative-Oxidation Training Matrix

Task	Discipline	Required Training	Other information
Feed Preparation: Completion requires short periods of time over several days.	Sampler	Radiation Worker II Drum sampling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	Health and Safety sampling/monitoring required Radioparticulate - 2 per day Continuous organic vapor monitoring with Hnu
	Laborer	Radiation Worker II Drum handling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Radiation Control Technician	Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Observers outside controlled area	GERT	
System Check: Requires 2 days, running 24 hours per day.	Sampler	Radiation Worker II Drum sampling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	Methylene Chloride Methanol Sampling is needed to assess exposure to chemicals. 3 area samples and 3 personal samples
	Operator	Radiation Worker II Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Radiation Control Technician	Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Laborer	Radiation Worker II Drum Handling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Observers outside controlled area	GERT	

Evaporative-Oxidation Training Matrix

Task	Discipline	Required Training	Other information
Testing: Takes place over 4 to 6 days, operating 24 hours per day.	Sampler	Radiation Worker II Drum sampling Respirator Wearer - Requires pulmonary function test and full face APR fit test	Methylene Chloride Isopropyl Alcohol 1,1,1-Trichloroethylene Ethylbenzene Toluene Xylene Mercury Isopropyl Alcohol Ammonia Uranium powder Sampling is needed to assess exposure to chemicals. Radioparticulate - 2 samples per 8 hour shift
	Operator	Radiation Worker II Respirator Wearer - Requires pulmonary function test and full face APR fit test	
	Radiation Control Technician	Respirator Wearer - Requires pulmonary function test and full face APR fit test	
	Laborer	Radiation Worker II Drum Handling Respirator Wearer - Requires pulmonary function test and full face APR fit test	
	Observers outside controlled area	GERT	
Shipment: Blow down, Re-drum, Teardown, and Release.	Sampler	Radiation Worker II Drum sampling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	Methylene Chloride Isopropyl Alcohol 1,1,1-Trichloroethylene Ethylbenzene Toluene Xylene Mercury Isopropyl alcohol Ammonia Uranium powder Exposure to chemicals should already be assessed; therefore, no further personal or area IH sampling is required. Radioparticulate - 2 samples per 8 hour shift Continuous organic vapor monitoring with Hnu
	Operator	Radiation Worker II Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Radiation Control Technician	Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Laborer	Radiation Worker II Drum Handling Respirator Wearer - Requires pulmonary function test and full face APR fit test Hazard Communication - MSDS, pre-job briefing	
	Observers outside controlled area	GERT	

Abbreviations/Acronyms:
APR - Air Purifying Respirator
MSDS - Material Safety Data Sheet
IH - Industrial Hygiene
GERT - General Employee Radiological Training

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Appendix B

Run History

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B1.0 Introduction

Feed preparation on the LANL and GJPO samples was performed during the latter part of August 1994. Treatability tests began in September and continued into mid-December. This Appendix describes the work performed in these operations and summarizes some of the lessons learned.

B1.1 Feed Preparation

The first samples of feed were received at GJPO in August 1994, and the first phase of feed preparation at the site began on August 23. This phase of feed preparation was performed in an outdoor area at the GJPO because the indoor facility for the PO*WW*ER unit was not yet available.

The LANL L16 overpack drum was opened on August 23. The pH of the liquid measured 6.4, so no further pH adjustment was required. The liquid was screened to remove coarse solids, samples of the treated feed were collected and submitted to the GJPO Analytical Laboratory for analysis, and the remaining liquid was transferred to two numbered 55-gallon drums.

The LANL L17 overpack drum was opened on August 24. The pH of this sample measured 1.43. The L17 liquid was screened to remove coarse solids and transferred to a numbered 55-gallon drum. The sample was then neutralized to a final pH of 6.15 by adding 1,225 mL of 10N sodium hydroxide and 2,400 mL of 1N sodium hydroxide. Samples were taken and submitted to the GJPO Analytical Laboratory for analysis. The other LANL waste samples also were opened on August 24 so that the health and safety technicians could sample the vapor space, but they were immediately resealed and no liquid samples were taken from these drums at that time.

The LANL New 6 overpack drum was opened for feed preparation on August 26. The pH of this sample measured 9.95. The New 6 liquid was screened to remove coarse solids and transferred to a numbered 55-gallon drum. The contents of the drum were then neutralized to a final pH of 7.86 by adding 2,170 mL of concentrated (98-percent) sulfuric acid, and samples were taken and submitted to the GJPO Analytical Laboratory for analysis.

The LANL New 5 overpack drum was opened for feed preparation on August 30. The pH of this sample measured 11.13. The New 5 liquid was screened to remove coarse solids and transferred to two numbered 55-gallon drums. The contents of the first LANL New 5 55-gallon drum were then neutralized to a final pH of 8.08 by adding 8 L of concentrated (98-percent) sulfuric acid, and samples were taken for laboratory analysis. During this operation, the temperature of the sample rose to 70 °C because of the heat of reaction, and copious fumes and a distinct odor of alcohol were observed in the area. Because 70 °C is above the boiling point of isopropanol, the major hazardous constituent of this waste, the team became concerned that a significant part of the isopropanol might have been lost during feed preparation, which would affect the quality of the treatability test. The project team decided to set aside this first 55-gallon drum, hereafter referred to as New 5X, and perform feed preparation on the second 55-gallon drum of New 5 waste, taking care this time to keep the sample temperature down.

The second LANL New 5 drum was opened for feed preparation on August 31. The contents of this drum were titrated to a pH of 2.71 by adding 44 L of 20-percent sulfuric acid and 4.5 L of concentrated (98-percent) sulfuric acid. The temperature was kept below 34 °C at all times during this operation by adding 5 gallons of ice water and 22 gallons of ice. The contents of the drum were then back-titrated to a final pH of 6.23 by adding 250 mL of 1N NaOH and 500 mL of 10N NaOH, and samples were taken and submitted to the GJPO Analytical Laboratory for analysis.

The last waste sample on which feed preparation was performed during this phase of the process was the GJPO TG1 sample, which was opened on September 1. This sample is described as "aqueous liquid, > 1 percent sludge" in the *Treatability Test Plan*. When the drum was opened, it contained about 2 gallons of aqueous liquid on top of a drum full of compacted sludge. The liquid portion was decanted into a 5-gallon bucket. The pH of the aqueous phase was 6; therefore, no neutralization was necessary. Samples of the liquid were taken for analysis by the GJPO Laboratory, and the solids were resealed in the original drum for testing later using thermal desorption.

Augmentation of the solids content of the waste samples remained controversial. The *Treatability Test Plan* recommends adding benign organic salts to achieve a total solids content of more than 8 percent. The drawback to augmenting the dissolved-solids contents was that, since the final evaporator brine samples produced during the treatability tests were to be used for stabilization studies, the soluble solids composition of the brine samples should be representative of the brine that will be produced in actual treatment, in terms of relative composition if not of actual concentration. The project team therefore questioned the usefulness of solids addition as part of the test work at GJPO.

To help resolve this and other technical issues that arose during the initial operation, Brian Eichlin, the designer of the mini-PO*WW*ER unit and a 50-gallon-per-minute (gal/m) Hong Kong-based PO*WW*ER unit, was invited to GJPO for a consultation. In a meeting held on September 15, 1994, Eichlin recommended that "spiking the feed with inorganic salts was inappropriate."

Analysis of the LANL New 5 and New 6 samples after feed preparation showed that the TDS concentration in these liquids was due almost entirely to the solids that were added during feed preparation. In Table B–1, the "Reported" TDS is the value reported by the laboratory for the prepared feed, and "Calculated" TDS is the TDS calculated from the quantity of acid and base added during neutralization.

Table B–1. Dissolved Solids Concentration of LANL Samples

Sample	TDS (mg/L)	
	Reported	**Calculated**
L16	16,580	0 (no neutralization)
L17	17,520	5,806
New 6	27,560	27,481
New 5	89,800	106,692
New 5X	167,500	170,143

The calculated TDS addition is higher than the reported final TDS concentration in some cases because the sample volumes were estimated rather than measured precisely and because the dilutions, particularly the amount of water actually contributed by the ice and ice water additions, were likewise not measured precisely. The difference between the New 5 and the New 5X samples results from the much higher dilution of the New 5 sample with ice and ice water added during neutralization of that sample.

It was apparent that in "as-received" condition, the dissolved-solid concentrations of the New 5 and the New 6 samples must have been close to zero. The neutralization process served to augment the solids concentration of those samples just as if "benign salts" had been added according to the original proposal in the *Treatability Test Plan.* Brines resulting from testing these samples would be of suspect value for stabilization studies, just as if the solids concentration had been purposefully altered.

The project team was unable to determine the rationale for the requirement that the feed be pH adjusted to between 6 and 8. Eichlin reported that "previous test studies were performed at a maximum pH of 10 to 10.5." The principal concern regarding operation at pH values above this range is that the AL6XN alloy metallurgy of the evaporator and the associated equipment is subject to caustic stress corrosion at pH values above 11.0. Eichlin also expressed a concern about foaming at high-brine pH values. He did not suggest any problems with low pH. The pH of the final brine can be adjusted, if necessary, to remove the corrosivity characteristic after treatment is completed and volume is minimized. Neither the New 5 nor the New 6 samples, as received at GJPO, were in the pH range that would be considered characteristic for corrosivity.

Eichlin and the project team were concerned that the feed-preparation process had so altered the composition of the New 5 and the New 6 samples that they would bear little resemblance to the composition of the waste stream from which they were drawn, and treatability tests that were based on these samples would be of no value to the program. Therefore, LANL was asked to send additional samples of these waste streams. These new samples became known as "New New 5" and "New New 6;" the earlier samples were referred to as "Old New 5," "Old New 5X, and "Old New 6." The "Old" samples were not used in the treatability tests performed at GJPO, except that a portion of the "Old New 5" sample was used in one test of unit performance at high-solids concentration.

The remaining feed preparation steps specified in the *Treatability Test Plan* are

- Addition of methanol for halide scavenging.
- Dilution with water to a TOC content of less than 5 percent.

The rationale behind the water dilution was unclear in the original CTC submission. Eichlin explained that the reason for water dilution was to control the reaction exotherm, because the catalyst effectiveness drops off below about 500 °C, but the catalyst cannot be used above about 650 °C. The water is used to take up the heat of reaction. Eichlin recommended, in place of the blanket requirement of 5-percent TOC, that the feed concentration be adjusted as necessary to limit the calculated bed temperature rise to no more than 500 °F (278 °C). The project team decided to dilute the waste with water, where necessary, as the feed carboys were prepared, rather than attempting to dilute entire drums of feed.

The use of methanol for halide scavenging is based on the original catalyst development work done by ARI, Inc. According to Derrick McManus, ARI's chief chemist, either water or propane was added to organic halide streams to prevent the formation of Cl_2 gases (e.g., promote formation of HCl). This catalyst development work was done on nonaqueous systems. ARI found that the maximum effectiveness was obtained when propane or methane addition was supplemented with steam injection.

For the aqueous PO*WW*ER system, CTC recommended using methanol as the hydrogen donor and adding the methanol to the waste feed to achieve a 4:1 organic-hydrogen-to-organic-halide mole ratio. However, it was unclear whether any hydrogen donor was required in an aqueous process or whether the water content of the feed would provide all the hydrogen activity that the process required. The project team elected to leave methanol addition, like water dilution, as a step to be performed as the final feed carboys were prepared and, if possible, to perform tests with and without methanol addition to see if any difference in catalyst performance could be detected.

B1.2 PO*WW*ER Unit Operation

The first run made with the mini-PO*WW*ER unit at GJPO was a demonstration run to verify the functioning of all pieces of the unit and to gain operating experience. The demonstration run consisted of a period of initial operation of the unit on water only, followed by operation of the unit on a series of surrogate waste streams to demonstrate the destruction efficiency of the catalyst on feeds with known concentrations.

The initial startup of the unit began at 2045 on September 27, 1994, with the first water feed being started at 0235 on September 28. At 1150 on September 28, the feed was changed to a surrogate waste of 2-percent IPA in water (this concentration was determined by temperature-rise calculations), but was changed back to water 20 minutes later after high CO and NO_x were detected in the off gas. IPA and water feed was restarted at 1610 on September 28 and continued until 1920.

Feed of the second surrogate mixture, water containing 2-percent IPA plus 1-percent DCM, began at 2345 on September 28 and was stopped at 0105 on September 29 after high levels of DCM were detected in the off gas. Shortly afterwards, the unit was shut down because of a plug that was caused by catalyst pellets in the desuperheater. The unit was restarted on October 5, 1994. The IPA and DCM feed was initiated at 1520 on that date and continued until 1735, when all the prepared IPA and DCM feed was consumed.

The tests on 2-percent IPA established that the observed temperature rise in the bed was only about half of the value calculated on the basis of the reaction exotherm. Accordingly, addition of a solution of 4-percent IPA in water began at 2006 on October 5 and continued until 0013 on October 6. This run established that the mini-PO*WW*ER unit was capable of treating feeds of much higher concentration than would be expected on the basis of the calculated temperature rise.

Operational problems consumed most of the next day. At 0522 on October 7, the last surrogate test was started. This test, which was intended to simulate the non-pH-adjusted LANL New 5 Feed, used a solution of 50-mL ammonium hydroxide per liter of water, adjusted to a pH of 11.6. This test lasted until 0936.

B1.2.1 First Treatability Tests

Run 1, the first mixed-waste sample to be tested with the mini-PO*WW*ER unit at GJPO, was the GJPO TG1 sample. Approximately 27.5 pounds of this waste was run through the unit, starting at 1458 on October 7 and finishing at 1845 on the same day. During the shutdown at the end of this run, an observed high pressure in the heat exchanger resulted in extended unit downtime for safety review, process modifications, and additional operator training lasting until October 26.

Restart of the unit on water began at 0645 on October 26. Run 2, testing of the LANL New 5 waste sample, began at 0255 on October 27. The bed temperature quickly rose above the established maximum operating temperature of 650 °C, and feed was switched back to water at 0319 to avoid overheating the catalyst. At 0725 on October 27, feed of LANL New 5 waste diluted 1:1 with water was reinitiated. At 0912, feed of New 5 waste diluted with 1 part water per 2 parts of waste was initiated and continued until 1356 on October 28. The total amount of waste fed during this run was 252 pounds.

After another period of downtime for unit maintenance, the unit was restarted for Run 3, testing of LANL New 6 waste, beginning at 1005 on November 7. Waste feed began at 1804 on November 7. As with New 5, the bed temperature rapidly rose above the action limit, and waste feed was stopped at 1830. Waste feed was restarted at 1841 and continued with various dilution ratios until 1953 on November 8. Because of the high dilution used during this run (averaging almost 3.8 parts water per part waste), the total amount of waste fed during the 25.5 hours of this treatability test was only about 58 pounds.

Following a "hot turnaround," during which the bed was kept hot with warm-up air while the evaporator was drained and rinsed, Run 4, the treatability test of LANL L17 waste, began at 0631 on November 9. The unit was able to treat this waste with no dilution. Testing of the L17 waste continued without interruption until 0817 on November 10 when all of the L17 waste had been consumed. During this period, the total waste fed was 310 pounds.

