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Study for a Pilot-Scale Non-Radioactive
Low-Level Waste Vitrification Facility**

R. A. Thompson

M. F. Morrissey

March 1996

**Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest National Laboratory
Richland, Washington 99352**

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Summary

This report presents a pre-conceptual design study for a Non-Radioactive Low-Level Waste, Pilot-Scale Vitrification System. This pilot plant would support the development of a full-scale LLW Vitrification Facility and would ensure that the full-scale facility can meet its programmatic objectives. Use of the pilot facility will allow verification of process flowsheets, provide data for ensuring product quality, assist in scaling to full scale, and support full-scale start-up. The facility will vitrify simulated non-radioactive LLW in a manner functionally prototypic to the full-scale facility. This pre-conceptual design study does not fully define the LLW Pilot-Scale Vitrification System; rather, it estimates the funding required to build such a facility. This study includes identifying all equipment necessary to prepare feed, deliver it into the melter, convert the feed to glass, prepare emissions for atmospheric release, and discharge and handle the glass. The conceived pilot facility includes support services and a structure to contain process equipment.

In accordance with the Tri-Party Agreement, Westinghouse Hanford Company (WHC) is demonstrating and evaluating melter technologies for LLW vitrification in two phases. Phase 1 will determine if a system can consistently produce quality glass from a LLW simulant. Systems that appear viable in Phase 1 may be selected to enter Phase 2. After the second phase, WHC will specify a reference system and at least one alternative. The TPA required that WHC begin Phase 1 testing by September 1994 and requires that WHC test melter feasibility, select melters, and establish a reference LLW glass composition by June 1996. Because testing is now in Phase 1, this preconceptual design study did not have the benefit of a reference or alternative melter. Consequently, this document provides pre-conceptual designs for generic pilot-scale Joule-heated and combustion melter systems. The flowsheets used for these generic systems are based on one potential configuration and do not match current TWRS flowsheets (Orme, 1994).

The pre-conceptual designs are based on pilot-scale vitrification systems that would produce 5000 kg of glass per day, or 1/20th of a full-scale 100 MT/day LLW vitrification facility. Estimated low-level waste stream composition, LLW glass specifications, and engineering judgement were used to determine flow rates and compositions for all streams entering and leaving the facility. Equipment vendors identified process equipment that would allow the pilot-scale facility to perform as required and supplied the costs for these components.

After choosing process equipment, engineers at Pacific Northwest Laboratory (PNL) worked with Kaiser Engineers Hanford to estimate the costs of pilot plants. The conclusion is that a combustion melter system would cost approximately \$25,860,000, and a Joule-heated system, approximately \$23,020,000. The estimate included a 50% contingency, which brought the combustion system to \$38,800,000 and the Joule-heated system to \$34,530,000. These rough order-of-magnitude estimates are believed to be accurate to within +40% to -30%. After contingency is added, they can be broken down as follows:

- Facility - \$10,000,000
- Combustion Melter Process - \$28,800,000
- Joule-Heated Melter Process - \$24,530,000

The process equipment includes melter, melter electrical/or fuel systems, feed preparation equipment, off gas processing equipment, vessel vent system, glass product handling equipment, vessels, and instrumentation and control. The facility cost includes sitework, concrete, metal buildings, cranes, service piping, HVAC system, electrical, compressed air, boiler and freight elevator.

Acronyms

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
AWWA	American Water Works Association
DOE	Department of Energy
HEME	High Efficiency Mist Eliminator
HEMF	High Efficiency Metal Fiber
HLW	High Level Waste
HPS	Hanford Plant Standards
KEH	Kaiser Engineers Hanford
LLW	Low Level Waste
MT	Metric Tons
PNL	Pacific Northwest Laboratory
PVTD	PNL Vitrification Testing Demonstration
ROM	Rough Order of Magnitude
SCR	Silicon Controlled Rectifiers
SIPT	Slurry Integrated Performance Test
SPC	Sulfur Polymer Cement
TPA	Tri-Party Agreement
TWRS	Tank Waste Remediation System
UPS	Uninterruptible Power Supply
VV	Vessel Vent
WFQ	waste form qualification
WHC	Westinghouse Hanford Company

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1.0 Introduction

In January, 1994, Washington State, the U.S. Environmental Protection Agency, and the U.S. Department of Energy (DOE) signed a revised Hanford Federal Facility Agreement and Consent Order (Ecology et al. 1992, also known as the Tri-Party Agreement or TPA). This revision commits the DOE to dispose of the Hanford Site radioactive waste inventory currently stored in underground single-shell and double-shell tanks and defines technologies for doing so. Low-level wastes separated from the tank wastes are to be converted to a glass waste form for final storage or disposal. Disposing of the Hanford inventory in this manner will generate approximately 210,000 m³ of LLW glass at a rate of 100 to 200 tons/day (Wilson 1994).

Westinghouse Hanford Company (WHC) is demonstrating and evaluating melter technologies for LLW vitrification in two phases. Phase 1 will determine if a system can consistently produce quality glass from a LLW simulant. In this phase, vendors will provide testing strategy, general operating behavior including perturbations and operating concerns, volume processed, processing rates, mass and energy balances, off-gas characteristics, melt characteristics including phase separations, and product composition, consistency, and uniformity (Wilson 1994). Systems that appear viable in Phase 1 may be selected to enter Phase 2, which will provide a basis for selecting a reference and a first alternative system.

The TPA required that WHC begin Phase 1 by September 1994 and requires that they test melter feasibility, select melters, and establish a reference LLW glass composition by June 1996. Testing is in Phase 1; therefore, this preconceptual design study does not have the benefit of a reference or alternative melter. Consequently, this document provides pre-conceptual designs for generic Joule-heated and combustion melter systems.

1.1 Testing Strategy

To implement a full-scale vitrification process, an equipment testing strategy has been proposed that includes radioactive and non-radioactive testing at crucible and bench-scales and non-radioactive testing at pilot-scale to provide scale-up to the full-scale radioactive facility (Morrissey, 1994).

Researchers may use laboratory-scale (crucible) testing to develop the glass waste form and identify materials for use in the melter. Most laboratory-scale testing will use non-radioactive simulants, but some tests may require radioactive tracers to elucidate the behavior of radionuclides, such as technetium, that do not have adequate surrogates. Laboratory testing with actual wastes will validate non-radioactive simulant data.

Testing to develop the process, select equipment, gather data, test the integrated system, and verify product quality may be conducted at bench- and pilot-scales with non-radioactive simulants. Scale will depend on the technologies selected in the vendor evaluation. Correlations between bench- and pilot-scale will provide guidance in designing the full-scale facility. Because of the difficulties associated with using actual wastes, testing to validate simulants and determine the impacts of minor waste components will occur at small scale with functionally identical radioactive and non-radioactive systems.

Vendors will perform initial non-radioactive testing. Non-radioactive small- and pilot-scale testing will follow immediately and may use a vendor's facilities. Because waste and glass formulations vary with tank composition as well as retrieval and pretreatment techniques, bench and pilot facilities will remain in service through full-scale start-up and initial production campaigns. The final segment of testing is non-radioactive checkout of the full-scale plant, which may include water testing of plant hydraulics and non-radioactive testing with simulants to verify the process and equipment performance.

1.2 Objectives for the LLW Pilot-Scale System

The preconceptual design specifies a facility that would allow evaluation of the following issues (Morrissey, 1994):

- flowsheet verification
- waste form performance
- regulatory and permitting concerns
- equipment reliability
- materials selection
- constituent accumulations
- control scheme development
- potential process hazards.

2.0 Scope

The pre-conceptual design of the LLW Pilot-Scale Vitrification System used for this study allows estimation of the funding required to build such a facility. Kaiser Engineers Hanford (KEH) prepared a rough order of magnitude (ROM) cost estimate with an accuracy of +40%, -30%, a contingency of 50%, and in accordance with 1995 dollars. The estimate is sufficiently detailed that it may easily be adjusted to account for changes in cost if an existing facility were used rather than constructing a new facility. A glass production rate of 5000 kg per day was assumed. The pilot plant will vitrify simulated non-radioactive LLW in a manner functionally prototypic to the full-scale facility. It will include all equipment necessary to prepare feed, deliver it to the melter, prepare emissions for atmospheric release, and discharge and handle glass. Remote operation and maintenance features are not included in the pilot plant design. The facility will include support services and a structure to contain process equipment.

3.0 Pre-Conceptual Design

3.1 General

This section describes the preconceptual design used to arrive at cost estimates. The evaluation does not have the benefit of reference and alternative melter systems; therefore, this design assumed the pilot-scale system will use either a generic Joule-heated or combustion melter. The flowsheets used in this study will require revision once a melter technology and associated systems are selected. Although the final design may differ from the one presented here, this evaluation will assist planners in determining necessary resources.

3.2 Process Equipment and Plant Layout

3.2.1 General

The preconceptual design assumes the plant will produce 5,000 kg of glass per day. Figure 1 shows a floor layout for the facility and Figures 2 and 3 show process flow diagrams for combustion and Joule-heated systems. Mass balance calculations for both systems including details of feed, off-gas, and glass compositions appear in Appendix A; Appendix B includes specifications for each piece of process equipment and a basis for each specification; Appendix C presents LLW characterizations; and cost estimates for each system constitute Appendix D. Parenthetical numbers and descriptions in each of the following headings correspond to item numbers in Appendix B.

The pilot-scale flowsheet is simplified and is not consistent with the TWRS flowsheets in all areas. No capability to process sulfur polymer cement (SPC) was assumed. The removal of SO_2 from the off gas occurs in a caustic scrubber rather than utilizing a Claus reactor system. Glass was assumed to be cast into containers and no equipment for producing or handling cullet was included. Other minor differences exist between the pilot-scale and TWRS flowsheets.

The LLW simulant and glass formers was assumed to be purchased premixed. When it is necessary to adjust chemical makeup, including pH levels, it was assumed that chemicals will be brought in drums, and a storage vessel for such chemicals will not be needed.

3.2

Figure 2 Combustion Melter Process Flow Diagram

Figure 3
Joule-Heated Melter
Process Flow Diagram

3.2.2 Feed Preparation

Simulant Receipt Tank (137/237)

Vendors will deliver pre-mixed simulated LLW to the pilot plant and unload it into a 24,000-gallon simulant receipt tank. This capacity will permit more than one week of continuous operation. Because this vessel will remain outside and the simulant will have high salt concentration, keeping constituents dissolved will require a heating and insulation system. A desire for operating flexibility and the need to handle hazardous constituents require that the vessel have stainless steel construction, containment dikes, and a vent system to draw off vapors. Verifying and adjusting simulant composition will require tank penetrations for sampling, monitoring instruments, and adding solids and liquids. Operators will have to remove all tank contents before final decommissioning and possibly between batches; therefore, the vessel must have a large opening that will permit entry for cleaning.

The receipt tank will require a system to transfer feed from the vendor's truck or railroad car to the vessel. The average tanker truck holds approximately 4,000 gallons; filling the simulant-storage tank will therefore require approximately 5 tankers. The logistics of connecting and disconnecting tankers suggests that delivering feed by rail may prove more convenient.

Dry Frit/Silica Hopper (142/242)

Vendors will deliver dry chemicals as well as simulated LLW. These chemicals may include dry frit, silica, or other glass formers. Operators will store chemicals required to adjust the feed to a storage area inside the facility, but some chemicals, such as glass formers, will arrive in large volumes and will require storage outside the high bay area.

The Pilot Plant will have a Dry Chemical Handling and Storage Area with equipment to unload dry chemicals from a tanker or railroad car into a storage hopper. If the melter runs 7 days between deliveries, the hopper must have a capacity of at least 35 m³. The feed preparation system will prepare two batches of feed per week. To transfer one batch of feed in one hour, the conveyance system will move glass formers to the Feed Preparation tank at 350 kg/min. Since dry chemicals will present a dusting hazard, the dust collection system must maintain a vacuum in the hopper and the conveyance systems.

Feed Preparation Tank (118/218)

Operators will begin preparing feed by transferring the simulated LLW into the Feed Preparation Tank. This vessel will hold 10,000 gallons, enough for 3.5 days of operation without recharge. Vendor-supplied information indicates that slurry homogeneity will require an agitator with a 15 hp motor and two Hastelloy™ C276 impellers.

Since LLW will arrive in the facility at 6 M, and the melter will process feed at 10 M, the vessel must supply enough heat to concentrate the feed from 6 M to 10 M by evaporating water. Researchers assumed for the preconceptual design that the evaporation will not require more than 4 hours, and thus the heating coils must supply 150,000 Btu/min. During evaporation, vapor leaving the tank will pass through a demister, a condenser with 150,000 Btu/min cooling capacity, and another demister. The

condenser and both demisters will have stainless steel construction. Condensate will drain to a 3,000-gallon Condensate Collection Tank.

Operators will complete the feed makeup by combining glass formers with the simulated LLW concentrate. The dry addition conveyor will transport dry frit or silica into the Feed Preparation Tank. Weight-sensing capabilities in the conveyor system will ensure an accurate delivery. Small quantities of other chemicals may need to be added by means of a test and adjustment loop, which will be incorporated with the Feed Preparation Tank.

Transferring 3.5 days worth of feed to the Melter Feed Tank in one hour will require a transfer pump with 100-gallon per minute capacity. Such a pump will use 3-in. lines and consume approximately 75 scfm of air at 90 psi.

Melter Feed Tank (120/220)

The Melter Feed Tank will hold 7,500 gallons. Vendor-supplied information indicates that slurry homogeneity will require an agitator with a 15 hp agitator with Hastelloy™ C276 impellers and a stainless steel shaft. The vessel will require temperature control, level detection, and sampling ports. Transferring feed into the melter will require a pulseless metering pump that can deliver 120 gallons per hour. To avoid settling of particulates and glass formers, the Melter Feed Tank will be placed in close proximity to the Melter and a pump with a high discharge pressure will be used. The pump will have 3/4-in. inlet and outlet with a Hastelloy™ C body and tungsten carbide check valve balls and seats. Leak detection capability behind the pump diaphragms is necessary to avoid permanent damage to the pump.

Condensate Collection Tank (128/228)

Concentrating the feed sodium concentration from 6 M to 10 M will release approximately 2,500 kg/d of water; vitrification will generate an additional 3,000 kg/d from the Joule-heated melter and 6,250 kg/d from the combustion system. This water can leave the facility as steam or as condensate. Since the pilot plant will permit operational flexibility, the facility must allow for variations in the amount of water that condenses in the off gas system.

Concentration requires evaporating water in the Feed Preparation Tank, condensing in the condenser, and draining to the Condensate Collection Tank (128), from which water may go to the Evaporator (145), which will discharge it to the vessel vent system (138 - 141) as steam. Water can also return to the slurry receipt tank or be used to flush the HEME or the HEMF.

3.2.3 Melter

Joule-Heated Melter (201)

The assumption was made under this preconceptual design that the Joule-heated melter is functionally identical to the Small-Scale High Temperature Melter described in Perez et al. (1994). The melter will be scaled to 5,000 kg/d, have 64 ft² of melt surface area, and use four molybdenum electrodes. It will require 1,200 kW to melt glass at 1,350°C. The plenum temperature will probably remain between 500 and 700°C during operation. The melter will emit approximately 530 scfm of non-condensable off gas and 1.12 kg/min of water vapor. Off gas will pass through a film cooler that will add approximately 200 scfm of air. The design allows for an off-gas flow rate of 1,000 scfm. Consequently, maintaining a flow velocity greater than 60 ft/sec will require 8-inch ducts.

Combustion Melter (101)

This design study was based on a combustion melter similar the one built and tested by Vortec. While it may not necessarily have a counter-rotating vortex combustor and a cyclone melter, the operating characteristics are assumed to be equivalent. This unit will consume 50,000 BTU/min to produce 5,000 kg/d of glass. Oxidizing the fuel will require approximately 33,000 kg/d of air heated to 260°C. Preheating combustion air will require greater compressed-air capacity and a system for heating the air. The flame will burn at 1,650°C and off gas will exit at 1,450°C. Since the LLW-simulant tests with the Vortec melter produced nearly 5,000 kg/d, they provide accurate estimates of the pilot-scale system's off-gas composition and flow rate. The Vortec data suggest that a combustion melter will generate about 500 scfm of non-condensable off gas (Vortec, 1993). The Small-Scale High Temperature Melter tests did not provide an accurate estimate of off-gas flow rates; therefore, the design assumes the non-condensable off-gas flow rates for the Joule-heated melter will equal those of the combustion melter minus the amount of CO₂ generated as a result of oxidizing the fuel. In addition to non-condensable off gases, the combustion melter also emits more water vapor, due to hydrocarbon oxidation. The combustion melter emits about 6,252 kg/d of water vapor; the Joule-heated unit releases only about 3,000 kg/d. The greater flow of non-condensable off gas and water vapor and higher off-gas temperature make the off-gas processing equipment of the combustion melter significantly more expensive.

3.2.4 Off-Gas Processing

Off-gas processing will begin by passing the stream through a quench tower that can process 1,000 scfm. Off gas from the Joule-heated melter will probably enter at approximately 200°C, but if the film cooler failed, the gas temperature could reach 700°C. For cost estimating, the design assumes a primary gas temperature of 700°C. The combustion system will deliver combustion products at 1,425 °C.

After passing through the quench tower, off gas will enter a hydrosonic scrubber/separator. This unit and the quench tower will work together to remove water, cool the off gas, and decrease particulate loading. Since the combustion melter will have hotter off gas, higher water content, and greater particulate loading, the Quench Tower for the combustion melter must be more elaborate and expensive than those of the Joule-heated melter.

From the hydrosonic scrubber/separator, off gas will enter a high efficiency mist eliminator (HEME), a preheater, and a high efficiency metal fiber (HEMF) filter. These components will remove all solid matter and water droplets from the stream before it enters the NO_x reducer. Preliminary calculations indicate the Joule-heated system emits approximately 135 kg/d of NO_x, and the combustion melter will generate about 860 kg/d. This greater flow will require a more elaborate NO_x reducer for the combustion system. The preconceptual design assumes the NO_x reducer will decrease [NO_x] by 90 %. After NO_x reduction, off gas will pass through a blower and leave the facility through a stack.

Water that condenses in or becomes entrapped by the off-gas scrubbing equipment, including wash water, will drain to the Scrubber Catch Tank (113), which will also receive water that has condensed in the quench tower and the hydrosonic scrubber/separator. Because water content differs between the Joule-heated and combustion processes, the respective melters will require a 4,000-gallon and 7,000-gallon Scrubber Catch Tanks to collect all the water from the off gas during 3.5 days of operation.

The Quench Water Pump (114/214) can transfer condensate to the Evaporator or to the Heat Exchanger (116/216) and Filtration system for cooling and removal of particulates before the condensate enters the Quench Tower (104/204) or the Hydrosonic Scrubber/Separator (105/205). The Recycle Sludge Pump B (117/217) will recycle sediment from the Scrubber Catch Tank to the Feed Preparation Tank (118/218). Detailed specifications for these pumps appear in the Equipment Specifications list.

3.2.5 Glass Handling Systems

Glass will flow from the melter into canisters. To prevent possible devitrification, cooling coils in the canister holder will permit cooling of the glass at a controlled rate. The canister transport systems will probably be much less sophisticated than those used at Savannah River and West Valley, because LLW waste does not require the elaborate shielding and remote handling of HLW glass. No provisions for handling cullet were included in this study.

3.3 Support Systems

Engineering judgement and experience with similar facilities provided the basis for support system specifications. In some instances, specifications include governing regulations

3.3.1 Building

The building will be rectangular with annexes for dry chemical handling, HVAC equipment, and Off-gas and Vessel Vent Blowers. The structure will have a steel frame and a sheet-metal exterior.

High Bay

Dimensions: 60 ft wide by 50 deep ft by 70 ft high

Stairwells: 2; see layout

Roll up door dimensions: 20 ft by 30 ft Truck entrance

Freight Elevator Capacity = 2,000 lb

Insulation in accordance with DOE and Uniform Building Code standards.

Control Room

Dimensions: 15 ft by 21 ft

Restroom per Uniform Building Code.

Design will accommodate offices for administrative, engineering, and operations personnel. The offices will not be in the process area but in the facility or nearby. Sufficient restrooms, lunch room space, and lockers will exist. Office and work station space will exist for operations and shift supervision.

Dry Chemical Handling Area

Dimensions: 20 ft by 40 ft by 25 ft

Roll up doors: 2 (one for entering, one for leaving)

Blower Room

Dimensions: 8 ft by 16 ft by 8 ft

Concrete

Vessels will require a catch basin.

Pad placement: As necessary

Drains

Floors will slope to a low-point drain where non-hazardous chemical usage permits free draining. Areas that may require cleanup of hazardous chemicals will have flat floors with collection trenches that drain to a low point. Process and non-process drains will not connect. The drain systems will prevent backflow. Curbs around process equipment and areas that handle hazardous chemicals will contain spills.

Floor Drains Process drain piping will comply with ANSI B31.1-1983 (ANSI/ASME 1983). Drains will route liquid waste to collection tanks located within the process area. Flow detectors will monitor drain and tank status.

Sanitary Drains Sanitary drains will comply with the *Uniform Plumbing Code* (ICBO 1988).

Storm Drains Storm drains will comply with DOE Order 6430.1A (DOE 1989).

Chemical Drains Chemical drains will serve the chemical makeup and main process area. Drains

will route chemical waste in accordance with DOE Order 6430.1A (DOE 1989) to suitable retention facilities and separate organic, inorganic, and caustic and acids.

Service Vents Service vents will not connect to process vents.

Sanitary Vents Sanitary vents will comply with DOE Order 6430.1A (DOE 1989) and remain independent of service or process vents.

3.3.2 HVAC System

Control Room

The HVAC system will maintain the area at $72^{\circ}\text{F} \pm 5^{\circ}$. Humidity will remain below 50% to protect electronic equipment. The control room contains no large heat loads. Lighting and electronic equipment will create a small heat load.

High Bay

The high bay is a full-time work location, so that temperature control is necessary. The building will consume 15,000 lb/hr of steam, but most of this energy will leave the facility through the closed-loop energy-transport system and the cooling tower. This system should lose $< 5\%$ of the transported heat to the building. The melter will lose approximately 10% (120 kW) of its heat to the area; large motors will add about 160 kW, and hot glass containers will contribute approximately 100 kW. The equipment may not operate for lengthy periods during the winter, so maintenance of comfortable working conditions will require heating.

3.3.3 Piping and Vessels

Embedded and Rack Piping

For ease of maintenance and flexibility, the facility will minimize use of embedded piping. Rack piping will remain in accordance with ANSI/ASME B31.3 1987 (ANSI/ASME 1987). Process piping will be easily removable. Permanently installed process piping will have a service life equal to that of the facility. Rack and embedded piping installations will meet seismic requirements. Embedded lines will have adequate spares or be replaceable.

Other Piping

Other piping will use bolted flanges, flex hoses, orifices, and block valves to expedite maintenance. Piping for sprinkler systems will comply with NFPA standards (NFPA 1990). Piping for cold chemicals or instrument air will comply with ANSI 831.1 (ANSI/ASME 1983), B31.3 (ANSI/ASME 1987), or B31.9 (ANSI/ASME 1982). Cylinder gas piping will comply with Compressed Gas Association guidelines. Piping identification will comply with OSHA standards. The facility will separate potable water supplies from other water supplies and use backflow-preventers to comply with the *Uniform Plumbing Code* (ICBO 1988).

3.3.4 Electrical

Electrical designs will conform to NFPA 70-1990, National *Electrical Code* (NFPA 1990); *ANSI C2 Handbook* (ANSI 1987); and DOE Order 6430.1A (DOE 1989). Use of aluminum conductors may require further evaluation. Electrical design will conform to the following provisions.

- Load centers and motor control centers will supply power.
- An engine-driven motor generator set(s), or equivalent, will deliver standby power to load centers.
- Separate enclosure will contain the standby load centers.
- Standby power-source controls will automatically activate and transfer selected loads to standby power on loss of normal power.
- Standby power will maintain exhaust airflow for hazardous fumes, critical process monitoring and mixing in selected vessels, emergency lighting, compressed air service, crane operations, continuous air monitors, stack and effluent monitoring equipment, computers, alarms, process instrumentation and controls, and the MOG System.
- The Uninterruptible Power Supply (UPS) will provide emergency power to the computer(s), alarms, critical equipment, process instrumentation, and emergency lighting circuits. A UPS will operate where continuity proves essential.
- Lightning protection/grounding will comply with DOE Order 6430.1A (DOE 1989).
- Electrical equipment for the process areas will meet NFPA 70-1990, Article 500 (NFPA 1990).
- Panels will have 25 percent expansion capacity.
- Spare conduit and tray space will include expansion considerations.

3.3.5 Lighting

Normal lighting will comply with the *IES Lighting Engineers Handbook*. New emergency lighting will comply with NFPA 70 and 101 (NFPA 1990) codes.

3.3.6 Waste Handling

Liquid Waste

A process sewer will route hazardous liquid waste and process water to processing and retention facilities.

Cooling Water

An effluent sewer for closed-loop process cooling water will route facility cooling water to disposal facilities. The cooling water system will permit measuring flow rate and toxicity, and diverting the

stream for treatment.

Steam Condensate

Steam condensate not in contact with the process will drain to a steam condensate sewer. Flash tanks will operate in areas where high-pressure condensate contacts low-pressure condensate. The steam condensate system will permit measurement of condensate toxicity and diversion of the stream for treatment.

Sanitary Sewer

The sanitary sewer will permit 7-day/week, 24-hour/day operation for the maximum number of people that may use the facility.

3.3.7 Raw and Sanitary Water

Sanitary (potable) water will comply with WAC-248-54 (WAC 1988) and the NFPA (NFPA 1990) and American Water Works Association (AWWA) standards. In accordance with DOE Order 6430.1A (DOE 1989), sanitary water will not contact nonpotable water. An auxiliary water supply will meet process equipment requirements. Raw water will supply cooling-tower makeup. The sanitary water system will supply the fire-suppression system.

3.3.8 Bottled Gases

Bottled nitrogen gas may be required as a purge gas for the melter electrodes. However, it was not considered in this design study due to insufficient information.

3.3.9 Cranes

Cranes and hoists will conform to ANSI Standards Series B30 (ANSI/ASME 1983, 1985, 1987) and the *Specifications for Electric Overhead Traveling Cranes* (CMAA 1983). New installations will have maintenance platforms.

High Bay Crane

- Main Hoist Capacity: 25 tons
- Auxiliary Hoist Capacity: 5 tons

Dry Chemical Handling Area Crane

- Capacity: 2 tons
- Cranes will allow removal of critical components.

3.3.10 Compressed Air

High pressure air will operate at 100 psig and have a sufficiently low dew point to prevent condensation in the piping. Air will remain free of particulates and oil.

Instrument air will have a dew point of 38 °F at 100 psig; prove free of moisture, oil ($< 1 \text{ p/M}$), and particulates; and comply with HPS-DG-405-I. The dew point at atmospheric pressure will be approximately -10°F.

Breathing air will conform to specifications for compressor-supplied breathing air systems as presented in OSHA 1910.134 (29 CFR 1910). This system will remain in the process and chemical makeup areas. Self-contained breathing apparatus may operate in lieu of a breathing-air system.

3.4 Design Life

The facility will have a 15-year design life. Components and systems will have design lives based on safety, operability, maintainability, and economy.

3.5 Location

The facility location will comply with guidelines in DOE Order 6430.1A (DOE 1989). Locating the facility will require evaluating the following site specific factors:

- utilities/Site services
- process waste streams
- effluent streams
- site interferences
- environmental and safety considerations
- maintenance facilities
- analytical laboratory facilities
- accessibility
- office and personnel facilities and or space for new ones

3.6 Integration

The location will permit connection to existing railroads (if required), roadways, utilities, and waste handling facilities. The location will minimize interference with existing underground encasements, piping, radioactive contamination, or burial grounds.

3.7 Decommissioning

The pilot plant will permit removing and decommissioning equipment, structural modifications, and barriers at the end of the facility's mission. The design will incorporate the following principles to the extent practicable. In non-hazardous chemical areas, floors will slope toward drains. Hazardous chemical areas will have flat, non-porous floors that contain wash-down collection trenches that drain to low-point collection systems that will not mix with other drain systems. Drains and similar piping will have provisions for cleaning. Piping will slope and contain no traps except for those required to isolate the process. Adequate overhead clearance will allow moving equipment above installed piping. Aisles will permit equipment transfer.

4.0 Safety

4.1 Hazardous Substances

The facility will permit safely handling and processing anticipated hazardous substances. Zones where operators might use toxic chemicals for maintenance, cleaning, neutralization of spills, or fire protection will have emergency first aid stations.

4.2 Industrial Safety

Safety showers and eyewash stations will exist in appropriate locations. Protection from hot fluids and high voltage interfaces (i.e., melter electrodes) will exist. Protection against hydrogen explosion will exist, if required.

4.3 Fire Protection

The design will include fire protection, detection, alarm, and suppression. Alarms will notify a local fire station in case of any events. No combustible materials or volatile liquids will enter the facility without approval. Fire protection systems will meet NFPA codes (NFPA 1990) and DOE Order 6430.1A (DOE 1989).

4.3.1 Sprinklers

A sprinkler system, in compliance with NFPA codes (NFPA 1990) and DOE Order 6430.1A (DOE 1989), will protect the facility against fire damage. Certain electrical systems may require stand-alone Halon fire protection systems.

4.3.2 Alarms

A central alarm panel in the main entrance will connect to the local fire department. The panel will indicate fire location and other relevant information. An annunciator will sound in the control room. The system will transmit alarms to the fire station by radio alarm masterbox in accordance with DOE-RL Order 5480.7A, *Fire Protection* (DOE-RL 1988). Emergency signals will sound throughout the facility.

4.4 Environmental Protection and Compliance

Design will comply with DOE Order 6430.1A (DOE 1989).

4.5 Risks

The design will have passive configurations, unique connections, and fill station separation for each chemical service to prevent mixing incompatibles. The effect of all hazards will appear in a hazards analysis. Hazards that require further design, prevention, or mitigation will appear in a preliminary safety analysis.

5.0 Cost Estimates

5.1 General

In preparing conceptual designs for combustion and Joule-heated melter systems, the low-level waste stream composition, LLW glass specifications, and engineering judgement were used to determine flow rates and compositions for all waste streams entering and leaving the facility. The basis for these values appears in Appendix A. After determining mass balances, vendors were contacted to identify process equipment that would allow the facility to perform as expected. Vendors also supplied the costs for these components.

After choosing process equipment, PNL engineers worked with an estimating team from Kaiser Engineers Hanford to estimate the cost of a pilot plant with a combustion or Joule-heated melter. This work fell under Job Number Z285SAA/95CMBS. The detailed cost estimate appears in Appendix D, along with summary spreadsheets. The evaluation determined a combustion melter system would cost approximately \$25,860,000, while a Joule-heated system would cost approximately \$23,020,000. The estimate then included a 50% contingency which brought the combustion system to \$38,800,000 and the Joule-heated system to \$34,530,000.

The Joule-heated system proves less expensive for a variety of reasons. First, the combustion system generates more water vapor. Processing this requires a larger quench tower, and increased capacity for the condensate processing system. Second, the combustion melter emits hotter off gas, which forces the off gas system to use materials that can withstand extreme temperatures. Higher temperatures also require a greater capacity not only for cooling water but for air conditioning. Furthermore, the combustion system produces more non condensible off gas, and thus it requires a higher capacity off-gas system. Finally, the combustion system generates more NO_x . Consequently, this system must have a more elaborate NO_x reduction system.

The combustion melter must have a larger and more sophisticated off-gas processing system. As the cost of equipment increases, so do the costs for engineering, construction management, project management, installation and instrumentation. After considering the combustion melter's increased equipment requirements and the other associated cost increases, the actual cost difference between the two melters is probably greater than that presented here.

5.2 Assumptions

Estimating the costs of the pilot-scale systems requires making a number of assumptions. These appear below:

- The study used current KEH craft rates as issued by KEH Finance on 10/1/93. These include fringe benefits, labor insurance, taxes and travel, per Hanford Site Stabilization Agreement, Appendix A (9/6/93). Non craft rates come from the 1994 fiscal year budget liquidation rates as issued by KEH Finance on 10/1/93.

- Technical services and craft overhead are a composite percentage based on the KEH estimating billing schedule, revision 16 dated 10/1/93.
- The percentage for onsite construction labor is 93% for shop work and 134% for field work.
- Fixed price contractor overhead, profit, bond and insurance costs apply at the following percentages: labor 53%, Material 5%, equipment 5% and subcontracts 10%.
- The study uses 1995 dollars with no provisions for escalation.
- The estimate does not include costs for connecting water, electricity or communications lines.
- Engineering will cost 40% and construction management will cost 10% of the prices of the equipment and facility, project management will require 10% of the entire project.
- The study does not include allowances for delays.
- The estimate assumes overhead profit is 53% for labor, 5% each for material and equipment, and 10% for subcontract.
- Buildings fall into category III.
- Installation factors include piping and valves within the room where the equipment operates.
- Instrumentation will cost 25% of the equipment price.

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In addition to the above standards, subsequent design will use OSHA standards, National Consensus codes, and standards developed by ASME, American Society for Testing Materials, ANSI, American Concrete Institute, Instrument Society of America, AWWA, and IEEE.

Appendix A.

Mass Balances

Appendix A

Mass Balances

The Preconceptual Design assumes the pilot-scale system will use a combustion or a Joule-heated melter. Both will use the same feed to produce the same glass, but each will produce different flow rates of non-condensable off gas and water vapor. Furthermore, off gases will differ in composition. The Joule-heated system will include a film cooler, while the combustion system will not. The mass balance will combine air added by the film cooler to the melter off gas to determine the total flow to the Joule-heated melter's off-gas processing equipment.

LLW Simulant Flow Rate at 6 M Na⁺

Feed processing begins with 6 M Na⁺ feed. Evaporating the water brings the [Na⁺] up to 10 M. Mass balance calculations begin by determining the flow rates of all constituents of the 6 M simulated LLW.

Assume

The melter produces 5 metric tons/day of glass.

All Na⁺ from the LLW forms glass.