Following another hot turnaround, Run 5, the treatability test of LANL L16 waste, began at 1910 on November 10. The unit was able to treat this waste without dilution. The test on this waste was punctuated with numerous operating and equipment problems, the most serious being a loss of one of the heater elements and a failure of the evaporator circulating pump. Although the unit was in operation almost 93 hours during this period (not counting the downtime to replace the heater element and repair the circulating pump), the total time during which waste was actually being fed to the unit was less than 33 hours. The total for L16 waste was 383 pounds.

B1.2.2 Solids Concentration Test

After the circulating pump was repaired, the unit was restarted for Run 6, a test of operating parameters at high-solids concentration. The feed for this run was the Old New 5 waste, which had had its dissolved solids concentration augmented by addition of a large volume of sulfuric acid for neutralization during feed preparation. (The New 5 waste that was tested during Run 2 was a second sample from the same waste stream; however, it arrived with a pH of about 4 and was not pH adjusted because there was no need.) Feed of this waste began at 0434 on November 17 and continued (with experimentation on dilution) until 0606 on November 18. Brine data showed that the solids concentration at that point still had not reached the desired target value, so waste feed was restarted at 1028. At 1853 on the same day, the desired specific gravity was reached and the unit was shut down.

The last waste samples scheduled to be tested were two small samples from SNL/NM. Startup of the unit for testing these samples began at 0800 on November 30. Physical examination of one of the SNL/NM samples, which occurred when the sample was transferred from its metal shipping can into a glass carboy for feed to the unit, indicated that the sample was pure organics and unsuitable for treatment in PO*WW*ER. Laboratory analysis confirmed this composition, and the unit was shut down until further information on the waste samples was received from SNL/NM.

B1.2.3 Shutdown for Modifications

Although the destruction efficiencies achieved during the tests made to this point had been encouraging, the concentration of impurities in the product condensate samples was still above UTSs for wastewater disposal. Therefore, it was determined that an additional series of runs was necessary to demonstrate that the technology is capable of producing condensate that can meet UTSs without requiring further treatment. Most of the remaining waste samples on hand would be tested, and the product condensate made during the previous tests would be reprocessed through the unit.

During the shutdown before beginning this last series of runs, two significant changes were made to the unit:

- The depth of the catalyst bed was doubled, from 8 to 16 inches, effectively doubling contact time at equivalent flow rates.
- The heat tape on the bed inlet was replaced with a new type of tape that has 3 times the heat capability, making it possible to achieve higher bed temperatures on samples such as L16 and L17 that have low reaction exotherms.

B1.2.4 Second Series of Treatability Tests

Startup of the unit for this final series of tests began at 0815 on December 6. Run 7, using LANL New 6 waste diluted with product condensate from the previous New 6 run (Run 3), began at 1304 on December 6. By 1807 on December 7, all the old product condensate had been processed, and the run continued using New 6 waste diluted with tap water until 0243 on December 8. The dilution during this run averaged almost 4 parts water to 1 part waste. The total waste fed to the unit during this run was 95 pounds, and the total product condensate reprocessed during the run was 286 pounds.

Following the end of waste feed, some remaining residuals from the New 6 waste tests were run through the unit to consolidate the volumes and to simulate the operation of the mobile treatment unit during actual waste treatment operation. Processing of these residuals began at 0245 on December 8 and concluded at 1951 on the same day. Residuals processed totaled 185 pounds. Data and residuals from this test on New 6 waste and residuals are referred to as New 6 Prime to differentiate them from the earlier New 6 test.

Run 8, LANL New 5 waste diluted approximately 1:1 with product condensate from the previous LANL New 5 run (Run 2), began at 1951 on December 8. All the remaining New 5 waste, a total of 264 pounds, was consumed by 1742 on December 10. Processing of the remaining 58 pounds of product condensate took until 2236. The total New 5 product condensate fed to the unit during this run was 350 pounds. Data and residuals from this test on New 5 waste and residuals are referred to as New 5 Prime to differentiate them from the earlier New 5 test.

After another hot turnaround, Run 9, using the remaining LANL L16 waste with no dilution, began at 1110 on December 11 and finished at 1913 the same day. Total waste fed was 99 pounds.

Feed to the unit was immediately switched to product condensate from the previous L16 run, which was fed until 2329 on December 13. Total condensate fed during this time was 601 pounds. Then residuals from the previous L16 run, including brine, evaporator and scrubber rinses, and scrubber blowdown, were fed to the unit to reduce the volume of these leftover materials. This run ended at

1105 on December 15; residuals processed during this period totaled 478 pounds. Data and residuals from this test on L16 waste and residuals are referred to as L16 Prime to differentiate them from the earlier L16 test.

Following a brief turnaround, the product condensate from the previous LANL L17 run was fed to the unit (all of the L17 waste sample had been consumed in the test on November 9–10). This run is called 9.1 since no actual waste was fed. Feed of this material began at 1245 on December 15 and ended at 1611 on December 16; total condensate fed was 340 pounds. Data and residuals from this test on L17 residuals are referred to as L17 Prime to differentiate them from the earlier L17 test. The unit then was shut down for the weekend.

Because the LANL New 5 residuals had not been run earlier, reprocessing and consolidation of New 5 residuals began at 1149 on December 19 and continued until 0939 on December 20; 284 pounds of residuals were processed during this period. Data and residuals from this reprocessing of New 5 residuals are referred to as New 5 Double Prime (or sometimes as New 5 Prime Prime) to differentiate them from the earlier New 5 tests.

B1.2.5 Sandia Waste Test

Run 10, the last treatability test at GJPO, used a 17-pound sample from SNL/NM. Feed of this waste was initiated at 1226 on December 20, following a hot turnaround, and ended at 1344. The unit then was shut down for final decontamination.

B1.3 Feed Limitations

The *Treatability Test Plan* states that ". . . the design rate for the mini-PO*WW*ER unit is 1 gal/h." The basis for this statement was information in the draft submittal of the *Treatability Test Plan* from CTC, which is based on their operating experience with the unit at CTC.

Early in the test program, however, it became apparent that high heat losses to ambient made it very difficult to reach the target minimum oxidizer-bed temperature of 500 °C at a feed rate of 1 gallon per hour (gal/h). An increase in the feed rate to 1.3-1.5 gal/h greatly improved this situation, improving heat transfer from the heater walls to the vapor and providing a more stable operation because the heaters were running at lower sheath temperatures (even though the bed temperature was higher) and were not as likely to shut down on high sheath temperature.

Discussions with the designers of the unit and review of the design calculations confirmed that the mini-PO*WW*ER unit was designed to accommodate a fairly wide range of feed rates, from 0.5 to 1.5 gal/h and higher, depending on the quality of the feed. The improvement in heat transfer at the higher flow rate observed at GJPO can be attributed in part to the fact that the pressure increased with increased flow rate, increasing the vapor density. The improved performance of the unit at higher rates at GJPO compared with those used at CTC may be due to the lower atmospheric pressure at the GJPO site; higher gauge pressures would compensate for lower atmospheric pressures.

An additional advantage of higher feed rates from a heat-transfer standpoint is that, although the heat transferred into the heaters and oxidizer is directly proportional to the feed rate, heat losses to ambient are proportional to the temperature difference between the heated surface and the ambient air. The insulation on the heaters, oxidizer, and piping acts to reduce the actual surface temperature (and, thus, the driving force for heat loss to ambient), damping out variations caused by changing internal temperatures. As a result, heat losses to ambient tend to be almost constant at operating conditions, although heat input increases with increasing feed rate. Therefore, increasing the feed rate will transfer more heat to the oxidizer bed because proportionately less heat is lost to the atmosphere.

Heat-exchanger capacity was not a limiting factor during the treatability tests because the heat exchanger was designed to operate at higher solids concentrations and fouling factors than those obtained at GJPO. In fact, the heat exchanger operated at low temperature differentials (generally between 3.5 ° and 4.5 °C) throughout the treatability tests. Toward the end of Run 6, the solids concentration run of November 17–18 with Old New 5 feed, the temperature differential did rise to nearly 5.5 °C, but this differential is still quite modest compared to typical design practice for evaporators.

The maximum feed rate of the mini-PO*WW*ER unit during the GJPO treatability tests was found to be approximately 1.7 gal/h (14 lb/h). The limiting factor on feed rate was in the pressure drop through the system. Because pressure drop increases by the square of flow rate, the unit could operate comfortably at feed rates up to 1.5-gal/h, but above this rate, pressure drop rapidly became a limitation. Feed rates higher than 1.7 gal/h would cause the evaporator overhead pressure to rise above 8 psig. Since the steam pressure averaged about 7 psi higher than the heat exchanger pressure, an evaporator overhead pressure of more than 8 psig would cause the steam pressure to rise above 15 psig, which was the high-pressure alarm setting.

Appendix C

Summary of PO*WW*ER Waste Sample Feeds

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Summary of PO*WW*ER Waste Sample Feeds

Each line entry in the tables in this Appendix, with the exception of the summaries on the last two pages, presents data for a single feed carboy (i.e., the date and time that the carboy was started and completed; beginning and end weights for the carboy; and calculated total feed weight, waste feed weight [minus dilution water], and total feed rate).

Table C–1. Demonstration Run — Surrogate Waste Samples

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
2% IPA	09/28	1150	09/28	1210	00:20				
	09/28	1610	09/28	1920	03:10				
IPA/DCM	09/28	2345	09/29	0105	01:20	21.0	-	15.7	1.9
IPA/DCM	10/05	1520	10/05	1735	02:15	31.7	-	14.1	1.7
4% IPA	10/05	2006	10/06	0013	04:07	56.9	-	13.8	1.7
NH_4OH	10/07	0522	10/07	0936	04:14				
	Start Date	Start Time	End Date	End Time	Total Hours				
	09/28	1150	10/07	0936	15.43				

Table C–2. Run 1 — GJPO TG1

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
TG1	10/07	1458	10/07	1845	03:47	40.1	27.5	10.6	1.3

Table C–3. Run 2 — LANL New 5

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
New 5	10/27	0255	10/27	0319	00:24	5.1	5.1	12.8	1.5
	10/27	0725	10/27	0912	01:47	19.6	9.8	11.0	1.3
	10/27	0912	10/27	1107	01:55	26.7	17.8	13.9	1.7
	10/27	1107	10/27	1532	04:25	48.9	32.6	11.1	1.3
	10/27	1533	10/27	2028	04:55	57.6	38.4	11.7	1.4
	10/27	2031	10/28	0051	04:20	57.8	38.5	13.3	1.6
	10/28	0051	10/28	0515	04:24	51.9	34.6	11.8	1.4
	10/28	0515	10/28	0946	04:31	58.1	38.7	12.9	1.5
	10/28	1014	10/28	1356	03:42	54.9	36.6	14.8	1.8
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	10/27	0255	10/28	1356	30.38	380.6	252.2	12.5	1.5

Table C–4. Run 3 — LANL New 6

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
New 6	11/07	1804	11/07	1830	00:26	4.2	3.8	9.7	1.2
H_2O	11/07	1830	11/07	1841					
New 6	11/07	1841	11/07	2148	03:07	34.6	17.3	11.1	1.3
	11/07	2149	11/07	2345	01:56	20.4	8.2	10.6	1.3
	11/07	2350	11/08	0418	04:28	53.6	7.7	12.0	1.4
	11/08	0418	11/08	0900	04:42	45.0	6.4	9.6	1.1
	11/08	0900	11/08	1425	05:25	53.0	7.6	9.8	1.2
	11/08	1425	11/08	1953	05:28	51.5	7.4	9.4	1.1
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	11/07	1804	11/08	1953	25.53	262.3	58.4	10.3	1.2

Table C–5. Run 4 — LANL L17

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
L17	11/09	0631	11/09	0846	02:15	27.5	27.5	12.2	1.5
	11/09	0846	11/09	1321	04:35	56.8	56.8	12.4	1.5
	11/09	1321	11/09	1549	02:28	31.2	31.2	12.6	1.5
	11/09	1549	11/09	2000	04:11	53.6	53.6	12.8	1.5
	11/09	2000	11/10	0117	05:17	59.0	59.0	11.2	1.3
	11/10	0117	11/10	0621	05:04	56.4	56.4	11.1	1.3
	11/10	0621	11/10	0817	01:56	25.9	25.9	13.4	1.6
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	11/09	0631	11/10	0817	25.77	310.4	310.4	12.0	1.4

Table C–6. Run 5 — LANL L16

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
L16	11/10	1910	11/10	2118	02:08	28.4	28.4	13.3	1.6
	11/10	2118	11/11	0155	04:37	61.0	61.0	13.2	1.6
	11/11	0155	11/11	0827	06:32	60.7	60.7	9.3	1.1
	11/11	0827	11/11	0930	01:03	9.9	9.9	9.4	1.1
H_2O	11/11	0930	11/11	1221					
L16	11/11	1221	11/11	1356	01:35	15.0	15.0	9.5	1.1
H_2O	11/11	1356	11/11	1609					
L16	11/14	1626	11/14	1950	03:24	48.6	48.6	14.3	1.7
L16/IPA	11/14	1950	11/15	0052	05:02	61.6	61.6	12.2	1.5
L16/IPA	11/15	0052	11/15	0538	04:46	39.8	39.8	8.3	1.0
H_2O	11/15	0538	11/15	0925					
IPA/H_2O	11/16	0830	11/16	0927					
L16/IPA	11/16	0927	11/16	1019	00:52	13.2	13.2	15.2	1.8
"	11/16	1021	11/16	1231	02:10	34.5	34.5	15.9	1.9
"	11/16	1234	11/16	1244	00:10	2.3	2.3	13.8	1.7
H_2O	11/16	1244	11/16	1255					
IPA/H_2O	11/16	1255	11/16	1355					
L16/IPA	11/16	1355	11/16	1431	00:36	7.9	7.9	13.2	1.6
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	11/10	1910	11/11	1609	15.92	175.0	175.0	11.0	1.3
	11/14	1626	11/15	0538	13.20	150.0	150.0	11.4	1.4
	11/16	0927	11/16	1431	3.80	57.9	57.9	15.2	1.8

Table C–7. Run 6 — LANL Old New 5

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
Old New 5	11/17	0434	11/17	0912	04:38	56.7	28.4	12.2	1.5
	11/17	0912	11/17	0943	00:31	3.5	1.5	6.8	0.8
	11/17	0958	11/17	1015	00:17	2.9	1.2	10.2	1.2
	11/17	1015	11/17	1025	00:10	2.0	0.5	12.0	1.4
	11/17	1025	11/17	1331	03:06	40.0	15.3	12.9	1.5
	11/17	1331	11/17	1636	03:05	47.1	23.6	15.3	1.8
	11/17	1643	11/17	2108	04:25	57.2	28.6	13.0	1.6
	11/17	2110	11/18	0021	03:11	41.7	20.9	13.1	1.6
	11/18	0021	11/18	0501	04:40	58.3	29.2	12.5	1.5
	11/18	0502	11/18	0606	01:04	5.0	2.2	4.7	0.6
	11/18	1028	11/18	1235	02:07	18.1	9.1	8.6	1.0
	11/18	1236	11/18	1443	02:07	27.8	27.8	13.1	1.6
	11/18	1443	11/18	1635	01:52	24.9	24.9	13.3	1.6
	11/18	1637	11/18	1853	02:16	28.6	28.6	12.6	1.5
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	11/17	0434	11/18	0606	25.12	314.4	151.2	12.5	1.5
	11/18	1028	11/18	1853	8.37	99.4	90.3	11.9	1.4

Table C–8. Run 7 — LANL New 6

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
New 6 Prime/PC	12/06	1304	12/06	1700	03:56	52.7	10.5	13.4	1.6
	12/06	1700	12/06	1821	01:21	15.7	3.9	11.6	1.4
	12/06	1825	12/06	1843	00:18	3.6	0.8	12.0	1.4
	12/06	1843	12/06	2120	02:37	31.5	6.3	12.0	1.4
	12/06	2121	12/06	2145	00:24	2.3	0.5	5.8	0.7
	12/06	2145	12/07	0152	04:07	48.4	9.7	11.8	1.4
	12/07	0152	12/07	0545	03:53	49.5	9.9	12.7	1.5
	12/07	0545	12/07	1000	04:15	48.8	9.8	11.5	1.4
	12/07	1001	12/07	1408	04:07	52.5	10.5	12.8	1.5
	12/07	1408	12/07	1817	04:09	54.0	10.8	13.0	1.6
New 6 Prime/H_2O	12/07	1820	12/07	2223	04:03	53.7	10.7	13.3	1.6
	12/07	2229	12/08	0243	04:14	56.5	11.3	13.3	1.6
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/06	1304	12/08	0243	37.40	469.2	94.7	12.5	1.5

Table C–9. Run 7.1 — LANL New 6 Residuals

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
Ent Sep[a]	12/08	0245	12/08	0252	00:07	1.0	-	8.6	1.0
New 6 Conc[b]	12/08	0252	12/08	0521	02:29	31.8	-	12.8	1.5
New 6 SR[c]	12/08	0521	12/08	1018	04:57	56.2	-	11.4	1.4
H_2O	12/08	1018	12/08	1415	03:57	53.9	-	13.6	1.6
	12/08	1417	12/08	1634	02:17	31.9	-	14.0	1.7
	12/08	1854	12/08	1951	00:57	10.5	-	11.1	1.3
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight		Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/08	0245	12/08	1951	14.73	185.3		12.6	1.5

Table C–10. Run 8 — LANL New 5

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
New 5 Prime/PC	12/08	1951	12/08	2115	01:24	16.8	8.4	12.0	1.4
	12/08	2116	12/09	0003	02:47	34.8	17.4	12.5	1.5
	12/09	0004	12/09	0422	04:18	52.6	26.3	12.2	1.5
	12/09	0422	12/09	0822	04:00	54.7	27.4	13.7	1.6
	12/09	0822	12/09	1311	04:49	54.8	27.4	11.4	1.4
	12/09	1312	12/09	1713	04:01	48.9	24.5	12.2	1.5
	12/09	1715	12/09	2159	04:44	55.6	27.8	11.7	1.4
	12/09	2203	12/10	0250	04:47	56.9	28.5	11.9	1.4
	12/10	0250	12/10	0800	05:10	61.9	31.0	12.0	1.4
	12/10	0800	12/10	1254	04:54	56.8	28.4	11.6	1.4
	12/10	1256	12/10	1742	04:46	61.9	17.3	13.0	1.6
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/08	1951	12/10	1742	45.67	555.7	264.2	12.2	1.5

Table C–11. Run 8.1 — LANL New 5 Residuals

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
PC	12/10	1743	12/10	2236	04:53	58.3	-	11.9	1.4
H_2O	12/10	2237	12/11	0122	02:45	33.7	-	12.3	1.5
H_2O	12/11	0129	12/11	0600	04:31	48.0	-	10.6	1.3
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight		Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/10	1743	12/11	0600	12.15	140.0		11.5	1.4

[a] Ent Sep = entrainment separator blowdown.
[b] Conc = concentrate (brine) from an earlier test of the same waste.
[c] SR = scrubber rinse water.

Table C–12. Run 9 — LANL L16

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
L16 Prime	12/11	1110	12/11	1314	02:04	25.7	25.7	12.4	1.5
	12/11	1314	12/11	1454	01:40	20.6	20.6	12.4	1.5
	12/11	1455	12/11	1713	02:18	31.2	31.2	13.6	1.6
	12/11	1714	12/11	1913	01:59	21.9	21.9	11.0	1.3
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/11	1110	12/11	1913	8.02	99.4	99.4	12.4	1.5

Table C–13. Run 9.1 — LANL L16 Residuals

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
L16 PC	12/11	1914	12/11	2341	04:27	53.0	-	11.9	1.4
	12/11	2341	12/12	0458	05:17	59.4	-	11.2	1.3
	12/12	0459	12/12	1000	05:01	60.0	-	12.0	1.4
	12/12	1000	12/12	1443	04:43	54.3	-	11.5	1.4
	12/12	1443	12/12	1856	04:13	49.4	-	11.7	1.4
	12/12	1857	12/12	2303	04:06	47.9	-	11.7	1.4
	12/12	2305	12/13	0402	04:57	56.5	-	11.4	1.4
	12/13	0402	12/13	0843	04:41	49.8	-	10.6	1.3
	12/13	0844	12/13	1343	04:59	57.6	-	11.6	1.4
	12/13	1344	12/13	1854	05:10	57.9	-	11.2	1.3
	12/13	1855	12/13	2329	04:34	55.4	-	12.1	1.5
L16 Brine	12/13	2330	12/14	0225	02:55	25.5	-	8.7	1.0
H_2O	12/14	0225	12/14	0516	02:51	39.0	-	13.7	1.6
L16 Brine	12/14	0516	12/14	0749	02:33	37.3	-	14.6	1.8
L16 ER1[a]	12/14	0749	12/14	1026	02:37	36.9	-	14.1	1.7
L16 ER2[b]	12/14	1027	12/14	1320	02:53	40.9	-	14.2	1.7
L16 SR[c]	12/14	1321	12/14	1520	01:59	28.5	-	14.4	1.7
Tap H_2O Cont	12/14	1526	12/14	1956	04:30	66.4	-	14.8	1.8
L16 SB[d]	12/14	1957	12/15	0036	04:39	54.0	-	11.6	1.4
SB	12/15	0036	12/15	0501	04:25	63.6	-	14.4	1.7
SR	12/15	0501	12/15	0512	00:11	1.9	-	10.4	1.2
Blowdown	12/15	0512	12/15	0651	01:39	23.0	-	13.9	1.7
L16 SR	12/15	0651	12/15	1105	04:14	60.4	-	14.3	1.7
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/11	1914	12/15	1105	87.57	1078.6		12.3	1.5

[a] ER1 = evaporator rinse water (from an earlier test of the same waste).
[b] ER2 = evaporator rinse water (from an earlier test of the same waste).
[c] SR = scrubber rinse water (from the current test or an earlier one).
[d] SB = scrubber blowdown (from the current test or an earlier one).

Table C–14. Run 9.2 — LANL L17 Residuals

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
L17 PC	12/15	1245	12/15	1716	04:31	57.8	-	12.8	1.5
	12/15	1716	12/15	2104	03:48	46.9	-	12.3	1.5
	12/15	2105	12/16	0124	04:19	49.1	-	11.4	1.4
	12/16	0124	12/16	0533	04:09	49.7	-	12.0	1.4
	12/16	0533	12/16	0941	04:08	51.6	-	12.5	1.5
	12/16	0942	12/16	1343	04:01	55.1	-	13.7	1.6
	12/16	1344	12/16	1611	02:27	29.9	-	12.2	1.5
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/15	1245	12/16	1611	27.38	340.1		12.4	1.5

Table C–15. Run 9.3 — LANL Miscellaneous Residuals

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
New 5 Prime SB[a]	12/19	1149	12/19	1332	01:43	22.7	-	13.2	1.6
New 5 Prime Res[b]	12/19	1332	12/19	1347	00:15	2.5	-	10.0	1.2
New 5 Prime SB	12/19	1347	12/19	1826	04:39	64.2	-	13.8	1.7
New 6 Prime ES[c], ED[d]	12/19	1826	12/19	2152	03:26	46.6	-	13.6	1.6
Clean PC	12/19	2155	12/20	0109	03:14	44.1	-	13.6	1.6
New 5 Prime Brine	12/20	0109	12/20	0415	03:06	40.0	-	12.9	1.5
SB	12/20	0415	12/20	0930	05:15	63.7	-	12.1	1.5
	Start Date	Start Time	End Date	End Time	Total Hours	Total Weight	Total Waste	Avg. Rate (lb/h)	Avg. Rate (lb/h)
	12/19	1149	12/20	0930	21.63	283.8		13.1	1.6

Table C–16. Run 10 — SNL/NM Grinding Sludge

Sample	Date On	Time On	Date Off	Time Off	Total Time	Total Feed (lb)	Waste Feed (lb)	Rate (lb/h)	Rate (gal/h)
SNL	12/20	1226	12/20	1344	01:18	16.8	16.8	12.9	1.5

[a]SB = scrubber blowdown.
[b]Res = unclassified residuals.
[c]ES = entrainment separator blowdown.
[d]ED = evaporator drain.

Table C–17. Total by Date

Waste	Date	Hours	Total Weight (lb)	Total Waste (lb)	Avg. Flow (lb/h)	Avg. Flow (gal/h)
TG1	10/07	3.8	40	27	10.6	1.3
New 5	10/27	16.9	204	135	12.1	1.4
	10/28	13.5	176	117	13.1	1.6
New 6	11/07	5.6	61	29	10.8	1.3
	11/08	19.9	201	29	10.1	1.2
L17	11/09	17.5	214	214	12.2	1.5
	11/10	8.3	97	97	11.7	1.4
L16	11/10	4.8	64	64	13.3	1.6
	11/11	11.1	111	111	10.0	1.2
	11/14	7.6	100	100	13.2	1.6
	11/15	5.6	50	50	8.9	1.1
	11/16	3.8	58	58	15.2	1.8
Old New 5	11/17	19.0	247	118	13.0	1.6
	11/18	14.5	167	124	11.6	1.4
New 6	12/06	10.9	132	27	12.2	1.5
	12/07	23.8	301	60	12.6	1.5
	12/08	2.7	36	7	13.3	1.6
New 5	12/08	4.1	51	25	12.3	1.5
	12/09	23.9	290	145	12.2	1.5
	12/10	17.7	214	94	12.1	1.5
L16	12/11	8.0	99	99	12.4	1.5
SNL	12/20	1.3	17	17	12.9	1.5
Total		244	2931	1748	12.0	1.4

Table C–18. Total by Waste

Waste	Total Hours	Total Weight (lb)	Total Waste (lb)	Avg. Flow (lb/h)	Avg. Flow (gal/h)	Dilution
TG1	3.8	40	27	10.6	1.3	0.46
New 5	76.1	936	516	12.3	1.5	0.81
New 6	62.9	732	153	11.6	1.4	3.78
L17	25.8	310	310	12.0	1.4	0
L16	40.9	482	482	11.8	1.4	0
Old New 5	33.5	414	242	12.4	1.5	0.71
SNL	1.3	17	17	12.9	1.5	0
Total	244.3	2931	1748	12.0	1.4	0.68

Table C–19. Residuals Management

Waste	Total Hours	Total Weight (lb)	Total Waste (lb)	Avg. Flow (lb/h)	Avg. Flow (gal/h)
New 6 PC	29.1	286	-	9.8	-
New 5 PC	45.7	291	-	6.4	-
L16 PC	52.1	601	-	11.5	1.4
L17 PC	27.4	340	-	12.4	1.5
Misc Res	64.6	850	-	13.2	1.6
Total	218.9	2369			

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Appendix D

Analytical Results

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Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 501	L16	feed	08/23/94	1100	93034904	16,600,000	17,400,000	~429,000	1,390,000
NBE 502	L17	feed	08/25/94	0830	L17	17,500,000	3,570,000	~402,000	340,000
NBE 504	Old New 6	feed	08/26/94	0900	Old New 6	27,600,000	<10	~203,000	71,300,000
NBE 505	Old New 6	feed	08/31/94	0900	Old New 5	89,800,000	<10	~24,000	22,900,000
NBE 506	TG1	feed	09/01/94		TG-1	49,700,000	1,640,000	5,530,000	1,360,000
NBE 507	New 5 X	feed	09/01/94		New 5X	168,000,000	~50	~258,000	38,600,000
NBE 508	Perf IPA 2%	scrubber	09/28/94	1800	VO 39				
NBE 509	Perf IPA 2%	PC	09/28/94	1800	VO 24				
NBE 510	Perf IPA 2%	brine	09/28/94	1800	VO 10				
NBE 511	Perf IPA 2%	brine	09/28/94	2335	VO 10				
NBE 512	Perf IPA/MC	brine	10/05/94	1920	VO 10				
NBE 513	Perf IPA/MC	scrubber	10/05/94	1930	VO 39				
NBE 514	Perf IPA/MC	PC	10/05/94	1930	VO 24				
NBE 515	Perf IPA 4%	PC	10/05/94	1700	VO 24				
NBE 516	Perf IPA 4%	brine	10/05/94	2315	VO 10				
NBE 517	Perf IPA 4%	scrubber	10/05/94	2315	VO 39				
NBE 518	Perf IPA 4%	PC	10/05/94	2315	VO 24				
NBE 519	Perf NH_3	scrubber	10/07/94	0627	VO 39				
NBE 520	Perf NH_3	PC	10/07/94	0627	VO 24				
NBE 521	Perf NH_3	brine	10/07/94	1450	VO 10				
NBE 522	TG1	brine	10/07/94	1900	VO 10				3,170
NBE 523	TG1	scrubber	10/07/94	2000	VO 39				3,410
NBE 524	TG1	PC	10/07/94	2000	VO 24				870
NBE 525	TG1	brine	10/07/94	2200	VO 10				21,800
NBE 526	TG1	scrubber	10/07/94	2200	VO 39				1,550
NBE 527	TG1		10/07/94	2200	VO 24				~220
NBE 528	TG1	brine	10/07/94	1900	VO 10				
NBE 529	TG1	brine	10/07/94	2200	VO 10				
NBE 530	TG1 Rinse	scrubber rinse	10/08/94	0050	VO 39				
NBE 531	TG1 Rinse	brine rinse	10/08/94	0100	VO 08				
NBE 532	Trip Blank	blank	10/25/94	1530	VO 47				
NBE 533	TG1 Rinse	brine rinse	10/25/94	1530	Brine Rinse				
NBE 534	New New 5	feed	10/26/94	1800	Drum 1285				21,400,000
NBE 535	New New 5	feed	10/26/94	1800	Drum				
NBE 536	New New 5	feed	10/26/94	1800	Drum				
NBE 537	New New 5	feed	10/26/94	1800	Drum				
NBE 538	New New 5	scrubber	10/27/94	1230	VO 39				
NBE 539	New New 5	PC	10/27/94	1230	VO 24				
NBE 540	New New 6	feed	10/27/94	1000	Drum				
NBE 541	Old New 5	feed	10/27/94	1000	Archive				
NBE 542	Old New 6	feed	10/27/94	1000	Archive				
NBE 543	New New 5	brine	10/27/94	2030	VO 10				1,210,000