6 M LLW has a density of 1.31 kg/l (Lokken 1994).

Since LLW glass has 20 weight % Na₂O (Perez 1994), and glass formers do not contain Na⁺ (Perez 1994), LLW must supply 1,000 kg of Na₂O/d.

$$F_{\text{GlassNa}_2\text{O}} = 1,000 \text{ kg/d}$$

$$MW_{\text{Na}} = 22.989 \text{ g/mol}$$

$$MW_{\text{Na}_2\text{O}} = 22.989 \text{ g/mol} \times 2 + 15.9994 \text{ g/mol}$$

$$MW_{\text{Na}_2\text{O}} = 61.978 \text{ g/mol}$$

$$F_{\text{GlassNa}} = F_{\text{GlassNa}_2\text{O}} \times n_{\text{Na}}/n_{\text{Na}_2\text{O}} \times MW_{\text{Na}}/MW_{\text{Na}_2\text{O}}$$

$$F_{\text{GlassNa}} = 1,000 \text{ kg of Na}_2\text{O/day} \times 2 \text{ mol Na/mol Na}_2\text{O} \times 22.989 \text{ g/mol}/61.978 \text{ g/mol}$$

$$F_{\text{GlassNa}} = 741.736 \text{ kg of Na/d}$$

$$F_{\text{GlassNa}} = F_{\text{6MLLWNa}}$$

$$F_{6\text{MLLWN}_2} = 741.736 \text{ kg of Na/d}$$

$$V_{6\text{MLLW}} = F_{6\text{MLLWN}_2} \times 1,000 \text{ g/l kg} \times 1/\text{MW}_{\text{Na}} \times 1/[\text{Na}^+]_{\text{LLW}}$$

$$V_{6\text{MLLW}} = 741.736 \text{ kg Na}^+/\text{d} \times 1,000 \text{ g/kg} \times 1 \text{ mol}/22.989 \text{ g} \times 1 \text{ l}/6 \text{ mol of Na}^+$$

$$V_{6\text{MLLW}} = 5,377.28 \text{ l/d}$$

$$F_{6\text{MLLW}} = V_{6\text{MLLW}} \times \rho_{6\text{MLLW}}$$

$$F_{6\text{MLLW}} = 5,377.28 \text{ l/d} \times 1.31 \text{ kg/l}$$

$$F_{6\text{MLLW}} = 7,044.24 \text{ kg/d}$$

Table A.1. Composition & Flow Rate of LLW at 6 M Na⁺

X	[X]	F _{X,LLW}	Additive	MW _{Additive}
Al ⁺³	0.612 M	88.79 kg/day	Al(NO ₃) ₃ x 9H ₂ O	375.14 g/mol
Ca ⁺²	0.0006 M	0.14 kg/day	Ca(NO ₃) ₂ x 4H ₂ O	236.16 g/mol
Cl ⁻	0.0960 M	18.30 kg/day	NaCl	58.45 g/mol
CO ₃ ⁻²	0.1620 M	52.28 kg/day	Na ₂ CO ₃	106.00 g/mol
Cr ⁺³	0.0052 M	1.46 kg/day	Cr(NO ₃) ₃ x 9H ₂ O	400.17 g/mol
Cs ⁺	0.0102 M	7.29 kg/day	CsNO ₃	194.91 g/mol
F ⁻	0.1500 M	15.32 kg/day	NaF	41.988 g/mol
Fe ⁺³	0.0005 M	0.14 kg/day	Fe(NO ₃) ₃ x 9H ₂ O	404.01 g/mol
H ₂ O	50.263 M	4,865.01 kg/day	H ₂ O	18.00 g/mol
IO ₃ ⁻	0.0102 M	9.59 kg/day	NaIO ₃	197.98 g/mol
K ⁺	0.300 M	63.08 kg/day	KOH	56.10 g/mol
Mg ⁺²	0.00062 M	0.08 kg/day	Mg(NO ₃) ₂ x 6H ₂ O	256.41 g/mol
Mn ⁺²	0.00025 M	0.07 kg/day	Mn(NO ₃) ₂	178.94 g/mol
Mo ⁺⁶	0.0102 M	5.26 kg/day	Na ₂ MoO ₄ x 2H ₂ O	241.95 g/mol
Na ⁺	6.000 M	741.74 kg/day		
NO ₂ ⁻	1.0020 M	247.88 kg/day	NaNO ₂	69.00 g/mol
NO ₃ ⁻	1.9020 M	643.16 kg/day		
OH ⁻	2.2980 M	210.07 kg/day	NaOH	39.99 g/mol
PO ₄ ⁻³	0.0258 M	13.18 kg/day	NaH ₂ PO ₄ x H ₂ O	138.00 g/mol
SO ₄ ⁻²	0.0258 M	13.33 kg/day	Na ₂ SO ₄	142.06 g/mol
Sr ⁺²	0.0102 M	4.81 kg/day	SrCl ₂	158.52 g/mol
TOC	0.8100 M	52.27 kg/day	Na ₄ EDTA	416.20 g/mol
Total	NA	7,044.24 kg/day	Not Applicable	

LLW Simulant Flow at 10 M Na⁺

Determine the flow rate of 10 M LLW.

Assume

The melter produces 5 metric tons/day of glass.

All Na⁺ from the LLW forms glass.

10 M LLW has a density of 1.42 kg/l (Lokken 1994).

Since LLW glass has 20 weight % Na₂O (Perez 1994), and glass formers do not contain Na⁺ (Perez 1994), LLW must supply 1,000 kg of Na₂O/day.

$$F_{\text{GlassNa}_2\text{O}} = 1,000 \text{ kg/day}$$

$$MW_{\text{Na}} = 22.989 \text{ g/mol}$$

$$MW_{\text{Na}_2\text{O}} = 22.989 \text{ g/mol} \times 2 + 15.9994 \text{ g/mol}$$

$$MW_{\text{Na}_2\text{O}} = 61.978 \text{ g/mol}$$

$$F_{\text{GlassNa}} = F_{\text{GlassNa}_2\text{O}} \times \text{mol Na/mol Na}_2\text{O} \times MW_{\text{Na}}/MW_{\text{Na}_2\text{O}}$$

$$F_{\text{GlassNa}} = 1,000 \text{ kg of Na}_2\text{O/d} \times 2 \text{ mol Na/mol Na}_2\text{O} \times 22.989 \text{ g/mol}/61.978 \text{ g/mol}$$

$$F_{\text{GlassNa}} = 741.736 \text{ kg of Na/d}$$

$$F_{\text{GlassNa}} = F_{10\text{MLLWNa}}$$

$$F_{10\text{MLLWNa}} = 741.736 \text{ kg of Na/d}$$

$$V_{10\text{MLLW}} = F_{10\text{MLLWNa}} \times 1,000 \text{ g/kg} \times 1/MW_{\text{Na}} \times 1/[\text{Na}^+]_{\text{LLW}}$$

$$V_{10\text{MLLW}} = 741.736 \text{ kg Na}^+/\text{d} \times 1,000 \text{ g/kg} \times 1 \text{ mol}/22.989 \text{ g} \times 1 \text{ l}/10 \text{ mol of Na}^+$$

$$V_{10\text{MLLW}} = 3,226.48 \text{ l/day}$$

$$F_{10\text{MLLW}} = V_{10\text{MLLW}} \times \rho_{10\text{MLLW}}$$

$$F_{10\text{MLLW}} = 3,226.48 \text{ l/d} \times 1.42 \text{ kg/l}$$

$$F_{10\text{MLLW}} = 4,581.60 \text{ kg/d}$$

Table A.2. 10 M Na⁺LLW Composition & Flow Rate

X	[X]	F _{X10M LLW}
Al ⁺³	1.02 M	88.79 kg/day
Ca ⁺²	0.00105 M	0.14 kg/day
Cl ⁻	0.160 M	18.30 kg/day
CO ₃ ⁻²	0.27 M	52.28 kg/day
Cr ⁺³	0.0087 M	1.46 kg/day
Cs ⁺	0.017 M	7.29 kg/day
F ⁻	0.25 M	15.32 kg/day
Fe ⁺³	0.00077 M	0.14 kg/day
H ₂ O	41.3657 M	2,402.37 kg/day
IO ₃ ⁻	0.017 M	9.59 kg/day
K ⁺	0.50 M	63.08 kg/day
Mg ⁺²	0.00103 M	0.08 kg/day
Mn ⁺²	0.00042 M	0.07 kg/day
Mo ⁺⁶	0.017 M	5.26 kg/day
Na ⁺	10.0 M	741.74 kg/day
NO ₂ ⁻	1.67 M	247.88 kg/day
NO ₃ ⁻	3.17 M	634.16 kg/day
OH ⁻	3.83 M	210.07 kg/day
PO ₄ ⁻³	0.043 M	13.18 kg/day
SO ₄ ⁻²	0.043 M	13.33 kg/day
Sr ⁺²	0.017 M	4.81 kg/day
TOC	1.35 M	52.27 kg/day
Total	NA	4,581.60 kg/day

Water Lost to Evaporation

$$F_E = F_{6MLLW} - F_{10MLLW}$$

$$F_E = 7,044.24 \text{ kg/day} - 4,581.60 \text{ kg/day}$$

$$F_E = 2,462.64 \text{ kg/day}$$

Glass Former Flow Rate

Determine the ratio of glass formers to glass, M_{GF}/M_{Glass} . Perez 1994 presents chemicals in the glass formers and the weight percentages of the oxides.

$$M_{SiO_2}/M_{GF} = 75.85 \text{ g of SiO}_2/100 \text{ g of glass former oxides}$$

and

$$M_{SiO_2}/M_{Glass} = 55.91 \text{ grams of SiO}_2/100 \text{ grams of glass}$$

$$M_{GF}/M_{glass} = M_{SiO_2}/M_{Glass} \times M_{Oxides}/M_{SiO_2}$$

$$M_{GF}/M_{Glass} = 55.91 \text{ g of SiO}_2/100 \text{ g of glass} \times 100 \text{ g of glass former}/75.86 \text{ g of SiO}_2$$

$$M_{GF}/M_{Glass} = 0.737 \text{ glass former/glass}$$

Next determine the glass former flow rate.

$$F_{GF} = F_{Glass} \times M_{GF}/M_{Glass}$$

$$F_{GF} = 5,000 \text{ kg/d} \times 0.737$$

$$F_{GF} = 3,685.07 \text{ kg of glass former oxides/d}$$

Glass Former Composition by Oxide (Perez 1994)

Perez 1994 describes adding SiO_2 , $Al(OH)_3$, H_3BO_3 and $CaCO_3$ but gives the weight percentages of SiO_2 , Al_2O_3 , B_2O_3 and CaO . To track constituents, we have to convert oxide weight percentages to the weight percentages of Al^{+3} , B^{+3} , Ca^{+2} , CO_3^{-2} and OH^- .

Table A.3. Glass Former Weight Percentage by Oxide

Oxide	wt %	Flow Rate
SiO ₂	75.86 wt %	2,795.49 kg/day
Al ₂ O ₃	11.93 wt %	439.63 kg/day
B ₂ O ₃	6.79 wt %	250.22 kg/day
CaO	5.42 wt %	199.73 kg/day
Glass Former	100.00 wt %	3,685.07 kg/day

Convert oxide flow rates into elemental flow rates.

Al⁺³

$$F_{\text{GFAI2O3}} = 439.63 \text{ kg/d}$$

$$MW_{\text{Al2O3}} = 2 \text{ mol Al/mol Al}_2\text{O}_3 \times 26.9815 \text{ g/mol Al} + 3 \text{ mol O/mol Al}_2\text{O}_3 \times 15.9994 \text{ g/mol O}$$

$$MW_{\text{Al2O3}} = 101.96 \text{ g/mol}$$

$$F_{\text{GFAI}} = F_{\text{GFAI2O3}} \times MW_{\text{Al}}/MW_{\text{Al2O3}} \times 2 \text{ mol Al}^{+3}/1 \text{ mol Al}_2\text{O}_3$$

$$F_{\text{GFAI}} = 439.63 \text{ kg/d} \times 26.9815 \text{ g/mol}/101.96 \text{ g/mol} \times 2 \text{ mol Al}^{+3}/1 \text{ mol Al}_2\text{O}_3$$

$$F_{\text{GFAI}} = 232.67 \text{ kg/day}$$

B⁺³

$$F_{\text{GFB2O3}} = 250.22 \text{ kg/d}$$

$$MW_{\text{B2O3}} = 2 \text{ mol B/mol B}_2\text{O}_3 \times 10.811 \text{ g/mol} + 3 \text{ mol O/mol B}_2\text{O}_3 \times 15.9994 \text{ g/mol}$$

$$MW_{\text{B2O3}} = 69.66 \text{ g/mol}$$

$$F_{\text{GFB}} = F_{\text{GFB2O3}} \times MW_{\text{B}}/MW_{\text{B2O3}} \times 2 \text{ mol B}^{+3}/1 \text{ mol B}_2\text{O}_3$$

$$F_{\text{GFB}} = 250.22 \text{ kg/d} \times (10.811 \text{ g/mol}/69.66 \text{ g/mol}) \times 2 \text{ mol B}^{+3}/1 \text{ mol B}_2\text{O}_3$$

$$F_{\text{GFB}} = 77.67 \text{ kg/day}$$

Ca⁺²

$$F_{\text{GFCaO}} = 199.73 \text{ kg/d}$$

$$MW_{GFCaO} = 1 \text{ mol Ca/mol CaO} \times 40.08 \text{ g/mol} + 1 \text{ mol O/mol CaO} \times 15.9994 \text{ g/mol}$$

$$MW_{CaO} = 56.079 \text{ g/mol}$$

$$F_{GFCa} = F_{GFCaO} \times MW_{Ca}/MW_{CaO}$$

$$F_{GFCa} = 199.73 \text{ kg/d} \times 40.08 \text{ g/mol}/56.079 \text{ g/mol}$$

$$F_{GFCa} = 142.74 \text{ kg/day}$$

$$CO_3^{2-}$$

$$F_{GFCaO} = 199.73 \text{ kg/d}$$

$$F_{GFCO3} = F_{GFCaO} \times MW_{CO3}/MW_{GFCaO}$$

$$F_{GFCO3} = 199.73 \text{ kg/d} \times 60.00 \text{ g/mol}/56.079 \text{ g/mol}$$

$$F_{GFCO3} = 213.69 \text{ kg/day}$$

$$OH^-$$

$$F_{GFOH1} = F_{GFAI} \times MW_{OH}/MW_{Al} \times 3 \text{ mol OH}^-/1 \text{ mol Al}^{+3}$$

$$F_{GFOH1} = 232.52 \text{ kg/d} \times 17.00 \text{ g/mol}/26.9815 \text{ g/mol} \times 3 \text{ mol OH}^-/1 \text{ mol Al}_2O_3$$

$$F_{GFOH1} = 439.50 \text{ kg/day}$$

$$F_{GFOH2} = F_{GFB} \times MW_{OH}/MW_B \times 3 \text{ mol OH}^-/1 \text{ mol B}$$

$$F_{GFOH2} = 77.7 \text{ kg/d} \times (17.00 \text{ g/mol}/10.811 \text{ g/mol}) \times 3 \text{ mol OH}^-/1 \text{ mol B}$$

$$F_{GFOH2} = 366.54 \text{ kg/day}$$

$$F_{GFOH} = F_{GFOH1} + F_{GFOH2}$$

$$F_{GFOH} = 439.50 \text{ kg/day} + 366.54 \text{ kg/day}$$

$$F_{GFOH} = 806.04 \text{ kg/d}$$

Table A.4. Glass Former Weight Percentage by Component

X	wt %	F _{XGF}
Al ⁺³	5.45 weight %	232.67 kg/day
B ⁺³	1.82 weight %	77.67 kg/day
Ca ⁺²	3.34 weight %	142.74 kg/day
CO ₃ ⁻²	5.01 wt %	213.69 kg/day
OH ⁻	18.88 weight %	806.04 kg/day
SiO ₂	65.49 weight %	2,795.50 kg/day
Total	100 weight %	4,268.31 kg/day

Next determine the flow rates for Al(OH)₃, H₃BO₃ and CaCO₃.

$$F_{\text{Al(OH)}_3} = F_{\text{Al}} \times \text{MW}_{\text{Al(OH)}_3} / \text{MW}_{\text{Al}}$$

$$F_{\text{Al(OH)}_3} = 232.52 \text{ kg/d} \times 77.98 \text{ g/mol} / 26.9815 \text{ g/mol}$$

$$F_{\text{Al(OH)}_3} = 672.01 \text{ kg/d}$$

$$F_{\text{H}_3\text{BO}_3} = F_{\text{B}} \times \text{MW}_{\text{H}_3\text{BO}_3} / \text{MW}_{\text{B}}$$

$$F_{\text{H}_3\text{BO}_3} = 77.7 \text{ kg/d} \times 61.811 \text{ g/mol} / 10.811 \text{ g/mol}$$

$$F_{\text{H}_3\text{BO}_3} = 444.24 \text{ kg/d}$$

$$F_{\text{CaCO}_3} = F_{\text{Ca}} + F_{\text{CO}_3}$$

$$F_{\text{CaCO}_3} = 142.74 \text{ kg/d} + 213.69 \text{ kg/d}$$

$$F_{\text{CaCO}_3} = 356.43 \text{ kg/d}$$

Table A.5. Glass Former Weight Percentage by Additive

Additive	wt %	F_{Additive}
$\text{Al}(\text{OH})_3$	15.74 wt %	672.01 kg/day
CaCO_3	8.35 wt %	356.43 kg/day
H_3BO_3	10.41 wt %	444.24 kg/day
SiO_2	65.50 wt %	2,795.50 kg/day
Glass Former	100.00 wt %	4,268.18 kg/day

Melter Feed Flow Rate

Assume the melter feed density is 1.7 kg/l (Perez 1994).

$$F_{\text{MF}} = F_{\text{IOMLLW}} + F_{\text{GF}}$$

$$F_{\text{MF}} = 4,581.6 \text{ kg/d} + 4,268.18 \text{ kg/d}$$

$$F_{\text{MF}} = 8,849.78 \text{ kg/d}$$

$$F_{\text{MF}} = F_{\text{MF}} \times \rho_{\text{MF}}$$

$$F_{\text{MF}} = 8,849.78 \text{ kg/d} \times 1 \text{ l/1.7 kg}$$

$$F_{\text{MF}} = 5,205.75 \text{ l/d}$$

$$F_{\text{MF}} = 5,205.75 \text{ l/d} \times 1 \text{ d/24 hr}$$

$$F_{\text{MF}} = 216.91 \text{ l/hr}$$

Feed Composition

Determine composition by calculating the Al^{+3} , B^{+3} and Ca^{+2} , CO_3^{-2} and OH^- added to the feed.

Al^{+3}

$$F_{\text{MFAI}} = F_{\text{GFAI}} + F_{\text{IOMLLWAI}}$$

$$F_{\text{MFAI}} = 232.67 \text{ kg/d} + 88.79 \text{ kg/d}$$

$$F_{\text{MFAI}} = 321.46 \text{ kg/d}$$

Ca^{+2}

$$F_{MFCa} = F_{GFCa} + F_{10MLLWCa}$$

$$F_{MFCa} = 142.74 \text{ kg/d} + 0.14 \text{ kg/d}$$

$$F_{MFCa} = 142.88 \text{ kg/d}$$

$$\text{CO}_3^{2-}$$

$$F_{MFCO3} = F_{GFCO3} + F_{10MLLWCO3}$$

$$F_{MFCO3} = 213.69 \text{ kg/d} + 52.28 \text{ kg/d}$$

$$F_{MFCO3} = 265.97 \text{ kg/d}$$

$$\text{OH}^-$$

$$F_{MFOH} = F_{GFOH} + F_{10MLLWOH}$$

$$F_{MFOH} = 806.04 \text{ kg/d} + 210.07 \text{ kg/d}$$

$$F_{MFOH} = 1,016.11 \text{ kg/d}$$

Table A.6. Feed Flow Rate

Component	Flow
Al^{+3}	321.46 kg/d
B^{+3}	77.67 kg/d
Ca^{+2}	142.88 kg/d
Cl^-	18.30 kg/d
CO_3^{-2}	265.97 kg/d
Cr^{+3}	1.46 kg/d
Cs^+	7.29 kg/d
F^-	15.32 kg/d
Fe^{+3}	0.14 kg/d
H_2O	2,402.37 kg/d
IO_3^-	9.59 kg/d
K^+	63.08 kg/d
Mg^{+2}	0.08 kg/d
Mn^{+2}	0.07 kg/d
Mo^{+6}	5.26 kg/d
Na^+	741.74 kg/d
NO_2^-	247.88 kg/d
NO_3^-	634.16 kg/d
OH^-	1,016.11 kg/d
PO_4^{-3}	13.18 kg/d
SiO_2	2,795.50 kg/d
SO_4^{-2}	13.33 kg/d
Sr^{+2}	4.81 kg/d
TOC	52.27 kg/d
Total	8,850.00 kg/d

Table A.7. Glass Composition & Flow Rate (Perez 1994)

X	wt %	F _{xg}
Al ₂ O ₃	12.00 wt %	600 kg/d
B ₂ O ₃	5.00 wt %	250 kg/d
CaO	4.00 wt %	200 kg/d
Cl	0.35 wt %	17.5 kg/d
Cr ₂ O ₃	0.04 wt %	2 kg/d
Cs ₂ O	0.15 wt %	7.5 kg/d
F	0.29 wt %	14.5 kg/d
Fe ₂ O ₃	0.003 wt %	0.15 kg/d
I	0.13 wt %	6.5 kg/d
K ₂ O	1.46 wt %	73 kg/d
MgO	0.003 wt %	0.15 kg/d
MnO	0.002 wt %	0.1 kg/d
MoO ₃	0.15 wt %	7.5 kg/d
Na ₂ O	20.00 wt %	1,000 kg/d
P ₂ O ₅	0.19 wt %	9.5 kg/d
SiO ₂	55.91 wt %	2,795.5 kg/d
SO ₃	0.21 wt %	10.5 kg/d
SrO	0.11 wt %	5.5 kg/d
Glass	100.00 wt %	5,000 kg/d

Combustion Air

The combustion melter will require preheated combustion air (CA). Flows presented below come from the mass balance that Vortec performed on its own melter (WHC PO# MJB-SVV-096473).

$$F_{CAVt} = F_{CA1} + F_{CA2} + F_{CA3} + F_{PilotBurnerAir} + F_{Transport\&AtomizingAir}$$

$$F_{CAVt} = 1,037 \text{ lb/hr} + 1,268.19 \text{ lb/hr} + 212.54 \text{ lb/hr} + 443.97 \text{ lb/hr} + 443.97 \text{ lb/hr}$$

$$F_{CAVt} = 3,406 \text{ lb/hr}$$

$$F_{CACM} = F_{CAVt} \times F_{Glass} / F_{GlassVT}$$

$$F_{\text{CACM}} = 3,406 \text{ lb/hr} \times 5,000 \text{ kg/d} / 5,601.15 \text{ kg/d}$$

$$F_{\text{CACM}} = 3,040 \text{ lb/hr} \times 0.45359 \text{ kg/lb}$$

$$F_{\text{CACM}} = 1,379 \text{ kg/hr} \times 24 \text{ hr/d}$$

$$F_{\text{CACM}} = 33,095 \text{ kg/d}$$

Combustion Melter Off-Gas

To determine off-gas composition for the pilot-scale LLW combustion melter, look at the Vortec mass balance. This information allows predicting flow rates for combustion products, particulate carryover, scrubber sediment and CO loss. The Vortec information also permits calculating the flow rate of natural gas required to melt 5 tons of glass/d.

Scaling Factor

First establish a scaling factor to scale from the Vortec to the pilot-scale LLW melter.

$$F_{\text{GlassVt}} = 514.52 \text{ lbs/hr}$$

$$F_{\text{GlassVt}} = 514.52 \text{ lbs/hr} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb}$$

$$F_{\text{GlassVt}} = 5,601.15 \text{ kg/d}$$

$$F_{\text{Glass}} = 5,000 \text{ kg/d}$$

$$S_{\text{LLW/Vt}} = F_{\text{Glass}} / F_{\text{GlassVt}}$$

$$S_{\text{LLW/Vt}} = 5,000 \text{ kg/d} / 5,601.15 \text{ kg/d}$$

$$S_{\text{LLW/Vt}} = 0.8926$$

Combustion Products (Non Condensable Off Gases & Water Vapor)

$$F_{\text{CombustionProductsVt}} = 3,313.59 \text{ lb/hr}$$

$$F_{\text{CombustionProducts}} = F_{\text{CombustionProductsVt}} \times 24 \text{ hr/day} \times 0.45359 \text{ kg/lb} \times S_{\text{LLW/Vt}}$$

$$F_{\text{CombustionProducts}} = 3,313.59 \text{ lb/hr} \times 24 \text{ hr/day} \times 0.45359 \text{ kg/lb} \times 0.8926$$

$$F_{\text{CombustionProducts}} = 3,313.59 \text{ lb/hr} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{CombustionProducts}} = 32,200.77 \text{ kg/d}$$

Particulate Carryover

$$F_{\text{ParticulateCarryoverVt}} = 14.7 \text{ lb/hr}$$

$$F_{\text{ParticulateCarryover}} = F_{\text{ParticulateCarryoverVt}} \times 24 \text{ hr/day} \times 0.45359 \text{ kg/lb} \times S_{\text{LLW/Vt}}$$

$$F_{\text{ParticulateCarryover}} = 14.7 \text{ lb/hr} \times 24 \text{ hr/day} \times 0.45359 \text{ kg/lb} \times 0.8926$$

$$F_{\text{ParticulateCarryover}} = 14.7 \text{ lb/hr} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{ParticulateCarryover}} = 142.73 \text{ kg/d}$$

Scrubber Sediment

$$F_{\text{ScrubberSedimentVt}} = 4.91 \text{ lb/hr}$$

$$F_{\text{ScrubberSediment}} = F_{\text{ScrubberSedimentVt}} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times S_{\text{LLW/Vt}}$$

$$F_{\text{ScrubberSediment}} = 4.91 \text{ lb/hr} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times 0.8926$$

$$F_{\text{ScrubberSediment}} = 4.91 \text{ lb/hr} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{ScrubberSediment}} = 47.67 \text{ kg/d}$$

CO Loss

$$F_{\text{COLossVT}} = 0.21 \text{ lb/hr}$$

$$F_{\text{COLoss}} = F_{\text{COLossVT}} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times S_{\text{LLW/Vt}}$$

$$F_{\text{COLoss}} = 0.21 \text{ lb/hr} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times 0.8926$$

$$F_{\text{COLoss}} = 0.21 \text{ lb/hr} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{COLoss}} = 2.04 \text{ kg/d}$$

Natural Gas (CH₄) Consumed

$$F_{\text{CH4Vt}} = 13.76 \text{ lb/hr} + 135.94 \text{ lb/hr} = 149.7 \text{ lb/hr}$$

$$F_{\text{CH4}} = F_{\text{Natural GasVT}} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times S_{\text{LLW/Vt}}$$

$$F_{\text{CH4}} = 149.7 \text{ lb/hr} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb} \times 0.8926$$

$$F_{\text{CH4}} = 149.7 \text{ lb/hr} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{CH4}} = 1,453.58 \text{ kg/d}$$

Water Generation

Oxidizing natural gas will generate CO_2 and H_2O as in the equation below.

$$\text{MW}_{\text{CH}_4} = 12.011 \text{ g/mol} + 4 \times 1.00794 \text{ g/mol}$$

$$\text{MW}_{\text{CH}_4} = 16.042 \text{ g/mol}$$

$$\text{MW}_{\text{H}_2\text{O}} = 2 \times 1.00794 \text{ g/mol} + 15.9994 \text{ g/mol}$$

$$\text{MW}_{\text{H}_2\text{O}} = 18.015 \text{ g/mol}$$

$$\text{MW}_{\text{CO}_2} = 12.011 \text{ g/mol} + 2 \times 15.9994 \text{ g/mol}$$

$$\text{MW}_{\text{CO}_2} = 44.0098 \text{ g/mol}$$

Calculate the moles of CH_4 required

$$F_{\text{CH}_4} = 1,453.58 \text{ kg/d} \times 1,000 \text{ g/kg} \times 1 \text{ mol of } \text{CH}_4 / 16.042 \text{ g}$$

$$F_{\text{CH}_4} = 90,610.89 \text{ mol/d}$$

Next look at water generation.

$$F_{\text{CH}_4\text{H}_2\text{O}} = F_{\text{CH}_4} \times \text{mol H}_2\text{O/mol CH}_4$$

$$F_{\text{CH}_4\text{H}_2\text{O}} = 90,610.89 \text{ mol of CH}_4/\text{d} \times 2 \text{ mol H}_2\text{O/mol CH}_4$$

$$F_{\text{CH}_4\text{H}_2\text{O}} = 181,221.79 \text{ mol of H}_2\text{O/day} \times 18.015 \text{ g/mol H}_2\text{O} \times 1 \text{ kg/1,000 g}$$

$$F_{\text{CH}_4\text{H}_2\text{O}} = 3,264.7 \text{ kg/d}$$

The combustion melter's off gas will have all the water vapor of the Joule-heated melter plus the water vapor generated through CH_4 oxidation. To determine the water vapor flow for the combustion melter, first determine water flow in the Joule-heated melter's off gas. This water will come from melter feed, EDTA oxidation and hydroxide.

Melter Feed

$$F_{\text{MFH}_2\text{O}} = 2,402.37 \text{ kg/d}$$

EDTA

$$F_{\text{EDTA}} = [\text{EDTA}]_{10\text{MLLW}} \times F_{10\text{MLLW}}$$

$$F_{\text{EDTA}} = 0.135 \text{ moles EDTA/l} \times 3,226.48 \text{ l 10 M feed/d}$$

$$F_{\text{EDTA}} = 435.57 \text{ kg/d}$$

1 mole of EDTA will form 6 moles of water

$$F_{\text{EDTAH}_2\text{O}} = F_{\text{EDTA}} \times \text{mole H}_2\text{O/mol EDTA} \times \text{MW}_{\text{H}_2\text{O}}$$

$$F_{\text{EDTAH}_2\text{O}} = 435.57 \text{ l/d} \times 6 \text{ mole H}_2\text{O/mol EDTA} \times 18 \text{ g/mol H}_2\text{O} \times 1 \text{ kg/1,000 g}$$

$$F_{\text{EDTAH}_2\text{O}} = 47.04 \text{ kg/d}$$

OH⁻

$$F_{\text{MFOH}} = F_{\text{OH}} \times \text{MW}_{\text{OH}}$$

$$F_{\text{MFOH}} = 1,016.11 \text{ kg/d} \times 1 \text{ mol OH}^-/17.00 \text{ grams} \times 1,000 \text{ grams/kg}$$

$$F_{\text{MFOH}} = 59,771.18 \text{ moles OH}^-/\text{d}$$

1 mole of OH⁻ forms 0.5 moles of H₂O

$$F_{\text{OHH}_2\text{O}} = F_{\text{MFOH}} \times \text{mole H}_2\text{O/mol OH}^- \times \text{MW}_{\text{H}_2\text{O}}$$

$$F_{\text{OHH}_2\text{O}} = 59,771.18 \text{ moles OH}^-/\text{day} \times 0.5 \text{ mole H}_2\text{O/mol OH}^- \times 18 \text{ g/mol H}_2\text{O} \times 1 \text{ kg/1,000 g}$$

$$F_{\text{OHH}_2\text{O}} = 537.94 \text{ kg/d}$$

Water Vapor in the Off-Gas of the Joule-Heated Melter

Sum the flows to determine the water vapor in the Joule-heated melter's off gas.

$$F_{\text{OGH}_2\text{OJHM}} = F_{\text{MFH}_2\text{O}} + F_{\text{EDTAH}_2\text{O}} + F_{\text{OHH}_2\text{O}}$$

$$F_{\text{OGH}_2\text{OJHM}} = 2,402.37 \text{ kg/d} + 47.04 \text{ kg/d} + 537.94 \text{ kg/d}$$

$$F_{\text{OGH}_2\text{OJHM}} = 2,987.35 \text{ kg/d}$$

Water Vapor in the Off-Gas of the Combustion Melter

To determine the water flow in the combustion melter's off gas, add the water generated from combustion.

$$F_{\text{OGH}_2\text{OCM}} = F_{\text{OGH}_2\text{OJHM}} + F_{\text{CH}_4\text{H}_2\text{O}}$$

$$F_{\text{OGH}_2\text{OCM}} = 2,987.35 \text{ kg/d} + 3,264.7 \text{ kg/d}$$

$$F_{\text{OGH}_2\text{OCM}} = 6,252.05 \text{ kg/d}$$

Non-Condensable Off Gases

First look at the combustion melter.

$$F_{\text{NCOGV}_1} = F_{\text{Combustion Products}} - F_{\text{H}_2\text{O/JHM}}$$

$$F_{\text{NCOGV}_1} = 32,200.77 \text{ kg/d} - 6,252.05 \text{ kg/d}$$

$$F_{\text{NCOGV}_1} = 25,948.72 \text{ kg/d}$$

To determine the CO_2 concentration, determine the CO_2 generated by burning the natural gas and the CO_2 generated from vitrifying LLW (Perez 1994).

Natural Gas

$$F_{\text{CH}_4\text{CO}_2} = F_{\text{CH}_4} \times \text{mol CO}_2/\text{mol CH}_4$$

$$F_{\text{CH}_4\text{CO}_2} = 90,610.89 \text{ mol of CH}_4/\text{d} \times 1 \text{ mol CO}_2/\text{mol CH}_4$$

$$F_{\text{CH}_4\text{CO}_2} = 90,610.89 \text{ mol of CO}_2/\text{d} \times 44.0098 \text{ g/mol H}_2\text{O} \times 1 \text{ kg/1,000 g}$$

$$F_{\text{CH}_4\text{CO}_2} = 3,987.76 \text{ kg/d}$$

CO_3^{2-} , CaCO_3 and EDTA will also generate CO_2 .