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 544	New New 5	brine	10/27/94	2030	VO 10				
NBE 545	New New 5	brine	10/27/94	2030	VO 10				
NBE 546	New New 5	brine	10/27/94	2030	VO 10				
NBE 547	New New 5	scrubber	10/27/94	2030	VO 39				2,280
NBE 548	New New 5	scrubber	10/27/94	2030	VO 39				
NBE 549	New New 5	scrubber	10/27/94	2030	VO 39				
NBE 550	New New 5	PC	10/27/94	2030	VO 24				3,640
NBE 551	New 6 Prime	PC	12/07/94	2300	VO 24				
NBE 552	New 6 Prime	scrubber	12/08/94	0215	VO 39			14.0	8,800
NBE 553	New 6 Prime	brine	12/08/94	0445	VO 08				
NBE 554	New 6 Prime	PC	12/08/94	0445	VO 24				
NBE 555	New 6 Prime	brine	12/08/94	0645	VO 08				
NBE 556	New 6 Prime	PC	12/08/94	0645	VO 24				
NBE 557	New 6 Prime	PC	12/08/94	0900	VO 24				
NBE 558	New 6 Prime	brine	12/08/94	0900	VO 08				
NBE 560	New 6 Prime	brine	12/08/94	1045	VO 08				
NBE 561	New 6 Prime	PC	12/08/94	1045	VO 24				
NBE 562	New 6 Prime	brine	12/08/94	1245	VO 08				
NBE 563	New 6 Prime	PC	12/08/94	1245	VO 24				
NBE 564	New 6 Prime	brine	12/08/94	1400	VO 08			122	1,570,000
NBE 565	New 6 Prime	PC	12/08/94	1400	VO 24			<5.0	580
NBE 566	New 5 Prime	PC	12/08/94	2200	VO 24				
NBE 567	New 5 Prime	PC	12/09/94	0600	VO 24				
NBE 568	New 5 Prime	PC	12/09/94	1400	VO 24				
NBE 569	New 5 Prime	PC	12/09/94	2150	VO 24				
NBE 570	New 5 Prime	PC	12/10/94	0600	VO 24				
NBE 571	New 5 Prime	scrubber	12/10/94	1239	VO 39			<5,000	1,550
NBE 572	New 5 Prime	brine	12/11/94	0600	VO 08			152,000	564,000
NBE 573	New 5 Prime	PC composite	12/11/94	0600	COMP			<5,000	200
NBE 574	New 5 Prime	PC	12/11/94	1405	VO 24				
NBE 575	New 5 Prime	PC	12/11/94	2210	VO 24				
NBE 601	New New 5	PC	10/27/94	2030	VO 24				
NBE 602	New New 5	PC	10/27/94	2030	VO 24				
NBE 603	New New 5	brine	10/28/94	0430	VO 10				1,420,000
NBE 604	New New 5	brine	10/28/94	0430	VO 10				
NBE 605	New New 5	brine	10/28/94	0430	VO 10				
NBE 606	New New 5	brine	10/28/94	0430	VO 10				
NBE 607	New New 5	scrubber	10/28/94	0430	VO 39				6,680
NBE 608	New New 5	scrubber	10/28/94	0430	VO 39				
NBE 609	New New 5	scrubber	10/28/94	0430	VO 39				
NBE 610	New New 5	PC	10/28/94	0430	VO 24				<560

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 611	New New 5	PC	10/28/94	0430	VO 24				
NBE 612	New New 5	PC	10/28/94	0430	VO 24				
NBE 613	New New 5	brine	10/28/94	1330	VO 10				1,530,000
NBE 629	New New 5	brine	10/28/94	1330	VO 10				
NBE 630	New New 5	brine	10/28/94	1330	VO 10				
NBE 631	New New 5	brine	10/28/94	1330	VO 10				
NBE 632	New New 5	scrubber	10/28/94	1330	VO 39				5,800
NBE 633	New New 5	scrubber	10/28/94	1330	VO 39				
NBE 634	New New 5	scrubber	10/28/94	1330	VO 39				
NBE 635	New New 5	PC	10/28/94	1330	VO 24				<560
NBE 636	New New 5	PC	10/28/94	1330	VO 24				
NBE 637	New New 5	PC	10/28/94	1330	VO 24				
NBE 638	New New 5	evaporator rinse	10/28/94	2200	VO O8				
NBE 639	New New 5	scrubber rinse	10/28/94	2200	VO 39				
NBE 640	New New 5	scrubber rinse	10/28/94	2200	VO 39				
NBE 643	New New 6	feed	11/01/94	1330	Drum 1284				40,900,000
NBE 644	New New 6	feed	11/01/94	1330	Drum				
NBE 645	New New 6	feed	11/01/94	1330	Drum				
NBE 646	New New 5	feed residual	11/01/94	1300	Carboy				
NBE 647	Drum 1303	PC composite	11/03/94	1600	Drum 1303				
NBE 648	New 6 Prime	PC	12/07/94	2300	VO 24				
NBE 649	New 6 Prime	PC	12/07/94	2300	VO 24				
NBE 650	H_2O		12/07/94	2300	VO 47				
NBE 651	New New 5	brine rinse	10/28/94	2100	VO 08?				
NBE 652	New New 5	scrubber rinse	10/28/94	2100	VO 39			11	
NBE 653	New New 5	PC composite	10/28/94	2100	VO 24?			ND	
NBE 655	New New 6	PC	11/07/94	2100	VO 24				
NBE 656	New New 6	scrubber	11/07/94	2100	VO 39				
NBE 657	New New 6	gas	11/07/94	2100	Vent				
NBE 658	L16	PC	11/14/94	2205	VO 24				
NBE 659	L16	scrubber	11/14/94	2205	VO 39				
NBE 660	L16	gas	11/14/94	2205	Vent				
NBE 661	L16	scrubber	11/15/94	1130	VO 39				
NBE 662	Old New 5	scrubber rinse	11/18/94	2000	VO 39				
NBE 663	Old New 5	evaporator rinse	11/18/94	2000	VO 08				
NBE 664	SNL/TCE	feed	11/30/94	1545	Bucket				
NBE 665	SNL 2	feed	12/01/94	0900	Bucket				
NBE 666	Water		12/03/94	1500					
NBE 667	Water		12/03/94	1500					

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 668		PC	12/06/94	1600	VO 24				
NBE 669	New 6 PC	feed	12/06/94	1700					
NBE 670	New 6 Prime	PC	12/06/94	2305	VO 24				
NBE 671	New 6 Prime	PC	12/07/94	0700	VO 24				
NBE 672	New 6 Prime	feed	12/07/94	0700	Carboy A				
NBE 673	New 6 Prime	PC	12/07/94	1535	VO 24				
NBE 674	New 6 Prime	PC	12/07/94	1535	VO 24				
NBE 675	New 6 Prime	scrubber	12/07/94	1535	VO 39				
NBE 686	New New 6	scrubber	11/09/94	0030	VO 39				42,700
NBE 687	New New 6	scrubber	11/09/94	0030	VO 39				
NBE 688	New New 6	PC	11/09/94	0030	VO 24				182,000
NBE 689	New New 6	PC	11/09/94	0030	VO 24				
NBE 690	New New 6	brine	11/09/94	0030	VO 08				
NBE 691	New New 6	brine	11/09/94	0030	VO 08			182,000	3,880,000
NBE 692	New New 6	brine	11/09/94	0030	VO 08				
NBE 693	New New 6	evaporator rinse	11/09/94	0200	VO 08				
NBE 694	New New 6	scrubber rinse	11/09/94	0200	VO 39				
NBE 695	New New 6	evaporator rinse	11/09/94	0300	VO 08				
NBE 696	New New 6	scrubber rinse	11/09/94	0300	VO 39				
NBE 697	L17 carry	evaporator carryover	11/09/94	0330	VO 08				
NBE 698	L17 carry	scrub carryover	11/09/94	0330	VO 39				
NBE 699	New 6 carry	evaporator carryover	11/07/94	1445	VO 08				
NBE 700	New New 6	PC	11/09/94	0100	VO 24				
NBE 701	New New 6	PC composite	11/09/94	0100	PC Drum				
NBE 702	L17	PC	11/09/94	0915	VO 24				
NBE 703	L17	scrubber	11/09/94	0915	VO 39				
NBE 704	L17	gas	11/09/94	0915	Vent				
NBE 705	L17	feed	11/09/94	1100	Drum				
NBE 706	L17	feed	11/09/94	1100	Drum				
NBE 707	L17	brine	11/10/94	1400	VO 08				
NBE 708	L17	brine	11/10/94	1400	VO 08			880,000	98,800
NBE 709	L17	scrubber	11/10/94	0900	VO 39			23,000	
NBE 710	L17	scrubber	11/10/94	0900	VO 39				6,040
NBE 711	L17	PC	11/10/94	1400	VO 24?			<5,000	
NBE 712	L17	PC	11/10/94	1400	VO 24?				840
NBE 713	L17	evaporator rinse	11/10/94	1455	VO 08				
NBE 714	L17	scrubber rinse	11/10/94	1555	VO 39				
NBE 715	L17	evaporator rinse	11/10/94	1555	VO 08				
NBE 717	L16 carry	evaporator carryover	11/10/94	1610	VO 08				
NBE 718	L16 carry	scrub carryover	11/10/94	1610	VO 39				
NBE 719	L17	brine solids	11/10/94	1400	VO 08				
NBE 720	L16	scrubber	11/10/94	2120	VO 39				
NBE 721	L16	PC	11/10/94	2120	VO24				

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 722	L16	gas	11/10/94	2120	Vent				
NBE 723	L16	feed	11/11/94	1500	Drum 1139				
NBE 724	L16	feed	11/11/94	1500	Drum 1139				
NBE 725	Tap H_20 blank	Tap H_2O	12/07/94	2300	VO 47?				
NBE 726	L16	brine	11/16/94	1932	VO 08				
NBE 727	L16	brine	11/16/94	1932	VO 08			660,000	1,620,000
NBE 728	L16	scrubber	11/16/94	1932	VO 39				
NBE 729	L16	scrubber	11/16/94	1932	VO 39			880,000	4,400
NBE 730	L16	PC composite	11/16/94	0420	Drum				
NBE 731	L16	PC composite	11/16/94	0420	Drum			5,000	72,100
NBE 732	L16	evaporator rinse	11/16/94	1932	VO 08				
NBE 733	L16	scrubber rinse	11/16/94	1932	VO 39				
NBE 734	L16	evaporator rinse	11/16/94	1932	VO 08				
NBE 735	Old New 5	evaporator carryover	11/17/94	0015	VO 08				
NBE 736	Old New 5	scrub carryover	11/17/94	0015	VO 39				
NBE 737	Old New 5	scrubber	11/17/94	0630	VO 39				
NBE 738	Old New 5	PC	11/17/94	0630	VO 24				
NBE 739	Old New 5	gas	11/17/94	0630	Vent				
NBE 740	L16	PC	11/16/94	1400	VO 24				
NBE 741	Old New 5	feed	11/18/94	0030	Drum 1111				
NBE 742	Old New 5	feed	11/18/94	0930	Drum 1111				
NBE 743	Old New 5	brine	11/18/94	2000	VO 08				
NBE 744	Old New 5	brine	11/18/94	2000	VO 08			50,000	158,000
NBE 745	Old New 5	brine	11/18/94	2000	VO 08				
NBE 746	Old New 5	scrubber	11/18/94	2000	VO 39				
NBE 747	Old New 5	scrubber	11/18/94	2000	VO 39				3,890
NBE 748	Old New 5	PC composite	11/18/94	2000	Drum 1327				
NBE 749	Old New 5	PC composite	11/18/94	2000	Drum 1327				<140
NBE 750	Old New 5	evaporator rinse	11/18/94	2000	VO 08				
NBE 851	New 5 Prime	brine	12/11/94	0040	VO 08				
NBE 852	New 5 Prime	PC	12/11/94	0040	VO 24				
NBE 853	New 5 Prime	brine	12/11/94	0240	VO 08				
NBE 854	New 5 Prime	PC	12/11/94	0240	VO 24				
NBE 855	New 5 Prime	brine	12/11/94	0440	VO 08				
NBE 856	New 5 Prime	PC	12/11/94	0440	VO 24				
NBE 857	New 5 Prime	evaporator rinse	12/11/94	0745	VO 08				
NBE 858	New 5 Prime	scrubber rinse	12/11/94	0745	VO 39				
NBE 859	L16 Prime	PC	12/11/94	1400	VO 24				
NBE 860	L16 Prime	PC	12/11/94	1700	VO 24				
NBE 861	L16 Prime	brine	12/11/94	1935	VO 08				
NBE 862	L16 Prime	PC	12/11/94	1935	VO 24				
NBE 863	L16 Prime	scrubber	12/11/94	2005	VO 39			396,000	39,300
NBE 864	L16 Prime	brine	12/11/94	2400	VO 08				

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (µg/L)			
						TDS	TOX	TSS	TOC
NBE 865	L16 Prime	PC	12/11/94	2400	VO 24				
NBE 866	L16 Prime	brine	12/12/94	0600	VO 08				
NBE 867	L16 Prime	PC	12/12/94	0600	VO 24				
NBE 868	L16 Prime	brine	12/11/94	1700	VO 08				
NBE 869	L16 Prime	PC	12/12/94	1710	VO24				
NBE 870	L16 Prime	PC	12/12/94	2210	VO 24				
NBE 871	L16 Prime	PC	12/13/94	0057	VO 24				
NBE 872	L16 Prime	PC	12/13/94	0900	VO 24				
NBE 873	L16 Prime	PC	12/13/94	1600	VO 24				
NBE 874	L16 Prime	PC	12/13/94	2205	VO24				
NBE 875	L16 Prime	PC	12/14/94	0950	VO24				
NBE 876	L16 Prime	PC	12/14/94	1150	VO24				
NBE 877	L16 Prime	brine	12/15/94	1200	VO 08			2,310,000	4,590,000
NBE 878	L16 Prime	PC composite	12/16/94	1700	Drum 1351			<5,000	1,300
NBE 879	L17 Prime	PC		2100	VO 24				
NBE 880	L17 Prime	PC	12/16/94	0500	VO 24				
NBE 881	L17 Prime	PC	12/16/94	1045	VO 24				
NBE 882	L17 Prime	PC	12/16/94	1600	VO 24				
NBE 883	L17 Prime	brine	12/16/94	1600	VO 08				
NBE 884	L17 Prime	brine	12/16/94	1820	VO 08				
NBE 885	L17 Prime	brine	12/16/94	2020	VO 08				
NBE 886	N5 DBL Prime	PC	12/19/94	1350	VO 24				
NBE 887	N5 DBL Prime	PC	12/19/94	1550	VO 24				
NBE 888	N5 DBL Prime	PC	12/19/94	2155	VO 24				
NBE 889	N5 DBL Prime	brine	12/20/94	0930	VO 08			738,000	356,000
NBE 890	N5 DBL Prime	PC composite	12/20/94	0930	Drum			<5,000	~230
NBE 891	N5 DBL Prime	evaporator rinse	12/20/94	1100	VO 08				
NBE 892	SNL 2	brine	12/20/94	1800	VO 08			~88,000	103,000
NBE 893	SNL 2	PC composite	12/20/94	1800	Drum			~5,000	<200
NBE 894	SNL 2	evaporator rinse	12/20/94	1930	VO 08				
NBE 895	SNL 2	evaporator carryover	12/20/94	1145	VO 08				
NBE 896	SNL 2	brine	12/20/94	1345	VO 08				1,790,000
NBE 897	SNL 2	brine	12/20/94	1545	VO 08				266,000
NBE 898	New New 5	evaporator rinse	01/04/95	1400	VO 08				
NBE 899	TG1	evaporator rinse	01/04/95	1400	VO 08				
NBE 900	New 5 Prime	evaporator rinse	01/04/95	1400	VO 08				
NBE 901	Acid Rinse	brine	12/29/94	1100	VO 08				
NBE 902	Acid Rinse	evaporator rinse	12/29/94		VO 08				
NBE 903	Acid Rinse	evaporator rinse	12/29/94		VO 08				
NBE 904	New 6 Prime	PC composite	12/30/94	1445	Drum 1350			<10,000	<200
NBE 905	L17 Prime	PC composite	12/30/94	1445	Drum 1354			<10,000	<200
NBE 906	L17 Prime	evaporator rinse	01/04/95	1400	VO 08				
NBE 907	New 5 DBL P	evaporator rinse	01/04/95	1400	VO 08				

Ticket Number	Waste Stream	Sample Type	Date	Time	Sample Point	Characterization Analyses (μg/L) TDS	TOX	TSS	TOC
NBE 908	SNL1	evaporator rinse	01/04/95	1400	VO 08				
NBE 909	L17 Prime	brine	01/04/95	1400	VO 08			550,000	694,000
NBE 910	Scrub Fail	scrubber failure	01/09/95	1400	Carboy				
NBE 911	PC "Old"	PC	01/09/95	1400	Carboy				
NBE 912	Power Fail	PC	01/09/95	1400	Bucket				
NBE 913	Bicarbonate	brine	01/09/95	1200	VO 08				
NBE 914	Bicarbonate	evaporator rinse	01/09/95	1200	VO 08				
NBE 915	Acid Rinse	brine	01/09/95	1200	VO 08				
NBE 916	Acid Rinse	evaporator rinse	01/09/95	1200	VO 08				
NBE 917	Acid Rinse	evaporator rinse	01/09/95	1200	VO 08				
NBE 918	Seal H20	drain	01/10/95	1400	Bucket				
NBE 919	L17 Prime	evaporator rinse	01/10/95	1500	VO 08				
NBE 920	pH probe	storage	01/10/95	1400	Carboy A				
NBE 921	Demonstration	brine	01/19/95	0830	NBE 521				
NBE 922	Demonstration	brine	01/19/95	0830	NBE 510				

Ticket Number	VOC (μg/L)									
	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 501		15,000,000	<5,000	<2,500	<2,500	<2,500				
NBE 502		1,800,000	<5,000	<2,500	<2,500	<2,500				
NBE 504		<500	<1,000	<500	<500	<500				
NBE 505		<1,000	<2,000	<1,000	<1,000	<1,000				
NBE 506		73,000	<5,000	3,500	<2,500	1,600,000				
NBE 507		<2,500	<5,000	<2,500	<2,500	1,800				
NBE 508	<4,840									
NBE 509	<4,840									
NBE 510	910,000									
NBE 511	<4,840									
NBE 512	<4,840	120	190	<25	<25	<25				
NBE 513	<4,840	10	2,000	<50	<50	<50				
NBE 514	<4,840	<10,000	390,000	<10,000	<10,000	<10,000				
NBE 515	<4,840									
NBE 516	<4,840									
NBE 517	<4,840									
NBE 518	<4,840									
NBE 519										
NBE 520										
NBE 521										
NBE 522		<5	48	<5	<5	3				
NBE 523		<5	5	<5	<5	<5				
NBE 524		4	100	2	<5	<5				
NBE 525		<5	13	<5	<5	<5				
NBE 526		<5	4	<5	<5	<5				
NBE 527		<5	7	<5	<5	<5				
NBE 528										
NBE 529										
NBE 530		<5	2	<5	<5	<5				
NBE 531		37	46	<5	<5	27				
NBE 532		<5	8	<5	<5	26				
NBE 533		2,000	130	1	9	440				
NBE 534		<250	~52,000	<250	<250	<250				
NBE 535										
NBE 536										
NBE 537	33,000,000									
NBE 538	ND									
NBE 539	ND									
NBE 540	43,000,000									
NBE 541	37,500,000									
NBE 542	89,300,000									
NBE 543		<250	930	<250	<250	<250				

Ticket	VOC (μg/L)									
Number	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 544										
NBE 545										
NBE 546										
NBE 547		<5	3	<5	<5	<5				
NBE 548										
NBE 549										
NBE 550		<5	29	<5	<5	<5				
NBE 551										
NBE 552		<5	2	<5	<5	<5				
NBE 553	ND	<500	<500	<500	<500	<500	65			
NBE 554										
NBE 555	ND	<500	<500	<500	<500	<500				
NBE 556										
NBE 557		<50	<50	<50	<50	<50				
NBE 558	ND	<500	<500	<500	<500	<500				
NBE 560	ND	<500	<500	<500	<500	<500				
NBE 561		<50	<50	<50	<50	<50				
NBE 562	ND	<50	<50	<50	<50	<50				
NBE 563		<50	<50	<50	<50	<50				
NBE 564		<50	37	<50	<50	<50				
NBE 565		1	3	<5	<5	<5				
NBE 566	ND	<50	<50	<50	<50	<50				
NBE 567	ND	<50	<50	<50	<50	<50				
NBE 568	ND	ND	ND	ND	ND	ND				170
NBE 569	<50	<50	<50	<50	<50	<50				
NBE 570	<50	<50	<50	<50	<50	<50				
NBE 571		<5	<20	<5	<5	<5				
NBE 572		<250	<1000	<250	<250	<250				
NBE 573		<25	>100	<25	<25	<25				
NBE 574	<50	<50	<50	<50	<50	<50				
NBE 575	<50	<50	<50	<50	<50	<50				
NBE 601										
NBE 602										
NBE 603		<250	1,100	<250	<250	<250				
NBE 604										
NBE 605										
NBE 606										
NBE 607		<5	<20	<5	<5	6				
NBE 608										
NBE 609										
NBE 610		<5	<20	<5	<5	<5				

Ticket	VOC (μg/L)									
Number	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 611										
NBE 612										
NBE 613		<250	3,000	<250	<250	<250				
NBE 629										
NBE 630										
NBE 631										
NBE 632		1	<20	<5	<5	<5				
NBE 633										
NBE 634										
NBE 635		1	<20	<5	<5	<5				
NBE 636										
NBE 637										
NBE 638	8,600									
NBE 639	<2,960									
NBE 640										
NBE 643		<330	~160,000	<330	<330	<330				400
NBE 644										
NBE 645										
NBE 646										
NBE 647										640
NBE 648	ND	<50	<50	<50	<50	<50				
NBE 649										
NBE 650										
NBE 651										
NBE 652										
NBE 653										
NBE 655	ND	ND	>5,100	1	60	2				
NBE 656	ND	ND	140	ND	62	2				
NBE 657		ND	ND	ND	ND	ND	12			
NBE 658		>650	ND	ND	ND	3				
NBE 659		ND	ND	ND	ND	ND				
NBE 660		ND	ND	ND	ND	ND				
NBE 661		ND	ND	ND	ND	ND				
NBE 662										
NBE 663										
NBE 664								~7.5%		
NBE 665		ND	ND	ND	ND	ND		63,000,000		
NBE 666		23	ND	ND	ND	ND	28			
NBE 667		180	ND	ND	ND	ND	12			

Ticket Number	VOC (μg/L)									
	IPA	DCM	Acetone	Benzene	CCl$_4$	CHCl$_3$	CH$_3$Cl	TCE	DCE	2-Butanone
NBE 668	R						>1400			
NBE 669	R									
NBE 670	ND	ND	ND	ND	ND	ND	610			
NBE 671	ND	ND	ND	ND	ND	ND	390			
NBE 672	9,253,000									
NBE 673	ND									
NBE 674	ND	<50	<50	<50	<50	<50				
NBE 675	ND									
NBE 686										
NBE 687										
NBE 688										
NBE 689										
NBE 690										
NBE 691										
NBE 692										
NBE 693										
NBE 694										
NBE 695										
NBE 696										
NBE 697										
NBE 698										
NBE 699										
NBE 700										
NBE 701										
NBE 702		>590	>400	ND	ND	ND		2		
NBE 703		25	ND	ND	ND	3				
NBE 704		ND	ND	ND	ND	ND	3			
NBE 705										
NBE 706										
NBE 707		2,900	280	<120	<120	<120				
NBE 708										
NBE 709		200	7	<5	<5	28				
NBE 710										
NBE 711		150	<20	<5	<5	<5				
NBE 712										
NBE 713										
NBE 714										
NBE 715										
NBE 717										
NBE 718										
NBE 719										
NBE 720		>210	ND	ND	ND	ND				
NBE 721		>3,000	7	ND	ND	6				

Ticket Number	VOC (μg/L)									
	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 722		ND	ND	ND	ND	ND				
NBE 723										
NBE 724										
NBE 725										
NBE 726		3,796	452	ND	ND	ND				
NBE 727										
NBE 728		10,200	10,700	ND	ND	7.4				
NBE 729										
NBE 730		159,000	ND	ND	ND	ND				
NBE 731										
NBE 732										
NBE 733										
NBE 734										
NBE 735										
NBE 736										
NBE 737	ND									
NBE 738	ND									
NBE 739										
NBE 740		37	270	ND	ND	ND				
NBE 741										
NBE 742										
NBE 743		<250	<1000	<250	<250	<250				
NBE 744										
NBE 745										
NBE 746		8	<20	<5	<5	<5				
NBE 747										
NBE 748		44	<20	<5	<5	<5				
NBE 749										
NBE 750										
NBE 851		<500	<500	<500	<500	<500				
NBE 852										
NBE 853										
NBE 854										
NBE 855										
NBE 856										
NBE 857										
NBE 858										
NBE 859		287	176	10	ND	ND	38	142.5	145	
NBE 860		52.5	ND	ND	ND	ND		13.5		
NBE 861		6,345	ND	ND	ND	ND				
NBE 862										
NBE 863		<25	<100	<25	<25	<25				
NBE 864										

Ticket Number	VOC (µg/L)									
	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 865										
NBE 866										
NBE 867										
NBE 868										
NBE 869		<50	<50	<50	<50	<50				
NBE 870		65.5	94.5	8.5	ND	ND	24.5	29	59	237
NBE 871		ND	ND	ND	ND	ND	5.5			98
NBE 872		<50	<50	<50	<50	<50				
NBE 873		<50	<50	<50	<50	<50				
NBE 874		<50	<50	<50	<50	<50				
NBE 875		<50	<50	<50	<50	<50				16
NBE 876		<50	<50	<50	<50	<50				
NBE 877		450	<1000	<250	<250	<250				
NBE 878		47	<100	<25	<25	<25				
NBE 879		<50	<50	<50	<50	<50				
NBE 880		<50	<50	<50	<50	<50				
NBE 881		<50	<50	<50	<50	<50				
NBE 882		<50	<50	<50	<50	<50				
NBE 883		79	<50	<50	<50	<50				
NBE 884		79	<50	<50	<50	<50				
NBE 885		79	<50	<50	<50	<50				
NBE 886		28.5	<50	<50	<50	<50				
NBE 887		<50	<50	<50	<50	<50				
NBE 888		<50	<50	<50	<50	<50				
NBE 889		<200	<800	<200	<200	<200				
NBE 890		ND	ND	ND	ND	ND				
NBE 891										
NBE 892		<100	<400	<100	<100	<100				
NBE 893		<100	<400	<100	<100	<100				
NBE 894										
NBE 895										
NBE 896										
NBE 897										
NBE 898		<25	<140	<25	<25	<25				
NBE 899		100	2,000	<62	<62	<62				
NBE 900										
NBE 901										
NBE 902										
NBE 903										
NBE 904		<25	<50	<25	<25	<25	230			
NBE 905		<25	<50	<25	<25	<25				
NBE 906										
NBE 907										

Ticket Number	VOC (µg/L)									
	IPA	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	CH_3Cl	TCE	DCE	2-Butanone
NBE 908										
NBE 909		290	<200	<50	<50	<50				
NBE 910										
NBE 911										
NBE 912										
NBE 913										
NBE 914										
NBE 915										
NBE 916										
NBE 917										
NBE 918										
NBE 919										
NBE 920										
NBE 921										
NBE 922										

Ticket Number	Gross Radiation (pCi/L)		Inorganic Analyses (µg/L)			
	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 501	2,200	3,200				
NBE 502	25,000	460				
NBE 504	63,000	22,600				
NBE 505	14,000	15,800				
NBE 506	59,000	24,000				
NBE 507						
NBE 508						
NBE 509						
NBE 510						
NBE 511						
NBE 512						
NBE 513						
NBE 514						
NBE 515						
NBE 516						
NBE 517						
NBE 518						
NBE 519				48,600	24,000	18,880
NBE 520				868,000	390,000	1,080
NBE 521				123,000	43,000	4,380
NBE 522						
NBE 523	<30	<60				
NBE 524	<2	<6				
NBE 525						
NBE 526	<10	<16				
NBE 527	<2	<6				
NBE 528	11,500	11,400				
NBE 529	8,400	8,300				
NBE 530	<11	<15				
NBE 531	310	130				
NBE 532	<10	<11				
NBE 533	1,060	280				
NBE 534	480,000	790,000				
NBE 535						499,000
NBE 536			2,400	3,110,000		
NBE 537						
NBE 538						
NBE 539						
NBE 540						
NBE 541						
NBE 542						
NBE 543						

Ticket Number	Gross Radiation (pCi/L)		Inorganic Analyses (μg/L)			
	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 544						
NBE 545						765,000
NBE 546			<1,140	6,240,000	1,490	
NBE 547						
NBE 548				110		
NBE 549			1,470	426	10,800	
NBE 550						
NBE 551						
NBE 552	<1000	<1000		222,000	8,690,000	2,570
NBE 553						
NBE 554						
NBE 555						
NBE 556						
NBE 557						
NBE 558						
NBE 560						
NBE 561						
NBE 562						
NBE 563						
NBE 564	35,400	9,320		6,330,000	159,000	1,860,000
NBE 565	<5.3	<7.2		376,000	110,000	865
NBE 566						
NBE 567						
NBE 568						
NBE 569						
NBE 570						
NBE 571	<9.4	11.4		1,960	23,400	50.6
NBE 572	1,428,000	796,000		25,400,000	1,620	3,990,000
NBE 573	<5.1	<7.2		1,230	635	135
NBE 574						
NBE 575						
NBE 601						110
NBE 602			8,660	65.5	785	
NBE 603						
NBE 604						
NBE 605						1,380,000
NBE 606			<1,140	10,500,000	<2.0	
NBE 607						
NBE 608						112
NBE 609			252,000	497	10,100	
NBE 610						

Ticket	Gross Radiation (pCi/L)		Inorganic Analyses (µg/L)			
Number	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 611						59.2
NBE 612			10,200	89.7	324	
NBE 613						
NBE 629						
NBE 630						2,100,000
NBE 631			1,140	16,200,000	685	
NBE 632						
NBE 633						34
NBE 634			199,000	612	15,700	
NBE 635						
NBE 636						18.8
NBE 637			7,210	79.8	306	
NBE 638	159,000	219,000				25,600
NBE 639	<5	<10				127
NBE 640				62,700	<2.0	
NBE 643	3,800	53,000				
NBE 644						50,500,000
NBE 645			38,100	2,090,000		
NBE 646	660,000	690,000				
NBE 647	3	<7				
NBE 648						
NBE 649						
NBE 650						
NBE 651	440,000	610,000				
NBE 652	10	<19				
NBE 653	<2	<7				
NBE 655						79,000
NBE 656						4,560
NBE 657						
NBE 658						
NBE 659						
NBE 660						
NBE 661						
NBE 662	<16	<30				
NBE 663	11,500	19,600				
NBE 664						
NBE 665						
NBE 666						
NBE 667						