CO_3^{2-}

$$F_{\text{CO}_3\text{CO}_2} = F_{\text{MFCO}_3} \times \text{MW}_{\text{CO}_2}/\text{MW}_{\text{CO}_3}$$

$$F_{\text{CO}_3\text{CO}_2} = 52.28 \text{ kg/d} \times 44.0098 \text{ g/mol}/60.0092 \text{ g/mol}$$

$$F_{\text{CO}_3\text{CO}_2} = 38.34 \text{ kg/d}$$

CaCO_3

$$F_{\text{CaCO}_3\text{CO}_2} = F_{\text{MFCaCO}_3} \times \text{MW}_{\text{CO}_2}/\text{MW}_{\text{CaCO}_3}$$

$$F_{\text{CaCO}_3\text{CO}_2} = 356.43 \text{ kg/d} \times 44.0098 \text{ g/mol}/100.0876 \text{ g/mol}$$

$$F_{\text{CaCO}_3\text{CO}_2} = 156.72 \text{ kg/d}$$

EDTA

$$F_{\text{EDTACO}_2} = F_{\text{EDTA}} \times \text{mol C/mol EDTA} \times \text{MW}_{\text{CO}_2}$$

$$F_{\text{EDTACO}_2} = 436 \text{ mol/d} \times 10 \text{ mol C/mol EDTA} \times 44.0098 \text{ g/mol} \times 1 \text{ kg/1,000 g}$$

$$F_{\text{EDTACO}_2} = 191.88 \text{ kg/d}$$

CO₂ for the Combustion Melter

Sum the sources

$$F_{\text{OGCO}_2\text{CM}} = F_{\text{CO}_3\text{CO}_2} + F_{\text{CO}_3\text{CO}_2} + F_{\text{EDTACO}_2} + F_{\text{CH}_4\text{CO}_2}$$

$$F_{\text{OGCO}_2\text{CM}} = 38.34 \text{ kg/d} + 156.72 \text{ kg/d} + 191.88 \text{ kg/d} + 3,987.76 \text{ kg/d}$$

$$F_{\text{OGCO}_2\text{CM}} = 4,374.70 \text{ kg/d}$$

O₂ Required to Burn CH₄

Determine the O₂ consumed by oxidizing natural gas.

$$F_{\text{CH}_4\text{O}_2} = F_{\text{CH}_4} \times \text{mol O}_2/\text{mol CH}_4$$

$$F_{\text{CH}_4\text{O}_2} = 90,610.89 \text{ mol of CH}_4/\text{d} \times (-2 \text{ mol O}_2/\text{mol CH}_4)$$

$$F_{\text{CH}_4\text{O}_2} = -181,221.79 \text{ mol of O}_2/\text{d} \times 31.9988 \text{ g/mol O}_2 \times 1 \text{ kg}/1,000 \text{ g}$$

$$F_{\text{CH}_4\text{O}_2} = -5,798.87 \text{ kg/d}$$

H₂

Assume the $F_{\text{OGH}_2\text{CM}}$ is the same as that generated by the Joule-heated melter. This flow comes from Perez 1994.

$$F_{\text{OGH}_2\text{CM}} = F_{\text{OGH}_2\text{JHM}}$$

$$F_{\text{OGH}_2\text{CM}} = 0.59 \text{ kg/d}$$

N₂

$$F_{\text{N}_2} = F_{\text{NCOG}} \times 0.755 \text{ kg N}_2/\text{kg air} \times 24 \text{ hr/d} \times 0.45359 \text{ kg/lb}$$

$$F_{\text{N}_2} = 25,948.72 \text{ kg/d} \times 0.755 \text{ kg N}_2/\text{kg air}$$

$$F_{\text{N}_2} = 3,405.47 \text{ lb/hr} \times 0.755 \text{ kg N}_2/\text{kg air} \times 9.71 \text{ hr} \times \text{kg/d} \times \text{lb}$$

$$F_{\text{N}_2} = 19,591.28 \text{ kg of N}_2/\text{d}$$

NO

[NO] = 1000 ppm for the Vortec Test.

$$F_{\text{OGNO}} = F_{\text{NCOGCM}} \times 1,000 \text{ parts NO}/1,000,000 \text{ parts off gas}$$

$$F_{\text{OGNO}} = 25,948.72 \text{ kg/d} \times 1,000 \text{ parts NO}/1,000,000 \text{ parts off gas}$$

$$F_{\text{OGNO}} = 25.95 \text{ kg/d}$$

But the Vortec test had substantially less $([\text{NO}_2^-] + [\text{NO}_3^-])$ than actual LLW simulant.

$$[\text{NaNO}_3]_{\text{JHM}} = 501 \text{ g/l}$$

$$[\text{NaNO}_2]_{\text{JHM}} = 48.3 \text{ g/l}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{JHM}} = [\text{NaNO}_3]_{\text{JHM}} + [\text{NaNO}_2]_{\text{JHM}}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{JHM}} = 501 \text{ g/l} + 48.3 \text{ g/l}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{JHM}} = 549.3 \text{ g/l}$$

$$M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{SlurryJHM}} = 549.3 \text{ g/l} \times 1 \text{ l/1510 g of slurry}$$

$$M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{SlurryJHM}} = 0.3637$$

Next look at the Vortec Melter

$$[\text{NaNO}_3]_{\text{vt}} = 82.4 \text{ g/l}$$

$$[\text{NaNO}_2]_{\text{vt}} = 0 \text{ g/l}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{vt}} = [\text{NaNO}_3]_{\text{vt}} + [\text{NaNO}_2]_{\text{vt}}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{vt}} = 82.4 \text{ g/l} + 0 \text{ g/l}$$

$$([\text{NaNO}_3] + [\text{NaNO}_2])_{\text{vt}} = 82.4 \text{ g/l}$$

$$M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{Slurryvt}} = 82.4 \text{ g/l} \times 1 \text{ l/1250 g of slurry}$$

$$M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{Slurryvt}} = 0.06592$$

Now compare the two

$$[\text{NO}_2^- + \text{NO}_3^-]_{\text{JHM/vt}} = (M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{SlurryJHM}}) / (M_{\text{NaNO}_2 + \text{NaNO}_3} / M_{\text{Slurryvt}})$$

$$[\text{NO}_2^- + \text{NO}_3^-]_{\text{JHM/vt}} = 0.3637 / 0.06592$$

$$[\text{NO}_2^- + \text{NO}_3^-]_{\text{JHM/vt}} = 5.51$$

$$F_{\text{OGNOCM}} = F_{\text{OGNOvt}} \times [\text{NO}_2^- + \text{NO}_3^-]_{\text{JHM/vt}}$$

$$F_{\text{OGNO}} = 25.95 \text{ kg/d} \times 5.51$$

$$F_{\text{OGNO}} = 142.98 \text{ kg/d}$$

NO_2

$[\text{NO}_2] = 5,000 \text{ ppm for the Vortec Test.}$

$$F_{\text{OGN02Vt}} = F_{\text{NCOG}} \times 5,000 \text{ parts NO}_2 / 1,000,000 \text{ parts off gas}$$

$$F_{\text{OGN02Vt}} = 25,948.72 \text{ kg/d} \times 5,000 \text{ parts NO}_2 / 1,000,000 \text{ parts off gas}$$

$$F_{\text{OGN02Vt}} = 129.74 \text{ kg/d}$$

$$F_{\text{OGN02Vt}} = F_{\text{OGN02}} \times [\text{NO}_2 + \text{NO}_3]_{\text{JHM/Vt}}$$

$$F_{\text{OGN02}} = 129.74 \text{ kg/d} \times 5.51$$

$$F_{\text{OGN02}} = 714.86 \text{ kg/d}$$

N_2O

$$F_{\text{OGN20CM}} = F_{\text{OGN20JHM}}$$

$$F_{\text{OGN20CM}} = 72.34 \text{ kg/d}$$

O_2

$$F_{\text{O}_2} = F_{\text{NCOGCM}} - F_{\text{CO}} - F_{\text{OGCO2CM}} - F_{\text{H}_2} - F_{\text{N}_2} - F_{\text{NO}} - F_{\text{NO}_2} - F_{\text{N}_2\text{O}}$$

$$F_{\text{O}_2} = 25,948.72 \text{ kg/d} - 2.04 \text{ kg/d} - 4,374.70 \text{ kg/d} - 0.59 \text{ kg/d} - 19,591.28 \text{ kg/d} - 142.98 \text{ kg/d} - 714.86 \text{ kg/d} - 72.34 \text{ kg/d}$$

$$F_{\text{O}_2} = 1,049.93 \text{ kg/d}$$

Table A.8. Off-Gas Flows for the Combustion Melter

Component	Flow
CO	2.04 kg/d
CO ₂	4,374.70 kg/d
H ₂	0.59 kg/d
N ₂	19,591.28 kg/d
NO	142.98 kg/d
NO ₂	714.86 kg/d
N ₂ O	72.34 kg/d
O ₂	1,049.93 kg/d
Total	25,948.72 kg/d

Off Gas Composition for the Joule-Heated Melter

Processing LLW simulant through the high temperature melter at 16 liters/hr caused the following off-gas emissions (Perez 1994).

Table A.9. Off-Gas for the High Temperature Melter Processing LLW Simulant

x	MW _x	F ₁₆ l/hr	F _{217.4} l/hr	F _{217.4} l/hr	F _{217.4} l/hr
CO	28.01 g/mol	0.054 mol/m	0.734 mol/m	0.021 kg/m	29.60 kg/d
CO ₂	44.01 g/mol	0.039 mol/m	0.530 mol/m	0.023 kg/m	33.58 kg/d
H ₂	2.02 g/mol	0.015 mol/m	0.204 mol/m	0.000 kg/m	0.59 kg/d
N ₂	28.01 g/mol	149.65 mol/m	2,033 mol/m	56.96 kg/m	82,031 kg/d
NO	30.01 g/mol	0.217 mol/m	2.949 mol/m	0.088 kg/m	127.41 kg/d
NO ₂	46.01 g/mol	0.010 mol/m	0.136 mol/m	0.006 kg/m	9.00 kg/d
N ₂ O	44.01 g/mol	0.084 mol/m	1.141 mol/m	0.050 kg/m	72.34 kg/d
O ₂	32.00 g/mol	39.790 mol/m	540.67 mol/m	17.301 kg/m	24,913 kg/d
Total	NA	190.1 mol/m	2,583 mol/m	74.5 kg/m	107,216 kg/d

If all off-gas flows increase directly with feed flow, total off-gas flow for a 5 ton/d melter becomes unreasonably large. This discrepancy occurs because the small scale melter has relatively greater air inleakage than the large scale-melter. For this preconceptual design, assume the combustion melter and the Joule-heated melter have the same total off gas flow rate of non condensable gases, but the Joule-heated melter does not generate the CO₂ associated with methane oxidation.

Now consider the N₂.

$$n_{\text{N}_2}/n_{\text{CH}_4} = n_{\text{O}_2}/n_{\text{CH}_4} * n_{\text{N}_2}/n_{\text{O}_2}$$

$$n_{\text{N}_2} = 2 \text{ mol O}_2/\text{mol CH}_4 * 0.79 \text{ mol N}_2/ 0.21 \text{ mol O}_2$$

$$n_{\text{N}_2}/n_{\text{CH}_4} = 7.52$$

Now the equation becomes

Consequently, burning one mol of CH_4 will generate 1 mole CO_2 and 7.52 mol N_2 .

$$F_{\text{CH}_4\text{CO}_2} = F_{\text{CH}_4} \times n_{\text{CO}_2}/n_{\text{CH}_4}$$

$$F_{\text{CH}_4\text{CO}_2} = 90,610.89 \text{ mol of CH}_4/\text{d} \times 1 \text{ mol CO}_2/\text{mol CH}_4$$

$$F_{\text{CH}_4\text{CO}_2} = 90,610.89 \text{ mol of CO}_2/\text{d} \times 44.0098 \text{ g/mol CO}_2 \times 1 \text{ kg}/1,000 \text{ g}$$

$$F_{\text{CH}_4\text{CO}_2} = 3,987.76 \text{ kg/d}$$

$$F_{\text{NCOGJHM}} = F_{\text{NCOGCM}} - F_{\text{CH}_4\text{CO}_2}$$

$$F_{\text{NCOGJHM}} = 25,948.72 \text{ kg/d} - 3,987.76 \text{ kg/d}$$

$$F_{\text{NCOGJHM}} = 21,960.96 \text{ kg/d.}$$

Assume flows for gases other than O_2 and N_2 remain constant and calculate the new values for O_2 and N_2 .

$$F_{\text{NCOGJHM}} = F_{\text{COJHM}} + F_{\text{CO}_2\text{JHM}} + F_{\text{H}_2\text{JHM}} + F_{\text{NOJHM}} + F_{\text{N}_2\text{JHM}} + F_{\text{NO}_2\text{JHM}} + F_{\text{N}_2\text{OJHM}} + F_{\text{O}_2\text{JHM}}$$

$$F_{\text{N}_2\text{JHM}} + F_{\text{O}_2\text{JHM}} = F_{\text{NCOGJHM}} - F_{\text{COJHM}} - F_{\text{CO}_2\text{JHM}} - F_{\text{H}_2\text{JHM}} - F_{\text{NOJHM}} - F_{\text{NO}_2\text{JHM}} - F_{\text{N}_2\text{OJHM}}$$

$$F_{\text{N}_2\text{JHM}} + F_{\text{O}_2\text{JHM}} = 21,960.96 \text{ kg/d} - 29.6 \text{ kg/d} - 33.5 \text{ kg/d} - 0.59 \text{ kg/d} - 127.4 \text{ kg/d} - 9.0 \text{ kg/d} - 72.3 \text{ kg/d}$$

$$F_{\text{N}_2\text{JHM}} + F_{\text{O}_2\text{JHM}} = 21,688.57 \text{ kg/d}$$

$$F_{\text{N}_2\text{JHM}} = F_{\text{Air}} \times 0.755 \text{ kg N}_2/\text{kg air}$$

$$F_{\text{N}_2\text{JHM}} = 21,688.57 \text{ kg/d} \times 0.755 \text{ kg N}_2/\text{kg air}$$

$$F_{\text{N}_2\text{JHM}} = 16,374.87 \text{ kg/d}$$

$$F_{\text{O}_2\text{JHM}} = F_{\text{NCOGJHM}} - F_{\text{COJHM}} - F_{\text{CO}_2\text{JHM}} - F_{\text{H}_2\text{JHM}} - F_{\text{NOJHM}} - F_{\text{NO}_2\text{JHM}} - F_{\text{N}_2\text{OJHM}} - F_{\text{N}_2\text{JHM}}$$

$$F_{\text{O}_2\text{JHM}} = 21,960.96 \text{ kg/d} - 29.6 \text{ kg/d} - 33.5 \text{ kg/d} - 0.59 \text{ kg/d} - 127.4 \text{ kg/d} - 9.0 \text{ kg/d} - 72.3 \text{ kg/d} - 16,374.87 \text{ kg/d}$$

$$F_{\text{O}_2\text{JHM}} = 5,313.7 \text{ kg/d}$$

Table A.10. Off-Gas Flows for the Generic Joule-Heated Melter

X	F _{OGJHM}
CO	29.60 kg/d
CO ₂	33.58 kg/d
H ₂	0.59 kg/d
N ₂	16,374.87 kg/d
NO	127.41 kg/d
NO ₂	9.00 kg/d
N ₂ O	72.34 kg/d
O ₂	5,313.7 kg/d
Total	21,960.96 kg/d

References

Lokken, R. O., Martin, P. F. C., Makeup Procedures and Characterization Data for Simulated Low Level Wastes, TDD-94-151C-21-0.04E, May 1994:

Perez, J. M., Shafer, P. J., Buchmiller, W. C., Preliminary Data Package of LLW Processing in a Small-Scale High Temperature Melter, September 1994.

Phase 1 Test Results, High Capacity Melter Services for Westinghouse Hanford Company, Purchase Order MJB-SVV-096473, by Vortec Corporation, 3770 Ridge Pike, Collegeville, Pennsylvania 19426, (215) 489 - 2255, September 30th, 1993.

Combustion Melter

Mass Balance

Evaporated Overheads

$F_v = 2,462.64 \text{ kg/d}$

$H_2O = 2,462.64 \text{ kg/d}$

Glass Formers

As added

$F_{GF} = 4,268.18 \text{ kg/d}$

$Al(OH)_3 = 672.01 \text{ kg/d}$

$CaCO_3 = 356.43 \text{ kg/d}$

$H_3BO_3 = 444.25 \text{ kg/d}$

$SiO_2 = 2,795.50 \text{ kg/d}$

$F_{Natural Gas} = 1,453.58 \text{ kg/d}$

Glass Formers

as Oxides

$F_{GF_{Oxide}} = 3,685.07 \text{ kg/d}$

$Al_2O_3 = 439.63 \text{ kg/d}$

$B_2O_3 = 250.21 \text{ kg/d}$

$CaO = 199.73 \text{ kg/d}$

$SiO_2 = 2,795.49 \text{ kg/d}$

Off Gas

$F_{Oxides} = 18.23 \text{ kg/d}$

$Al_2O_3 = 7.34 \text{ kg/d}$

$B_2O_3 = 0.09 \text{ kg/d}$

$CaO = 0.00 \text{ kg/d}$

$Cl = 0.80 \text{ kg/d}$

$Cr_2O_3 = 3.85 \text{ kg/d}$

$Cs_2O = 0.23 \text{ kg/d}$

$F = 0.82 \text{ kg/d}$

$Fe_2O_3 = 0.05 \text{ kg/d}$

$I = 0.46 \text{ kg/d}$

$K_2O = 2.99 \text{ kg/d}$

$MgO = 0.00 \text{ kg/d}$

$MnO = 0.00 \text{ kg/d}$

$MoO_3 = 0.39 \text{ kg/d}$

$Na_2O = 0.00 \text{ kg/d}$

$P_2O_5 = 0.32 \text{ kg/d}$

$SiO_2 = 0.00 \text{ kg/d}$

$SO_3 = 0.61 \text{ kg/d}$

$SrO = 0.19 \text{ kg/d}$

$F_{Off Gas} = 25,948.72 \text{ kg/d}$

$CO = 2.04 \text{ kg/d}$

$CO_2 = 4,374.70 \text{ kg/d}$

$H_2 = 0.59 \text{ kg/d}$

$N_2 = 19,591.28 \text{ kg/d}$

$NO = 142.98 \text{ kg/d}$

$N_2O = 72.34 \text{ kg/d}$

$NO_2 = 714.86 \text{ kg/d}$

$O_2 = 1,049.93 \text{ kg/d}$

$F_{H_2O} = 6,252.05 \text{ kg/d}$

Simulant Receipt
Tank

Feed Prep Tank

Feed Prep Tank

Melter

6 M Na⁺ LLW
 $F_{6M Na^+ LLW} = 7,044.24 \text{ kg/d}$

$Al^{3+} = 88.79 \text{ kg/d}$
 $Ca^{2+} = 0.14 \text{ kg/d}$
 $Cl^- = 18.30 \text{ kg/d}$
 $CO_3^{2-} = 52.28 \text{ kg/d}$
 $Cr^{3+} = 1.46 \text{ kg/d}$
 $Cs^+ = 7.29 \text{ kg/d}$
 $F^- = 15.32 \text{ kg/d}$
 $Fe^{3+} = 0.14 \text{ kg/d}$
 $H_2O = 4,865.01 \text{ kg/d}$
 $IO_3^- = 9.59 \text{ kg/d}$
 $K^+ = 63.08 \text{ kg/d}$
 $Mg^{2+} = 0.08 \text{ kg/d}$
 $Mn^{2+} = 0.07 \text{ kg/d}$
 $Mo^{6+} = 5.26 \text{ kg/d}$
 $Na^+ = 741.74 \text{ kg/d}$
 $NO_2^- = 247.88 \text{ kg/d}$
 $NO_3^- = 634.16 \text{ kg/d}$
 $OH^- = 210.07 \text{ kg/d}$
 $PO_4^{3-} = 13.18 \text{ kg/d}$
 $SO_4^{2-} = 13.33 \text{ kg/d}$
 $Sr^{2+} = 4.81 \text{ kg/d}$
 $TOC = 52.27 \text{ kg/d}$

10 M Na⁺ LLW
 $F_{10M Na^+ LLW} = 4,581.60 \text{ kg/d}$

$Al^{3+} = 88.79 \text{ kg/d}$
 $Ca^{2+} = 0.14 \text{ kg/d}$
 $Cl^- = 18.30 \text{ kg/d}$
 $CO_3^{2-} = 52.28 \text{ kg/d}$
 $Cr^{3+} = 1.46 \text{ kg/d}$
 $Cs^+ = 7.29 \text{ kg/d}$
 $F^- = 15.32 \text{ kg/d}$
 $Fe^{3+} = 0.14 \text{ kg/d}$
 $H_2O = 2,402.37 \text{ kg/d}$
 $IO_3^- = 9.59 \text{ kg/d}$
 $K^+ = 63.08 \text{ kg/d}$
 $Mg^{2+} = 0.08 \text{ kg/d}$
 $Mn^{2+} = 0.07 \text{ kg/d}$
 $Mo^{6+} = 5.26 \text{ kg/d}$
 $Na^+ = 741.74 \text{ kg/d}$
 $NO_2^- = 247.88 \text{ kg/d}$
 $NO_3^- = 634.16 \text{ kg/d}$
 $OH^- = 210.07 \text{ kg/d}$
 $PO_4^{3-} = 13.18 \text{ kg/d}$
 $SO_4^{2-} = 13.33 \text{ kg/d}$
 $Sr^{2+} = 4.81 \text{ kg/d}$
 $TOC = 52.27 \text{ kg/d}$

Melter Feed
 $F_{MF} = 8,850.00 \text{ kg/d}$

$Al^{3+} = 321.46 \text{ kg/d}$
 $B^{3+} = 77.67 \text{ kg/d}$
 $Ca^{2+} = 142.88 \text{ kg/d}$
 $Cl^- = 18.30 \text{ kg/d}$
 $CO_3^{2-} = 265.97 \text{ kg/d}$
 $Cr^{3+} = 1.46 \text{ kg/d}$
 $Cs^+ = 7.29 \text{ kg/d}$
 $F^- = 15.32 \text{ kg/d}$
 $Fe^{3+} = 0.14 \text{ kg/d}$
 $H_2O = 2,402.37 \text{ kg/d}$
 $IO_3^- = 9.59 \text{ kg/d}$
 $K^+ = 63.08 \text{ kg/d}$
 $Mg^{2+} = 0.08 \text{ kg/d}$
 $Mn^{2+} = 0.07 \text{ kg/d}$
 $Mo^{6+} = 5.26 \text{ kg/d}$
 $Na^+ = 741.74 \text{ kg/d}$
 $NO_2^- = 247.88 \text{ kg/d}$
 $NO_3^- = 634.16 \text{ kg/d}$
 $OH^- = 1,016.11 \text{ kg/d}$
 $PO_4^{3-} = 13.33 \text{ kg/d}$
 $SiO_2 = 2,795.50 \text{ kg/d}$
 $SO_4^{2-} = 13.33 \text{ kg/d}$
 $Sr^{2+} = 4.81 \text{ kg/d}$
 $TOC = 52.27 \text{ kg/d}$

LLW Glass
 $F_{Glass} = 5,000 \text{ kg/d}$

$Al_2O_3 = 600 \text{ kg/d}$
 $B_2O_3 = 250.00 \text{ kg/d}$
 $CaO = 200 \text{ kg/d}$
 $Cl = 17.5 \text{ kg/d}$
 $Cr_2O_3 = 2.00 \text{ kg/d}$
 $Cs_2O = 7.50 \text{ kg/d}$
 $F = 14.50 \text{ kg/d}$
 $Fe_2O_3 = 0.15 \text{ kg/d}$
 $I = 6.5 \text{ kg/d}$
 $K_2O = 73.00 \text{ kg/d}$
 $MgO = 0.15 \text{ kg/d}$
 $MnO = 0.1 \text{ kg/d}$
 $MoO_3 = 7.50 \text{ kg/d}$
 $Na_2O = 1,000 \text{ kg/d}$
 $P_2O_5 = 9.50 \text{ kg/d}$
 $SiO_2 = 2,795.50 \text{ kg/d}$
 $SO_3 = 10.5 \text{ kg/d}$
 $SrO = 5.5 \text{ kg/d}$

Joule-Heated Melter

Mass Balance

Evaporated Overheads

$F_e = 2,462.64 \text{ kg/d}$

$H_2O = 2,462.64 \text{ kg/d}$

Glass Formers As added

$F_{GF} = 4,268.18 \text{ kg/d}$

$Al(OH)_3 = 672.01 \text{ kg/d}$

$CaCO_3 = 356.43 \text{ kg/d}$

$H_3BO_3 = 444.24 \text{ kg/d}$

$SiO_2 = 2,795.50 \text{ kg/d}$

Glass Formers as Oxides

$F_{GFoxide} = 3,685.07 \text{ kg/d}$

$Al_2O_3 = 439.63 \text{ kg/d}$

$B_2O_3 = 250.21 \text{ kg/d}$

$CaO = 199.73 \text{ kg/d}$

$SiO_2 = 2,795.50 \text{ kg/d}$

Off Gas

$F_{Oxides} = 18.23 \text{ kg/d}$

$Al_2O_3 = 7.43 \text{ kg/d}$

$B_2O_3 = 0.09 \text{ kg/d}$

$CaO = 0.00 \text{ kg/d}$

$Cl = 0.80 \text{ kg/d}$

$Cr_2O_3 = 3.85 \text{ kg/d}$

$Cs_2O = 0.23 \text{ kg/d}$

$F = 0.82 \text{ kg/d}$

$Fe_2O_3 = 0.05 \text{ kg/d}$

$I = 0.46 \text{ kg/d}$

$K_2O = 2.99 \text{ kg/d}$

$MgO = 0.00 \text{ kg/d}$

$MnO = 0.00 \text{ kg/d}$

$MoO_3 = 0.39 \text{ kg/d}$

$Na_2O = 0.00 \text{ kg/d}$

$P_2O_5 = 0.32 \text{ kg/d}$

$SiO_2 = 0.00 \text{ kg/d}$

$SO_3 = 0.61 \text{ kg/d}$

$SrO = 0.19 \text{ kg/d}$

$F_{onmass} = 21,960.96 \text{ kg/d}$

$CO = 29.60 \text{ kg/d}$

$CO_2 = 33.58 \text{ kg/d}$

$H_2 = 0.59 \text{ kg/d}$

$N_2 = 16,374.87 \text{ kg/d}$

$NO = 127.41 \text{ kg/d}$

$N_2O = 72.34 \text{ kg/d}$

$NO_2 = 9.00 \text{ kg/d}$

$O_2 = 5,313.7 \text{ kg/d}$

$F_{H_2O} = 2,987.35 \text{ kg/d}$

Primary Stream Spreadsheet

X	MW _x	F _{6MLLW}	F _{10MLLW}	F _{Feed}	X _{AOB}	MW _{XAOB}	F _{XAOB}	F _{Glass}	F _{OffGas}
Al ⁺³	26.98 g/mol	88.79 kg/d	88.79 kg/d	321.46 kg/d	Al ₂ O ₃	101.97 g/mol	607.43 kg/d	600.00 kg/d	7.43 kg/d
B ⁺³	10.81 g/mol	0.00 kg/d	0.00 kg/d	77.67 kg/d	B ₂ O ₃	69.62 g/mol	250.09 kg/d	250.00 kg/d	0.09 kg/d
Ca ⁺²	40.08 g/mol	0.14 kg/d	0.14 kg/d	142.88 kg/d	CaO	56.08 g/mol	199.91 kg/d	200.00 kg/d	-0.09 kg/d
Cl ⁻	35.45 g/mol	18.30 kg/d	18.30 kg/d	18.30 kg/d	Cl	35.45 g/mol	18.30 kg/d	17.50 kg/d	0.80 kg/d
CO ₃ ⁻²	60.01 g/mol	52.28 kg/d	52.28 kg/d	265.97 kg/d					
Cr ⁺³	52.00 g/mol	1.46 kg/d	1.46 kg/d	1.46 kg/d	Cr ₂ O ₃	151.99 g/mol	5.85 kg/d	2.00 kg/d	3.85 kg/d
Cs ⁺	132.91 g/mol	7.29 kg/d	7.29 kg/d	7.29 kg/d	Cs ₂ O	281.81 g/mol	7.73 kg/d	7.50 kg/d	0.23 kg/d
F ⁻	19.00 g/mol	15.32 kg/d	15.32 kg/d	15.32 kg/d	F	19.00 g/mol	15.32 kg/d	14.50 kg/d	0.82 kg/d
Fe ⁺³	55.85 g/mol	0.14 kg/d	0.14 kg/d	0.14 kg/d	Fe ₂ O ₃	159.69 g/mol	0.20 kg/d	0.15 kg/d	0.05 kg/d
H ₂ O	18.00 g/mol	4,865.01 kg/d	2,402.37 kg/d	2,402.40 kg/d					
IO ₃ ⁻	174.90 g/mol	9.59 kg/d	9.59 kg/d	9.59 kg/d	I	126.90 g/mol	6.96 kg/d	6.50 kg/d	0.46 kg/d
K ⁺	39.10 g/mol	63.08 kg/d	63.08 kg/d	63.08 kg/d	K ₂ O	94.20 g/mol	75.99 kg/d	73.00 kg/d	2.99 kg/d
Mg ⁺²	24.31 g/mol	0.08 kg/d	0.08 kg/d	0.08 kg/d	MgO	40.31 g/mol	0.13 kg/d	0.15 kg/d	-0.02 kg/d
Mn ⁺²	54.94 g/mol	0.07 kg/d	0.07 kg/d	0.07 kg/d	MnO	70.94 g/mol	0.09 kg/d	0.10 kg/d	-0.01 kg/d
Mo ⁺⁶	95.94 g/mol	5.26 kg/d	5.26 kg/d	5.26 kg/d	MoO ₃	143.94 g/mol	7.89 kg/d	7.50 kg/d	0.39 kg/d
Na ⁺	22.99 g/mol	741.74 kg/d	741.74 kg/d	741.74 kg/d	Na ₂ O	61.98 g/mol	999.84 kg/d	1,000.00 kg/d	-0.16 kg/d
NO ₂ ⁻	46.01 g/mol	247.88 kg/d	247.88 kg/d	247.88 kg/d					
NO ₃ ⁻	62.00 g/mol	634.16 kg/d	634.16 kg/d	634.16 kg/d					
OH ⁻	17.00 g/mol	210.07 kg/d	210.07 kg/d	1,016.11 kg/d					
PO ₄ ⁻³	94.97 g/mol	13.18 kg/d	13.18 kg/d	13.18 kg/d	P ₂ O ₅	141.58 g/mol	9.82 kg/d	9.50 kg/d	0.32 kg/d
SiO ₂	60.08 g/mol	0.00 kg/d	0.00 kg/d	2,795.50 kg/d	SiO ₂	60.08 g/mol	2,795.50 kg/d	2,795.50 kg/d	0.00 kg/d
SO ₄ ⁻²	96.06 g/mol	13.33 kg/d	13.33 kg/d	13.33 kg/d	SO ₃	80.06 g/mol	11.11 kg/d	10.50 kg/d	0.61 kg/d
Sr ⁺²	87.62 g/mol	4.81 kg/d	4.81 kg/d	4.81 kg/d	SrO	103.62 g/mol	5.69 kg/d	5.50 kg/d	0.19 kg/d
TOC	12.00 g/mol	52.27 kg/d	52.27 kg/d	52.27 kg/d					

Totals

7,044.25 kg/d 4,581.61 kg/d 8,849.95 kg/d

5,017.85 kg/d 4,999.90 kg/d 17.95 kg/d

Off-Gas Spreadsheet

Off-Gas Flow Rates for the Generic Joule-Heated Melter

T_{JHM}	1,623 K	P_{JHM}	1.05 atm
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X	MW	F @ 16 l/hr	F @ 217.4 l/hr	F @ 217.4 l/hr	F @ 217.4 l/hr	F_{JHM}	F_{JHM}	F_{JHM}
CO	28.01 g/mol	0.05 mol/m	0.73 mol/m	0.02 kg/m	29.60 kg/d	93.1 l/m	3.3 ft ³ /m	0.6 scfm
CO ₂	44.01 g/mol	0.04 mol/m	0.53 mol/m	0.02 kg/m	33.58 kg/d	67.2 l/m	2.4 ft ³ /m	0.4 scfm
H ₂	2.02 g/mol	0.02 mol/m	0.20 mol/m	0.00 kg/m	0.59 kg/d	25.9 l/m	0.9 ft ³ /m	0.2 scfm
N ₂	28.01 g/mol	37.58 mol/m	510.68 mol/m	14.31 kg/m	16,374.87 kg/d	51,488.5 l/m	1,818.3 ft ³ /m	336.1 scfm
NO	30.01 g/mol	0.22 mol/m	2.95 mol/m	0.09 kg/m	127.41 kg/d	374.0 l/m	13.2 ft ³ /m	2.4 scfm
NO ₂	46.01 g/mol	0.01 mol/m	0.14 mol/m	0.01 kg/m	9.00 kg/d	17.2 l/m	0.6 ft ³ /m	0.1 scfm
NO _x		0.23 mol/m	3.08 mol/m	0.09 kg/m	136.41 kg/d		0.0 ft ³ /m	0.0 scfm
N ₂ O	44.01 g/mol	0.08 mol/m	1.14 mol/m	0.05 kg/m	72.34 kg/d	144.8 l/m	5.1 ft ³ /m	0.9 scfm
O ₂	32.00 g/mol	9.99 mol/m	135.77 mol/m	4.34 kg/m	5,313.70 kg/d	14,627.2 l/m	516.6 ft ³ /m	95.5 scfm
Totals		38.23 mol/m	519.46 mol/m	14.50 kg/m	21,961.09 kg/d	66,837.9 l/m	2,360.4 ft ³ /m	436.3 scfm

H ₂ O	18.00 g/mol	4.59 mol/m	62.35 mol/m	1.12 kg/m	2,987.35 kg/d	14,618.8 l/m	516.3 ft ³ /m	95.4 scfm
Totals		42.82 mol/m	581.81 mol/m	15.62 kg/m	24,948.44 kg/d	81,456.7 l/m	2,876.6 ft ³ /m	531.7 scfm

Off-Gas Flow Rates for the Generic Combustion Melter

T_{CM}	1,475 K	P_{CM}	1.05 atm
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X	MW
CO	28.01 g/mol
CO ₂	44.01 g/mol
H ₂	2.02 g/mol
N ₂	28.01 g/mol
NO	30.01 g/mol
NO ₂	46.01 g/mol
N ₂ O	44.01 g/mol
O ₂	32.00 g/mol

F_{CM}	F_{CM}	F_{CM}	F_{CM}	F_{CM}
0.00 kg/m	2.04 kg/d	5.8 l/m	0.2 ft ³ /m	0.0 scfm
3.04 kg/m	4,374.70 kg/d	7,957.4 l/m	281.0 ft ³ /m	57.2 scfm
0.00 kg/m	0.59 kg/d	23.4 l/m	0.8 ft ³ /m	0.2 scfm
13.61 kg/m	19,591.28 kg/d	55,991.4 l/m	1,977.3 ft ³ /m	402.2 scfm
0.10 kg/m	142.98 kg/d	0.3 l/m	0.0 ft ³ /m	0.0 scfm
0.50 kg/m	714.86 kg/d	1,243.8 l/m	43.9 ft ³ /m	8.9 scfm
0.05 kg/m	72.34 kg/d	131.6 l/m	4.6 ft ³ /m	0.9 scfm
0.73 kg/m	1,049.93 kg/d	2,626.5 l/m	92.8 ft ³ /m	18.9 scfm
Totals	25,948.72 kg/d	67,980.1 l/m	2,400.7 ft ³ /m	488.3 scfm

H ₂ O	18.00 g/mol	13.86 mol/m	188.28 mol/m	3.39 kg/m	6,252.05 kg/d	27,804.9 l/m	981.9 ft ³ /m	199.7 scfm
Totals		13.86 mol/m	188.28 mol/m	21.41 kg/m	32,200.77 kg/d	95,785.1 l/m	3,382.6 ft ³ /m	688.0 scfm

Appendix B

Equipment Specifications

Appendix B

Equipment Specifications

Combustion Melter System	Joule-Heated Melter System	Comparison
101 Combustion Melter	201 Joule-Heated Melter	Different
	202 Film Cooler	Different
104 Quench Tower	204 Quench Tower	Different
105 Hydrosonic Scrubber/Separator	205 Hydrosonic Scrubber/Separator	Same
107 High Efficiency Mist Eliminator	207 High Efficiency Mist Eliminator	Same
108 Preheater	208 Preheater	Same
109 HEMF Filter	209 HEMF Filter	Same
110 Selective Catalytic NO _x Reducer	210 Selective Catalytic NO _x Reducer	Same
111 Off-Gas Blower	211 Off-Gas Blower	Same
112 Stack	212 Stack	Same
113 Scrubber Catch Tank	213 Scrubber Catch Tank	Different
114 Quench Water Pump	214 Quench Water Pump	Different
115 Scrub Solution Filter	215 Scrub Solution Filter	Same
116 Heat Exchanger	216 Heat Exchanger	Different
117 Recycle Sludge Pump A	217 Recycle Sludge Pump A	Same
118 Feed Prep Tank	218 Feed Prep Tank	Same
119 Feed Transfer Pump	219 Feed Transfer Pump	Same
120 Melter Feed Tank	220 Melter Feed Tank	Same
121 Melter Feed Pump	221 Melter Feed Pump	Same
122 Simulant Pump	222 Simulant Pump	Same
123 Chemical Addition Pump	223 Chemical Addition Pump	Same
124 Dry Addition Conveyor	224 Dry Addition Conveyor	Same
125 Demister A	225 Demister A	Same
126 Condenser	226 Condenser	Same
127 Demister B	227 Demister B	Same
128 Condensate Collection Tank	228 Condensate Collection Tank	Same
129 Condensate Pump	229 Condensate Pump	Same
	230 Melter Electrical System	Different
131 Product Canister	231 Product Canister	Same
132 Canister Mounting System	232 Canister Mounting System	Same
133 Cooling Tower	233 Cooling Tower	Same
137 Simulant Receipt Tank	237 Simulant Receipt Tank	Same
138 Vessel Vent (VV) Blower	238 Vessel Vent (VV) Blower	Same
140 VV Preheater	240 VV Preheater	Same
141 VV HEPA Filter	241 VV HEPA Filter	Same
142 Dry Frit/Silica Hopper	242 Dry Frit/Silica Hopper	Same
143 Dust Collection System	243 Dust Collection System	Same
144 Canister Storage Rack	244 Canister Storage Rack	Same
145 Evaporator	245 Evaporator	Same
146 Recycle Sludge Pump B	246 Recycle Sludge Pump B	Same
147 Makeup Water Pump	247 Makeup Water Pump	Same
148 Fuel Storage Tank		
149 Scrubber Catch Tank Agitator	249 Scrubber Catch Tank Agitator	Different
150 Feed Preparation Tank Agitator	250 Feed Preparation Tank Agitator	Same
151 Melter Feed Tank Agitator	251 Melter Feed Tank Agitator	Same
152 Condensate Collection Tank Agitator	252 Condensate Collection Tank Agitator	Same
153 Simulant Receipt Tank Agitator	253 Simulant Receipt Tank Agitator	Same

B.1 Functional Restrictions

- Pre-conceptual design will permit a rough order of magnitude cost estimate.
- Produce glass at 5 metric tons/day.
- Process a non-radioactive LLW simulant.
- Non site specific.
- NO_x generation ≤ 40 mt/yr.
- Design will evaluate Joule-heated and combustion melters.

B.2 Combustion Melter System Equipment

B.2.1 101 Combustion Melter

Specifications	Basis
Counter rotating vortex combuster	Vortec literature
Cyclone melter	Vortec literature
$Q_{CM} = 50,000$ Btu/min	Calculations below
$F_{\text{NaturalGas}} = 1,450$ kg/d	Vortec literature
$F_{\text{CombustionAirCM}} = 33,095$ kg/d	Mass balance calculations
$T_{\text{CombustionAir}} = 500$ °F	Vortec literature
$T_{\text{CombustionAir}} = 5^\circ\text{C}/9^\circ\text{F}(500^\circ\text{F} - 32^\circ\text{F})$	
$T_{\text{CombustionAir}} = 260^\circ\text{C}$	
$T_{\text{Flame}} = 3,000$ °F	Vortec literature
$T_{\text{Flame}} = 5^\circ\text{C}/9^\circ\text{F}(3,000^\circ\text{F} - 32^\circ\text{F})$	
$T_{\text{Flame}} = 1,650^\circ\text{C}$	
$T_{\text{OffGas}} = 2,600$ °F	Vortec literature
$T_{\text{OffGas}} = 5^\circ\text{C}/9^\circ\text{F}(2,600^\circ\text{F} - 32^\circ\text{F})$	
$T_{\text{OffGas}} = 1,425^\circ\text{C}$	

Calculations

$$Q_{VT} = Q_{\text{CombustionProducts}} + Q_{\text{UnburnedCOLoss}} + Q_{\text{Glass}} + Q_{\text{Melter}} + Q_{\text{Sep/Res}} + Q_{\text{CRVWalls}} + Q_A + Q_B$$

$$Q_{VT} = 2.19 \text{ MMBtu/h} + 0.001 \text{ MMBtu/h} + 0.36 \text{ MMBtu/h} + 0.08 \text{ MMBtu/h} + 0.21 \text{ MMBtu/h} + 0.20 \text{ MMBtu/h} + 0.08 \text{ MMBtu/h} + 0.06 \text{ MMBtu/h}$$

$$Q_{VT} = 3.181 \text{ MMBtu/h}$$

$$Q_{VT} = 3.181 \text{ MMBtu/h} * 1 \text{ h/60 min}$$

$$Q_{VT} = 0.0530166 \text{ MMBtu/min}$$

$$Q_{VT} = 53,016.6 \text{ Btu/min}$$

$$Q_{CM} = Q_{VT} * F_{GlassCM} / F_{GlassVT}$$

$$Q_{CM} = 53,016.6 \text{ Btu/min} * 5,000 \text{ kg/d} / 5,601.15 \text{ kg/d}$$

$$Q_{CM} = 47,326.52 \text{ Btu/min}$$

Round up

$$Q_{CM} = 50,000 \text{ Btu/min}$$

B.2.2 102 Film Cooler

The combustion melter will not have a film cooler.

B.2.3 104 Quench Tower

Specifications	Basis
$F_{InCM} \approx 1,000 \text{ scfm}$	Film Cooler Calculations
$T_{InCM} = 1,425^{\circ}\text{C}$	Vortec literature
$F_{ParticulatesCM} = 150 \text{ kg/d}$	See mass balance calculations
$F_{H2OInCM} = 6,500 \text{ kg/d}$	See mass balance calculations
Materials: Hastelloy C	Off-gas corrosivity
Liquid System: Recycle, neutralize & filter	Common practice
Diameter: 42"	Beco quote
Height: 15'	Beco quote
$F_{ExitGasCM} = 2,400 \text{ ACFM}$	Beco quote
$F_{RecycleCM} = 50 \text{ gpm}$	Beco quote
$F_{EvaporationCM} = 6 \text{ gpm}$	Beco quote
Cost: \$ 80,000	Beco quote

Cost includes Hastelloy quench tower and spray nozzles, non-metallic recycle pump and tank, pH control system with chemical feed pump, piping and controls.

Address: Post Office Box 443, Oakmont, Pennsylvania 15139

Contact: J. Michael Hobi

Phone: (412) 828-6144

B.2.4 105 Hydrosonic Scrubber/Separator

Specifications	Basis
$F_{\text{Scrubber/Separator}} \approx 1,000 \text{ scfm}$	Mass Balance Calculations
$F_{\text{Particulates}} = 150 \text{ kg/d}$	Mass balance calculations
Material: Stainless steel and fiberglass	Engineering judgement

Suggested Vendor: John Zink Co. Cost: \$200,000.

B.2.5 107 High Efficiency Mist Eliminator

Specifications	Basis
Flow: 1,000 scfm	Mass balance calculations
Material: Stainless steel	
Face velocity = 10 ft/min	Phone Quote 3/20/95
Vessel Height = 10'	Phone Quote 3/20/95
Vessel Diameter = 2'	Phone Quote 3/20/95
Efficiency: 99.95% at $< 3 \mu$	Phone Quote 3/20/95
P = 10" H ₂ O	Phone Quote 3/20/95

A large deluge spray nozzle is needed for batch cleaning capability. Manufacturer: Monsanto Enviro-Chem Systems Inc. Model: HE Plus (media). Price: \$ 32,000. Vendor: Christian Power Equipment.

B.2.6 108 Preheater

Specifications	Basis
$F_{\text{PreheaterIn}} = 1,000 \text{ scfm}$	Mass Balance Calculations
$F_{\text{PreheaterOut}} = 1,000 \text{ scfm}$	Mass Balance Calculations
$\Delta T = 10^\circ\text{C}$	Engineering judgement
Phases: 3	Engineering judgement
Voltage = 480 V	Engineering judgement
Control: Fully modulated	Engineering judgement
Power = 16 kW	Vendor's literature
Material: Stainless steel	Corrosive process stream

Suggested vendor: Vemco. Contact: Craig at (509) 534-9533. Cost: \$ 1,500/unit

B.2.7 109 HEMF Filter

Specifications	Basis
$F_{\text{HEMFFilter}} = 1,000 \text{ scfm}$	Mass Balance Calculations
Media: Stainless steel mesh	Cleaning capability

Suggested Manufacturer: Pall. Cost: \$ 110,000.

B.2.8 110 Selective Catalytic NO_x Reducer

Specifications	Basis
ARI Econ-NO _x SCR DeNO _x System	Engineering judgement
$F_{\text{AirIn}} = 1,000 \text{ scfm}$	Mass Balance Calculations
$F_{\text{NOxDesCM}} = 772.06 \text{ kg/d}$	See calculations below.

Suggested Vendor: Wheelabrator Clean Air Systems Inc. Phone: (708) 706-6900

Calculations

Determine an acceptable rate of NO_x destruction.

Assume the NOx destruction system reduces NOx flow by 90 % (Greg Whyatt).

$$F_{\text{NOxCM}} = F_{\text{NOCM}} + F_{\text{NO2CM}}$$

$$F_{\text{NOxCM}} = 142.98 \text{ kg/d} + 714.86 \text{ kg/d}$$

$$F_{\text{NOxCM}} = 857.84 \text{ kg/d}$$

$$\Delta F_{\text{NOXDesCM}} = E_{\text{Destruction}} * F_{\text{NOXCM}}$$

$$\Delta F_{\text{NOXDesCM}} = 0.90 * 857.84 \text{ kg/d}$$

$$\Delta F_{\text{NOXDesCM}} = 772.06 \text{ kg/d}$$

B.2.9 111 Off-Gas Blower

Specifications	Basis
$F_{\text{OffGasBlower}} = 1,000 \text{ scfm}$	Mass Balance Calculations
$\Delta P = -7" \text{ Hg}$	Engineering judgement
$T_{\text{In}} = 250^{\circ}\text{F}$	Engineering judgement

Suggested vendor: Nelson Mechanical. Contact: Mark Tollefsen. Phone: (509) 747-3296

B.2.10 112 Stack

Specifications	Basis
Materials: Sheet metal	Common practice
The stack will exhaust 6' above the top of the building.	Common practice
$d_{\text{Stack}} = 1'$	Calculations below
$V_{\text{Flow}} = 100 \text{ ft/min}$	Common practice

The stack will decrease worker exposure to off gas to an acceptable level.

Calculations

Assume the process emits 1,000 scfm, and the vessel vent system also emits 1,000 scfm. Gases exit the stack at 90 C and 60 ft/sec.

$$90^{\circ}\text{C} = 363 \text{ K}$$

$$25^{\circ}\text{C} = 298 \text{ K}$$

$$A_{\text{Ducts}} = 2,000 \text{ ft}^3/\text{min} * 1 \text{ min}/60 \text{ sec} * 1 \text{ sec}/60 \text{ ft} * 363 \text{ K}/298 \text{ K}$$

$$A_{\text{Ducts}} = 0.676 \text{ ft}^2$$

$$A_{\text{Ducts}} = \pi(d/2)^2$$

$$(d/2)^2 = A_{\text{Ducts}}/\pi$$

$$d_{\text{Ducts}} = (4 * A_{\text{Ducts}}/\pi)^{1/2}$$

$$d_{\text{Ducts}}' = (4 \cdot 0.676 \text{ ft}^2 / \pi)^{1/2}$$

$$d_{\text{Ducts}}' = 0.93 \text{ ft} \cdot 12 \text{ in/ft}$$

$$d_{\text{Ducts}}' = 11.14 \text{ ft}$$

Round up

$$d_{\text{Ducts}} = 12''$$

B.2.11 113 Scrubber Catch Tank

Vessel Volume = 7,000 gallons

Operating Volume = 5,800 gallons. See calculations below.

Dimensions = 10' diameter X 12' tall

Wall Thickness = 0.5"

Bottom Geometry = ASME Dish

Material: stainless steel

Cooling coils will withdraw 2,000 Btu/min.

Penetrations:

6 x 3" top for instruments

1 x 2" top for adding liquids

1 x 1' top for an agitator

1 x 3' side for cleanout and inspection

1 x 2" bottom for draining

Quality Assurance: ASME pedigree, inspection and certifications

Cost = \$ 75,000

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

Assume the Scrubber Catch Tank collects all water that would exit the melter through the off gas system. This assumption will generate a conservative estimate of the required Scrubber Catch Tank capacity.

$$F_{\text{OffGasH}_2\text{OCH}} = 6,252.05 \text{ kg/d}$$

$$F_{\text{OffGasH}_2\text{OCH}} = 6,252.05 \text{ kg/d} * 1 \text{ l/kg} * 1 \text{ gal/3.78514 l}$$

$$F_{\text{OffGasH}_2\text{OCH}} = 1,651.62 \text{ g/d}$$

The vessel should have capacity for 3.5 days of operation between vessel evacuations.

$$V_{\text{ScrubberCatchTankCM}} = 1,651.62 \text{ g/d} * 3.5 \text{ days}$$

$$V_{\text{ScrubberCatchTankCM}} = 5,780.67 \text{ gallons}$$

To allow for head space, round up to 7,000 gallons

$$V_{\text{ScrubberCatchTankCM}} = 7,000 \text{ gallons}$$

B.2.12 114 Quench Water Pump

Specifications	Basis
Pump Type: Duriron Centrifugal	Engineering judgement
$F_{\text{QuenchWaterPumpCM}} = 100 \text{ gpm}$	Quench tower requirements
Cost: \$ 4,500	Duriron quote

B.2.13 115 Scrub Solution Filter

Specifications	Basis
Filtration Media: Sintered stainless steel	Engineering judgement
$F_{\text{ScrubberSolutionFilter}} = 100 \text{ gpm}$	
$\Delta P_{\text{ScrubberSolutionFilter}} = 10 \text{ lb/in}^2$	Engineering judgement
Surface Area: ?	Determined by testing
Pore size: ?	Determined by testing
Material of Construction: Stainless steel	Engineering judgement

Suggested Manufacturer: Mott Metallurgical Corporation. Phone: (203) 677-7311. Cost: \$ 300,000 EDL has a similar system which cost \$210,000 in 1994.

B.2.14 116 Heat Exchanger

Specifications	Basis
$F_{\text{Cooling Water}} = 100 \text{ gpm}$	See calculations below
$F_{\text{HeatExchangerCM}} = 2 \text{ g/min}$	See calculations below
$Q_{\text{HeatExchanger}} = 4,800,000 \text{ BTU/hr}$	Corrosive process solution
Material: stainless steel	Engineering judgement
$T_{\text{in}} = 180^{\circ}\text{F}$	Engineering judgement
$T_{\text{Out}} = 85^{\circ}\text{F}$	

Calculations

$$Q_{\text{HeatExchanger}} = 100 \text{ gal/min} * 8.3 \text{ lb/gal} * 1.0 \text{ BTU/lb} * ^{\circ}\text{F} * (180^{\circ}\text{F} - 85^{\circ}\text{F}) * 60 \text{ m/h}$$

$$Q_{\text{HeatExchanger}} = 4,731,000 \text{ BTU/hr}$$

$$Q_{\text{HeatExchanger}} = 4,731,000 \text{ BTU/hr} * 1 \text{ h/60 min}$$

$$Q_{\text{HeatExchanger}} = 78,850 \text{ BTU/min}$$

$$Q_{\text{HeatExchanger}} = 80,000 \text{ BTU/min}$$

B.2.15 117 Recycle Sludge Pump A

Specifications	Basis
Type: Air-operated double diaphragm	Diaphragm pumps can operate on sludges
$F_{\text{RecycleSludgePumpACM}} = 125 \text{ gpm}$	See calculations below
$D_{\text{RecycleSludgePumpACM}} = 3" \text{ Female NPT}$	Wilden® literature
$P_{\text{RecycleSludgePump}} = 10 \text{ psi}$	Engineering judgement
$F_{\text{Air}} = 100 \text{ scfm}$	Wilden® literature
Housing: Stainless steel	Corrosive process solution
Elastomers: Nordel™	Corrosive process solution

The air must remain free from particulates, but the pump will have a filter to provide redundancy. The air inlet line will have an oiler. The facility will accommodate the oily discharge that will exit through the air exhaust. Cost: \$ 4,000. Wilden® M15.

Calculations

Recycle Sludge Pump A will discharge the contents of the Scrubber Catch Tank in one hour.

$$F_{\text{RecycleSludgePumpACM}'} = V_{\text{ScrubberCatchTank}} / t_{\text{Batch}}$$

$$F_{\text{RecycleSludgePumpACM}'} = 5,780.67 / 60 \text{ min}$$

$$F_{\text{RecycleSludgePumpACM}'} = 96.34 \text{ gpm}$$

Round up

$$F_{\text{RecycleSludgePumpACM}} = 125 \text{ g/min}$$

B.2.16 118 Feed Prep Tank

Specifications	Basis
Vessel Volume = 10,000 gallons	
Operating Volume = 6,500 gallons	
Dimensions = 11' diameter X 14' tall	
Wall Thickness = 0.5"	
Bottom Geometry = ASME Dish	
Material: stainless steel	
<u>Penetrations:</u>	
6 x 3" top for instruments	
1 x 3" top for adding liquids	
1 x 1' top for adding solids	
1 x 2' top for an agitator	
1 x 3' side for cleanout and inspection	
1 x 3" bottom for draining	
Heating coils will evaporate 15 gpm of water.	
$t_{\text{Residence}} = 3.5 \text{ days}$	Engineering judgement
$Q_{\text{FeedPrepTank}} = 250,000 \text{ BTU/min}$	
Quality Assurance: ASME pedigree, inspection and certifications	
Cost = \$ 91,000	

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

Operators add glass formers to 6 M Na⁺ LLW then boil down to 10 M Na⁺.

First look at the 6 M Na⁺ LLW simulant.

$$M_{6MLLW} = F_{6MLLW} * t_{Residence}$$

$$M_{6MLLW} = 7,044.24 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{6MLLW} = 24,654.84 \text{ kg}$$

$$V_{6MLLW} = M_{6MLLW} * \rho_{6MLLW}$$

$$V_{6MLLW} = 24,654.84 \text{ kg} * 1 \text{ l} / 1.31 \text{ kg}$$

$$V_{6MLLW} = 18,820 \text{ l} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{6MLLW} = 4,972 \text{ gal}$$

Next look at the glass formers

$$M_{GlassFormers} = F_{GlassFormers} * t_{Residence}$$

$$M_{GlassFormers} = 4,268.18 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{GlassFormers} = 14,938.63 \text{ kg}$$

$$V_{GlassFormers} = M_{GlassFormers} * \rho_{GlassFormers}$$

$$V_{GlassFormers} = 14,938.63 \text{ kg} * 1 \text{ l} / 2.65 \text{ kg}$$

$$V_{GlassFormers} = 5,637.22 \text{ l} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{GlassFormers} = 1,489.2 \text{ gal}$$

$$V_{Feed} = V_{6MLLW} + V_{GlassFormers}$$

$$V_{Feed} = 4,972 \text{ gal} + 1,489.2 \text{ gal}$$

$$V_{Feed} = 6,461.2 \text{ gal}$$

The feed will foam substantially so we must allow substantial head volume

$$V_{FeedPrepTank} = 10,000 \text{ gal}$$

B.2.17 119 Feed Transfer Pump

Specifications	Basis
Pump Type: Air-operated double diaphragm	Engineering judgement
Pump Size = 3"	Wilden Pump Charts
Solids handling up to 1/4" diameter particles	Slurry characteristics
$F_{\text{FeedTransferPump}} = 100 \text{ gpm}$	See calculations below.
$D_{\text{FeedTransferPump}} = 3" \text{ Female NPT}$	Wilden literature
Estimated Cost: \$ 4,000	Wilden M15
$P_{\text{FeedTransferPump}} = 20 \text{ psi}$	Engineering judgement
Housing: Stainless steel	Wilden literature
Elastomers: Nordel™	Wilden literature
$F_{\text{Air}} = 200 \text{ scfm}$	Wilden literature
$3 \text{ ft/s} < V_{\text{Feed}} < 10 \text{ ft/s}$	SIPT experience

Required transfer time < 1 hr.

Calculations

The Feed Transfer Pump will discharge one batch of feed to the Melter Feed Tank in 1 hour.

$$F_{\text{Feed}} = F_{\text{Feed}} * \rho_{\text{Feed}}$$

$$F_{\text{Feed}} = 8,850 \text{ kg/d} * 1 \text{ l/1.66 kg}$$

$$F_{\text{Feed}} = 5,331.32 \text{ l/d}$$

$$F_{\text{Feed}} = 5,331.32 \text{ l/d} * 1 \text{ gal/3.7854 l}$$

$$F_{\text{Feed}} = 1,408.39 \text{ gal/d}$$

$$V_{\text{Feed}} = F_{\text{Feed}} * t_{\text{Residence}}$$

$$V_{\text{Feed}} = 1,408.93 \text{ gal/d} * 3.5 \text{ d}$$

$$V_{\text{Feed}} = 4,929.37 \text{ gal}$$

$$F_{\text{FeedTransferPump}} = V_{\text{Feed}} / t_{\text{Batch}}$$

$$F_{\text{FeedTransferPump}} = 4,929.37 \text{ gal} / 60 \text{ min}$$

$$F_{\text{FeedTransferPump}} = 82.16 \text{ gpm}$$

Round up

$$F_{\text{FeedTransferPump}} = 100 \text{ gpm}$$

B.2.18 120 Melter Feed Tank

Specifications	Basis
Vessel Volume = 7,500 gallons	See calculations below
Operating Volume = 5,000 gallons	
Dimensions = 10' diameter X 13' tall	
Wall Thickness = 0.5"	
Bottom Geometry = ASME Dish	
Material: stainless steel	

Penetrations:

6 x 3" top for instrumentation

1 x 3" top for adding liquids

1 x 1' top for adding solids

1 x 2' top for an agitator

1 x 3' side for cleanout and inspection

1 x 3" bottom for draining

Heating coils sufficient to maintain slurry near boiling.

Rigorous mixing of a very abrasive slurry will occur in the vessel.

Quality Assurance: ASME pedigree, inspection and certifications

Cost = \$ 75,000

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

$$M_{\text{MelterFeed}} = F_{\text{MelterFeed}} * t_{\text{Residence}}$$

$$M_{\text{MelterFeed}} = 8,850.00 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{\text{MelterFeed}} = 30,975 \text{ kg}$$

$$V_{\text{MelterFeed}} = M_{\text{MelterFeed}} * \rho_{\text{MelterFeed}}$$

$$V_{\text{MelterFeed}} = 30,975 \text{ kg} * 1 \text{ l/1.66 kg}$$

$$V_{\text{MelterFeed}} = 18,659.64 \text{ l}$$

$$V_{\text{MelterFeed}} = 18,659.64 \text{ l} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{\text{MelterFeed}} = 4,929.37 \text{ gal}$$

Round up

$$V_{\text{FelterFeedTank}} = 7,500 \text{ gal}$$

B.2.19 121 Melter Feed Pump

Specifications	Basis
Type: Metering	
Capacity: 0 - 125 gpm	See calculations below
Feed System: Direct feed	
Model: PL-16138-09A91 (EV-1)	
Description: Pulseless metering pump for caustic and frit	
Check Valve materials: tungsten carbide	
Body Material: Hastelloy C	
Diaphragm Material: Gylon	
Diaphragm Leak Detection System	
Remaining components: stainless steel	
Power: 3/4 horsepower	
Cost: \$6,125	

Manufacturer: The Duriron Company, Inc. West Valley City, UT. Phone: (801) 972-9513.
Contact: Gary B. Kaiser.

Calculations

$$V_{\text{MelterFeed}} = M_{\text{MelterFeed}} * \rho_{\text{MelterFeed}}$$

$$V_{\text{MelterFeed}} = 8,850.00 \text{ kg/d} * 1 \text{ l} / 1.66 \text{ kg}$$

$$V_{\text{MelterFeed}} = 5,331.32 \text{ l/d}$$

$$V_{\text{MelterFeed}} = 5,331.32 \text{ l/d} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{\text{MelterFeed}} = 1,408.39 \text{ gal/d} * 1 \text{ d} / 24 \text{ hr} * 1 \text{ hr} / 60 \text{ min}$$

$$V_{\text{MelterFeed}} = 0.98 \text{ g/min}$$

Round up

$$V_{\text{MeterFeedPump}} = 1 \text{ gpm}$$

B.2.20 122 Simulant Pump

Specifications	Basis
Pump Type: Air-operated double diaphragm.	
Size = 3"	
Solids handling up to 1/4" diameter particles.	
$F_{\text{SimulantPump}} = 125 \text{ gpm}$	See calculation below
$P_{\text{SimulantPump}} = 30 \text{ psi}$	Engineering judgement
$D_{\text{SimulantPump}} = 3" \text{ Female NPT}$	Wilden® literature
Housing material: Stainless steel	Wilden® literature
Elastomers: Nordel™	Wilden® literature
Estimated Cost: \$ 4,000	Wilden® M15

Calculations

Must transfer 1 batch of 6 M Na⁺ LLW simulant in 1 hour.

$$M_{6\text{MLLW}} = F_{6\text{MLLW}} * t_{\text{Residence}}$$

$$M_{6\text{MLLW}} = 7,044.24 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{6\text{MLLW}} = 24,654 \text{ kg}$$

$$V_{6\text{MLLW}} = M_{6\text{MLLW}} * \rho_{6\text{MLLW}}$$

$$V_{6\text{MLLW}} = 24,654 \text{ kg} * 1 \text{ l} / 1.31 \text{ kg}$$

$$V_{6\text{MLLW}} = 18,820 \text{ l} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{6\text{MLLW}} = 4,972 \text{ gal}$$

$$F_{\text{SimulantPump}} = V_{6\text{MLLW}} / t_{\text{Batch}}$$

$$F_{\text{SimulantPump}} = 4,972 \text{ gal} / 60 \text{ min}$$

$$F_{\text{SimulantPump}} = 82.86 \text{ g/min}$$

Round up

$$F_{\text{Simulant Pump}} = 125 \text{ g/min}$$

B.2.21 123 Chemical Addition Pump

Specifications	Basis
Pump Type: Air-operated double diaphragm	Engineering judgement
$D_{\text{Chemical Addition Pump In}} = 1" \text{ Female NPT}$	Wilden® literature
$D_{\text{Chemical Addition Pump Out}} = 3/4" \text{ Female NPT}$	Wilden® literature
Solids handling up to 1/4" diameter particles.	
$F_{\text{Chemical Addition Pump}} = 10 \text{ gpm}$	Engineering judgement
$P_{\text{Chemical Addition Pump}} = 20 \text{ psi}$	Wilden® literature
Housing: Stainless steel	Wilden® literature
Elastomers: Nordel™	Wilden® literature
Estimated Cost: \$ 1,000	Wilden® M2.

B.2.22 124 Dry Addition Conveyor

Specifications	Basis
Configuration: Screw conveyor	Engineering judgement
$F_{\text{Dry Addition Conveyor}} = 300 \text{ kg/min}$	See calculations below
<u>Power Requirements:</u>	
Phase: 3 phase	Engineering judgement
Frequency: 60 cycle	Engineering judgement
Voltage: 480 Volt	Engineering judgement
Instrumentation: mass	Engineering judgement
Flush/Cleaning Capability Required	

Calculations

The Dry Addition Conveyor must add one batch of glass formers to the Feed Prep Tank on 1 hour.

$$M_{\text{Glass Formers}} = F_{\text{Glass Formers}} * t_{\text{Residence}}$$

$$M_{\text{Glass Formers}} = 4,268.18 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{\text{Glass Formers}} = 14,938.63 \text{ kg}$$

$$F_{\text{Dry Addition Conveyor}} = M_{\text{Glass Formers}} / t_{\text{Batch}}$$

$$F_{\text{DryAdditionConveyor}} = 14,938.63 \text{ kg / 60 min}$$

$$F_{\text{DryAdditionConveyor}} = 248.97 \text{ kg/min}$$

Round up

$$F_{\text{DryAdditionConveyor}} = 300 \text{ kg/min}$$

B.2.23 125 Demister A

Specifications	Basis
Chevron Demister	
Face Velocity: 1,100 fpm	
Material: 316 Stainless steel	
Model: T271	
Description: Vertical mist eliminator	
Area = 2.22 ft ²	
Dimensions: 44" X 26" X 9"	
Connections: 12"	
Cost: \$ 2,735	

Suggested Vendor: Munters Corporation. Contact: John Constantineau. Phone:(800) 446-5696.

B.2.24 126 Condenser

Specifications	Basis
$F_{\text{Condenser}} = 15 \text{ gpm}$	See calculations below.
Shell & Tube type, down draft flow	
$Q_{\text{Condenser}} = 150,000 \text{ BTU/min}$	
Process Flow Rate = 160 scfm dry air	
Hot fluid on tube side, cooling water on shell side	
Meets ASME BPV Code, Section VIII, Division 1-1992	
$P_{\text{Tube}} = 125 \text{ psi}$	
$P_{\text{Shell}} = 135 \text{ psi}$	
$T_{\text{Tube side}} = 250^{\circ}\text{F}$	
$T_{\text{Shell side}} = 150^{\circ}\text{F}$	

Calculations

The condenser must condense water as rapidly as the Feed Prep Tank turns it into steam. The Feed Prep Tank will take 3.5 days worth of feed at 6 M Na⁺ and boil off water to increase [Na⁺] to 10 M in 4 hours.

$$M_{\text{H}_2\text{OEvaporated}} = F_{\text{H}_2\text{OEvaporated}} * t_{\text{Residence}}$$

$$M_{\text{H}_2\text{OEvaporated}} = 2,462.62 \text{ kg/d} * 3.5 \text{ d}$$

$$M_{\text{H}_2\text{OEvaporated}} = 8,619.17 \text{ kg}$$

$$V_{\text{H}_2\text{OEvaporated}} = M_{\text{H}_2\text{OEvaporated}} * \rho_{\text{H}_2\text{O}}$$

$$V_{\text{H}_2\text{OEvaporated}} = 8,619.17 \text{ kg} * 1 \text{ l/1 kg}$$

$$V_{\text{H}_2\text{OEvaporated}} = 8,619.17 \text{ l}$$

$$V_{\text{H}_2\text{OEvaporated}} = 8,619.17 \text{ l} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$V_{\text{H}_2\text{OEvaporated}} = 2,276.95 \text{ gal}$$

$$F_{\text{H}_2\text{OCondenser}} = V_{\text{H}_2\text{OEvaporated}} / t_{\text{Batch}}$$

$$F_{\text{H}_2\text{OCondenser}} = 2,276.95 \text{ gal} / 4 \text{ h} * 1 \text{ hr/60 min}$$

$$F_{\text{H}_2\text{OCondenser}} = 9.48 \text{ g/min}$$

Round up

$$F_{\text{Condenser}} = 15 \text{ gpm}$$

Next look at the energy required to condense 15 gpm.

$$F_{\text{Condenser}} = 15 \text{ g/min} * 3.7854 \text{ l/gal}$$

$$F_{\text{Condenser}} = 56.78 \text{ l/min}$$

$$F_{\text{Condenser}} = 56.78 \text{ l/min} * 1,000 \text{ g/l}$$

$$F_{\text{Condenser}} = 56,780 \text{ g/min}$$

$$Q_{\text{Condensation}} = F_{\text{Condenser}} * \Delta H_{\text{Condensation}}$$

$$Q_{\text{Condensation}} = 56,780 \text{ g/min} * 540 \text{ Cal/g}$$

$$Q_{\text{Condensation}} = 30,661,200 \text{ Cal/min}$$

$$Q_{\text{Condensation}} = 30,661,200 \text{ Cal/min} * 0.00396832 \text{ Btu/Cal}$$

$$Q_{\text{Condensation}} = 121,672.83 \text{ Btu/min}$$

Since the condenser will not operate at 100 % efficiency, we must round up substantially.

$$Q_{\text{Condenser}} = 150,000 \text{ Btu/min}$$

B.2.25 127 Demister B

Specifications	Basis
Same as Demister A	

B.2.26 128 Condensate Tank

Specifications	Basis
Vessel Volume = 3,000 gallons	
Operating Volume = 2,000 gallons	See calculations below.
Instrumentation: Level, T & P	
Dimensions = 8' diameter X 8' tall	
Wall Thickness = 0.5"	
Bottom Geometry = ASME Dish	
Material: stainless steel	

Penetrations:

6 x 3" top for instruments

1 x 1' top for an agitator

1 x 2" for adding liquids

1 x 3' side for cleanout and inspection

1 x 2" bottom for draining

Quality Assurance: ASME pedigree, inspection and certifications

Cost = \$ 39,000

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

Assume the Condensate Tank can contain 3.5 days worth of condensate

$$V_{\text{Condensate}} = F_{\text{Condensate}} * t_{\text{Residence}}$$

$$V_{\text{Condensate}} = 650 \text{ gal/d} * 3.5 \text{ d}$$

$$V_{\text{Condensate}} = 1,950 \text{ gal}$$

Round Up

$$V_{\text{CondensateCollectionTank}} = 3,000 \text{ gal}$$

B.2.27 129 Condensate Pump

Specifications	Basis
Pump: Duriron Centrifugal Pump	
$F_{\text{CondensatePump}} = 100 \text{ gpm}$	See calculations below
$D_{\text{CondensatePumpIn}} = 2" \text{ Female NPT}$	Duriron literature
$D_{\text{CondensatePumpOut}} = 2" \text{ Female NPT}$	Duriron literature
Housing: stainless steel	Duriron literature
Elastomers: Nordel™	Duriron literature
Estimated Cost: \$ 4,500	

Calculations

Assume the pump drains the Condensate Tank in 1 hour.

$$F_{\text{CondensatePump}} = V_{\text{Condensate}} / t_{\text{Batch}}$$

$$F_{\text{CondensatePump}} = 1,950 \text{ gal} / 60 \text{ min}$$

$$F_{\text{CondensatePump}} = 32.5 \text{ gal/min}$$

Round up

$$F_{\text{CondensatePump}} = 50 \text{ gpm}$$

B.2.28 131 Product Canister

Specifications	Basis
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Diameter = 2'	West Valley and Savannah River
Length = 10'	West Valley and Savannah River
Material: Stainless steel	
Cost: \$ 4,000	

B.2.29 132 Canister Mounting System

Specifications	Basis
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Rack to hold/carry canister	WVNS & Savannah River
Material: Carbon Steel	
Cooling water to control cooling rate.	Engineering judgement

B.2.30 133 Cooling Tower

Specifications	Basis
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$Q_{\text{Cooling Tower}} = 220,000 \text{ BTU/min}$	See calculations below
$F_{\text{CW Cooling Tower}} = 2640 \text{ g/min}$	See calculations below
$T_{\text{HW In}} = 95^\circ\text{F}$	Engineering judgement
$T_{\text{CW Out}} = 85^\circ\text{F}$	Engineering judgement
$T_{\text{WB}} = 67^\circ\text{F}$	Local Conditions
Estimated Cost = \$ 41,000	Tower Tech Quote

Accessories:

6' substructure kit
NEMA 12 Starter Panel
Heater Control Panel
Heater Element
4 Point Temperature Controller
Prewire Motor to J Box

Model: TTMT-216-319. Manufacturer: Tower Tech. Contact: Garrett Thornton. Address: Post Office Box 1838, Chickasha, Oklahoma 73023-1838. Phone: (405) 222-2876. Fax: (405) 222-2885.