Ticket	Gross Radiation (pCi/L)		Inorganic Analyses (µg/L)			
Number	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 668						
NBE 669						
NBE 670						
NBE 671						
NBE 672						
NBE 673						
NBE 674						
NBE 675						
NBE 686	<30	<40				27,800
NBE 687				34,300	1,400,000	
NBE 688	<2	<7				1,530,000
NBE 689				197,000	131,000	
NBE 690	39,000	115,000				
NBE 691						
NBE 692						881,000
NBE 693	41,000	59,000				
NBE 694	<5	<11				
NBE 695	22,000	26,900				
NBE 696	<5	<11				
NBE 697	16,300	20,100				
NBE 698	<7	<18				
NBE 699	21,000	35,000				
NBE 700						3,710,000
NBE 701						1,470,000
NBE 702						
NBE 703						
NBE 704						
NBE 705			170			
NBE 706				679,000		
NBE 707	350,000	290,000				
NBE 708						
NBE 709	<60	<100				
NBE 710						
NBE 711	<2	<6				
NBE 712						
NBE 713	34,000	56,000				
NBE 714	<16	<30				
NBE 715	4,600	9,600				
NBE 717	5,500	9,000				
NBE 718						
NBE 719	66,000	115,000				
NBE 720						
NBE 721						

Ticket Number	Gross Radiation (pCi/L)		Inorganic Analyses (μg/L)			
	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 722						
NBE 723			850			
NBE 724				50,200		
NBE 725						
NBE 726	15000	55000				
NBE 727						
NBE 728	<500	<1000				
NBE 729						
NBE 730	<3	18				
NBE 731						
NBE 732	27,000	73,000				
NBE 733	<17	<30				
NBE 734	2,900	16,500				
NBE 735	3,400	6,500				
NBE 736						
NBE 737						
NBE 738						
NBE 739						
NBE 740						
NBE 741						
NBE 742						25,000,000
NBE 743	90,000	215,000				
NBE 744						
NBE 745						142,000,000
NBE 746	<50	<100				188
NBE 747				3,290	189,000	
NBE 748	<2	<6				728
NBE 749				3,000	8,250	
NBE 750	24,000	41,000				
NBE 851						
NBE 852						
NBE 853						
NBE 854						
NBE 855						
NBE 856						
NBE 857	267,000	207,800				
NBE 858	34	49				
NBE 859						
NBE 860						
NBE 861						
NBE 862						
NBE 863	<1,660	<1,000				
NBE 864						

Ticket	Gross Radiation (pCi/L)		Inorganic Analyses (µg/L)			
Number	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 865						
NBE 866						
NBE 867						
NBE 868						
NBE 869						
NBE 870						
NBE 871						
NBE 872						
NBE 873						
NBE 874						
NBE 875						
NBE 876						
NBE 877	75,500	148,500				
NBE 878	<5.1	<7.2				
NBE 879						
NBE 880						
NBE 881						
NBE 882						
NBE 883						
NBE 884						
NBE 885						
NBE 886						
NBE 887						
NBE 888						
NBE 889	637,000	275,000				
NBE 890	<5.1	<7.2				
NBE 891	52,100	36,900				
NBE 892	6,370	11,320				
NBE 893	<5.1	<7.2				
NBE 894	6,740	5,570				
NBE 895	10.80 F	11.26 F				
NBE 896						
NBE 897						
NBE 898	35,300	33,500				
NBE 899	1,140	<1000				
NBE 900	348,000	246,900				
NBE 901	159.1	31.1				
NBE 902	2,730	3,110				
NBE 903	2,505	2,384				
NBE 904	<5.4	<7.1				728
NBE 905	<5.3	<7.1				
NBE 906	16,800	42,300				
NBE 907	106,800	80,200				

Ticket Number	Gross Radiation (pCi/L)		Inorganic Analyses (μg/L)			
	Alpha	Beta	TIC	NO_3	NO_2	NH_3
NBE 908	5,420	3,400				
NBE 909	23,000	34,600				
NBE 910	<60	<100				
NBE 911	3	<6				
NBE 912	78	63				
NBE 913	210,000	140,000				
NBE 914	21,000	37,000				
NBE 915	77,000	80,000				
NBE 916	1,350	1,520				
NBE 917	1,900	3,200				
NBE 918	<6	<160				
NBE 919	6,600	24,100				
NBE 920	130	102				
NBE 921	<40	<100				
NBE 922	<50	<130				

Ticket Number	Ions (µg/L)					TCLP VOC (µg/L)					Loss On Drying (%)
	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	
NBE 501											
NBE 502											
NBE 504											
NBE 505											
NBE 506											
NBE 507											
NBE 508											
NBE 509											
NBE 510											
NBE 511											
NBE 512											
NBE 513											
NBE 514											
NBE 515											
NBE 516											
NBE 517											
NBE 518											
NBE 519											
NBE 520											
NBE 521											
NBE 522											
NBE 523	382,000										
NBE 524	238										
NBE 525											
NBE 526	290,000										
NBE 527	~0.0602										
NBE 528											
NBE 529											
NBE 530	17,000										
NBE 531											
NBE 532											
NBE 533											
NBE 534											
NBE 535											
NBE 536	52,400	63,600	<280	~255	369						99.54
NBE 537											
NBE 538											
NBE 539											
NBE 540											
NBE 541											
NBE 542											
NBE 543											

Ticket Number	Ions (μg/L)					TCLP VOC (μg/L)					Loss On Drying (%)
	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	
NBE 544											
NBE 545											
NBE 546		342,000	<28.0								99.26
NBE 547											
NBE 548											
NBE 549		12,300	<28.0								
NBE 550											
NBE 551											
NBE 552	447,000					<5	11	<5	<5	<5	
NBE 553											
NBE 554											
NBE 555											
NBE 556											
NBE 557											
NBE 558											
NBE 560											
NBE 561											
NBE 562											
NBE 563											
NBE 564	401,000					<100	<400	<100	<100	<100	
NBE 565	~1,930					<5	11	<5	<5	<5	
NBE 566											
NBE 567											
NBE 568											
NBE 569											
NBE 570											
NBE 571	44,300					<5	<20	<5	<5	<5	
NBE 572	499,000					<120	<500	<120	<120	<120	
NBE 573	34.4					<5	<20	<5	<5	<5	
NBE 574											
NBE 575											
NBE 601											
NBE 602		65.5	<28.0								
NBE 603											
NBE 604											
NBE 605											
NBE 606		464,000	ND								98.72
NBE 607											
NBE 608											
NBE 609		22,200	349								
NBE 610											

Ticket	Ions (μg/L)					TCLP VOC (μg/L)					Loss On
Number	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	Drying (%)
NBE 611											
NBE 612		<15.0	523								
NBE 613											
NBE 629											
NBE 630											
NBE 631		569,000	<280								98.18
NBE 632											
NBE 633											
NBE 634		24,200	398								
NBE 635											
NBE 636											
NBE 637		<15.0	379								
NBE 638											
NBE 639											
NBE 640											
NBE 643											
NBE 644											
NBE 645	94,400	3,000	26,000	~687	<510						99.96
NBE 646											
NBE 647						81	500,000	20	<5	<5	
NBE 648											
NBE 649											
NBE 650											
NBE 651											
NBE 652											
NBE 653											
NBE 655											
NBE 656											
NBE 657											
NBE 658											
NBE 659											
NBE 660											
NBE 661											
NBE 662						<5	<20	<5	<5	<5	
NBE 663						11	<100	<25	<25	<25	
NBE 664											
NBE 665											
NBE 666											
NBE 667											

Ticket	Ions (μg/L)					TCLP VOC (μg/L)					Loss On
Number	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	Drying (%)
NBE 668											
NBE 669											
NBE 670											
NBE 671											
NBE 672											
NBE 673											
NBE 674											
NBE 675											
NBE 686											
NBE 687	29,300										
NBE 688											
NBE 689											
NBE 690											
NBE 691											
NBE 692											
NBE 693						<25	<100	<25	<25	<25	
NBE 694						<5	68	<5	<5	12	
NBE 695						<25	<50	<25	<25	30	
NBE 696						<5	7	1	<5	39	
NBE 697											
NBE 698											
NBE 699											
NBE 700											
NBE 701											
NBE 702											
NBE 703											
NBE 704											
NBE 705											
NBE 706	80,900	11,100,000	<140	~258	1,590						
NBE 707						3,200	300	<25	<25	<25	
NBE 708											
NBE 709	2,040,000					190	160	<25	<25	13	
NBE 710											
NBE 711	~67.8					200	130	<25	<25	<25	
NBE 712											
NBE 713						2,440	280	ND	ND	ND	
NBE 714						ND	114	ND	ND	ND	
NBE 715						452	98.5	ND	ND	14.5	
NBE 717											
NBE 718											
NBE 719											
NBE 720											
NBE 721											

Ticket	Ions (µg/L)					TCLP VOC (µg/L)					Loss On
Number	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	Drying (%)
NBE 722											
NBE 723											
NBE 724	141,000	7,980,000	<560	<60.0	410						
NBE 725											
NBE 726						5,000	51	6	25	ND	
NBE 727											
NBE 728	13,300,000					150	ND	8	ND	17	
NBE 729											
NBE 730	2,540					150,000	ND	ND	ND	ND	
NBE 731											
NBE 732						980	ND	8	ND	ND	
NBE 733						ND	54	7	ND	ND	
NBE 734						280	ND	ND	ND	15	
NBE 735											
NBE 736											
NBE 737											
NBE 738											
NBE 739											
NBE 740											
NBE 741											
NBE 742											
NBE 743						<120	190	<120	<120	<120	
NBE 744											
NBE 745											
NBE 746						5	16	<5	<5	<5	
NBE 747	1,160,000										
NBE 748						38	94	<5	<5	<5	
NBE 749	~197										
NBE 750						26	ND	ND	ND	ND	
NBE 851											
NBE 852											
NBE 853											
NBE 854											
NBE 855											
NBE 856											
NBE 857						100	500	<50	<50	<50	
NBE 858						<5	<20	<5	<5	18	
NBE 859											
NBE 860											
NBE 861											
NBE 862											
NBE 863	41,200,000					<5	110	<5	<5	<5	
NBE 864											

Ticket Number	Ions (µg/L)					TCLP VOC (µg/L)					Loss On Drying (%)
	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	
NBE 865											
NBE 866											
NBE 867											
NBE 868											
NBE 869											
NBE 870											
NBE 871											
NBE 872											
NBE 873											
NBE 874											
NBE 875											
NBE 876											
NBE 877						160	<1000	<250	<250	<250	
NBE 878	693					35	<100	<25	<25	<25	
NBE 879											
NBE 880											
NBE 881											
NBE 882											
NBE 883											
NBE 884											
NBE 885											
NBE 886											
NBE 887											
NBE 888											
NBE 889						ND	<1000	<250	<250	<250	
NBE 890						ND	ND	ND	ND	ND	
NBE 891						17	<50	<25	<25	<25	
NBE 892						<100	<400	<100	<100	<100	
NBE 893						<25	<100	<25	<25	<25	
NBE 894						31	<50	<25	<25	27	
NBE 895											
NBE 896											
NBE 897											
NBE 898											
NBE 899											
NBE 900						<25	70	<25	<25	<25	
NBE 901											
NBE 902											
NBE 903											
NBE 904	~63.9					<25	<50	<25	<25	<25	
NBE 905						<25	<50	<25	<25	<25	
NBE 906						<25	<100	<25	<25	<25	
NBE 907						26	<100	<25	<25	<25	

Ticket	Ions (µg/L)					TCLP VOC (µg/L)					Loss On
Number	Cl^-	SO_4	PO_4	Bromide	Fluoride	DCM	Acetone	Benzene	CCl_4	$CHCl_3$	Drying (%)
NBE 908						11	54	<25	<25	<25	
NBE 909						300	<1000	<250	<250	<250	
NBE 910						48	7,200	<25	<25	<25	
NBE 911						11	29,000	<25	<25	<25	
NBE 912						23	420	<25	<25	<25	
NBE 913						9	10	<25	<25	<25	
NBE 914						35	<100	<25	<25	<25	
NBE 915						400	49	<25	<25	<25	
NBE 916						40	<100	<25	<25	<25	
NBE 917						13	61	<25	<25	<25	
NBE 918						<25	110	<25	<25	<25	
NBE 919						400	<100	<25	<25	<25	
NBE 920						14,000	<3,300	<830	<830	<830	
NBE 921											
NBE 922											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 501		342.771	1,417.91 C								
NBE 502		2,216.09	3,344.15 C								
NBE 504				3,499.50	12,208	6,664.3	3,020	38.5	441		
NBE 505				12,382.00	14,850	6,664.3	11,000	132	1,250		
NBE 506				25,740	21,052	95.61	11,700	540	13,500	1,350	96
NBE 507											
NBE 508											
NBE 509											
NBE 510											
NBE 511											
NBE 512											
NBE 513											
NBE 514											
NBE 515											
NBE 516											
NBE 517											
NBE 518											
NBE 519											
NBE 520											
NBE 521											
NBE 522											
NBE 523											
NBE 524											
NBE 525											
NBE 526											
NBE 527											
NBE 528											
NBE 529											
NBE 530											
NBE 531											
NBE 532											
NBE 533											
NBE 534							560,317	9,799	77,452		
NBE 535											
NBE 536											
NBE 537											
NBE 538											
NBE 539											
NBE 540											
NBE 541											
NBE 542											
NBE 543											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 544											
NBE 545											
NBE 546											
NBE 547											
NBE 548											
NBE 549											
NBE 550											
NBE 551	equipment malfunction										
NBE 552											
NBE 553											
NBE 554	equipment malfunction										
NBE 555											
NBE 556	equipment malfunction										
NBE 557											
NBE 558											
NBE 560											
NBE 561											
NBE 562											
NBE 563											
NBE 564											
NBE 565											
NBE 566											
NBE 567											
NBE 568	carbon disulfide=6 ppb										
NBE 569											
NBE 570											
NBE 571											
NBE 572											
NBE 573											
NBE 574											
NBE 575											
NBE 601											
NBE 602											
NBE 603											
NBE 604											
NBE 605											
NBE 606											
NBE 607											
NBE 608											
NBE 609											
NBE 610											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 611											
NBE 612											
NBE 613											
NBE 629											
NBE 630											
NBE 631											
NBE 632											
NBE 633											
NBE 634											
NBE 635											
NBE 636											
NBE 637											
NBE 638											
NBE 639											
NBE 640											
NBE 643							668	42	242		
NBE 644											
NBE 645											
NBE 646											
NBE 647											
NBE 648											
NBE 649	equipment malfunction										
NBE 650	equipment malfunction										
NBE 651											
NBE 652											
NBE 653											
NBE 655											
NBE 656											
NBE 657											
NBE 658											
NBE 659											
NBE 660											
NBE 661											
NBE 662											
NBE 663											
NBE 664											
NBE 665											
NBE 666											
NBE 667											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 668	bromomethane=290 ppb										
NBE 669											
NBE 670	bromomethane=110 ppb										
NBE 671	bromomethane=61 ppb										
NBE 672											
NBE 673	equipment malfunction										
NBE 674											
NBE 675	equipment malfunction										
NBE 686											
NBE 687											
NBE 688											
NBE 689											
NBE 690											
NBE 691											
NBE 692											
NBE 693											
NBE 694											
NBE 695											
NBE 696											
NBE 697											
NBE 698											
NBE 699											
NBE 700											
NBE 701											
NBE 702											
NBE 703											
NBE 704											
NBE 705											
NBE 706											
NBE 707											
NBE 708											
NBE 709											
NBE 710											
NBE 711											
NBE 712											
NBE 713											
NBE 714											
NBE 715											
NBE 717											
NBE 718											
NBE 719											
NBE 720											
NBE 721											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 722											
NBE 723											
NBE 724											
NBE 725	equipment malfunction										
NBE 726											
NBE 727											
NBE 728											
NBE 729											
NBE 730											
NBE 731											
NBE 732											
NBE 733											
NBE 734											
NBE 735											
NBE 736											
NBE 737											
NBE 738											
NBE 739											
NBE 740											
NBE 741											
NBE 742											
NBE 743											
NBE 744											
NBE 745											
NBE 746											
NBE 747											
NBE 748											
NBE 749											
NBE 750											
NBE 851	carbon disulfide=85 ppb										
NBE 852											
NBE 853											
NBE 854											
NBE 855											
NBE 856											
NBE 857											
NBE 858											
NBE 859	vinyl chloride=13.5 ppb										
NBE 860											
NBE 861											
NBE 862											
NBE 863											
NBE 864											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 865											
NBE 866											
NBE 867											
NBE 868											
NBE 869											
NBE 870	chlorobenzene=8.5 ppb										
NBE 871											
NBE 872											
NBE 873											
NBE 874											
NBE 875											
NBE 876											
NBE 877											
NBE 878											
NBE 879											
NBE 880											
NBE 881											
NBE 882											
NBE 883											
NBE 884											
NBE 885											
NBE 886											
NBE 887											
NBE 888											
NBE 889											
NBE 890											
NBE 891											
NBE 892											
NBE 893											
NBE 894											
NBE 895											
NBE 896											
NBE 897											
NBE 898											
NBE 899											
NBE 900											
NBE 901											
NBE 902											
NBE 903											
NBE 904	bromomethane=56 ppb										
NBE 905	carbon disulfide=11 ppb										
NBE 906											
NBE 907											