Calculations

The Cooling Tower must have sufficient capacity to withdraw heat at the maximum rate heat might enter the facility.

Maximum cooling will prove necessary if workers operate the melter and the condenser at full capacity and cool the off gas to ambient conditions. To obtain a conservative estimate, assume a Joule-heated melter system.

$$Q_{\text{Cooling Tower}} = Q_{\text{JHM}} + Q_{\text{Condenser}}$$

$$Q_{\text{Cooling Tower}} = 70,000 \text{ Btu/min} + 150,000 \text{ Btu/min}$$

$$Q_{\text{Cooling Tower}} = 220,000 \text{ Btu/min}$$

B.2.31 137 Simulant Receipt Tank

Specifications	Basis
Vessel Volume = 24,000 gallons	
Operating Volume = 20,000 gallons	
Instrumentation: P, LL & T	Experience with SIPT and HWVP
Dimensions = 14' diameter X 20' tall	
Wall Thickness = 0.5"	
Bottom Geometry = ASME Dish	
Material: stainless steel	

Penetrations:

6 x 3" top for instruments

1 x 2' top for an agitator

1 x 3" top for adding liquids

1 x 3' side for cleanout and inspection

1 x 3" bottom for draining

Heating coils will maintain the simulant at 50°C.

The vessel will be outside.

Quality Assurance: ASME pedigree, inspection and certifications

Cost = \$ 139,000

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

$$V_{\text{SlurryReceiptTank}} = 2 * V_{\text{FeedPrepTank}}$$

$$V_{\text{SlurryReceiptTank}} = 2 * 10,000 \text{ gal}$$

$$V_{\text{SlurryReceiptTank}} = 20,000 \text{ gal}$$

B.2.32 138 Vessel Vent Blower

Specifications	Basis
$V_{\text{VesselVentBlower}} = 650 \text{ scfm}$	Mass balance calculations
$P_{\text{VesselVentBlower}} = -3" \text{ Hg}$	Engineering judgement
$T_{\text{VesselVentBlower}} = 150^{\circ}\text{F}$	Engineering judgement

Suggested vendor: Nelson Mechanical. Contact: Mark Tollefsen. Phone: (509) 747-3296.

B.2.33 140 Vessel Vent Preheater

Specifications	Basis
Flow = 650 cfm	Phone quote 11/4/94
$T = 10 \text{ C}$	Phone quote 11/4/94
Power: 480 V, 3-phase; fully modulated	Phone quote 11/4/94
Material: stainless steel	
Cost: \$ 1,500	Phone quote 11/4/94

Manufacturer: Dell Mfg. Suggested Vendor: Vemco. Address: Spokane, Washington. Phone: (509) 534-9533.

B.2.34 141 Vessel Vent HEPA Filter

Specifications	Basis
Flow = 650 scfm	
P = 1" H ₂ O	
Material: 304 Stainless steel, metal frame filter.	
Manufacturer: American Air Seal	Phone Quote 3/20/95
Model: 4H28 with an Astro Seal Housing	Phone Quote 3/20/95
Element Dimensions: 24" x 24" x 12"	Phone Quote 3/20/95
Filter Efficiency: 99.99%	
Housing: \$ 4,330	Phone Quote 3/20/95
Filter: \$795	Phone Quote 3/20/95

Vendor: Nelson Mechanical Equipment Company. Address: Spokane, Washington. Phone: (509) 747-3296. Contact: Mark C. Tollefsen.

B.2.35 142 Dry Frit/Silica Hopper

Specification	Basis
$V_{\text{Hopper}} = 15 \text{ m}^3$	See calculations below.
Material: Stainless steel on extreme wear surfaces	

Calculations

Must hold enough for 7 days of operation.

$$\rho_{\text{GlassFormers}} = 2,650 \text{ kg/m}^3$$

$$V_{\text{Hopper}} = F_{\text{GlassFormers}} * t_{\text{Residence}} * \rho_{\text{GlassFormers}}$$

$$V_{\text{Hopper}} = 4,268.18 \text{ kg/d} * 7 \text{ d} * 1 \text{ m}^3/2,650 \text{ kg}$$

$$V_{\text{Hopper}} = 11.27 \text{ m}^3$$

Round Up

$$V_{\text{Hopper}} = 15 \text{ m}^3$$

B.2.36 143 Dust Collection System

Specifications	Basis
The Dust control/collection system will operate in the Dry Frit/Silica Hopper, Dry Conveyor area and the feed preparation tank area.	
Number of Units = 2	
Power/Unit = 3 horsepower	Phone Quote

B.2.37 144 Canister Storage Rack

Specifications	Basis
Capacity: 10 Canisters	See calculations below
Cooling Mechanism: Free convection in air.	
Material: carbon steel	WVNS
Approximate Weight: 5000 lb. empty	WVNS

Calculations

Storage time in building = 3.5 days

Canister capacity = 1,800 kg of glass

$$N_{\text{Canisters}} = 5 \text{ t/d} * 3.5 \text{ d} / 1.8 \text{ t/can}$$

$$N_{\text{Canisters}} = 9.7$$

Round up

$$N_{\text{Canisters}} = 10$$

B.2.38 145 Evaporator

Specifications	Basis
$F_{\text{EvaporatorCM}} = 2 \text{ gpm}$	See calculations below
$P_{\text{Steam}} = 150 \text{ psig}$	Standard practice
$Q_{\text{Evaporator}} = 30,000 \text{ Btu/min}$	See calculations below
Material: Stainless steel	Feed characteristics
Cost Estimate: \$ 77,000	
Model: Lakeview Engineering E-1200 Hot Bottom Waste Water Evaporator	
Electrical Requirements: 208, 230/460V, 3 phase and 60 Hz.	
$P_{\text{Steam}} > 40 \text{ psi}$	

Suggested Vendor: Power Plant Service, Inc. Address: 2500 West Jefferson Boulevard, Fort Wayne, Indiana 46802-4824. Contact: John Titus & John Boerger. Phone: (219) 432-6716. Fax: (219) 436-3340.

Calculations

Assume all water entering the process exits through the evaporator

$$F_{\text{H}_2\text{O CM}} = F_{\text{Evaporation}} + F_{\text{H}_2\text{O off Gas CM}}$$

$$F_{\text{H}_2\text{O CM}} = 2,462.62 \text{ kg/d} + 4,880.8 \text{ kg/d}$$

$$F_{\text{H}_2\text{O CM}} = 7,343.42 \text{ kg/d} * 1 \text{ l/kg}$$

$$F_{\text{H}_2\text{O CM}} = 7,343.42 \text{ l/d} * 1 \text{ d} / 24 \text{ hr} * 1 \text{ hr} / 60 \text{ min}$$

$$F_{\text{H}_2\text{O CM}} = 5.09 \text{ l/min}$$

$$F_{\text{H}_2\text{O CM}} = 5.09 \text{ l/min} * 1 \text{ gal} / 3.7854 \text{ l}$$

$$F_{\text{H}_2\text{O CM}} = 1.34 \text{ gal/min}$$

Round up

$$F_{\text{Evaporator JHM}} = 2.0 \text{ gal/min}$$

Assume the water enters the evaporator at 25°C. The evaporator heats it to 100°C and then vaporizes it. The process must operate at 2 gpm.

First look at heating from 25°C to 100°C.

$$F_{\text{Evaporator}} = 2 \text{ g/min} * 3.7854 \text{ l/gal}$$

$$F_{\text{Evaporator}} = 7.57 \text{ l/min}$$

$$F_{\text{Evaporator}} = 7.57 \text{ l/min} * 1,000 \text{ g/l}$$

$$F_{\text{Evaporator}} = 7,570 \text{ g/min}$$

$$Q_{\text{Heating}} = F_{\text{Evaporator}} * H * \Delta TQ$$

$$Q_{\text{Heating}} = 7,570 \text{ g/min} * 1 \text{ Cal/g} * (100^{\circ}\text{C} - 25^{\circ}\text{C})$$

$$Q_{\text{Heating}} = 567,750 \text{ Cal/min}$$

$$Q_{\text{Evaporation}} = 7,570 \text{ g/min} * 540 \text{ Cal/g}$$

$$Q_{\text{Evaporation}} = 4,087,800 \text{ Cal/min}$$

$$Q_{\text{Total}} = Q_{\text{Heating}} + Q_{\text{Evaporation}}$$

$$Q_{\text{Total}} = 567,750 \text{ Cal/min} + 4,087,800 \text{ Cal/min}$$

$$Q_{\text{Total}} = 4,664,550 \text{ Cal/min}$$

$$Q_{\text{Total}} = 4,664,550 \text{ Cal/min} * 0.00396832 \text{ Btu/Cal}$$

$$Q_{\text{Total}} = 18,510 \text{ Btu/min}$$

Since the evaporator will not operate at 100 % efficiency, we must round up substantially.

$$Q_{\text{Evaporator}} = 30,000 \text{ Btu/min}$$

B.2.39 146 Recycle Sludge Pump B

Specifications	Basis
Pump: Air-operated double diaphragm.	They work well on sludge.
$D_{\text{RecycleSludgePumpBIn}} = 1" \text{ Female NPT}$	Wilden® literature
$D_{\text{RecycleSludgePumpBOut}} = 3/4" \text{ Female NPT}$	Wilden® literature
maximum particle diameter = 1/4"	Feed characteristics
$F_{\text{RecycleSludgePumpB}} = 5 \text{ gpm}$	Engineering judgement
Housing: stainless steel	Wilden® literature
Elastomers: Nordel™	Wilden® literature
Estimated Cost: \$ 1,000	Wilden® M2

B.2.40 147 Makeup Water Pump

Specifications	Basis
Pump: Duriron Mark III 1K3X1.5-62RV	Phone Quote 3/20/95
Flow = 100 gpm	
Power = 6.8 hp	Phone Quote 3/20/95
P = 60 psi	
Cost: \$ 4,239	Phone Quote 3/20/95

Vendor: Duriron Company, Inc. Address: West Valley City, Utah. Phone: (801) 972-9513.
Contact: Gary B. Kaiser

B.2.41 148 Fuel Storage Tank

Specifications	Basis
Vessel Volume = 12,000 gallons	
Operating Volume = 10,000 gallons	
Instrumentation: LL & T	
Dimensions = 12' diameter X 15' tall	
Wall Thickness = 0.375"	
Bottom Geometry = ASME Dish	
Material: carbon steel	
Quality Assurance: ASME pedigree, inspection and certifications	
Cost = \$12,000	

Calculations

$$F_{\text{Natural Gas}} = 172.84 \text{ lb/hr. Vortec Literature}$$

$$F_{\text{Kerosene}} = 172.84 \text{ lb/hr} * 23,879 \text{ BTU/lb}_{\text{Natural Gas}} / 135,800 \text{ BTU/lb}_{\text{Kerosene}}$$

$$F_{\text{Kerosene}} = 209 \text{ lb/hr} / 6.88 \text{ lb/gal}$$

$$F_{\text{Kerosene}} = 30.4 \text{ gal/hr}$$

$$V_{\text{Fuel Storage Tank}} = 30.4 \text{ gal/hr} * 24 \text{ hr/day} * 7 \text{ day/wk} * 2 \text{ wks}$$

$$V_{\text{Fuel Storage Tank}} = 10,000 \text{ gallons}$$

B.2.42 149 Scrubber Catch Tank Agitator

Specifications	Basis
Power = 1.5 hp	
Speed = 1,800 RPM	
Motor: TEFC Chemical Duty	
Voltage = 230/460 Volt	
Phase = 3 phase	
Frequency = 60 Hz	
Impellers: 3 low shear hydrofoil blades with a stabilizing ring	
Blade Diameter = 15"	
Shaft Diameter = 1.5"	
Shaft Length = 110"	
Wetted Parts Material: 316 stainless steel	
Tank Top: Closed	
Seal: Mechanical	
Cost: \$ 7,000	

Suggested Model: POG-15. Suggested Manufacturer: Philadelphia Mixers Corporation.
Suggested Vendor: Richard Styles & Associates. Address: 22931 NE 27th Place, Redmond,
Washington 98053.

B.2.43 150 Feed Preparation Tank Agitator

Specifications

Power = 15 hp
Speed = 1,800 RPM
Motor: TEFC Chemical Duty
Gear Reducer: Pedestal mounted double reduction helical & spiral bevel
Voltage = 230/460 Volt
Phase = 3 phase
Frequency = 60 Hz
Impeller Material: Hastelloy C276
Upper Impeller: 4 blade low shear
Upper Impeller Diameter: 60"
Lower Impeller: 4 blade with 45° pitch turbine
Lower Impeller Diameter: 46"
Shaft Diameter = 3"
Shaft Length = 190"
Output Shaft Speed: 56 rpm
Wetted Parts Material: 316 stainless steel

Seal: Double mechanical with carbon and tungsten carbide faces
Flange Mount: 150 pound ANSI
Flange Size: 12"
Cost: \$ 40,000

Suggested Manufacturer: Philadelphia Mixers Corporation. Suggested Model: 3835-PTM.
Suggested Vendor: Richard Styles & Associates. Address: 22931 NE 27th Place, Redmond,
Washington 98053.

B.2.44 151 Melter Feed Tank Agitator

Specifications

Power = 10 hp
Speed = 1,800 RPM
Motor: TEFC Chemical Duty
Gear Reducer: Pedestal mounted double reduction helical & spiral bevel
Voltage = 230/460 Volt
Phase = 3 phase
Frequency = 60 Hz
Impeller Material: Hastelloy C276
Upper Impeller: 4 blade low shear
Upper Impeller Diameter: 56"
Lower Impeller: 4 blade with 45° pitch turbine
Lower Impeller Diameter: 42"
Shaft Diameter = 3"
Shaft Length = 174"
Output Shaft Speed: 56 rpm
Wetted Parts Material: 316 stainless steel
Seal: Double mechanical with carbon and tungsten carbide faces
Flange Mount: 150 pound ANSI
Flange Size: 12"
Cost: \$ 35,000

Suggested Manufacturer: Philadelphia Mixers Corporation. Suggested Model: 3835-PTM.
Suggested Vendor: Richard Styles & Associates. Address: 22931 NE 27th Place, Redmond,
Washington 98053.

B.2.45 152 Condensate Collection Tank Agitator

Specifications

Power = 0.5 hp
Speed = 1800 RPM
Motor: TEFC Chemical Duty
Voltage = 230/460 Volt

Phase = 3 phase
Frequency = 60 Hz
Impellers: 2 low shear blades with a stabilizing ring
Blade Diameter = 12"
Shaft Diameter = 1.25"
Shaft Length = 100"
Wetted Parts Material: 316 stainless steel
Tank Top: Closed
Seal: Mechanical
Cost: \$ 6,000

Suggested Manufacturer: Philadelphia Mixers Corporation. Suggested Model: POG-12.
Suggested Vendor: Richard Styles & Associates. Address: 22931 NE 27th Place, Redmond,
Washington 98053.

B.2.46 153 Simulant Receipt Tank Agitator

Specifications

Power = 25 hp
Speed = 1,200 RPM
Motor: TEFC Chemical Duty
Gear Reducer: Pedestal mounted double reduction helical & spiral bevel
Voltage = 230/460 Volt
Phase = 3 phase
Frequency = 60 Hz
Upper Impeller: 4 blade low shear
Upper Impeller Diameter: 74"
Lower Impeller: 4 blade with 45° pitch turbine
Lower Impeller Diameter: 62"
Shaft Diameter = 4"
Shaft Length = 248"
Output Shaft Speed: 45 rpm
Wetted Parts Material: 304 stainless steel
Seal: Double mechanical with carbon and tungsten carbide faces
Flange Mount: 150 pound ANSI
Flange Size: 16"
Cost: \$ 40,000

Suggested Manufacturer: Philadelphia Mixers Corporation. Suggested Model: 3836-PTM.
Suggested Vendor: Richard Styles & Associates. Address: 22931 NE 27th Place, Redmond,
Washington 98053.

B.3 Equipment for the Joule-Heated Melter System

B.3.1 201 Joule-Heated Melter

Specifications	Basis
Glass Production Rate = 5,000 kg/d	Morrissey, 1994
Glass Flux = 52 kg/h*m ² @ 650 g of oxides/l	Perez, et al.
Power: 3 phase, 1,200 kW	Small Scale High Temperature Melter
Q _{JHM} = 70,000 Btu/min	See calculations below
Electrode material: Inconel 690	Hanford Waste Vitrification Program
Number of electrodes = 4	HWVP
Melt Surface Area = 64 ft ²	Calculations presented below
T _{Glass} = 1,350°C	SSHTM
T _{Picnum} = 500°C	SSHTM
Melter Efficiency N _M = 0.27	Perez et al.
The melter will have four feed nozzles.	HWVP

Calculations

Melter Surface Area (assume LLW simulant):

Glass Production Rate = 52 kg/hr*m² @650 g-ox/l

$$A_{JHM'} = (5,000 \text{ kg/d} * 1 \text{ d/24 hr}) / 52 \text{ kg/hr*m}^2$$

$$A_{JHM'} = 4 \text{ m}^2$$

$$A_{JHM'} = 4 \text{ m}^2 * 10.758 \text{ ft}^2/\text{m}^2$$

$$A_{JHM'} = 43 \text{ ft}^2$$

Since the processing rate might not scale linearly, we will assume a design factor of 1.5.

$$A_{JHM'} = A_{JHM'} * f_{\text{Design}}$$

$$A_{JHM'} = 43 \text{ ft}^2 * 1.5$$

$$A_{JHM'} = 64.5 \text{ ft}^2$$

For simplicity, assume the melter surface is square with 8' sides, so the surface area would be 64 ft².

$$A_{JHM} = 64 \text{ ft}^2$$

Power Requirements

$$Q_{JHM'} = 1200 \text{ kW}$$

$$Q_{JHM'} = 1200 \text{ kW} * 56.869 \text{ Btu/min/kW}$$

$$Q_{JHM'} = 68,242 \text{ Btu/min}$$

Round up

$$Q_{JHM} = 70,000 \text{ Btu/min}$$

B.3.2 202 Film Cooler

Specifications	Basis
Curved piping from the film cooler will minimize the potential of molten glass depositing on walls.	PNL-7142/UC-721; PSCM-23 Test Report
Material: Inconel 690	PNL-7142/UC-721
Air Supply ($F_{\text{FilmCooler}}$) = 200 scfm	See calculations below
$F_{\text{FilmCoolerOutJHM}} \approx 800 \text{ scfm}$	

Calculations

$$F_{\text{FilmCoolerInJHM}} \approx 532 \text{ scfm. Mass Balance Calculations}$$

$$F_{\text{FilmCoolerSSHTM}} = 53 \text{ scfm. Perez et al.}$$

$$F_{\text{FeedJHM}} = 217 \text{ l/hr. Mass balance calculations}$$

$$F_{\text{FeedSSHTM}} = 16 \text{ l/hr. Perez et al.}$$

$$F_{\text{FilmCoolerJHM}} = F_{\text{FilmCoolerSSHTM}} * F_{\text{FeedJHM}} / F_{\text{FeedSSHTM}}$$

$$F_{\text{FilmCoolerJHM}} = 53 \text{ scfm} * 217 \text{ l/hr} / 16 \text{ l/hr}$$

$$F_{\text{FilmCoolerJHM}} = 718.8 \text{ scfm}$$

This flow rate assumes linear scale up from the SSHTM to a 5 t/d melter. If we use this technique, the Joule-heated melter generates a non-condensable off gas flow of 107,216 kg/d (F_{NCOffGas}). Since this flow is unreasonably high, we assume the Joule heated melter will generate the same flow rate of non condensable off gas as the combustion melter minus the CO_2 resulting from hydrocarbon oxidation. We can use this flow to better estimate the actual film cooler flow rate.

$$F_{\text{FilmCoolerJHM}} = F_{\text{FilmCoolerJHM}} * F_{\text{NCOffGas}} / F_{\text{NCOffGas}}$$

$$F_{\text{FilmCoolerJHM}} = 718.8 \text{ scfm} * 21,961 \text{ kg/d} / 107,216 \text{ kg/d}$$

$$F_{\text{FilmCoolerJHM}} = 147 \text{ scfm}$$

Round up

$$F_{\text{FilmCooler}} = 200 \text{ scfm}$$

$$F_{\text{FilmCoolerOutJHM}} \approx F_{\text{FilmCoolerInJHM}} + F_{\text{FilmCooler}}$$

$$F_{\text{FilmCoolerOutJHM}} \approx 532 \text{ scfm} + 200 \text{ scfm}$$

$$F_{\text{FilmCoolerOutJHM}} \approx 732 \text{ scfm}$$

$$F_{\text{FilmCoolerOutCM}} \approx 688 \text{ scfm}$$

For simplicity, we round up to 1,000 scfm for both the Joule-heated and combustion melters.

We wish to maintain a flow velocity of 60 ft/sec (v_{Flow}) through our off gas system, so we must size the lines appropriately. The flow velocity comes from discussion with Greg Whyatt.

$$90^{\circ}\text{C} = 363 \text{ K}$$

$$25^{\circ}\text{C} = 298 \text{ K}$$

$$A_{\text{Ducts}} = 1,000 \text{ ft}^3/\text{min} * 1 \text{ min}/60 \text{ sec} * 1 \text{ sec}/60 \text{ ft} * 363 \text{ K}/298 \text{ K}$$

$$A_{\text{Ducts}} = 0.338 \text{ ft}^2$$

$$A_{\text{Ducts}} = \pi(d/2)^2$$

$$(d/2)^2 = A_{\text{Ducts}}/\pi$$

$$d_{\text{Ducts}} = (4 * A_{\text{Ducts}}/\pi)^{1/2}$$

$$d_{\text{Ducts}} = (4 * 0.338 \text{ ft}^2/\pi)^{1/2}$$

$$d_{\text{Ducts}} = 0.65 \text{ ft} * 12 \text{ in/ft}$$

$$d_{\text{Ducts}} = 7.81 \text{ in}$$

Round up

$$d_{\text{Ducts}} = 8"$$

B.3.3 204 Quench Tower

Specifications	Basis
$F_{InJHM} \approx 1,000$ scfm	Film Cooler Calculations
$T_{InJHM} = 500^{\circ}\text{C}$	Vortec literature
$F_{ParticulatesJHM} = 20$ kg/d	See mass balance calculations
$F_{H2OInJHM} = 3,000$ kg/d	See mass balance calculations
Materials: Hastelloy C	Off-gas corrosivity
Liquid System: Recycle, neutralize & filter	Common practice
Diameter: 30"	Beco quote
Height: 10'	Beco quote
$F_{ExitGasJHM} = 1,500$ ACFM	Beco quote
$F_{RecycleJHM} = 15$ gpm	Beco quote
$F_{EvaporationJHM} = 1.5$ gpm	Beco quote
Cost: \$ 50,000	Beco quote

Cost includes Hastelloy quench tower and spray nozzles, non-metallic recycle pump and tank, pH control system with chemical feed pump, piping and controls. Suggested Manufacturer: Beco Engineering Company. Address: Post Office Box 443, Oakmont, Pennsylvania 15139. Contact: J. Michael Hobi. Phone: (412) 828-6144

Calculations

To obtain a conservative estimate, assume the Quench Tower removes all water that would exit the melter through the off gas system.

First look at the Joule-heated melter.

$$F_{\text{QuenchTowerH2OJHM}} = 2,987.35 \text{ kg/d}$$

$$F_{\text{QuenchTowerH2OJHM}} = 2,987.35 \text{ kg/d} * 1 \text{ l/kg} * 1 \text{ gal/3.78514 l}$$

$$F_{\text{QuenchTowerH2OJHM}} = 789.18 \text{ g/d}$$

$$F_{\text{QuenchTowerH2OJHM}} = 789.18 \text{ g/d} * 1 \text{ d/24 h} * 1 \text{ hr/60 min}$$

$$F_{\text{QuenchTowerH2OJHM}} = 0.54 \text{ g/min}$$

Round up to 1.0 gpm

$$F_{\text{QuenchTowerH2OJHM}} = 1.0 \text{ g/min}$$

B.3.4 205 Hydrosonic Scrubber/Separator for the Joule-Heated Melter System

Specifications	Basis
$F_{\text{Scrubber/Separator}} \approx 1,000 \text{ scfm}$	Mass Balance Calculations
$F_{\text{Particulates}} = 20 \text{ kg/d}$	Mass balance calculations
Material: Stainless steel and fiberglass	Engineering judgement
Suggested Vendor: John Zink Co	
Cost: \$200,000	

B.3.5 207 High Efficiency Mist Eliminator

Same as for the Combustion Melter System.

B.3.6 208 Preheater

Same as for the Combustion Melter System.

B.3.7 209 HEMF

Same as for the Combustion Melter System..

B.3.8 210 Selective Catalytic NO_x Reducer

Specifications	Basis
ARI Econ-NO _x SCR DeNO _x System	Engineering judgement
$F_{\text{Airln}} = 1,000 \text{ scfm}$	Mass Balance Calculations
$F_{\text{NOXDesJHM}} = 122.77 \text{ kg/d}$	See calculations below.

Suggested Vendor: Wheelabrator Clean Air Systems Inc. Phone: (708) 706-6900.

Calculations

Determine an acceptable rate of NO_x destruction.

Assume the NO_x destruction system reduces NO_x flow by 90 % (Greg Whyatt).

$$F_{\text{NOXJHM}} = F_{\text{NOJHM}} + F_{\text{NO2JHM}}$$

$$F_{\text{NOXJHM}} = 127.41 \text{ kg/d} + 9.00 \text{ kg/d}$$

$$F_{\text{NOXJHM}} = 136.41 \text{ kg/d}$$

$$\Delta F_{\text{NOXJHM}} = E_{\text{Destruction}} * F_{\text{NOXJHM}}$$

$$\Delta F_{\text{NOXJHM}} = 0.90 * 136.41 \text{ kg/d}$$

$$\Delta F_{\text{NOXJHM}} = 122.77 \text{ kg/d}$$

B.3.9 211 Off-Gas Blower

Same as for the Combustion Melter System.

B.3.10 212 Stack

Same as for the Combustion Melter System.

B.3.11 213 Scrubber Catch Tank

Specifications	Basis
Vessel Volume = 4,000 gallons	See calculations below
Operating Volume = 2,800 gallons	
Dimensions = 8' diameter X 11' tall	
Wall Thickness = 0.5"	
Bottom Geometry = ASME Dish	
Material: stainless steel	
Cooling coils will withdraw 2,000 Btu/min.	

Penetrations:

6 x 3" top for instruments

1 x 2" top for adding liquids

1 x 1' top for an agitator

1 x 3' side for cleanout and inspection

1 x 2" bottom for draining

Quality Assurance: ASME pedigree, inspection and certifications

Cost = \$ 47,000

Suggested Manufacturer: Nicholson Manufacturing Company. Address: 3670 East Marginal Way South, Seattle, Washington 98134. Phone: (206) 682-2752. Contact: Ib Andersen.

Calculations

Assume the Scrubber Catch Tank collects all water that would exit the melter through the off gas system. This assumption will generate a conservative estimate of the required Scrubber Catch Tank capacity.

$$F_{\text{OffGasH}_2\text{OJHM}} = 2,987.35 \text{ kg/d}$$

$$F_{\text{OffGasH}_2\text{OJHM}} = 2,987.35 \text{ kg/d} * 1 \text{ l/kg} * 1 \text{ gal/3.78514 l}$$

$$F_{\text{OffGasH}_2\text{OJHM}} = 789.18 \text{ g/d}$$

The vessel should have capacity for 3.5 days of operation between vessel evacuations.

$$V_{\text{ScrubberCatchTankJHM}} = 789.18 \text{ g/d} * 3.5 \text{ days}$$

$$V_{\text{ScrubberCatchTankJHM}} = 2,762.13 \text{ gallons}$$

To allow for head space, round up to 4,000 gallons

$$V_{\text{ScrubberCatchTankJHM}} = 4,000 \text{ gallons}$$

B.3.12 214 Quench Water Pump

Specifications	Basis
Pump Type: Duriron Centrifugal	Engineering judgement
$F_{\text{QuenchWaterPumpJHM}} = 20 \text{ gpm}$	Quench Tower Requirements
Cost: \$ 4,000	Duriron quote

Calculations

Assume the Quench Water pump would have to drain the scrubber catch tank in 1 hour.

$$F_{\text{QuenchWaterPumpJHM}} = V_{\text{ScrubberCatchTankJHM}} / t_{\text{Batch}}$$

$$F_{\text{QuenchWaterPumpJHM}} = 2,762.13 \text{ gal} / 60 \text{ min}$$

$$F_{\text{QuenchWaterPumpJHM}} = 46.03 \text{ gpm}$$

Round up

$$F_{\text{QuenchWaterPumpJHM}} = 50 \text{ gpm}$$

B.3.13 215 Scrub Solution Filter

Specifications	Basis
Filtration Media: Sintered stainless steel	Engineering judgement
$F_{\text{ScrubberSolutionFilter}} = 25 \text{ gpm}$	Quench tower requirements
$\Delta P_{\text{ScrubberSolutionFilter}} = 10 \text{ lb/in}^2$	Engineering judgement
Surface Area: ?	Determined by testing
Pore size: ?	Determined by testing
Material of Construction: Stainless steel	Engineering judgement
Cost: \$ 300,000	

Suggested Manufacturer: Mott Metallurgical Corporation. Phone: (203) 677-7311. EDL has a similar system which cost \$210,000 in 1994.

B.3.14 216 Heat Exchanger

Specifications	Basis
$F_{\text{Cooling Water}} = 25 \text{ gpm}$	Quench tower requirements
$F_{\text{HeatExchangerJHM}} = 0.5 \text{ g/min}$	See calculations below
$F_{\text{HeatExchangerCM}} = 1.5 \text{ g/min}$	See calculations below
$Q_{\text{HeatExchanger}} = 1,200,000 \text{ BTU/hr}$	See calculations below
Material: stainless steel	Corrosive process solution
$T_{\text{in}} = 180^{\circ}\text{F}$	Engineering judgement
$T_{\text{Out}} = 85^{\circ}\text{F}$	Engineering judgement

Calculations

$$Q_{\text{HeatExchanger}} = 25 \text{ gal/min} * 8.3 \text{ lb/gal} * 1.0 \text{ BTU/lb}^{\circ}\text{F} * (180^{\circ}\text{F} - 85^{\circ}\text{F}) * 60 \text{ m/h}$$

$$Q_{\text{HeatExchanger}} = 1,182,750 \text{ BTU/hr}$$

$$Q_{\text{HeatExchanger}} = 1,182,750 \text{ BTU/hr} * 1 \text{ h/60 min}$$

$$Q_{\text{HeatExchanger}} = 19,713 \text{ BTU/min}$$

$$Q_{\text{HeatExchanger}} = 20,000 \text{ BTU/min}$$

B.3.15 217 Recycle Sludge Pump A

Specifications	Basis
Type: Air-operated double diaphragm	Diaphragm pumps can operate on sludges
$F_{\text{RecycleSludgePumpAJHM}} = 50 \text{ gpm}$	See calculations below
$D_{\text{RecycleSludgePumpAJHM}} = 2" \text{ Female NPT}$	Wilden® literature
Estimated Cost: \$ 2,000	Wilden® M8
$P_{\text{RecycleSludgePump}} = 10 \text{ psi}$	Engineering judgement
$F_{\text{Air}} = 100 \text{ scfm}$	Wilden® literature
Housing: Stainless steel	Corrosive process solution
Elastomers: Nordel™	Corrosive process solution

The air must remain free from particulates, but the pump will have a filter to provide redundancy. The air inlet line will have an oiler. The facility will accommodate the oily discharge that will exit through the air exhaust.

Calculations

Recycle Sludge Pump A will discharge the contents of the Scrubber Catch Tank in one hour.

$$F_{\text{RecycleSludgePumpAJHM}} = V_{\text{ScrubberCatchTank}} / t_{\text{Batch}}$$

$$F_{\text{RecycleSludgePumpAJHM}} = 2,762.13 \text{ gal} / 60 \text{ min}$$

$$F_{\text{RecycleSludgePumpAJHM}} = 46.03 \text{ gpm}$$

Round up

$$F_{\text{RecycleSludgePumpAJHM}} = 50 \text{ g/min}$$

B.3.16 218 Feed Prep Tank

Same as for the combustion melter system.

B.3.17 219 Feed Transfer Pump

Same as for the combustion melter system.

B.3.18 220 Melter Feed Tank

Same as for the combustion melter system.

B.3.19 221 Melter Feed Pump

Same as for the combustion melter system.

B.3.20 222 Simulant Pump

Same as for the combustion melter system.

B.3.21 223 Chemical Addition Pump

Same as for the combustion melter system.

B.3.22 224 Dry Addition Conveyor

Same as for the combustion melter system.

B.3.23 225 Demister A

Same as for the combustion melter system.

B.3.24 226 Condenser

Same as for the combustion melter system.

B.3.25 227 Demister B

Same as for the combustion melter system.

B.3.26 228 Condensate Collection Tank

Same as for the combustion melter system.

B.3.27 229 Condensate Pump

Same as for the combustion melter system.

B.3.28 230 Melter Electrical System

Specifications	Basis
Output: 480 Volts, 3 phase, 60 cycles, 1,450 kW. Contains no regulated materials (no PCB's). Air or water cooled. Includes: Main Electrode Heating, Plenum Heating, Discharge Heating, and Bottom Drain Heating. Water-cooled Silicon Controlled Rectifiers (SCR). Local Breakers and Disconnects. Control Circuitry Included.	

B.3.29 231 Product Canister

Same as for the combustion melter system.

B.3.30 232 Canister Mounting System

Same as for the combustion melter system.

B.3.31 233 Cooling Tower

Same as for the combustion melter system.

B.3.32 237 Slurry Receipt Tank

Same as for the combustion melter system.

B.3.33 238 Vessel Vent Blower

Same as for the combustion melter system.

B.3.34 240 Vessel Vent Preheater

Same as for the combustion melter system.

B.3.35 241 Vessel Vent HEPA Filter

Same as for the combustion melter system.

B.3.36 242 Dry Frit/Silica Hopper

Same as for the combustion melter system.

B.3.37 243 Dust Collection System

Same as for the combustion melter system.

B.3.38 244 Canister Storage Rack

Same as for the combustion melter system.

B.3.39 245 Evaporator

Same as for the combustion melter system.

B.3.40 246 Recycle Sludge Pump B

Same as for the combustion melter system.

B.3.41 247 Makeup Water Pump

Same as for the combustion melter system.

B.3.42 249 Scrubber Catch Tank Agitator

Specifications

Power = 1 hp

Speed = 1800 RPM

Motor: TEFC Chemical Duty

Voltage = 230/460 Volt

Phase = 3 phase

Frequency = 60 Hz

Impellers: 3 low shear hydrofoil blades with a stabilizing ring

Blade Diameter = 14"

Shaft Diameter = 1.25"

Shaft Length = 100"

Wetted Parts Material: 316 stainless steel

Tank Top: Closed

Seal: Mechanical

Suggested Model: POG-11

Cost: \$ 6,500

B.3.43 250 Feed Preparation Tank Agitator

Same as for the combustion melter system.

B.3.44 251 Melter Feed Tank Agitator

Same as for the combustion melter system.

B.3.45 252 Condensate Collection Tank Agitator

Same as for the combustion melter system.

B.3.46 253 Simulant Receipt Tank Agitator

Same as for the combustion melter system.

Appendix C

LLW and Simulant Characteristics

Appendix C

LLW and Simulant Characteristics

Several processes generated Hanford's tank waste; thus, waste varies in composition. Older single-shell tanks (SSTs) contain mostly precipitated sludges and saltcake; newer double-shell tanks (DSTs) contain mostly liquid wastes. In the reference process, operators will wash sludges (low solubility) and saltcake (high solubility) to produce a large volume liquid waste and a small volume of washed solids that contains most of the radionuclides. Ion exchange will remove most of the ^{137}Cs from the liquid waste to produce feed for the LLW Vitrification Facility. Cesium will be combined with HLW.

Hanford will retrieve waste from DSTs before SSTs. LLW from DSTs will differ from LLW from SSTs. Although operators will blend wastes as much as possible to minimize variability, LLW will fall into two categories: double shell slurry feed (DSSF) and "remaining inventory," which includes material from SSTs and wastes from pretreated DSTs. LLW will probably contain 4 to 6 M Na^+ , and less than 1 volume% undissolved solids (Wilson 1994). The process may mandate concentrating this feed to 10 or 15 M Na^+ , to reduce water content before vitrification. Concentrating LLW may cause salts to crystallize and increase solids loading to 10 to 30 volume %.

For Phase 1 melter technology testing WHC chose a DSSF simulant composition based on actual DST characterizations; composition and compounds needed to prepare the simulant appear in Table A.1. For the remaining inventory of non-DSSF, DST, and SST LLW, Table A.2 provides a preliminary composition, and compounds needed to achieve the composition. Table A.3 provides calcined solids compositions, which assume no halide or metal oxide volatility; and the relative quantities of volatile components for the two LLW simulants.

A weighted average of six DSTs provides a basis for the Phase 1 DSSF simulant composition. Many minor constituents, mostly those contributing less than 0.02 wt%, are not included in the Phase 1 DSSF simulant. The simulant includes all major constituents in DSSF and spike concentrations of constituents that may volatilize during vitrification, such as cesium, iodine, chlorine, and molybdenum. Molybdenum simulates the behavior of ^{99}Tc . The simulant also contains constituents that may exceed their solubility in silicate glasses, such as PO_4 , SO_4 , chlorine, and fluorine. The simulant includes strontium, because ^{90}Sr will have the highest activity of any radionuclide in LLW. The simulant will include 0.01 M cesium, strontium, iodine, and molybdenum to provide sufficient concentrations of these elements to allow mass balance verification. Additional LLW simulants for Phase 2 testing will probably include minor components omitted from the simulants described in Tables A.1 through A.3. Additional simulants may also include higher concentrations of PO_4 , SO_4 , NO_3 , fluorine, chlorine, hydroxide, and chromium to allow identification of melter technologies that provide the most flexibility for processing these constituents.

Table C.1. LLW Simulant for DSSF Tanks Normalized to 6.0 M Na⁺ (Wilson 1994)

Component	Target concentration M	Compound	Molecular weight (g/mol)	M required
Al ³⁺	0.61	Al (NO ₃) ₃ *9H ₂ O	375.14	0.61
Ca ²⁺	0.00063	Ca (NO ₃) ₂ *4H ₂ O	236.16	0.00063
Ca ²⁺	0.0052	Cr (NO ₃) ₃ *9H ₂ O	400.17	0.0052
Fe ³⁺	0.00046	Fe (NO ₃) ₃ *9H ₂ O	404.01	0.00046
K ⁺	0.30	KOH	56.10	0.30
Mg ²⁺	0.00062	Mg (NO ₃) ₂ *6H ₂ O	256.41	0.00062
Mn ²⁺	0.00025	Mn (NO ₃) ₂	178.94	0.00025
Mo ⁺⁶ (a)	0.010	Na ₂ MoO ₄ *H ₂ O	241.95	0.010
Na ⁺	6.0	—	—	—
Sr ⁺² (a)	0.010	SrCl ₂	158.52	0.010
Cs ⁺ (a)	0.010	CsNO ₃	194.91	0.010
PO ₄ ⁻³	0.026	NaH ₂ PO ₄ *H ₂ O	138.00	0.026
IO ₃ ⁻ (a)	0.010	NaIO ₃	197.89	0.010
CO ₃ ⁻²	0.16	Na ₂ CO ₃	106.0	0.16
Cl ⁻	0.096	NaCl	58.45	0.076
F ⁻	0.15	NaF	42.00	0.15
SO ₄ ⁻²	0.026	Na ₂ SO ₄	142.06	0.026
NO ₃	1.9	—	—	—
NO ₂ ⁻	1.0	NaNO ₂	69.00	1.0
OH ⁻ (b)	2.3	NaOH	40.00	4.0
TOC	0.81 (9.7 g/L)	Na ₄ EDTA, (C ₁₀)	416.20	0.081

(a) Spiked with 0.01 M Cs, Sr, I, and Mo to allow mass balance verification.

(b) Contains an excess of 1.4 moles of NaOH To neutralize hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn & Sr.

TOC = Total organic carbon.

**Table C.2. LLW Simulant for the Remaining Inventories (Less DSSF)
Normalized to 6.0 M Na⁺ (Wilson 1994)**

Component	Target Molarity M	Compound	Molecular weight (g/mol)	Required Molarity M
Al ⁺ ³	0.16	Al(NO ₃) ₃ *9H ₂ O	375.14	0.16
Ca ⁺ ²	0.00040	Ca(NO ₃) ₂ *4H ₂ O	236.16	0.00040
Cr ⁺ ³	0.0042	Cr(NO ₃) ₃ *9H ₂ O	400.17	0.0042
Fe ⁺ ³	0.00024	Fe(NO ₃) ₃ *9H ₂ O	404.01	0.00024
K ⁺	0.0058	KOH	56.10	0.0058
Mg ⁺ ²	1.1 E-06	Mg(NO ₃) ₂ *6H ₂ O	256.41	1.1E-06
Mn ⁺ ²	0.0010	Mn(NO ₃) ₂	178.94	0.0010
Mo ⁺ ⁶ (a)	0.010	Na ₂ MoO ₄ *H ₂ O	241.95	0.010
Na ⁺	6.0	—	—	—
Sr ⁺ ² (a)	0.010	Sr(NO ₃) ₂	149.63	0.010
Cs ⁺ (a)	0.010	CsNO ₃	194.91	0.010
PO ₄ ⁻³	0.11	NaH ₂ PO ₄ *H ₂ O	138.00	0.11
IO ₃ ⁻ (a)	0.010	NaIO ₃	197.89	0.010
CO ₃ ⁻²	0.050	Na ₂ CO ₃	106.00	0.050
Cl ⁻	0.0092	NaCl	58.45	0.0092
F ⁻	0.13	NaF	42.00	0.13
SO ₄ ⁻²	0.038	Na ₂ SO ₄	142.06	0.038
NO ₃ ⁻	3.6	NaNO ₃	85.00	3.0
NO ₂ ⁻	0.26	NaNO ₂	69.00	0.26
OH ⁻ (b)	1.4	NaOH	40.00	2.2
TOC	0.11 (1.3 g/L)	Na ₄ EDTA, (C ₁₀)	416.20	0.011

(a) Spiked with 0.01 M Cs, Se, I, and Mo to allow a mass balance verification.

(b) Contains an excess of 0.8 moles of NaOH to neutralize acidic hydrolyzable salts of Al, Ca, Cr, Fe, Mg, Mn & Sr.

TOC = Total organic carbon

Table C.3. DSSF and Remaining Inventory Compositions on Calcined Solids Weight Basis (Wilson 1994)

LLW Simulant on Calcined Solids Weight % Basis

Component	DSSF	Remaining Inventory
Na ₂ O	72.67	85.36
K ₂ O	5.77	0.13
Al ₂ O ₃	12.70	3.84
CaO	0.01	0.01
Cr ₂ O ₃	0.16	0.15
Cs ₂ O	0.58	0.66
Fe ₂ O ₃	0.01	0.01
MgO	0.01	0.00
MnO ₂	0.01	0.04
MoO ₃	0.59	0.68
SrO	0.42	0.49
P ₂ O ₅	0.75	3.68
SO ₃	0.85	1.43
NaCl	2.29	0.25
NaF	2.57	2.57
NaI	0.61	0.71
Total solids as g/L @ 6.0 M Na ⁺	245.05	212.49

Volatiles as g/100g calcined solids

H ₂ O (estimated)	330	380
NO ₃ ⁻	48.07	105.04
NO ₂ ⁻	18.77	5.63
OH ⁻	15.96	11.20
CO ₃ ⁻	3.92	1.41
Organic carbon	3.96	0.61

Appendix D

Cost Estimate for the Combustion Melter System

Cost Summary for the Combustion Melter System

Process Equipment

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
221130.1142301	Combustion Melter	\$0	\$0	\$300,000	\$1,000,000	\$80,000	\$1,380,000
221130.1142303	Air Blower	\$0	\$0	\$100,000	\$300,000	\$25,000	\$425,000
221130.1142305	Furnace	\$0	\$0	\$1,250,000	\$2,500,000	\$250,000	\$4,000,000
221130.1142315	Quench Tower	\$0	\$0	\$24,000	\$80,000	\$6,400	\$110,400
221130.1142320	Hydrosonic Scrubber/Separator	\$0	\$0	\$60,000	\$200,000	\$16,000	\$276,000
221130.1142325	HEME	\$0	\$0	\$20,000	\$62,000	\$5,100	\$87,100
221130.1142330	Preheater	\$0	\$0	\$500	\$1,500	\$125	\$2,125
221130.1142335	HEMF	\$0	\$0	\$33,000	\$110,000	\$8,800	\$151,800
221130.1142340	SCR	\$25,600	\$0	\$0	\$300,000	\$40,600	\$366,200
221130.1142345	Off-Gas Blower	\$0	\$0	\$8,000	\$25,000	\$2,050	\$35,050
221130.1142350	Stack	\$0	\$0	\$50,000	\$0	\$5,000	\$55,000
221130.1142355	Scrubber Catch Tank	\$0	\$0	\$22,000	\$75,000	\$5,950	\$102,950
221130.1142360	Quench Water Pump	\$0	\$0	\$1,200	\$4,500	\$345	\$6,045
221130.1142365	Scrubber Solution Filter	\$0	\$0	\$90,000	\$300,000	\$24,000	\$414,000
221130.1142370	Heat Exchanger	\$0	\$0	\$24,000	\$80,000	\$6,400	\$110,400
221130.1142380	Recycle Sludge Pump A	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142385	Feed Preparation Tank	\$0	\$0	\$30,000	\$91,000	\$7,550	\$128,550
221130.1142386	Feed Preparation Tank Agitator	\$0	\$0	\$10,000	\$34,000	\$2,700	\$46,700
221130.1142390	Feed Transfer Pump	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142395	Melter Feed Tank	\$0	\$0	\$22,000	\$75,000	\$5,950	\$102,950
221130.1142396	Melter Feed Tank Agitator	\$0	\$0	\$9,000	\$30,000	\$2,400	\$41,400
221130.1142400	Melter Feed Pump	\$0	\$0	\$2,000	\$6,100	\$505	\$8,605
221130.1142405	Simulant Pump	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142410	Chemical Addition Pump	\$0	\$0	\$300	\$1,000	\$80	\$1,380
221130.1142415	Dry Chemical Addition Conveyor	\$0	\$0	\$190,000	\$190,000	\$28,500	\$408,500
221130.1142420	Demister A	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
221130.1142425	Condenser	\$0	\$0	\$24,000	\$80,000	\$6,400	\$110,400
221130.1142430	Demister B	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
221130.1142435	Condensate Tank	\$0	\$0	\$11,000	\$39,000	\$3,050	\$53,050
221130.1142440	Condensate Pump	\$0	\$0	\$1,200	\$4,200	\$330	\$5,730
221130.1142460	Product Canister	\$0	\$0	\$1,200	\$4,000	\$320	\$5,520
221130.1142465	Canister Mounting System	\$0	\$0	\$9,000	\$30,000	\$2,400	\$41,400
221130.1142470	Cooling Tower	\$0	\$0	\$12,000	\$41,000	\$3,250	\$56,250
221130.1142490	Slurry Receipt Tank	\$0	\$0	\$42,000	\$139,000	\$11,150	\$192,150
221130.1142492	Vessel Vent Blower	\$0	\$0	\$8,000	\$25,000	\$2,050	\$35,050
221130.1142493	Vessel Vent Preheater	\$0	\$0	\$500	\$1,500	\$125	\$2,125
221130.1142495	Vessel Vent HEPA	\$0	\$0	\$500	\$5,500	\$325	\$6,325
221130.1142500	Glass Former Hopper	\$0	\$0	\$10,000	\$25,000	\$2,250	\$37,250
221130.1142503	Dust Collection System	\$0	\$0	\$5,000	\$5,000	\$750	\$10,750
221130.1142505	Canister Storage Rack	\$0	\$3,750	\$13,500	\$0	\$1,538	\$18,788
221130.1142510	Evaporator	\$0	\$0	\$23,000	\$77,000	\$6,150	\$106,150
221130.1142515	Recycle Sludge Pump	\$0	\$0	\$300	\$1,000	\$80	\$1,380
221130.1142520	Makeup Water Pump	\$0	\$0	\$1,200	\$4,300	\$335	\$5,835
221130.1142525	Fuel Tank	\$0	\$0	\$3,000	\$12,000	\$900	\$15,900
221130.1142530	Scrubber Catch Tank Agitator	\$0	\$0	\$2,000	\$6,700	\$535	\$9,235
221130.1142535	Condensate Tank Agitator	\$0	\$0	\$2,000	\$5,600	\$480	\$8,080
221130.1142540	Simulant Receipt Tank Agitator	\$0	\$0	\$11,000	\$38,000	\$3,000	\$52,000
Equipment Subtotal		\$25,600	\$3,750	\$2,432,000	\$6,027,200	\$570,348	\$9,058,898
Tax		\$0	\$293	\$0	\$470,122	\$0	\$470,414
OH&P on Markups only		\$0	\$0	\$0	\$0	\$23,520	\$23,520
221130	Equipment Total	\$25,600	\$4,043	\$2,432,000	\$6,497,322	\$593,868	\$9,552,832

Facility

Sitework

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0200010	Excavation	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010	Sitework Total	\$0	\$0	\$8,000	\$0	\$800	\$8,800

Concrete

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0300010	Building Slab 50' x 60' x 2'	\$0	\$0	\$172,125	\$0	\$17,213	\$189,338
310010.0300020	Building Slab 20' x 40' x 2'	\$0	\$0	\$45,900	\$0	\$4,590	\$50,490
310010.0300030	Evaporator Building	\$0	\$0	\$104,805	\$0	\$10,481	\$115,286
310010	Concrete Total	\$0	\$0	\$322,830	\$0	\$32,283	\$355,113

Metals

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0500010	Metal Building 50' x 60' x 70'	\$0	\$0	\$300,000	\$0	\$30,000	\$330,000
310010.0500020	Metal Building 20' x 40' x 35'	\$0	\$0	\$40,000	\$0	\$4,000	\$44,000
310010.05	Metal Total	\$0	\$0	\$340,000	\$0	\$34,000	\$374,000

Wood & Plastics

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0600010	Control Room 10' x 20'	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000
310010	Wood & Plastics Total	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000

Windows & Doors

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0800010	Doors & windows	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.08	Windows & Doors Total	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000

Specialties

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1000000	Freight Elevator	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500
310010.1	Specialties Total	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500

Equipment

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1100010	20 ton Crane with 50' span	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000
310010.11	Equipment Total	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000

Mechanical

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1500010	Service Piping for 6000 ft^2	\$0	\$0	\$225,000	\$0	\$22,500	\$247,500
310010.1500015	Service Piping for 800 ft^2	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.1500025	Service Piping for Evaporator	\$0	\$0	\$10,200	\$0	\$1,020	\$11,220
310010.1500050	Fire Protection for 6,000 ft^2	\$0	\$0	\$60,000	\$0	\$6,000	\$66,000
310010.1500055	Fire Protection for 800 ft^2	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010.1500065	Fire Protection for Evaporator Building	\$0	\$0	\$2,720	\$0	\$272	\$2,992
310010.1500100	HVAC for 6,000 ft^2	\$0	\$0	\$100,000	\$0	\$10,000	\$110,000
310010.1500110	HVAC for 800 ft^2	\$0	\$0	\$16,000	\$0	\$1,600	\$17,600
310010.1500120	HVAC for Evaporator Building	\$0	\$0	\$5,500	\$0	\$550	\$6,050
310010.15	Mechanical Total	\$0	\$0	\$457,420	\$0	\$45,742	\$503,162

Electrical

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1600010	Cable Tray	\$0	\$0	\$47,736	\$0	\$4,774	\$52,510
310010.1600020	Cable	\$0	\$0	\$49,700	\$0	\$4,970	\$54,670
310010.1600030	Lighting for 6,000 ft^2	\$0	\$0	\$48,000	\$0	\$4,800	\$52,800
310010.1600035	Lighting for 800 ft^2	\$0	\$0	\$6,400	\$0	\$640	\$7,040
310010.1600045	Lighting for 272 ft^3	\$0	\$0	\$3,200	\$0	\$320	\$3,520
310010.1600075	Normal Electrical Distribution	\$0	\$0	\$65,000	\$218,000	\$17,400	\$300,400
310010.1600080	Normal Electrical Distribution	\$0	\$0	\$12,000	\$39,000	\$3,150	\$54,150
310010.1600085	Normal Electrical Distribution	\$0	\$0	\$80,000	\$267,000	\$21,350	\$368,350
310010.1600090	Normal Electrical Distribution	\$0	\$0	\$12,000	\$43,000	\$3,350	\$58,350
310010.1600095	Normal Electrical Distribution	\$0	\$0	\$1,000	\$6,000	\$400	\$7,400
310010.1600100	Standby Electrical Distribution	\$0	\$0	\$48,000	\$160,000	\$12,800	\$220,800
310010.1600105	Standby Electrical Distribution	\$0	\$0	\$41,000	\$135,000	\$10,850	\$186,850
310010.1600110	Standby Electrical Distribution	\$0	\$0	\$1,000	\$6,000	\$400	\$7,400
310010.1600115	Uninterruptible Power Supply	\$0	\$0	\$5,000	\$15,000	\$1,250	\$21,250
310010.1600120	Uninterruptible Power Supply	\$0	\$0	\$48,000	\$164,000	\$13,000	\$225,000
310010.1600125	Uninterruptible Power Supply	\$0	\$0	\$12,000	\$41,000	\$3,250	\$56,250
310010.1600130	DC Battery Control	\$0	\$0	\$18,000	\$59,000	\$4,750	\$81,750
310010.1600135	DC Battery Charger	\$0	\$0	\$3,000	\$10,000	\$800	\$13,800
310010.1600140	DC Distribution Panel	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
310010.1600150	Compressed Air	\$0	\$0	\$50,000	\$100,000	\$10,000	\$160,000
310010.1600152	Poles & Poles Line	\$0	\$0	\$5,000	\$0	\$500	\$5,500
310010.1600160	Steam Allowance	\$0	\$0	\$50,000	\$100,000	\$10,000	\$160,000
310010.1600210	Instrumentation	\$0	\$0	\$1,992,000	\$0	\$199,200	\$2,191,200

	Electrical Subtotal	\$0	\$0	\$2,599,036	\$1,366,000	\$328,204	\$4,293,240
	Tax	\$0	\$0	\$0	\$106,548	\$0	\$106,548
	OH&P on Markups only	\$0	\$0	\$0	\$0	\$5,327	\$5,327
310010.16	Electrical Total	\$0	\$0	\$2,599,036	\$1,472,548	\$333,531	\$4,405,115

Facility

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010	Sitework Total	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010.03	Concrete Total	\$0	\$0	\$322,830	\$0	\$32,283	\$355,113
310010.05	Metal Total	\$0	\$0	\$340,000	\$0	\$34,000	\$374,000
310010.06	Wood & Plastics Total	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000
310010.08	Windows & Doors Total	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.1	Specialties Total	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500
310010.11	Equipment Total	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000
310010.15	Mechanical Total	\$0	\$0	\$457,420	\$0	\$45,742	\$503,162
310010.16	Electrical Total	\$0	\$0	\$2,599,036	\$1,472,548	\$333,531	\$4,405,115

310010	Process Facility	\$0	\$0	\$4,162,286	\$1,472,548	\$489,856	\$6,124,690
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Engineering & Management

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
411000	Construction Management	\$2,560	\$404	\$659,429	\$796,987	\$108,372	\$1,567,752
511000	Project Management	\$3,840	\$606	\$989,143	\$1,195,480	\$162,558	\$2,351,628
110000	Engineering	\$10,240	\$1,617	\$2,637,714	\$3,187,948	\$433,489	\$6,271,008

	Engineering/CM/PM Total	\$16,640	\$2,628	\$4,286,286	\$5,180,415	\$704,420	\$10,190,389
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Project

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
	Engineering/CM/PM	\$16,640	\$2,628	\$4,286,286	\$5,180,415	\$704,420	\$10,190,389
310010	Process Facility	\$0	\$0	\$4,162,286	\$1,472,548	\$489,856	\$6,124,690
221130	Equipment	\$25,600	\$4,043	\$2,432,000	\$6,497,322	\$593,868	\$9,552,832
Escalated Total		\$42,240	\$6,670	\$10,880,572	\$13,150,285	\$1,788,143	\$25,867,910
Contingency		\$21,120	\$3,335	\$5,440,286	\$6,575,142	\$894,072	\$12,933,955
Project Total		\$63,360	\$10,005	\$16,320,858	\$19,725,427	\$2,682,215	\$38,801,865

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. Z285SAA1/95CHBS

**** TEST - INTERACTIVE ESTIMATING ****
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D COMBUSTION MELTER -- S T U D Y
DOE_R01 - PROJECT COST SUMMARY

PAGE 1 OF 4
DATE 05/02/95
BY T.L. WALDO

COST CODE =====	DESCRIPTION =====	ESCALATED TOTAL COST =====	CONTINGENCY % =====	TOTAL =====	TOTAL DOLLARS =====
000	ENGINEERING/CM/PM	10,190,000	50	5,100,000	15,290,000
501	BUILDINGS	6,120,000	50	3,060,000	9,180,000
700	SPECIAL EQUIP/PROCESS SYSTEMS	9,550,000	50	4,780,000	14,330,000
	(ADJUSTED TO MEET DOE 5100.4)				
		=====		=====	=====
	PROJECT TOTAL	25,860,000	50	12,940,000	38,800,000

D.S

TYPE OF
ESTIMATE

ROH - S T U D Y

REMARKS:

ARCHITECT
ENGINEER

OPERATING
CONTRACTOR

(ROUNDED/ADJUSTED TO THE NEAREST " 10,000 / 100,000 " - PERCENTAGES NOT RECALCULATED TO REFLECT ROUNDING)

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. Z285SAA1/95CHBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D COMBUSTION MELTER -- S T U D Y
DOE_R02 - WORK BREAKDOWN STRUCTURE SUMMARY

PAGE 2 OF 4
DATE 05/02/95
BY T.L. WALDO

WBS	DESCRIPTION	ESTIMATE SUBTOTAL	ONSITE INDIRECTS	SUB TOTAL	ESCALATION % TOTAL	SUB TOTAL	CONTINGENCY % TOTAL	TOTAL DOLLARS
110000	ENGINEERING	6270000	0	6270000	0.00	0	6270000	9405000
SUBTOTAL 1	ENGINEERING	6270000	0	6270000	0.00	0	6270000	9405000
221130	PROCESS EQUIPMENT	9552834	0	9552834	0.00	0	9552834	14329251
SUBTOTAL 22	PROCESS EQUIPMENT	9552834	0	9552834	0.00	0	9552834	14329251
SUBTOTAL 2	PROCUREMENT	9552834	0	9552834	0.00	0	9552834	14329251
310010	PROCESS FACILITY	6124691	0	6124691	0.00	0	6124691	9187037
SUBTOTAL 31	PROCESS FACILITY	6124691	0	6124691	0.00	0	6124691	9187037
SUBTOTAL 3	CONSTRUCTION	6124691	0	6124691	0.00	0	6124691	9187037
411000	CONSTRUCTION MANAGEMENT	1568000	0	1568000	0.00	0	1568000	2352000
511000	PROJECT MANAGEMENT	2352000	0	2352000	0.00	0	2352000	3528000
=====								
PROJECT TOTAL		25,867,525	0	25,867,525	0.00	0	25,867,525	38,801,288

KAISER ENGINEERS HANFORD
WESTINGHOUSE HANFORD COMPANY
JOB NO. Z157SAA1

**** TEST - INTERACTIVE ESTIMATING ****
PILOT SCALE LLW VITRIFICATION FACILITY
S T U D Y
DOE_R03 - ESTIMATE BASIS SHEET

PAGE 3 OF 4
DATE 5-2-95
BY T.L. WALDO

1. DOCUMENTS AND DRAWINGS

DRAWINGS: ENGINEERING SKETCHES AND FLOW SHEET.
EQUIPMENT LISTS DATED 11/1/94, 1/31/95, 2/21/95 AND 5/1/95.

2. MATERIAL PRICES

UNIT COSTS REPRESENT CURRENT PRICES FOR SPECIFIED MATERIAL. VENDOR INFORMATION WAS OBTAINED FOR THE FOLLOWING ITEMS:

3. LABOR RATES

CURRENT KEH BASE CRAFT RATES, AS ISSUED BY KEH FINANCE (EFFECTIVE 10-01-93), INCLUDE FRINGE BENEFITS; LABOR INSURANCE, TAXES AND TRAVEL WHERE APPLICABLE, PER HANFORD SITE STABILIZATION AGREEMENT, APPENDIX A (EFFECTIVE 9-06-93). NON CRAFT HOURLY RATES ARE BASED ON THE 1994 FISCAL YEAR BUDGET LIQUIDATION RATES AS ISSUED BY KEH FINANCE (EFFECTIVE 10-01-93).

4. GENERAL REQUIREMENTS/TECHNICAL SERVICES

- A.) ONSITE CONSTRUCTION FORCES GENERAL REQUIREMENTS, TECHNICAL SERVICES AND CRAFT OVERHEAD COSTS ARE INCLUDED AS A COMPOSITE PERCENTAGE BASED ON THE KEH ESTIMATING FACTOR/BILLING SCHEDULE, REVISION 16, DATED OCTOBER 01, 1993. THE TOTAL COMPOSITE PERCENTAGE APPLIED TO ONSITE CONSTRUCTION FORCES LABOR, FOR THIS PROJECT, IS 93% FOR SHOP WORK AND 134% FOR FIELD WORK, WHICH IS REFLECTED IN THE "OH&P/B&I" COLUMN OF THE ESTIMATE DETAIL.
- B.) ONSITE CONTRACT ADMINISTRATION AND CONSTRUCTION MANAGEMENT COSTS, ASSOCIATED WITH THE OVERALL MANAGEMENT OF THE FIXED PRICE CONTRACTS, ARE INCLUDED AS A COMPOSITE PERCENTAGE AND LUMP SUM ALLOWANCE (FOR BID PACKAGE PREP) BASED ON THE ESTIMATING FACTOR/BILLING SCHEDULE. THE TOTAL COMPOSITE PERCENTAGE AND LUMP SUM ALLOWANCE ARE APPLIED AGAINST THE TOTAL FIXED PRICE CONTRACT AMOUNT WHICH IS REFLECTED ON THE KEH SUMMARY REPORT DOER07, INCLUDED WITH THIS ESTIMATE. (FINAL ESTIMATES MAY BE PARTIALLY MANLOADED AND INCLUDED WITHIN THE ESTIMATE DETAIL)
- C.) FIXED PRICE CONTRACTOR OVERHEAD, PROFIT, BOND AND INSURANCE COSTS HAVE BEEN APPLIED AT THE FOLLOWING PERCENTAGES AND ARE REFLECTED IN THE "OH&P / B & I" COLUMN OF THE ESTIMATE DETAIL:
LABOR - 53% MATERIAL - 5% EQUIPMENT - 5% SUBCONTRACTS - 10%

5. ESCALATION

ESCALATION IS NOT INCLUDED AND THE COST ESTIMATE IS IN 1995 DOLLARS.

6. ROUNDING

U.S. DEPARTMENT OF ENERGY - DOE ORDER 5100.4 PAGE 1-32 SUBPARAGRAPH (M), REQUIRES ROUNDING OF ALL GENERAL PLANT PROJECTS (GPP'S) AND LINE ITEM (LI) COST ESTIMATES. REFERENCE: DOE 5100.4, FIGURE 1-11, DATED 10-31-84.

7. REMARKS

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- A.) THE ESTIMATE IS FOR DESIGN CONSTRUCTION OF A NEW FACILITY ONLY AND DOES NOT INCLUDE ANY COSTS FOR TIE-IN OR RADIOLOGICAL WORK WHICH WOULD BE DONE BY THE ON-SITE CONSTRUCTION CONTRACTOR.
- B.) ENGINEERING, PROJECT MANAGEMENT, CONSTRUCTION MANAGEMENT AND CONTINGENCY WAS APPLIED AS FOLLOWS:
ENGINEERING	40%
PROJECT MANAGEMENT	10%
CONSTRUCTION MANAGEMENT	10%
CONTINGENCY	50%
- C.) THE COST ESTIMATE IS IN 1995 DOLLARS AND DOES NOT INCLUDE ANY PERCENTAGES FOR ESCALATION SINCE A SCHEDULE HAS NOT BEEN PREPARED.
- D.) ALLOWANCES FOR CONTRACT DELAYS OR EXTENSION OF SCHEDULES IS NOT INCLUDED.
- E.) LABOR, MATERIAL, AND SUBCONTRACT OH & P WAS APPLIED AS FOLLOWS:
1. LABOR	53%
2. MATERIAL	5%
3. EQUIPMENT	5%
4. SUBCONTRACT	10%
- F.) UTILITIES TO THE SITE (IE. ELEC., WATER, EXFER LINES, ETC.) IS NOT INCLUDED.
- G.) EQUIPMENT COST IS BASED UPON BEING COMMERCIALY FABRICATED AND IS CONTACT MAINTAINED.
- H.) THIS FACILITY IS ESTIMATED AS A CATEGORY III FACILITY (BUTLER BUILDING).
- I.) EQUIPMENT INSTALLATION FACTOR INCLUDES PIPING AND VALVES WITHIN THE ROOM WHERE IT IS INSTALLED.
- J.) INSTRUMENTATION COST ALLOWANCE IS 25% OF EQUIPMENT COST.