Ticket Number	VOC Notes	Radiological Species (pCi/L)					Radiological Isotopes (pCi/L)				
		Am	Pu	U	Th	Ra	U-238	U-235	U-234	Th-230	Ra-226
NBE 908											
NBE 909											
NBE 910											
NBE 911											
NBE 912											
NBE 913											
NBE 914											
NBE 915											
NBE 916											
NBE 917											
NBE 918											
NBE 919											
NBE 920											
NBE 921											
NBE 922											

Ticket Number	TCLP Metals (µg/L)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 501								
NBE 502								
NBE 504								
NBE 505								
NBE 506								
NBE 507								
NBE 508								
NBE 509								
NBE 510								
NBE 511								
NBE 512								
NBE 513								
NBE 514								
NBE 515								
NBE 516								
NBE 517								
NBE 518								
NBE 519								
NBE 520								
NBE 521								
NBE 522								
NBE 523								
NBE 524								
NBE 525								
NBE 526								
NBE 527								
NBE 528								
NBE 529								
NBE 530								
NBE 531								
NBE 532								
NBE 533								
NBE 534								
NBE 535								
NBE 536								
NBE 537								
NBE 538								
NBE 539								
NBE 540								
NBE 541								
NBE 542								
NBE 543								

Ticket	TCLP Metals (μg/L)							
Number	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 544								
NBE 545								
NBE 546								
NBE 547								
NBE 548								
NBE 549								
NBE 550								
NBE 551								
NBE 552	~23	<280	<3.0	~25.0	5,120		<35.0	<89.0
NBE 553								
NBE 554								
NBE 555								
NBE 556								
NBE 557								
NBE 558								
NBE 560								
NBE 561								
NBE 562								
NBE 563								
NBE 564	~!22	<280	~140	~14.0	~80.0	<0.40	~72.0	<89.0
NBE 565	~12.0	<280	~9.0	~8.0	~40.0	<0.40	~38.0	<89.0
NBE 566								
NBE 567								
NBE 568								
NBE 569								
NBE 570								
NBE 571	<10.0	<280	~4	<2.0	~137		<35.0	<89.0
NBE 572	2,470	<280	~462	311	3,880		2,790	<89.0
NBE 573	<10.0	<280	<3.0	<2.0	~2.0		<35.0	<89.0
NBE 574								
NBE 575								
NBE 601								
NBE 602								
NBE 603								
NBE 604								
NBE 605								
NBE 606								
NBE 607								
NBE 608								
NBE 609								
NBE 610								

Ticket Number	TCLP Metals (µg/L)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 611								
NBE 612								
NBE 613								
NBE 629								
NBE 630								
NBE 631								
NBE 632								
NBE 633								
NBE 634								
NBE 635								
NBE 636								
NBE 637								
NBE 638								
NBE 639								
NBE 640								
NBE 643								
NBE 644								
NBE 645								
NBE 646								
NBE 647								
NBE 648								
NBE 649								
NBE 650								
NBE 651	165	ND	265	157	668		567	330
NBE 652	ND	ND	1,060	ND	278		ND	ND
NBE 653	ND	ND	290	ND	ND		ND	ND
NBE 655								
NBE 656								
NBE 657								
NBE 658								
NBE 659								
NBE 660								
NBE 661								
NBE 662	<10.0	<20.0	<3.0	<2.0	~209		<35.0	<89.0
NBE 663	<10.0	<20.0	~13	<2.0	~19		<35.0	<89.0
NBE 664								
NBE 665								
NBE 666								
NBE 667								

Ticket Number	TCLP Metals (µg/L)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 668								
NBE 669								
NBE 670								
NBE 671								
NBE 672								
NBE 673								
NBE 674								
NBE 675								
NBE 686	20	ND	274	ND	968	ND	ND	ND
NBE 687								
NBE 688	ND	ND	261	ND	ND	ND	ND	ND
NBE 689								
NBE 690	94	ND	45	ND	166	ND	ND	ND
NBE 691								
NBE 692								
NBE 693	~32.0	<2.0	~112	<2.0	~18.0	<0.40	<35.0	<89.0
NBE 694	<10.0	<2.0	~339	<2.0	~246	<0.40	<35.0	<89.0
NBE 695	<10.0	<2.0	~442	<2.0	~7.0	<0.40	<35.0	<89.0
NBE 696	<10.0	<2.0	~333	<2.0	~39.0	<0.40	<35.0	<89.0
NBE 697								
NBE 698								
NBE 699								
NBE 700								
NBE 701								
NBE 702								
NBE 703								
NBE 704								
NBE 705								
NBE 706								
NBE 707	~42.0	~5.9	~393	~73.0	~94.0		~148	<89.0
NBE 708								
NBE 709	<10.0	<2.0	~254	<2.0	<2.0		<35.0	<89.0
NBE 710								
NBE 711	<10.0	<2.0	~456	<2.0	<2.0		<35.0	<89.0
NBE 712								
NBE 713	ND	ND	ND	ND	ND		ND	ND
NBE 714	ND	ND	ND	ND	ND		ND	ND
NBE 715	ND	ND	ND	ND	ND		ND	ND
NBE 717								
NBE 718								
NBE 719								
NBE 720								
NBE 721								

Ticket	TCLP Metals (µg/L)							
Number	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 722								
NBE 723								
NBE 724								
NBE 725								
NBE 726	ND	ND	ND	ND	ND		ND	ND
NBE 727								
NBE 728	ND	ND	ND	ND	ND		ND	ND
NBE 729								
NBE 730	ND	ND	ND	ND	ND		ND	ND
NBE 731								
NBE 732	ND	ND	ND	ND	ND		ND	ND
NBE 733	ND	ND	ND	ND	ND		ND	ND
NBE 734	ND	ND	ND	ND	ND		ND	ND
NBE 735								
NBE 736								
NBE 737								
NBE 738								
NBE 739								
NBE 740								
NBE 741								
NBE 742								
NBE 743	~13.0	~100	~575	~138	3,350		~282	<89.0
NBE 744								
NBE 745								
NBE 746	<10.0	~97.1	<3.0	<2.0	~117		<35.0	<89.0
NBE 747								
NBE 748	<10.0	<20.0	<3.0	<2.0	<2.0		<35.0	<89.0
NBE 749								
NBE 750	ND	ND	84	10	112		ND	ND
NBE 851								
NBE 852								
NBE 853								
NBE 854								
NBE 855								
NBE 856								
NBE 857	<10.0	<280	<3.0	<2.0	~21.0		~35.0	<89.0
NBE 858	<10.0	<280	~30.0	<2.0	~10.0		<35.0	<89.0
NBE 859								
NBE 860								
NBE 861								
NBE 862								
NBE 863	~11.0	<280	~976	<2.0	~3.0		<35.0	<89.0
NBE 864								

Ticket	TCLP Metals (µg/L)							
Number	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 865								
NBE 866								
NBE 867								
NBE 868								
NBE 869								
NBE 870								
NBE 871								
NBE 872								
NBE 873								
NBE 874								
NBE 875								
NBE 876								
NBE 877	~105	<280	~700	~61.0	~12.0		~38.0	<89.0
NBE 878	<10.0	<280	~1260	<2.0	~3.0		<35.0	<89.0
NBE 879								
NBE 880								
NBE 881								
NBE 882								
NBE 883								
NBE 884								
NBE 885								
NBE 886								
NBE 887								
NBE 888								
NBE 889	1,380	<280	~613	281	2,350		1,450	814
NBE 890	<10.0	<280	~314	~2	~20.0		<35.0	<89.0
NBE 891	<10.0	<280	~123	<2.0	~17.0		<35.0	<89.0
NBE 892	<10.0	<280	~108	<2.0	<2.0		<35.0	<89.0
NBE 893	ND	ND	176		ND		ND	ND
NBE 894	<10.0	<280	~275	<2.0	~10.0		<35.0	<89.0
NBE 895								
NBE 896								
NBE 897								
NBE 898	~8.0	<57.0	~46.0	~2.0	<3.0	<0.40	<38.0	<111
NBE 899								
NBE 900	~373	<57.0	~61.0	~42.0	~678	<0.40	~698	<111
NBE 901								
NBE 902								
NBE 903								
NBE 904	~46	<57.0	~22.0	<2.0	~13.0	<0.40	<38.0	<111
NBE 905	<3.0	<57.0	~16.0	<2.0	<3.0	<0.40	<38.0	<111
NBE 906	<3.0	~57.0	~71.0	<2.0	<3.0	<0.40	<38.0	<111
NBE 907	<3.0	<57.0	~93.0	~55.0	~492	<0.40	~504	<111

Ticket Number	TCLP Metals (µg/L)							
	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
NBE 908	<3.0	<57.0	~79.0	<2.0	~13.0	<0.40	<38.0	<111
NBE 909	~5.0	<57.0	~233	<2.0	<3.0	<0.40	<38.0	<111
NBE 910	~4	<57.0	~1,990	~94.0	3,570	<0.40	<38.0	<111
NBE 911	~3.0	<57.0	~217	<2.0	~5.0	<0.40	<38.0	<111
NBE 912	~11.0	<57.0	~29.0	<2.0	<3.0	<0.40	<38.0	<111
NBE 913	<3.0	<57.0	~56.0	~19.0	~483	<0.40	~366	<111
NBE 914	<3.0	<57.0	~56.0	~3.0	~87.0	<0.40	~104	<111
NBE 915	<3.0	~57.0	~226	~25.0	1,120	<0.40	~430	<111
NBE 916	<3.0	<57.0	~46.0	<2.0	~7.0	<0.40	<38.0	<111
NBE 917	<3.0	~58.0	~34.0	<2.0	~6.0	<0.40	<38.0	<111
NBE 918	<3.0	<57.0	~75.0	<2.0	<3.0	<0.40	<38.0	<111
NBE 919	<3.0	<57.0	~51.0	<2.0	~6.0	<0.40	<38.0	<111
NBE 920	~12.0	<57.0	~52.0	<2.0	<3.0	<0.40	<38.0	<111
NBE 921								
NBE 922								

Ticket Number	General Notes	RCRA Metals (µg/L)				
		Fe	Cr	Al	Ag	As
NBE 501	feed prep					
NBE 502	feed prep					
NBE 504	4-Pentene-2-ol=900,000 µg/L					
NBE 505	4-Pentene-2-ol=400,000 µg/L					
NBE 506	feed prep					
NBE 507	4-Pentene-2-ol=500,000 µg/L					
NBE 508						
NBE 509						
NBE 510	see NBE 922 for gross αβ					
NBE 511						
NBE 512						
NBE 513						
NBE 514						
NBE 515						
NBE 516						
NBE 517						
NBE 518						
NBE 519						
NBE 520						
NBE 521	see NBE 921 for gross αβ					
NBE 522	RAD on NBE 528					
NBE 523						
NBE 524						
NBE 525	RAD on NBE 529					
NBE 526						
NBE 527						
NBE 528						
NBE 529						
NBE 530						
NBE 531						
NBE 532	domestic cold H_2O V105,VO 47					
NBE 533						
NBE 534			1,790		~702	<20.0
NBE 535	feed prep					
NBE 536	feed prep					
NBE 537						
NBE 538						
NBE 539						
NBE 540	feed characterization					
NBE 541						
NBE 542						
NBE 543						

Ticket Number	General Notes	RCRA Metals (µg/L)				
		Fe	Cr	Al	Ag	As
NBE 544			707		388	<20.0
NBE 545						
NBE 546						
NBE 547			70		<10.0	<20.0
NBE 548						
NBE 549						
NBE 550			<2.0		<10.0	<20.0
NBE 551	cond. duplicate with HCl					
NBE 552	end of waste, prior to buckets					
NBE 553	current feed=New 6 brine, first					
NBE 554						
NBE 555	current feed=N6 scrubber buckets					
NBE 556	current feed=N6 scrubber buckets					
NBE 557	current feed=N6 scrubber buckets					
NBE 558	current feed=N6 scrubber buckets					
NBE 560	current feed=Tap H_2O					
NBE 561	current feed=Tap H_2O					
NBE 562	current feed=Tap H_2O					
NBE 563	current feed=Tap H_2O					
NBE 564	final brine performance					
NBE 565	final PC performance					
NBE 566						
NBE 567						
NBE 568						
NBE 569						
NBE 570						
NBE 571						
NBE 572	final brine performance					
NBE 573	final PC performance					
NBE 574						
NBE 575						
NBE 601	LANL 91003421					
NBE 602	LANL 91003421					
NBE 603	LANL 91003421					
NBE 604	LANL 91003421		481		216	<20.0
NBE 605	LANL 91003421					
NBE 606	LANL 91003421					
NBE 607	LANL 91003421		179		<10.0	<20.0
NBE 608	LANL 91003421					
NBE 609	LANL 91003421					
NBE 610	LANL 91003421		<2.0		72	<20.0