KAISER ENGINEERS HANFORD
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** IEST - INTERACTIVE ESTIMATING **
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5MT/D COMBUSTION MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
110000	ENGINEERING										
110000.00	TECHNICAL SERVICES										
110000.0000001	ENGINEERING TITLE I, II & III	000	1 LOT	0	0	0	0	6270000	0	0	6270000
SUBTOTAL	TECHNICAL SERVICES			0	0	0	0	6,270,000	0	0	6,270,000
TOTAL	COST CODE 00000 WBS 110000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	6,270,000	0	0	6,270,000
TOTAL WBS 110000	ENGINEERING			0	0	0	0	6,270,000	0	0	6,270,000

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130	PROCESS EQUIPMENT										
221130.11	EQUIPMENT										
221130.1142301	101 GLASS MELTER 5MT/D KEROSENE, COMP. AIR ATOMIZED PH. QUOTE \$1M PLUS 30% INSTALL	700	1 EA	0	0	0	0	300000	1000000	80000	1380000
221130.1142303	101 GLASS MELTER 5MT/D COMBUSTION AIR BLOWER PH. QUOTE \$300K PLUS 30% INSTALL	700	1 EA	0	0	0	0	100000	300000	25000	425000
221130.1142305	101A FURNACE & CONVECT PASS CERAMIC LINED INCONEL 690 PHONE QUOTE \$2.5M PLUS 50% INSTALLATION	700	1 EA	0	0	0	0	1250000	2500000	250000	4000000
221130.1142315	104 QUENCH TOWER HASTELLOY C - 30% INSTALL 2400 ACFM @ 1200C, COOL 180F ENG VENDOR QUOTE - BECO ENG.	700	1 EA	0	0	0	0	24000	80000	6400	110400
221130.1142320	105 HYDRO SCRUBBER/SEPARATOR 304L S.S., EXIT TEMP. 200F 30% FIELD LAB & MATL INSTALL ENG. VENDOR QUOTE-J.ZINK	700	1 EA	0	0	0	0	60000	200000	16000	276000
221130.1142325	107 HIGH EFF. MIST ELIMINATR 3'D X 16'H 10GA 316L (HEME) 1146 SCFM 10C (-5 PSIG) 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	20000	62000	5100	87100
221130.1142330	108 PREHEATER TEMP DIFF. 10C FOR 650SCFM 30% FIELD LAB & MATL INSTALL ENG. VENDOR QUOTE - VEMCO	700	1 EA	0	0	0	0	500	1500	125	2125
221130.1142335	109 HEHF FILTER (METALLIC) PH QUOTE 1000 SCFM 10C 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	33000	110000	8800	151800
221130.1142340	110 SEL CATALYTIC NOX REDUCR 1000 SCFM. PH-QUOTE ARI ECON-NOx SCR DeNOx SYST. ALW 4MEN 5WKS/EA INSTALL	700	1 EA	800	25600	0	0	0	300000	40600	366200
221130.1142345	111 OFF-GAS BLOWER 1000 SCFM. @ 80" H2O VACUUM 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	8000	25000	2050	35050

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142350	PH QUOTE 112 --STACK -- NO INFO ALLOW 60' SHEETMETAL STACK ALW 1/2 OF LRG STACK MONITOR ALLOW \$25KSTACK &\$25K MONITR	700	1 LOT	0	0	0	0	50000	0	5000	55000
221130.1142355	113 SCRUBBER CATCH TANK 7000 GAL. S.S.(26,500L) 30% FIELD LAB & MATL INSTALL ENG.VENDOR QUOTE - NICHOLSON	700	1 EA	0	0	0	0	22000	75000	5950	102950
221130.1142360	114 QUENCH WATER PUMP 50GPM @ 60PSI 316SS ENG. VENDOR QUOTE-DURIRON 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	1200	4500	345	6045
221130.1142365	115 SCRUB SOLUTION FILTRATION 15GPM -- DIATOMACEOUS EARTH SIM TO BATTELLE SYS.SOP #98 RECYCLE TREATMENT SYSTEM	700	1 EA	0	0	0	0	90000	300000	24000	414000
221130.1142370	116 HEAT EXCHANGER 304L 15GPM -- 21,000BTU/MIN 30% FIELD LAB & MATL INSTALL REF. CASE 2B 231140.1144007	700	1 EA	0	0	0	0	24000	80000	6400	110400
221130.1142380	117 RECYCLE SLUDGE PUMP A 80GPM @ 60psi--AIR OPERATED 304L S.S. 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142385	118 FEED PREPARATION TANK 10,000GAL S.S.(37,900L) ENG.VENDOR QUOTE - NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	30000	91000	7550	128550
221130.1142386	150 FEED PREP TANK AGITATOR FOR 10,000GAL TANK 30%INSTAL ENG. VENDOR QUOTE-PHIL MIXER BLADES ARE HAST. C-276	700	1 EA	0	0	0	0	10000	34000	2700	46700
221130.1142390	119 FEED TRANSFER PUMP 100GPM @ 20PSI (30% INSTALL) ENG. VENDOR QUOTE-ARGO	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142395	120 MELTER FEED TANK 7,500GAL 304L S.S.(28,400L) ENG. VENDOR QUOTE-NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	22000	75000	5950	102950
221130.1142396	151 MELTER FEED TANK AGITATO FOR 7,500 GAL TANK	700	1 EA	0	0	0	0	9000	30000	2400	41400

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142400	ENG. VENDOR QUOTE-PHIL.MIXER 30% INSTALL 121 MELTER FEED PUMP 0-120GPH @ 15-275 PSI	700	1 EA	0	0	0	0	2000	6100	505	8605
221130.1142405	ENG.VENDOR QUOTE-DURIRON HASTELOY C/TUNG CARBIDE 122 SIMULANT PUMP 100GPH @ 20PSI (30% INSTALL)	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142410	ENG. VENDOR QUOTE-ARGO 123 CHEMICAL ADDITION PUMP ENG. VENDOR QUOTE-ARGO 10GPH @ 20PSI	700	1 EA	0	0	0	0	300	1000	80	1380
221130.1142415	30% INSTALL 124 DRY ADDITION CONVEYOR PNEUMATIC & SCREW CONVEYOR 5 MT PER DAY SYSTEM PH QUOTE	700	1 EA	0	0	0	0	190000	190000	28500	408500
221130.1142420	125 DEMISTER A 1100 FPM 30% INSTALL 316 S.S. ALLOW 3' X 3'	700	1 EA	0	0	0	0	1000	3000	250	4250
221130.1142425	ENG. VENDOR QUOTE-MUNTERS 126 CONDENSER 45,000 BTU/MIN (2.7MMBTU/HR) 160 SCFH DRY AIR-30% INSTALL REF. CASE 2B 231250.1144005	700	1 EA	0	0	0	0	24000	80000	6400	110400
221130.1142430	127 DEMISTER B 1100 FPM 30% INSTALL 316 S.S. ALLOW 3' X 3'	700	1 EA	0	0	0	0	1000	3000	250	4250
221130.1142435	ENG. VENDOR QUOTE-MUNTERS 128 CONDENSATE COLLECTION TK 3000 GAL (11,400L) S.S. ENG. VENDOR QUOTE-NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	11000	39000	3050	53050
221130.1142440	129 CONDENSATE PUMP 30% INSTALL S.S. 100GPM	700	1 EA	0	0	0	0	1200	4200	330	5730
221130.1142460	ENG.VENDOR QUOTE-DURIRON 131 PRODUCT CANISTER ENGINEERING ALLOWANCE 30% INSTALL	700	1 EA	0	0	0	0	1200	4000	320	5520
221130.1142465	NO INFO. PROVIDED - - 132 CANISTER MOUNTING SYSTEM C.S. 1500# -COOL SYS.NOT INC	700	1 EA	0	0	0	0	9000	30000	2400	41400

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
*****	*****	***	*****	*****	*****	*****	*****	*****	*****	*****	*****
	NO INFO OR SKETCHES. ALLOW \$20/# 30% INSTALL										
221130.1142470	133 COOLING TOWER 2640 GPM (95F IN & 85F OUT) WET BULB 67F	700	1 EA	0	0	0	0	12000	41000	3250	56250
221130.1142490	ENG.VENDOR QUOTE-TOWER TECH 137 SLURRY RECEIPT TNK 24,000 GAL -S.S.- ENG.VENDOR QUOTE-NICHOLSON 30% INSTALLATION	700	1 EA	0	0	0	0	42000	139000	11150	192150
221130.1142492	138 VESSEL VENT BLOWER PH QUOTE 650 SCFH	700	1 EA	0	0	0	0	8000	25000	2050	35050
221130.1142493	30% FIELD LAB & MATL INSTALL 140 VESSEL VENT PREHEATER 650 SCFH	700	1 EA	0	0	0	0	500	1500	125	2125
221130.1142495	30% FIELD LAB & MATL INSTALL 141 HEPA FILTER 1000 SCFH 10C	700	1 EA	0	0	0	0	500	5500	325	6325
221130.1142500	ENG. VENDOR QUOTE-NELSON MEC 142 DRY FRIT/SILICA HOPPER PH QUOTE 304 S.S. W/DUST CTL NO FINISH 60DEG CONE (26CY)	700	1 EA	0	0	0	0	10000	25000	2250	37250
221130.1142503	30% FIELD LAB & MATL INSTALL 143 DUST COLLECTION SYSTEM PH QUOTE 2EA 3HP UNITS. STAND EQUIP. 5K/EA REDUNDANT	700	1 EA	0	0	0	0	5000	5000	750	10750
221130.1142505	100% FAB & MATL INSTALL 144 CANISTER STORAGE RACK INFO FROM FLUOR STUDY (FMEF) .75/# C.S. SHAPES LAB=\$40 .05MH/#+35%SAFETY CLASS	700	5000 LBS	0	0	0	3750	13500	0	1538	18788
221130.1142510	145 EVAPORATOR 150 psig STEH 140 GAL PER HR. EVAPORATION 316 S.S. 30% INSTALL	700	1 LOT	0	0	0	0	23000	77000	6150	106150
221130.1142515	ENG.VENDOR QUOTE-POWER PLANT 146 RECYCLE SLUDGE PUMP B 5GPM @ --AIR OPERATED DIAPHR ENG.VENDOR QUOTE-ARGO 30% INSTALL	700	1 EA	0	0	0	0	300	1000	80	1380
221130.1142520	147 MAKEUP WATER PUMP 100GPM @ 60psi, 5HP	700	1 EA	0	0	0	0	1200	4300	335	5835

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142525	ENG.VENDOR QUOTE-DURIRON 30% INSTALL 148 FUEL STORAGE TANK 12,000GAL C.S. (45,400L) ALLOW \$1/GAL	700	1 EA	0	0	0	0	3000	12000	900	15900
221130.1142530	30% INSTALL 149 SCRUBBER TANK AGITATOR FOR SCRUBBER CATCH TANK ENG.VENDOR QUOTE-PHIL MIXER	700	1 EA	0	0	0	0	2000	6700	535	9235
221130.1142535	30% INSTALL 152 CONDENSATE COLL TK AGITR ENG.VENDOR QUOTE-PHIL MIXER	700	1 EA	0	0	0	0	2000	5600	480	8080
221130.1142540	30% INSTALL 153 SIMULANT RECT TK AGITATR ENG.VENDOR QUOTE-PHIL MIXER 25HP 30% INSTALL	700	1 EA	0	0	0	0	11000	38000	3000	52000
SUBTOTAL EQUIPMENT				800		0		2,432,000		570,348	
SALES TAX 7.80 %					25,600		3,750		6,027,200		9,058,898
OH&P (ON MARKUPS ONLY)							292		470121		470414
										23520	23520
TOTAL COST CODE 70011				800		0		2,432,000		593,868	
WBS 221130					25,600		4,042		6,497,321		9,552,832
(ESCALATION 0.00% - CONTINGENCY 50.00 %)											
TOTAL WBS 221130 PROCESS EQUIPMENT				800		0		2,432,000		593,868	
					25,600		4,042		6,497,321		9,552,832

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP. USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010	PROCESS FACILITY										
310010.02	SITWORK										
310010.0200010	EXCAVATION -- 3 ACRES CLEAN AND GRUB PLUS ALLOWANCE FOR FOOTINGS ALLOW 4 MEN 40MH/EA AT \$50/HR.	501	1 LOT	0	0	0	0	8000	0	800	8800
	SUBTOTAL			0	0	0	0	8,000	0	800	8,800
	TOTAL			0	0	0	0	8,000	0	800	8,800
	COST CODE 50102 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)										8,800
310010.03	CONCRETE										
310010.0300010	BUILDING SLAB=50'X60'X2'THK. ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	225 CY	0	0	0	0	172125	0	17213	189338
310010.0300020	BUILDING SLAB=20'X40'X2'THK. ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	60 CY	0	0	0	0	45900	0	4590	50490
310010.0300030	EVAP BUILDING--SEE T.O.137CY ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	137 CY	0	0	0	0	104805	0	10481	115286
	SUBTOTAL			0	0	0	0	322,830	0	32,284	355,114
	TOTAL			0	0	0	0	322,830	0	32,284	355,114
	COST CODE 50103 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)										355,114
310010.05	METALS										
310010.0500010	50'W X 60'L X 70'H -PH.QUOTE METAL BUILDING 3,000SF X 2 ALLOW GRATING FOR 2ND FLOOR BUILDING COSTS = \$300K	501	1 LOT	0	0	0	0	300000	0	30000	330000
310010.0500020	20'W X 40'L X 35'H METAL BUILDING 800SF	501	1 LOT	0	0	0	0	40000	0	4000	44000

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
*****	*****	****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	USE SAME COST/SF AS QUOTE \$300K/6000SF= \$50/SF X 800SF										
SUBTOTAL	METALS			0	0	0	0	340,000	0	34,000	374,000
TOTAL	COST CODE 50105 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	340,000	0	34,000	374,000
310010.06 310010.0600010	WOOD AND PLASTICS CONTROL ROOM AND RESTROOMS ALLOW 10' X 20'/EA DOES NOT INCL. CONT RM EQUIP	501	400 SF	0	0	0	0	20000	0	2000	22000
SUBTOTAL	WOOD AND PLASTICS			0	0	0	0	20,000	0	2,000	22,000
TOTAL	COST CODE 50106 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	20,000	0	2,000	22,000
310010.08 310010.0800010	DOORS, WINDOWS AND G 50'W X 60'L X 70'H -PH.QUOTE ALLOWANCE FOR 30' DOORS ALLOW 10% OF BLDG FOR DOORS BLDG = \$300K X 10%	501	1 LOT	0	0	0	0	30000	0	3000	33000
SUBTOTAL	DOORS, WINDOWS AND G			0	0	0	0	30,000	0	3,000	33,000
TOTAL	COST CODE 50108 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	30,000	0	3,000	33,000
310010.10 310010.1000010	SPECIALTIES GENERAL FREIGHT ELEVATOR NO INFO -- ALLOW 6,000# RICH 10-20 PG.3 \$42K + 30% INSTALL	501	1 LOT	0	0	0	0	55000	0	5500	60500
SUBTOTAL	SPECIALTIES			0	0	0	0	55,000	0	5,500	60,500

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS

TOTAL	COST CODE 50110			0		0		55,000		5,500	
	WBS 310010				0		0		0		60,500
	(ESCALATION 0.00% - CONTINGENCY 50.00 %)										
310010.11	EQUIPMENT										
310010.1100010	CRANE - 50' SPAN HAND CTRL	501	1 LOT	0	0	0	0	330000	0	33000	363000
	20T BRIDGE CRANE										
	\$275K PLUS 20% INSTALL										
	= \$330K										

SUBTOTAL	EQUIPMENT			0		0		330,000		33,000	
					0		0		0		363,000

TOTAL	COST CODE 50111			0		0		330,000		33,000	
	WBS 310010				0		0		0		363,000
	(ESCALATION 0.00% - CONTINGENCY 50.00 %)										
310010.15	MECHANICAL										
310010.1500010	BLDG SERV. PIPING - NO INFO	501	1500 LF	0	0	0	0	225000	0	22500	247500
	ALLOW .25LF/SF X 6,000SF										
	1EA 90DEG EL /10LF 304L (4")										
	2EA4"BW,10'PIPE,1-90EL,HNDLG										
310010.1500015	BLDG SERV. PIPING - NO INFO	501	200 LF	0	0	0	0	30000	0	3000	33000
	ALLOW .25LF/SF X 800SF										
	1EA 90DEG EL /10LF 304L (4")										
	2EA4"BW,10'PIPE,1-90EL,HNDLG										
310010.1500025	EVAP. BLDG PIPING - NO INFO	501	68 LF	0	0	0	0	10200	0	1020	11220
	ALLOW .25LF/SF X 272SF										
	1EA 90DEG EL /10LF 304L (4")										
	2EA4"BW,10'PIPE,1-90EL,HNDLG										
310010.1500050	FIRE PROTECTION -- NO INFO.	501	6000 SF	0	0	0	0	60000	0	6000	66000
	ALLOW FIRECYCLE SYSTEM										
	RICH. 15-105 PG.1										
310010.1500055	FIRE PROTECTION -- NO INFO.	501	800 SF	0	0	0	0	8000	0	800	8800
	ALLOW FIRECYCLE SYSTEM										
	RICH. 15-105 PG.1										
310010.1500065	EVAP BLDG.FIRE PROT- NO INFO	501	272 SF	0	0	0	0	2720	0	272	2992
	ALLOW FIRECYCLE SYSTEM										
	RICH. 15-105 PG.1										
310010.1500100	BLDG. NORMAL HVAC --NO INFO.	501	1 LOT	0	0	0	0	100000	0	10000	110000
	ALLOW 21,000CFM SYSTEM										

0.18

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. 2285SAA1/95CHBS

** IEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D COMBUSTION MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010.1500110	PH QUOTE VENDOR 21000/400CFM=52.5T X \$1800= BLDG. NORMAL HVAC --NO INFO. USE SAME COST/SF AS 6,000SF \$100K/6000SF= \$17/SF 800SF X \$20=	501	1 LOT	0	0	0	0	16000	0	1600	17600
310010.1500120	BLDG. NORMAL HVAC --NO INFO. USE SAME COST/SF AS 6,000SF \$100K/6000SF= \$17/SF 272SF X \$20=	501	1 LOT	0	0	0	0	5500	0	550	6050
SUBTOTAL MECHANICAL				0	0	0	0	457,420	0	45,742	503,162
TOTAL				0	0	0	0	457,420	0	45,742	503,162
COST CODE 50115 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)											
310010.16	ELECTRICAL										
310010.1600010	CABLE TRAY USE SAME AS PIPE 1EA 90DEG/10LF 12"W @ \$27/LF 1500'+200'+68= 1768LF	501	1768 LF	0	0	0	0	47736	0	4774	52510
310010.1600020	CABLE USE 4 X CABLE TRAY 1,768LF X 4 = 7,100 LF	501	7100 LF	0	0	0	0	49700	0	4970	54670
310010.1600030	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT ALLOW 1EA/100SF = 60EA 4MH @ \$50/HR + \$600/EA	501	60 EA	0	0	0	0	48000	0	4800	52800
310010.1600035	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT (800SF) ALLOW 1EA/100SF = 8EA 4MH @ \$50/HR + \$600/EA	501	8 EA	0	0	0	0	6400	0	640	7040
310010.1600045	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT (272SF) ALLOW 2EA/FLOOR = 4EA 4MH @ \$50/HR + \$600/EA	501	4 EA	0	0	0	0	3200	0	320	3520
310010.1600075	NORMAL ELEC. DISTRIBUTION SWITCHGEAR 13KV REF. CASE 2A 252027.1661601 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	65000	218000	17400	300400
310010.1600080	NORMAL ELEC. DISTRIBUTION TRANSFORMER 13KV/480V	501	1 EA	0	0	0	0	12000	39000	3150	54150

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** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
SMT/D COMBUSTION MELTER -- S T U D Y
DOE_RO8 - ESTIMATE DETAIL BY WBS. / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
*****	*****	----	*****	*****	*****	*****	*****	*****	*****	*****	*****
310010.1600085	REF. CASE 2A 252027.1661602 30% FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION LOAD CENTER 480V	501	1 EA	0	0	0	0	80000	267000	21350	368350
310010.1600090	REF. CASE 2A 252027.1661603 30% FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION MCC	501	1 EA	0	0	0	0	12000	43000	3350	58350
310010.1600095	REF. CASE 2A 252027.1661605 30% FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION DISTRIBUTION PANEL	501	1 EA	0	0	0	0	1000	6000	400	7400
310010.1600100	REF. CASE 2A 252027.1661606 30% FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION SWITCH GEAR	501	1 EA	0	0	0	0	48000	160000	12800	220800
310010.1600105	REF. CASE 2A 252027.1661701 30% FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION LOAD CENTERS	501	1 EA	0	0	0	0	41000	135000	10850	186850
310010.1600110	REF. CASE 2A 252027.1661702 30% FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION MCC	501	1 EA	0	0	0	0	1000	6000	400	7400
310010.1600115	REF. CASE 2A 252027.1661703 30% FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY DISTRIBUTION PANEL	501	1 EA	0	0	0	0	5000	15000	1250	21250
310010.1600120	REF. CASE 2A 252027.1661801 30% FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY OTHER PANELS	501	1 EA	0	0	0	0	48000	164000	13000	225000
310010.1600125	REF. CASE 2A 252027.1661802 30% FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY BATTERIES	501	1 EA	0	0	0	0	12000	41000	3250	56250
310010.1600130	REF. CASE 2A 252027.1661803 30% FIELD LAB & MATL INSTALL DC BATTERY CONTROL	501	1 EA	0	0	0	0	18000	59000	4750	81750
	REF. CASE 2A 252027.1661901 30% FIELD LAB & MATL INSTALL										

0.20

KAISER ENGINEERS HANFORD
R.A. THOMPSON
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** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5HT/D COMBUSTION MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010.1600135	DC BATTERY CHARGER REF. CASE 2A 252027.1661902 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	3000	10000	800	13800
310010.1600140	DC DISTRIBUTION PANEL REF. CASE 2A 252027.1661903 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	1000	3000	250	4250
310010.1600150	COMPRESSED AIR NO INFORMATION ALLOW \$100K USE 50% INSTALLATION	501	1 LOT	0	0	0	0	50000	100000	10000	160000
310010.1600152	ALLOW 300' POLE LINE ALLOW 2EA POLES \$500/EA 300' X 2WIRES X.5/LF=\$300 ALLOW 4MEN 24MH/EA. @ \$32/HR	501	1 LOT	0	0	0	0	5000	0	500	5500
310010.1600160	STEAM ALLOWANCE (15,000#/HR) PH QUOTE FOR OIL FIRED BOILR ALLOW 50% INSTALLATION	501	1 LOT	0	0	0	0	50000	100000	10000	160000
310010.1600210	INSTRUMENTATION ALLOW 25% OF EQUIP. COSTS. \$7,969,870 X.25% =	501	1 LOT	0	0	0	0	1992000	0	199200	2191200
<hr/>											
SUBTOTAL	ELECTRICAL			0	0	0	0	2,599,036		328,204	
	SALES TAX 7.80 %						0		1,366,000		4,293,240
	OH&P (ON MARKUPS ONLY)						0		106548		106548
										5327	5327
<hr/>											
TOTAL	COST CODE 50116 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	2,599,036		333,531	
									1,472,548		4,405,115
<hr/>											
TOTAL WBS 310010	PROCESS FACILITY			0	0	0	0	4,162,286		489,857	
									1,472,548		6,124,691

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** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
SMT/D COMBUSTION MELTER -- S T U D Y
DOE_ROB - ESTIMATE DETAIL BY WBS / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
411000	CONSTRUCTION MANAGEMENT										
411000.00	TECHNICAL SERVICES										
411000.0000001	CONSTRUCTION MANAGEMENT 10% OF DIRECTS	000	1 LOT	0	0	0	0	1568000	0	0	1568000
SUBTOTAL	TECHNICAL SERVICES			0	0	0	0	1,568,000	0	0	1,568,000
TOTAL	COST CODE 00000 WBS 411000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	1,568,000	0	0	1,568,000
TOTAL WBS 411000	CONSTRUCTION MANAGEMENT			0	0	0	0	1,568,000	0	0	1,568,000

0.22

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JOB NO. 2285SAA1/95CHBS

** IEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D COMBUSTION MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
511000	PROJECT MANAGEMENT										
511000.00	TECHNICAL SERVICES										
511000.0000001	PROJECT MANAGEMENT 10% OF DIRECTS, ENGINEERING & CONSTRUCTION MANAGEMENT.	000	1 LOT	0	0	0	0	2352000	0	0	2352000
SUBTOTAL	TECHNICAL SERVICES			0	0	0	0	2,352,000	0	0	2,352,000
TOTAL	COST CODE 00000 WBS 511000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	2,352,000	0	0	2,352,000
TOTAL WBS 511000	PROJECT MANAGEMENT			0	0	0	0	2,352,000	0	0	2,352,000

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JOB NO. 2285SAA1/95CMBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D COMBUSTION MELTER -- S T U D Y
DOE_ROB - ESTIMATE DETAIL BY WBS / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
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REPORT TOTAL

				800		0	16,784,286		1,083,726		
					25,600		4,042		7,969,869		25,867,524

Appendix E

Cost Estimate for the Joule-Heated Melter System

Cost Summary for the Joule-Heated Melter System

Process Equipment

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
221130.1142301	Joule -Heated Melter	\$0	\$0	\$0	\$3,500,000	\$175,000	\$3,675,000
221130.1142305	Film Cooler	\$0	\$0	\$9,000	\$30,000	\$2,400	\$41,400
221130.1142315	Quench Tower	\$0	\$0	\$15,000	\$50,000	\$4,000	\$69,000
221130.1142320	Hydrosonic Scrubber/Separator	\$0	\$0	\$60,000	\$200,000	\$16,000	\$276,000
221130.1142325	HEME	\$0	\$0	\$20,000	\$62,000	\$5,100	\$87,100
221130.1142330	Preheater	\$0	\$0	\$500	\$1,500	\$125	\$2,125
221130.1142335	HEMF	\$0	\$0	\$33,000	\$110,000	\$8,800	\$151,800
221130.1142340	SCR	\$25,600	\$0	\$0	\$300,000	\$40,600	\$366,200
221130.1142345	Off-Gas Blower	\$0	\$0	\$8,000	\$25,000	\$2,050	\$35,050
221130.1142350	Stack	\$0	\$0	\$50,000	\$0	\$5,000	\$55,000
221130.1142355	Scrubber Catch Tank	\$0	\$0	\$14,000	\$47,000	\$3,750	\$64,750
221130.1142360	Quench Water Pump	\$0	\$0	\$1,200	\$3,900	\$315	\$5,415
221130.1142365	Scrubber Solution Filter	\$0	\$0	\$90,000	\$300,000	\$24,000	\$414,000
221130.1142370	Heat Exchanger	\$0	\$0	\$24,000	\$80,000	\$6,400	\$110,400
221130.1142380	Recycle Sludge Pump A	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142385	Feed Preparation Tank	\$0	\$0	\$30,000	\$91,000	\$7,550	\$128,550
221130.1142386	Feed Preparation Tank Agitator	\$0	\$0	\$10,000	\$34,000	\$2,700	\$46,700
221130.1142390	Feed Transfer Pump	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142395	Melter Feed Tank	\$0	\$0	\$22,000	\$75,000	\$5,950	\$102,950
221130.1142396	Melter Feed Tank Agitator	\$0	\$0	\$9,000	\$30,000	\$2,400	\$41,400
221130.1142400	Melter Feed Pump	\$0	\$0	\$2,000	\$6,100	\$505	\$8,605
221130.1142405	Simulant Pump	\$0	\$0	\$1,200	\$4,100	\$325	\$5,625
221130.1142410	Chemical Addition Pump	\$0	\$0	\$300	\$1,000	\$80	\$1,380
221130.1142415	Dry Chemical Addition Conveyor	\$0	\$0	\$190,000	\$190,000	\$28,500	\$408,500
221130.1142420	Demister A	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
221130.1142425	Condenser	\$0	\$0	\$24,000	\$80,000	\$6,400	\$110,400
221130.1142430	Demister B	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
221130.1142435	Condensate Tank	\$0	\$0	\$11,000	\$39,000	\$3,050	\$53,050
221130.1142440	Condensate Pump	\$0	\$0	\$1,200	\$4,200	\$330	\$5,730
221130.1142441	Melter Electrical	\$0	\$0	\$150,000	\$300,000	\$30,000	\$480,000
221130.1142460	Product Canister	\$0	\$0	\$1,200	\$4,000	\$320	\$5,520
221130.1142465	Canister Mounting System	\$0	\$0	\$9,000	\$30,000	\$2,400	\$41,400
221130.1142470	Cooling Tower	\$0	\$0	\$12,000	\$41,000	\$3,250	\$56,250
221130.1142490	Slurry Receipt Tank	\$0	\$0	\$42,000	\$139,000	\$11,150	\$192,150
221130.1142492	Vessel Vent Blower	\$0	\$0	\$8,000	\$25,000	\$2,050	\$35,050
221130.1142493	Vessel Vent Preheater	\$0	\$0	\$500	\$1,500	\$125	\$2,125
221130.1142495	Vessel Vent HEPA	\$0	\$0	\$500	\$5,500	\$325	\$6,325
221130.1142500	Glass Former Hopper	\$0	\$0	\$10,000	\$25,000	\$2,250	\$37,250
221130.1142503	Dust Collection System	\$0	\$0	\$5,000	\$5,000	\$750	\$10,750
221130.1142505	Canister Storage Rack	\$0	\$3,750	\$13,500	\$0	\$1,538	\$18,788
221130.1142510	Evaporator	\$0	\$0	\$23,000	\$77,000	\$6,150	\$106,150
221130.1142515	Recycle Sludge Pump	\$0	\$0	\$300	\$1,000	\$80	\$1,380
221130.1142520	Makeup Water Pump	\$0	\$0	\$1,200	\$4,300	\$335	\$5,835
221130.1142530	Scrubber Catch Tank Agitator	\$0	\$0	\$2,000	\$6,300	\$515	\$8,815
221130.1142535	Condensate Tank Agitator	\$0	\$0	\$2,000	\$5,600	\$480	\$8,080
221130.1142540	Simulant Receipt Tank Agitator	\$0	\$0	\$11,000	\$38,000	\$3,000	\$52,000
Equipment Subtotal		\$25,600	\$3,750	\$921,000	\$5,986,200	\$417,198	\$7,353,748
Tax		\$0	\$293	\$0	\$466,924	\$0	\$467,216
OH&P on Markups only		\$0	\$0	\$0	\$0	\$23,360	\$23,360
221130 Equipment Total		\$25,600	\$4,043	\$921,000	\$6,453,124	\$440,558	\$7,844,324

Facility

Sitework

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0200010	Excavation	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010	Sitework Total	\$0	\$0	\$8,000	\$0	\$800	\$8,800

Concrete

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0300010	Building Slab 50' x 60' x 2'	\$0	\$0	\$172,125	\$0	\$17,213	\$189,338
310010.0300020	Building Slab 20' x 40' x 2'	\$0	\$0	\$45,900	\$0	\$4,590	\$50,490
310010.0300030	Evaporator Building	\$0	\$0	\$104,805	\$0	\$10,481	\$115,286
310010	Concrete Total	\$0	\$0	\$322,830	\$0	\$32,283	\$355,113

Metals

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0500010	Metal Building 50' x 60' x 70'	\$0	\$0	\$300,000	\$0	\$30,000	\$330,000
310010.0500020	Metal Building 20' x 40' x 35'	\$0	\$0	\$40,000	\$0	\$4,000	\$44,000
310010.05	Metal Total	\$0	\$0	\$340,000	\$0	\$34,000	\$374,000

Wood & Plastics

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0600010	Control Room 10' x 20'	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000
310010	Wood & Plastics Total	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000

Windows & Doors

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.0800010	Doors & windows	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.08	Windows & Doors Total	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000

Specialties

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1000000	Freight Elevator	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500
310010.1	Specialties Total	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500

Equipment

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1100010	20 ton Crane with 50' span	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000
310010.11	Equipment Total	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000

Mechanical

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1500010	Service Piping for 6000 ft^2	\$0	\$0	\$225,000	\$0	\$22,500	\$247,500
310010.1500015	Service Piping for 800 ft^2	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.1500025	Service Piping for Evaporator	\$0	\$0	\$10,200	\$0	\$1,020	\$11,220
310010.1500050	Fire Protection for 6,000 ft^2	\$0	\$0	\$60,000	\$0	\$6,000	\$66,000
310010.1500055	Fire Protection for 800 ft^2	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010.1500065	Fire Protection for Evaporator Building	\$0	\$0	\$2,720	\$0	\$272	\$2,992
310010.1500100	HVAC for 6,000 ft^2	\$0	\$0	\$100,000	\$0	\$10,000	\$110,000
310010.1500110	HVAC for 800 ft^2	\$0	\$0	\$16,000	\$0	\$1,600	\$17,600
310010.1500120	HVAC for Evaporator Building	\$0	\$0	\$5,500	\$0	\$550	\$6,050
310010.15	Mechanical Total	\$0	\$0	\$457,420	\$0	\$45,742	\$503,162

Electrical

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010.1600010	Cable Tray	\$0	\$0	\$47,736	\$0	\$4,774	\$52,510
310010.1600020	Cable	\$0	\$0	\$49,700	\$0	\$4,970	\$54,670
310010.1600030	Lighting for 6,000 ft^2	\$0	\$0	\$48,000	\$0	\$4,800	\$52,800
310010.1600035	Lighting for 800 ft^2	\$0	\$0	\$6,400	\$0	\$640	\$7,040
310010.1600045	Lighting for 272 ft^3	\$0	\$0	\$3,200	\$0	\$320	\$3,520
310010.1600075	Normal Electrical Distribution	\$0	\$0	\$65,000	\$218,000	\$17,400	\$300,400
310010.1600080	Normal Electrical Distribution	\$0	\$0	\$12,000	\$39,000	\$3,150	\$54,150
310010.1600085	Normal Electrical Distribution	\$0	\$0	\$80,000	\$267,000	\$21,350	\$368,350
310010.1600090	Normal Electrical Distribution	\$0	\$0	\$12,000	\$43,000	\$3,350	\$58,350
310010.1600095	Normal Electrical Distribution	\$0	\$0	\$1,000	\$6,000	\$400	\$7,400
310010.1600100	Standby Electrical Distribution	\$0	\$0	\$48,000	\$160,000	\$12,800	\$220,800
310010.1600105	Standby Electrical Distribution	\$0	\$0	\$41,000	\$135,000	\$10,850	\$186,850
310010.1600110	Standby Electrical Distribution	\$0	\$0	\$1,000	\$6,000	\$400	\$7,400
310010.1600115	Uninterruptible Power Supply	\$0	\$0	\$5,000	\$15,000	\$1,250	\$21,250
310010.1600120	Uninterruptible Power Supply	\$0	\$0	\$48,000	\$164,000	\$13,000	\$225,000
310010.1600125	Uninterruptible Power Supply	\$0	\$0	\$12,000	\$41,000	\$3,250	\$56,250
310010.1600130	DC Battery Control	\$0	\$0	\$18,000	\$59,000	\$4,750	\$81,750
310010.1600135	DC Battery Charger	\$0	\$0	\$3,000	\$10,000	\$800	\$13,800
310010.1600140	DC Distribution Panel	\$0	\$0	\$1,000	\$3,000	\$250	\$4,250
310010.1600150	Compressed Air	\$0	\$0	\$50,000	\$100,000	\$10,000	\$160,000
310010.1600152	Poles & Poles Line	\$0	\$0	\$5,000	\$0	\$500	\$5,500
310010.1600160	Steam Allowance	\$0	\$0	\$50,000	\$100,000	\$10,000	\$160,000
310010.1600210	Instrumentation	\$0	\$0	\$1,980,000	\$0	\$198,000	\$2,178,000