Ticket Number	General Notes	RCRA Metals (µg/L)				
		Fe	Cr	Al	Ag	As
NBE 611	LANL 91003421					
NBE 612	LANL 91003421					
NBE 613	LANL 91003421					
NBE 629	LANL 91003421		713		392	<20.0
NBE 630	LANL 91003421					
NBE 631	LANL 91003421					
NBE 632	LANL 91003421		1,230		<10.0	<20.0
NBE 633	LANL 91003421					
NBE 634	LANL 91003421					
NBE 635	LANL 91003421		<2.0		<10.0	<20.0
NBE 636	LANL 91003421					
NBE 637	LANL 91003421					
NBE 638	decontamination verification evaporator					
NBE 639	decontamination verification scrubber					
NBE 640	decontamination verification scrubber					
NBE 643	LANL 890103 feed prep		~2.0		<10.0	<20.0
NBE 644	LANL 890103 feed prep					
NBE 645	LANL 890103 feed prep					
NBE 646	feed PPT. residual					
NBE 647	PC composite					
NBE 648	HCl in VOC					
NBE 649	no HCl in VOC					
NBE 650	Tap H_2O blank with HCl					
NBE 651	residual management evaporator					
NBE 652	residual management scrubber					
NBE 653	residual management PC					
NBE 655	LANL 890103					
NBE 656	LANL 890103					
NBE 657	gas sample					
NBE 658						
NBE 659						
NBE 660	gas sample					
NBE 661	sample for troubleshooting	9,646,100	1,930,300	7,397		
NBE 662	IST scrub rinse					
NBE 663	final evaporator rinse					
NBE 664	feed sample					
NBE 665	feed sample					
NBE 666						
NBE 667						

Ticket Number	General Notes	RCRA Metals (µg/L)				
		Fe	Cr	Al	Ag	As
NBE 668	performance monitor					
NBE 669	PC characterization					
NBE 670	performance monitor					
NBE 671	performance monitor					
NBE 672	feed characterization					
NBE 673	performance monitor tank					
NBE 674	performance monitor bypass					
NBE 675	performance monitor scrubber					
NBE 686	final performance scrubber LANL 890103					
NBE 687	final performance scrubber LANL 890103					
NBE 688	final performance PC LANL 890103					
NBE 689	final performance PC LANL 890103					
NBE 690	final performance evaporator LANL 890103					
NBE 691	final performance evaporator LANL 890103					
NBE 692	final performance evaporator LANL 890103					
NBE 693	first evaporator rinse New New 6					
NBE 694	first scrubber rinse New New 6					
NBE 695	final evaporator rinse New New 6					
NBE 696	final scrubber rinse New New6					
NBE 697	baseline (follow New 6 decon)					
NBE 698	baseline (follow New 6 decon)					
NBE 699	baseline					
NBE 700	PC last collection NH_3 smell					
NBE 701	composite prior to add					
NBE 702	performance monitoring					
NBE 703	performance monitoring					
NBE 704	Tedlar bag					
NBE 705	feed sample		~7.0		<10.0	<20.0
NBE 706	feed sample					
NBE 707	final performance brine					
NBE 708	final performance brine					
NBE 709	final performance scrubber					
NBE 710	final performance scrubber					
NBE 711	final performance PC					
NBE 712	final performance PC					
NBE 713	first evaporator rinse					
NBE 714	first scrubber rinse					
NBE 715	final evaporator rinse					
NBE 717	baseline (follow L17)					
NBE 718	baseline (follow L17)					
NBE 719	solids, L17 evaporator, HNO_3					
NBE 720	2 hours past start of feed					
NBE 721	2 hours past start of feed					

Ticket Number	General Notes	RCRA Metals (µg/L)				
		Fe	Cr	Al	Ag	As
NBE 722	2 hours past start of feed					
NBE 723	feed sample		~22.0		<10.0	~20.5
NBE 724	feed sample					
NBE 725	Tap H_2O blank					
NBE 726	final performance brine					
NBE 727	final performance brine					
NBE 728	final performance scrubber					
NBE 729	final performance scrubber					
NBE 730	final performance PC composite					
NBE 731	final performance PC composite					
NBE 732	first rinse evaporator					
NBE 733	only scrubber rinse					
NBE 734	final rinse evaporator					
NBE 735	carryover from L16					
NBE 736	carryover from L16					
NBE 737	2 hours past start of feed					
NBE 738	2 hours past start of feed					
NBE 739	gas sample Tedlar bag					
NBE 740	not composite					
NBE 741	feed sample		3		<10.0	<280
NBE 742	feed sample					
NBE 743	final performance brine					
NBE 744	final performance brine					
NBE 745	final performance brine					
NBE 746	final performance scrubber					
NBE 747	final performance scrubber					
NBE 748	final performance PC composite					
NBE 749	final performance PC composite					
NBE 750	1ST rinse evaporator					
NBE 851	2 hours past waste feed=New New 5 Brine					
NBE 852	2 hours past waste feed=New New 5 Brine					
NBE 853	4 hours past waste feed=H_2O					
NBE 854	4 hours past waste feed=H_2O					
NBE 855	6 hours past waste feed=H_2O					
NBE 856	6 hours past waste feed=H_2O					
NBE 857	final evaporator					
NBE 858	final scrubber					
NBE 859	2 hours past start of waste					
NBE 860						
NBE 861	2 hours past end of waste					
NBE 862	2 hours past end of waste					
NBE 863	final scrubber performance					
NBE 864	4 hours past end of waste					

Ticket Number	General Notes	RCRA Metals ($\mu g/L$)				
		Fe	Cr	Al	Ag	As
NBE 865	4 hours past end of waste					
NBE 866	10 hours past end of waste					
NBE 867	10 hours past end of waste					
NBE 868	sample hold					
NBE 869	L16 PC with MeOH spike					
NBE 870	L16 PC with MeOH spike					
NBE 871	2 hours past L16 PC with MeOH					
NBE 872						
NBE 873						
NBE 874	L16 PC with MEOH spike					
NBE 875						
NBE 876						
NBE 877	final performance brine					
NBE 878	final performance PC composite					
NBE 879						
NBE 880						
NBE 881						
NBE 882						
NBE 883						
NBE 884	2 hours of H_2O					
NBE 885	4 hours of H_2O					
NBE 886	2 hours of feed					
NBE 887	4 hours of feed					
NBE 888	10 hours of feed					
NBE 889	final performance brine					
NBE 890	final performance PC composite					
NBE 891	rinse residual evaporator					
NBE 892	final performance brine					
NBE 893	final performance PC composite					
NBE 894	rinse residual evaporator					
NBE 895	carryover New 5 Prime to SNL					
NBE 896	end of SNL1					
NBE 897	2 hours past SNL1, H_2O feed					
NBE 898	first evaporator rinse					
NBE 899	first evaporator rinse					
NBE 900	first evaporator rinse					
NBE 901	acid rinse brine					
NBE 902	acid rinse, first rinse					
NBE 903	acid rinse, final rinse					
NBE 904	final performance, PC composite					
NBE 905	final performance, PC composite					
NBE 906	first evaporator rinse					
NBE 907	first evaporator rinse					

Ticket Number	General Notes	RCRA Metals ($\mu g/L$)				
		Fe	Cr	Al	Ag	As
NBE 908	first evaporator rinse					
NBE 909	final performance brine					
NBE 910	carboy labeled scrubber failure					
NBE 911	carboy = PC Old, ? L16					
NBE 912	bucket, PC power failure					
NBE 913	brine from bicarbonate rinse					
NBE 914	only rinse following bicarbonate					
NBE 915	duplicate gross $\alpha\beta$					
NBE 916	duplicate gross $\alpha\beta$					
NBE 917	duplicate gross $\alpha\beta$					
NBE 918	seal H_20 pump teardown					
NBE 919	final evaporator rinse					
NBE 920	H_2O, pH probe store					
NBE 921	brine from NH_3 run, HNO_3 added					
NBE 922	brine from IPA run, HNO_3 added					

Ticket Number	RCRA Metals (µg/L) (continued)						Lab Ticket Number
	Ba	Ca	Cd	Na	Pb	Se	
NBE 501							222197
NBE 502							222198
NBE 504							222199
NBE 505							222421
NBE 506							222422
NBE 507							222423
NBE 508							223637
NBE 509							223638
NBE 510							223639
NBE 511							223640
NBE 512							223799
NBE 513							223800
NBE 514							223801
NBE 515							223802
NBE 516							223803
NBE 517							223804
NBE 518							223805
NBE 519							223826
NBE 520							223827
NBE 521							225184
NBE 522							223863
NBE 523							223864,225190
NBE 524							223865,224185
NBE 525							223947
NBE 526							223948,225186
NBE 527							223949,225187
NBE 528							225188
NBE 529							225189
NBE 530							223950
NBE 531							223951
NBE 532							224144
NBE 533							224145
NBE 534	~307	141,000	~120	90,800	1,680	<89.0	224195
NBE 535							224196
NBE 536							224197
NBE 537							224174
NBE 538							224175
NBE 539							224176
NBE 540							224177
NBE 541							224178
NBE 542							224179
NBE 543							224198

Ticket Number	RCRA Metals (µg/L) (continued)						Lab Ticket Number
	Ba	Ca	Cd	Na	Pb	Se	
NBE 544	127		67		708	<89.0	224199
NBE 545							224200
NBE 546							224201
NBE 547	51		2		<35.0	<89.0	224202
NBE 548							224203
NBE 549							224204
NBE 550	<3.0		<2.0		<35.0	<89.0	224205
NBE 551							225300
NBE 552							225340,225343
NBE 553							225289
NBE 554							225295
NBE 555							225290
NBE 556							225296
NBE 557							225319
NBE 558							225320
NBE 560							225321
NBE 561							225322
NBE 562							225336
NBE 563							225337
NBE 564							225339,225342
NBE 565							225341,225344
NBE 566							225345
NBE 567							225346
NBE 568							225360
NBE 569							225380
NBE 570							225381
NBE 571							225401,225406
NBE 572							225400,225405
NBE 573							225402,225407
NBE 574							225382
NBE 575							225383
NBE 601							224206
NBE 602							224207
NBE 603							224208
NBE 604	84		116		470	<89.0	224209
NBE 605							224210
NBE 606							224211
NBE 607	<3.0		<2.0		<35.0	<89.0	224212
NBE 608							224213
NBE 609							224214
NBE 610	122		<2.0		<35.0	<89.0	224215

Ticket Number	RCRA Metals (µg/L) (continued) Ba	Ca	Cd	Na	Pb	Se	Lab Ticket Number
NBE 611							224216
NBE 612							224217
NBE 613							224294
NBE 629	122		169		704	<89.0	224295
NBE 630							224296
NBE 631							224297
NBE 632	<3.0		<2.0		<35.0	<89.0	224298
NBE 633							224299
NBE 634							224300
NBE 635	<3.0		<2.0		<35.0	<89.0	224301
NBE 636							224302
NBE 637							224303
NBE 638							224304
NBE 639							224305
NBE 640							224306
NBE 643	<3.0	~45.0	<2.0	25,900	<35.0	<89.0	224342
NBE 644							224343
NBE 645							224344
NBE 646							224341
NBE 647							224426
NBE 648							225291
NBE 649							225297
NBE 650							225298
NBE 651							224291,224307
NBE 652							224292,224308
NBE 653							224293,224309
NBE 655							224423
NBE 656							224424
NBE 657							224425
NBE 658							224716
NBE 659							224717
NBE 660							224718
NBE 661							224727
NBE 662							224950,224953
NBE 663							224951,224954
NBE 664							225191
NBE 665							225199
NBE 666							225278
NBE 667							225279

Ticket Number	RCRA Metals (µg/L) (continued)						Lab Ticket Number
	Ba	Ca	Cd	Na	Pb	Se	
NBE 668							225277
NBE 669							
NBE 670							225280
NBE 671							225281
NBE 672							225282
NBE 673							225293
NBE 674							225292
NBE 675							225294
NBE 686							224,525,224,526
NBE 687							224527
NBE 688							224529,224530
NBE 689							224531
NBE 690							224533,224534
NBE 691							224535
NBE 692							224536
NBE 693							224537,224539
NBE 694							224538,224540
NBE 695							224541,224543
NBE 696							224542,224544
NBE 697							224545
NBE 698							224546
NBE 699							224547
NBE 700							224548
NBE 701							224549
NBE 702							224550
NBE 703							224551
NBE 704							224552
NBE 705	~18.0	7,950	~24.0	5,590,000	<35.0	<89.0	224584
NBE 706							224585
NBE 707							224621,224622
NBE 708							224623
NBE 709							224624,224625
NBE 710							224626
NBE 711							224627,224628
NBE 712							224629
NBE 713							224664,224667
NBE 714							224665,224668
NBE 715							224666,224669
NBE 717							224662
NBE 718							
NBE 719							224663
NBE 720							224648
NBE 721							224649

Ticket Number	RCRA Metals (µg/L) (continued)						Lab Ticket Number
	Ba	Ca	Cd	Na	Pb	Se	
NBE 722							224650
NBE 723	~43.0	15,200	~31.0	2,240,000	<35.0	<89.0	224660
NBE 724							224661
NBE 725							225299
NBE 726							224833,224836
NBE 727							224839
NBE 728							224834,224837
NBE 729							224840
NBE 730							224835,224838
NBE 731							224841
NBE 732							224827,224830
NBE 733							224828,224831
NBE 734							224829,224832
NBE 735							224948
NBE 736							
NBE 737							224802
NBE 738							224803
NBE 739							
NBE 740							224804
NBE 741	<3.0		~4.0		<35.0	<89.0	224946
NBE 742							224947
NBE 743							224936,224939
NBE 744							224942
NBE 745							224943
NBE 746							224937,224940
NBE 747							224944
NBE 748							224938,224941
NBE 749							224945
NBE 750							224949,224952
NBE 851							225384
NBE 852							
NBE 853							
NBE 854							
NBE 855							
NBE 856							
NBE 857							225403,225408
NBE 858							225404,225409
NBE 859							225390
NBE 860							225391
NBE 861							225392
NBE 862							
NBE 863							225556,225559
NBE 864							

Ticket Number	**RCRA Metals (µg/L) (continued)**						**Lab Ticket Number**
	Ba	**Ca**	**Cd**	**Na**	**Pb**	**Se**	
NBE 865							
NBE 866							
NBE 867							
NBE 868							
NBE 869							225422
NBE 870							225423
NBE 871							225424
NBE 872							225446
NBE 873							225484
NBE 874							225485
NBE 875							225490
NBE 876							225491
NBE 877							225555,225558
NBE 878							225557,225560
NBE 879							225510
NBE 880							225511
NBE 881							225531
NBE 882							225532
NBE 883							225533
NBE 884							225534
NBE 885							225535
NBE 886							225569
NBE 887							225570
NBE 888							225571
NBE 889							225572,225574
NBE 890							225573,225575
NBE 891							225576,225577
NBE 892							225579,225581
NBE 893							225580,225582
NBE 894							225583,225584
NBE 895							225578
NBE 896							225585
NBE 897							225586
NBE 898							225677,225683
NBE 899							225684
NBE 900							225678,225685
NBE 901							225625
NBE 902							225626
NBE 903							225627
NBE 904							225638,225639
NBE 905							225640,225641
NBE 906							225679,225686
NBE 907							225680,225687

Ticket Number	RCRA Metals (µg/L) (continued)						Lab Ticket Number
	Ba	Ca	Cd	Na	Pb	Se	
NBE 908							225681,225688
NBE 909							225682,225689
NBE 910							255757,255749
NBE 911							225750,225758
NBE 912							225751,225759
NBE 913							225752,225760
NBE 914							225753,225761
NBE 915							225754,225762
NBE 916							225755,225763
NBE 917							225756,225764
NBE 918							225814,225816
NBE 919							225818,225819
NBE 920							225815,225817
NBE 921							225882
NBE 922							225883