	Electrical Subtotal	\$0	\$0	\$2,587,036	\$1,366,000	\$327,004	\$4,280,040
	Tax	\$0	\$0	\$0	\$106,548	\$0	\$106,548
	OH&P on Markups only	\$0	\$0	\$0	\$0	\$5,327	\$5,327
310010.16	Electrical Total	\$0	\$0	\$2,587,036	\$1,472,548	\$332,331	\$4,391,915

Facility

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
310010	Sitework Total	\$0	\$0	\$8,000	\$0	\$800	\$8,800
310010.03	Concrete Total	\$0	\$0	\$322,830	\$0	\$32,283	\$355,113
310010.05	Metal Total	\$0	\$0	\$340,000	\$0	\$34,000	\$374,000
310010.06	Wood & Plastics Total	\$0	\$0	\$20,000	\$0	\$2,000	\$22,000
310010.08	Windows & Doors Total	\$0	\$0	\$30,000	\$0	\$3,000	\$33,000
310010.1	Specialties Total	\$0	\$0	\$55,000	\$0	\$5,500	\$60,500
310010.11	Equipment Total	\$0	\$0	\$330,000	\$0	\$33,000	\$363,000
310010.15	Mechanical Total	\$0	\$0	\$457,420	\$0	\$45,742	\$503,162
310010.16	Electrical Total	\$0	\$0	\$2,587,036	\$1,472,548	\$332,331	\$4,391,915

310010	Process Facility	\$0	\$0	\$4,160,286	\$1,472,548	\$488,666	\$6,111,490
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Engineering & Management

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
110000	Engineering	\$10,240	\$1,617	\$2,028,514	\$3,170,269	\$371,685	\$5,582,325
411000	Construction Management	\$2,560	\$404	\$507,129	\$792,567	\$92,921	\$1,395,581
511000	Project Management	\$3,840	\$606	\$760,693	\$1,188,851	\$139,382	\$2,093,372

	Engineering/CM/PM Total	\$16,640	\$2,628	\$3,296,336	\$5,151,687	\$603,989	\$9,071,279
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Project

Account	Item	Labor	Material	Subcontract	Equipment	OH&P/B&I	Total
	Engineering/CM/PM	\$16,640	\$2,628	\$3,296,336	\$5,151,687	\$603,989	\$9,071,279
221130	Equipment	\$25,600	\$4,043	\$921,000	\$6,453,124	\$440,558	\$7,844,324
310010	Process Facility	\$0	\$0	\$4,150,286	\$1,472,548	\$488,656	\$6,111,490

Escalated Total	\$42,240	\$6,670	\$8,367,622	\$13,077,358	\$1,533,202	\$23,027,092
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50 % Contingency	\$21,120	\$3,335	\$4,183,811	\$6,538,679	\$766,601	\$11,513,546
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Project Total	\$63,360	\$10,005	\$12,551,433	\$19,616,037	\$2,299,802	\$34,540,638
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KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. Z285SAA1/95CHBS

**** IEST - INTERACTIVE ESTIMATING ****
PILOT SCALE LLW VITRIFICATION FACILITY
5HT/D JOULE HEATED MELTER -- S T U D Y
DOE_R01 - PROJECT COST SUMMARY

PAGE 1 OF 4
DATE 05/02/95
BY T.L. WALDO

COST CODE *****	DESCRIPTION *****	ESCALATED TOTAL COST *****	CONTINGENCY % *****	TOTAL *****	TOTAL DOLLARS *****
000	ENGINEERING/CH/PM	9,070,000	50	4,530,000	13,600,000
501	BUILDINGS	6,110,000	50	3,060,000	9,170,000
700	SPECIAL EQUIP/PROCESS SYSTEMS	7,840,000	50	3,920,000	11,760,000
	(ADJUSTED TO MEET DOE 5100.4)				
=====					
PROJECT TOTAL		23,020,000	50	11,510,000	34,530,000

E.5

TYPE OF
ESTIMATE ROH - S T U D Y

ARCHITECT
ENGINEER *H. Chadwick*

OPERATING
CONTRACTOR

REMARKS:

(ROUNDED/ADJUSTED TO THE NEAREST " 10,000 / 100,000 " - PERCENTAGES NOT RECALCULATED TO REFLECT ROUNDING)

E.C

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. 2285SAA1/95CMBS

** IEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
SMT/D JOULE HEATED MELTER -- S T U D Y
DOE_R02 - WORK BREAKDOWN STRUCTURE SUMMARY

PAGE 2 OF 4
DATE 05/02/95
BY T.L. WALDO

WBS	DESCRIPTION	ESTIMATE SUBTOTAL	ONSITE INDIRECTS	SUB TOTAL	ESCALATION % TOTAL	SUB TOTAL	CONTINGENCY % TOTAL	TOTAL DOLLARS
*****	*****	*****	*****	*****	*****	*****	*****	*****
110000	ENGINEERING	5580000	0	5580000	0.00	0	5580000	50 2790000 8370000
SUBTOTAL 1	ENGINEERING	5580000	0	5580000	0.00	0	5580000	50 2790000 8370000
221130	PROCESS EQUIPMENT	7844326	0	7844326	0.00	0	7844326	50 3922163 11766489
SUBTOTAL 22	PROCESS EQUIPMENT	7844326	0	7844326	0.00	0	7844326	50 3922163 11766489
SUBTOTAL 2	PROCUREMENT	7844326	0	7844326	0.00	0	7844326	50 3922163 11766489
310010	PROCESS FACILITY	6111491	0	6111491	0.00	0	6111491	50 3055746 9167237
SUBTOTAL 31	PROCESS FACILITY	6111491	0	6111491	0.00	0	6111491	50 3055746 9167237
SUBTOTAL 3	CONSTRUCTION	6111491	0	6111491	0.00	0	6111491	50 3055746 9167237
411000	CONSTRUCTION MANAGEMENT	1395000	0	1395000	0.00	0	1395000	50 697500 2092500
511000	PROJECT MANAGEMENT	2093000	0	2093000	0.00	0	2093000	50 1046500 3139500
=====								
PROJECT TOTAL		23,023,817	0	23,023,817	0.00	0	23,023,817	50 11,511,909 34,535,726

KAISER ENGINEERS HANFORD
WESTINGHOUSE HANFORD COMPANY
JOB NO. Z157SAA1

**** TEST - INTERACTIVE ESTIMATING ****
PILOT SCALE LLW VITRIFICATION FACILITY
S T U D Y
DOE_R03 - ESTIMATE BASIS SHEET

PAGE 3 OF 4
DATE 5-2-95
BY T.L. WALDO

1. DOCUMENTS AND DRAWINGS

DRAWINGS: ENGINEERING SKETCHES AND FLOW SHEET.
EQUIPMENT LISTS DATED 11/1/94, 1/31/95, 2/21/95 & 5/1/95.

2. MATERIAL PRICES

UNIT COSTS REPRESENT CURRENT PRICES FOR SPECIFIED MATERIAL. VENDOR INFORMATION WAS OBTAINED FOR THE FOLLOWING ITEMS:
TANKS; PUMPS; AGITATORS; BUILDING.

3. LABOR RATES

CURRENT KEH BASE CRAFT RATES, AS ISSUED BY KEH FINANCE (EFFECTIVE 10-01-93), INCLUDE FRINGE BENEFITS, LABOR INSURANCE, TAXES AND TRAVEL WHERE APPLICABLE, PER HANFORD SITE STABILIZATION AGREEMENT, APPENDIX A (EFFECTIVE 9-06-93). NON CRAFT HOURLY RATES ARE BASED ON THE 1994 FISCAL YEAR BUDGET LIQUIDATION RATES AS ISSUED BY KEH FINANCE (EFFECTIVE 10-01-93).

4. GENERAL REQUIREMENTS/TECHNICAL SERVICES

- A.) ONSITE CONSTRUCTION FORCES GENERAL REQUIREMENTS, TECHNICAL SERVICES AND CRAFT OVERHEAD COSTS ARE INCLUDED AS A COMPOSITE PERCENTAGE BASED ON THE KEH ESTIMATING FACTOR/BILLING SCHEDULE, REVISION 16, DATED OCTOBER 01, 1993. THE TOTAL COMPOSITE PERCENTAGE APPLIED TO ONSITE CONSTRUCTION FORCES LABOR, FOR THIS PROJECT, IS 93% FOR SHOP WORK AND 134% FOR FIELD WORK, WHICH IS REFLECTED IN THE "OH&P/B&I" COLUMN OF THE ESTIMATE DETAIL.
- B.) ONSITE CONTRACT ADMINISTRATION AND CONSTRUCTION MANAGEMENT COSTS, ASSOCIATED WITH THE OVERALL MANAGEMENT OF THE FIXED PRICE CONTRACTS, ARE INCLUDED AS A COMPOSITE PERCENTAGE AND LUMP SUM ALLOWANCE (FOR BID PACKAGE PREP) BASED ON THE ESTIMATING FACTOR/BILLING SCHEDULE. THE TOTAL COMPOSITE PERCENTAGE AND LUMP SUM ALLOWANCE ARE APPLIED AGAINST THE TOTAL FIXED PRICE CONTRACT AMOUNT WHICH IS REFLECTED ON THE KEH SUMMARY REPORT DOER07, INCLUDED WITH THIS ESTIMATE. (FINAL ESTIMATES MAY BE PARTIALLY MANLOADED AND INCLUDED WITHIN THE ESTIMATE DETAIL)
- C.) FIXED PRICE CONTRACTOR OVERHEAD, PROFIT, BOND AND INSURANCE COSTS HAVE BEEN APPLIED AT THE FOLLOWING PERCENTAGES AND ARE REFLECTED IN THE "OH&P / B & I" COLUMN OF THE ESTIMATE DETAIL:
LABOR - 53% MATERIAL - 5% EQUIPMENT - 5% SUBCONTRACTS - 10%

5. ESCALATION

ESCALATION IS NOT INCLUDED AND THE COST ESTIMATE IS IN 1995 DOLLARS.

6. ROUNDING

U.S. DEPARTMENT OF ENERGY - DOE ORDER 5100.4 PAGE 1-32 SUBPARAGRAPH (H), REQUIRES ROUNDING OF ALL GENERAL PLANT PROJECTS (GPP'S) AND LINE ITEM (LI) COST ESTIMATES. REFERENCE: DOE 5100.4, FIGURE 1-11, DATED 10-31-84.

7. REMARKS

PAGE 4 OF 4

- A.) THE ESTIMATE IS FOR DESIGN CONSTRUCTION OF A NEW FACILITY ONLY AND DOES NOT INCLUDE ANY COSTS FOR TIE-IN OR RADIOLOGICAL WORK WHICH WOULD BE DONE BY THE ON-SITE CONSTRUCTION CONTRACTOR.
- B.) ENGINEERING, PROJECT MANAGEMENT, CONSTRUCTION MANAGEMENT AND CONTINGENCY WAS APPLIED AS FOLLOWS:
 - ENGINEERING 40%
 - PROJECT MANAGEMENT 10%
 - CONSTRUCTION MANAGEMENT 10%
 - CONTINGENCY 50%
- C.) THE COST ESTIMATE IS IN 1995 DOLLARS AND DOES NOT INCLUDE ANY PERCENTAGES FOR ESCALATION SINCE A SCHEDULE HAS NOT BEEN PREPARED.
- D.) ALLOWANCES FOR CONTRACT DELAYS OR EXTENTION OF SCHEDULES IS NOT INCLUDED.
- E.) LABOR, MATERIAL, AND SUBCONTRACT OH & P WAS APPLIED AS FOLLOWS:
 - 1. LABOR 53%
 - 2. MATERIAL 5%
 - 3. EQUIPMENT 5%
 - 4. SUBCONTRACT 10%
- F.) UTILITIES TO THE SITE (IE. WATER, TRANSFER LINES, ETC.) IS NOT INCLUDED.
- G.) EQUIPMENT COST IS BASED UPON BEING COMMERCIALY FABRICATED AND IS CONTACT MAINTAINED. MOST OF THE TANKS, PUMPS AND AGITATOR COSTS WERE PROVIDED BY THE ENGINEER (AS RECEIVED FROM VENDORS).
- H.) THIS FACILITY IS ESTIMATED AS A CATEGORY III FACILITY (BUTLER BUILDING).
- I.) EQUIPMENT INSTALLATION FACTOR INCLUDES PIPING AND VALVES WITHIN THE ROOM WHERE EQUIPMENT IS INSTALLED.
- J.) INSTRUMENTATION COST ALLOWANCE IS 25% OF EQUIPMENT COST.

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. 2285SAA1/95CHBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5HT/D JOULE HEATED MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

PAGE 1.
DATE 05/01/95 16:59:15
BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
110000	ENGINEERING										
110000.00	TECHNICAL SERVICES										
110000.0000001	ENGINEERING TITLE I, II & III	000	1 LOT	0	0	0	0	5580000	0	0	5580000

SUBTOTAL	TECHNICAL SERVICES			0		0		5,580,000		0	

					0		0		0		5,580,000

TOTAL	COST CODE 00000 WBS 110000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0		0		5,580,000		0	

					0		0		0		5,580,000

TOTAL WBS 110000 ENGINEERING				0		0		5,580,000.		0	

					0		0		0		5,580,000

E10
KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. Z285SAA1/95CHBS

** IEST - INTERACTIVE ESTIMATING **
PILOT SCALE LEW VITRIFICATION FACILITY
5MT/D JOULE HEATED MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

PAGE 2
DATE 05/01/95 16:59:18
BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130	PROCESS EQUIPMENT										
221130.11	EQUIPMENT										
221130.1142301	301 GLASS MELTER 5MT/D JOULE HEATED MELTER PER ENGINEER \$3.5M INSTALLED COST	700	1 EA	0	0	0	0	0	3500000	175000	3675000
221130.1142305	302 FILM COOLER 10"ID X 2' L INCONEL 690 PER ENGINEER	700	1 EA	0	0	0	0	9000	30000	2400	41400
221130.1142315	304 QUENCH TOWER HASTELLOY C - 30% INSTALL 1500 ACFM @ 350C, COOL 140F ENG VENDOR QUOTE - BECO ENG.	700	1 EA	0	0	0	0	15000	50000	4000	69000
221130.1142320	305 HYDRO SCRUBBER/SEPARATOR 304L S.S., EXIT TEMP. 200F 30% FIELD LAB & MATL INSTALL ENG. VENDOR QUOTE-J.ZINK	700	1 EA	0	0	0	0	60000	200000	16000	276000
221130.1142325	307 HIGH EFF. MIST ELIMINATR 3'ID X 16'H 10GA 316L (HEME) 1146 SCFH 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	20000	62000	5100	87100
221130.1142330	308 PREHEATER TEMP DIFF. 10C FOR 650SCFH 30% FIELD LAB & MATL INSTALL ENG. VENDOR QUOTE - VEMCO	700	1 EA	0	0	0	0	500	1500	125	2125
221130.1142335	309 HEMF FILTER (METALLIC) PH QUOTE 1000 SCFH 10C 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	33000	110000	8800	151800
221130.1142340	310 SEL CATALYTIC NOx REDUCR 1000 SCFH. PH-QUOTE ARI ECON-NOx SCR DeNOx SYST. ALW 4MEN 5WKS/EA INSTALL	700	1 EA	800	25600	0	0	0	300000	40600	366200
221130.1142345	311 OFF-GAS BLOWER 1000 SCFH. @ 80" H2O VACUUM 30% FIELD LAB & MATL INSTALL PH QUOTE	700	1 EA	0	0	0	0	8000	25000	2050	35050
221130.1142350	312 --STACK -- NO INFO ALLOW 60' SHEETMETAL STACK ALW 1/2 OF LRG STACK MONITOR ALLOW \$25KSTACK &\$25K MONITR	700	1 LOT	0	0	0	0	50000	0	5000	55000

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. 2285SAA1/95CHBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
SMT/D JOULE HEATED MELTER -- S T U D Y
DOE_ROB - ESTIMATE DETAIL BY WBS / COST CODE

PAGE 3
DATE 05/01/95 16:59:22
BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142355	313 SCRUBBER CATCH TANK 4000 GAL. S.S.(15,150L) 30% FIELD LAB & MATL INSTALL ENG.VENDOR QUOTE - NICHOLSON	700	1 EA	0	0	0	0	14000	47000	3750	64750
221130.1142360	314 QUENCH WATER PUMP 20GPM @ 60PSI 316SS ENG. VENDOR QUOTE-DURIRON 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	1200	3900	315	5415
221130.1142365	315 SCRUB SOLUTION FILTRATION 15GPM -- DIATOMACEOUS EARTH SIM TO BATTELLE SYS.SOP #98 RECYCLE TREATMENT SYSTEM	700	1 EA	0	0	0	0	90000	300000	24000	414000
221130.1142370	316 HEAT EXCHANGER 304L 15GPM -- 21,000BTU/MIN 30% FIELD LAB & MATL INSTALL REF. CASE 28 231140.1144007	700	1 EA	0	0	0	0	24000	80000	6400	110400
221130.1142380	317 RECYCLE SLUDGE PUMP A 80GPM @ 60psi--AIR OPERATED 304L S.S. 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142385	318 FEED PREPARATION TANK 10,000GAL S.S.(37,900L) ENG.VENDOR QUOTE - NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	30000	91000	7550	128550
221130.1142386	350 FEED PREP TANK AGITATOR FOR 10,000GAL TANK 30%INSTALL ENG. VENDOR QUOTE-PHIL MIXER BLADES ARE HAST. C-276	700	1 EA	0	0	0	0	10000	34000	2700	46700
221130.1142390	319 FEED TRANSFER PUMP 100GPM @ 20PSI (30% INSTALL) ENG. VENDOR QUOTE-ARGO	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142395	320 MELTER FEED TANK 7,500GAL 304L S.S.(28,400L) ENG. VENDOR QUOTE-NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	22000	75000	5950	102950
221130.1142396	351 MELTER FEED TANK AGITATOR FOR 7,500 GAL TANK ENG. VENDOR QUOTE-PHIL.MIXER 30% INSTALL	700	1 EA	0	0	0	0	9000	30000	2400	41400
221130.1142400	321 MELTER FEED PUMP 0-120GPM @ 15-275 PSI ENG.VENDOR QUOTE-DURIRON	700	1 EA	0	0	0	0	2000	6100	505	8605

E.11

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. Z285SAA1/95CHBS

** IEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D JOULE HEATED MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

PAGE 4
DATE 05/01/95 16:59:27
BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142405	HASTELOY C/TUNG CARBIDE 322 SIMULANT PUMP 100GPM @ 20PSI (30% INSTALL) ENG. VENDOR QUOTE-ARGO	700	1 EA	0	0	0	0	1200	4100	325	5625
221130.1142410	323 CHEMICAL ADDITION PUMP ENG. VENDOR QUOTE-ARGO 10GPM @ 20PSI 30% INSTALL	700	1 EA	0	0	0	0	300	1000	80	1380
221130.1142415	324 DRY ADDITION CONVEYOR PNEUMATIC & SCREW CONVEYOR 5 MT PER DAY SYSTEM PH QUOTE	700	1 EA	0	0	0	0	190000	190000	28500	408500
221130.1142420	325 DEMISTER A 1100 FPM 30% INSTALL 316 S.S. ALLOW 3' X 3'	700	1 EA	0	0	0	0	1000	3000	250	4250
221130.1142425	ENG. VENDOR QUOTE-MUNTERS 326 CONDENSER 45,000 BTU/HIN (2.7MMBTU/HR) 160 SCFM DRY AIR-30% INSTALL REF. CASE 2B 231250.1144005	700	1 EA	0	0	0	0	24000	80000	6400	110400
221130.1142430	327 DEMISTER B 1100 FPM 30% INSTALL 316 S.S. ALLOW 3' X 3'	700	1 EA	0	0	0	0	1000	3000	250	4250
221130.1142435	ENG. VENDOR QUOTE-MUNTERS 328 CONDENSATE COLLECTION TK 3000 GAL (11,400L) S.S. ENG. VENDOR QUOTE-NICHOLSON 30% INSTALL	700	1 EA	0	0	0	0	11000	39000	3050	53050
221130.1142440	329 CONDENSATE PUMP 30% INSTALL S.S. 100GPM ENG. VENDOR QUOTE-DURIRON	700	1 EA	0	0	0	0	1200	4200	330	5730
221130.1142441	330 MELTER ELECTRICAL 50% INSTALL ENGINEERING ALLOWANCE	700	1 EA	0	0	0	0	150000	300000	30000	480000
221130.1142460	331 PRODUCT CANISTER ENGINEERING ALLOWANCE 30% INSTALL NO INFO. PROVIDED - -	700	1 EA	0	0	0	0	1200	4000	320	5520
221130.1142465	332 CANISTER MOUNTING SYSTEM C.S. 1500# -COOL SYS. NOT INC NO INFO OR SKETCHES.	700	1 EA	0	0	0	0	9000	30000	2400	41400

KAISER ENGINEERS HANFORD
R.A. THOMPSON
JOB NO. 2285SAA1/95CHBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
5MT/D JOULE HEATED MELTER -- S T U D Y
DOE ROB - ESTIMATE DETAIL BY WBS / COST CODE

PAGE 5
DATE 05/01/95 16:59:35
BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142470	ALLOW \$20/# 30% INSTALL 333 COOLING TOWER 2640 GPM (95F IN & 85F OUT) WET BULB 67F ENG.VENDOR QUOTE-TOWER TECH	700	1 EA	0	0	0	0	12000	41000	3250	56250
221130.1142490	337 SLURRY RECEIPT TNK 24,000 GAL -S.S.- ENG.VENDOR QUOTE-NICHOLSON 30% INSTALLATION	700	1 EA	0	0	0	0	42000	139000	11150	192150
221130.1142492	338 VESSEL VENT BLOWER PH QUOTE 650 SCFM 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	8000	25000	2050	35050
221130.1142493	340 VESSEL VENT PREHEATER 650 SCFM 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	500	1500	125	2125
221130.1142495	341 HEPA FILTER 1000 SCFM 10C ENG. VENDOR QUOTE-NELSON MEC	700	1 EA	0	0	0	0	500	5500	325	6325
221130.1142500	342 DRY FRIT/SILICA HOPPER PH QUOTE 304 S.S. W/DUST CTL NO FINISH 60DEG CONE (26CY) 30% FIELD LAB & MATL INSTALL	700	1 EA	0	0	0	0	10000	25000	2250	37250
221130.1142503	343 DUST COLLECTION SYSTEM PH QUOTE 2EA 3HP UNITS. STAND EQUIP. 5K/EA REDUNDANT 100% FAB & MATL INSTALL	700	1 EA	0	0	0	0	5000	5000	750	10750
221130.1142505	344 CANISTER STORAGE RACK INFO FROM FLUOR STUDY (FHEF) .75/# C.S. SHAPES LAB=\$40 .05MH/#+35XSafety CLASS	700	5000 LBS	0	0	0	3750	13500	0	1538	18788
221130.1142510	345 EVAPORATOR 150 psig STEM 140 GAL PER HR. EVAPORATION 316 S.S. 30% INSTALL ENG.VENDOR QUOTE-POWER PLANT	700	1 LOT	0	0	0	0	23000	77000	6150	106150
221130.1142515	346 RECYCLE SLUDGE PUMP B 5GPM @ --AIR OPERATED DIAPHR ENG.VENDOR QUOTE-ARGO 30% INSTALL	700	1 EA	0	0	0	0	300	1000	80	1380
221130.1142520	347 MAKEUP WATER PUMP 100GPM @ 60psi, 5HP ENG.VENDOR QUOTE-DURIRON	700	1 EA	0	0	0	0	1200	4300	335	5835

E.13

E.14

KAISER ENGINEERS HANFORD
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JOB NO. Z285AAA1/95CHBS

** TEST - INTERACTIVE ESTIMATING **
PILOT SCALE LLW VITRIFICATION FACILITY
SMT/D JOULE HEATED MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
221130.1142530	30% INSTALL 349 SCRUBBER TANK AGITATOR FOR SCRUBBER CATCH TANK ENG.VENDOR QUOTE-PHIL MIXER	700	1 EA	0	0	0	0	2000	6300	515	8815
221130.1142535	30% INSTALL 352 CONDENSATE COLL TK AGITR ENG.VENDOR QUOTE-PHIL MIXER	700	1 EA	0	0	0	0	2000	5600	480	8080
221130.1142540	30% INSTALL 353 SIMULANT RECT TK AGITATR ENG.VENDOR QUOTE-PHIL MIXER 25HP 30% INSTALL	700	1 EA	0	0	0	0	11000	38000	3000	52000
SUBTOTAL	EQUIPMENT			800		0		921,000		417,198	
	SALES TAX 7.80 %				25,600		3,750		5,986,200		7,353,748
	OH&P (ON MARKUPS ONLY)						292		466923		467216
										23360	23360
TOTAL	COST CODE 70011 WBS 221130 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			800		0		921,000		440,558	
					25,600		4,042		6,453,123		7,844,324
TOTAL WBS 221130 PROCESS EQUIPMENT				800		0		921,000		440,558	
					25,600		4,042		6,453,123		7,844,324

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** TEST -- INTERACTIVE ESTIMATING **
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5MT/D JOULE HEATED MELTER -- S T U D Y
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BY T.L. WALDO

ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010	PROCESS FACILITY										
310010.02	SITWORK										
310010.0200010	EXCAVATION -- 3 ACRES CLEAN AND GRUB PLUS ALLOWANCE FOR FOOTINGS ALLOW 4 MEN 40MH/EA AT \$50/HR.	501	1 LOT	0	0	0	0	8000	0	800	8800
	SUBTOTAL SITWORK			0	0	0	0	8,000	0	800	8,800
	TOTAL COST CODE 50102 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	8,000	0	800	8,800
310010.03	CONCRETE										
310010.0300010	BUILDING SLAB=50'X60'X2'THK. ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	225 CY	0	0	0	0	172125	0	17213	189338
310010.0300020	BUILDING SLAB=20'X40'X2'THK. ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	60 CY	0	0	0	0	45900	0	4590	50490
310010.0300030	EVAP BUILDING--SEE T.O.137CY ALLOW 10MH/CY-300#/CY REBAR MAT'L=\$75+150+25+15=\$265/CY S/C LAB ALLOW \$50/HR=\$500/CY	501	137 CY	0	0	0	0	104805	0	10481	115286
	SUBTOTAL CONCRETE			0	0	0	0	322,830	0	32,284	355,114
	TOTAL COST CODE 50103 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	322,830	0	32,284	355,114
310010.05	METALS										
310010.0500010	50'W X 60'L X 70'H --PH.QUOTE METAL BUILDING 3,000SF X 2 ALLOW GRATING FOR 2ND FLOOR BUILDING COSTS = \$300K	501	1 LOT	0	0	0	0	300000	0	30000	330000
310010.0500020	20'W X 40'L X 35'H METAL BUILDING 800SF	501	1 LOT	0	0	0	0	40000	0	4000	44000

E.15

E.16

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** IEST - INTERACTIVE ESTIMATING **
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SMT/D JOULE HEATED MELTER -- S T U D Y
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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
*****	*****	****	*****	*****	*****	*****	*****	*****	*****	*****	*****
	USE SAME COST/SF AS QUOTE \$300K/6000SF= \$50/SF X 800SF										
SUBTOTAL	METALS			0	0	0	0	340,000	0	34,000	374,000
TOTAL	COST CODE 50105 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	340,000	0	34,000	374,000
310010.06 310010.0600010	WOOD AND PLASTICS CONTROL ROOM AND RESTROOMS ALLOW 10' X 20'/EA DOES NOT INCL. CONT RM EQUIP	501	400 SF	0	0	0	0	20000	0	2000	22000
SUBTOTAL	WOOD AND PLASTICS			0	0	0	0	20,000	0	2,000	22,000
TOTAL	COST CODE 50106 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	20,000	0	2,000	22,000
310010.08 310010.0800010	DOORS, WINDOWS AND G 50'W X 60'L X 70'H -PH.QUOTE ALLOWANCE FOR 30' DOORS ALLOW 10% OF BLDG FOR DOORS BLDG = \$300K X 10%	501	1 LOT	0	0	0	0	30000	0	3000	33000
SUBTOTAL	DOORS, WINDOWS AND G			0	0	0	0	30,000	0	3,000	33,000
TOTAL	COST CODE 50108 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	30,000	0	3,000	33,000
310010.10 310010.1000010	SPECIALTIES GENERAL FREIGHT ELEVATOR NO INFO -- ALLOW 6,000# RICH 10-20 PG.3 \$42K + 30% INSTALL	501	1 LOT	0	0	0	0	55000	0	5500	60500
SUBTOTAL	SPECIALTIES			0	0	0	0	55,000	0	5,500	60,500

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS

TOTAL	COST CODE 50110 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	55,000	0	5,500	60,500
310010.11	EQUIPMENT										
310010.1100010	CRANE - 50' SPAN HAND CTRL 20T BRIDGE CRANE \$275K PLUS 20% INSTALL = \$330K	501	1 LOT	0	0	0	0	330000	0	33000	363000

SUBTOTAL	EQUIPMENT			0	0	0	0	330,000	0	33,000	363,000

TOTAL	COST CODE 50111 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	330,000	0	33,000	363,000
310010.15	MECHANICAL										
310010.1500010	BLDG SERV. PIPING - NO INFO ALLOW .25LF/SF X 6,000SF 1EA 90DEG EL /10LF 304L (4") 2EA4"BW,10'PIPE,1-90EL,HNDLG	501	1500 LF	0	0	0	0	225000	0	22500	247500
310010.1500015	BLDG SERV. PIPING - NO INFO ALLOW .25LF/SF X 800SF 1EA 90DEG EL /10LF 304L (4") 2EA4"BW,10'PIPE,1-90EL,HNDLG	501	200 LF	0	0	0	0	30000	0	3000	33000
310010.1500025	EVAP. BLDG PIPING - NO INFO ALLOW .25LF/SF X 272SF 1EA 90DEG EL /10LF 304L (4") 2EA4"BW,10'PIPE,1-90EL,HNDLG	501	68 LF	0	0	0	0	10200	0	1020	11220
310010.1500050	FIRE PROTECTION -- NO INFO. ALLOW FIRECYCLE SYSTEM RICH. 15-105 PG.1	501	6000 SF	0	0	0	0	60000	0	6000	66000
310010.1500055	FIRE PROTECTION -- NO INFO. ALLOW FIRECYCLE SYSTEM RICH. 15-105 PG.1	501	800 SF	0	0	0	0	8000	0	800	8800
310010.1500065	EVAP BLDG.FIRE PROT- NO INFO ALLOW FIRECYCLE SYSTEM RICH. 15-105 PG.1	501	272 SF	0	0	0	0	2720	0	272	2992
310010.1500100	BLDG. NORMAL HVAC --NO INFO. ALLOW 21,000CFM SYSTEM	501	1 LOT	0	0	0	0	100000	0	10000	110000

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** TEST - INTERACTIVE ESTIMATING **
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5HT/D JOULE HEATED MELTER -- S T U D Y
DOE_ROB - ESTIMATE DETAIL BY WBS / COST CODE

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
	PH QUOTE VENDOR										
310010.1500110	21000/400CFM=52.5T X \$1800= BLDG. NORMAL HVAC --NO INFO. USE SAME COST/SF AS 6,000SF \$100K/6000SF= \$17/SF 800SF X \$20=	501	1 LOT	0	0	0	0	16000	0	1600	17600
310010.1500120	BLDG. NORMAL HVAC --NO INFO. USE SAME COST/SF AS 6,000SF \$100K/6000SF= \$17/SF 272SF X \$20=	501	1 LOT	0	0	0	0	5500	0	550	6050
SUBTOTAL MECHANICAL				0	0	0	0	457,420	0	45,742	503,162
TOTAL				0	0	0	0	457,420	0	45,742	503,162
COST CODE 50115 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)											
310010.16	ELECTRICAL										
310010.1600010	CABLE TRAY USE SAME AS PIPE 1EA 90DEG/10LF 12"W @ \$27/LF 1500'+200'+68= 1768LF	501	1768 LF	0	0	0	0	47736	0	4774	52510
310010.1600020	CABLE USE 4 X CABLE TRAY 1,768LF X 4 = 7,100 LF	501	7100 LF	0	0	0	0	49700	0	4970	54670
310010.1600030	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT ALLOW 1EA/100SF = 60EA 4MH @ \$50/HR + \$600/EA	501	60 EA	0	0	0	0	48000	0	4800	52800
310010.1600035	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT (800SF) ALLOW 1EA/100SF = 8EA 4MH @ \$50/HR + \$600/EA	501	8 EA	0	0	0	0	6400	0	640	7040
310010.1600045	LIGHTING USE HIGH PRESSURE SODIUM 400 WATT (272SF) ALLOW 2EA/FLOOR = 4EA 4MH @ \$50/HR + \$600/EA	501	4 EA	0	0	0	0	3200	0	320	3520
310010.1600075	NORMAL ELEC. DISTRIBUTION SWITCHGEAR 13KV REF. CASE 2A 252027.1661601 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	65000	218000	17400	300400
310010.1600080	NORMAL ELEC. DISTRIBUTION TRANSFORMER 13KV/480V	501	1 EA	0	0	0	0	12000	39000	3150	54150

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** IEST - INTERACTIVE ESTIMATING **
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SMT/D JOULE HEATED MELTER -- S T U D Y
DOE_R08 - ESTIMATE DETAIL BY WBS / COST CODE

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010.1600085	REF. CASE 2A 252027.1661602 30X FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION LOAD CENTER 480V	501	1 EA	0	0	0	0	80000	267000	21350	368350
310010.1600090	REF. CASE 2A 252027.1661603 30X FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION HCC	501	1 EA	0	0	0	0	12000	43000	3350	58350
310010.1600095	REF. CASE 2A 252027.1661605 30X FIELD LAB & MATL INSTALL NORMAL ELEC. DISTRIBUTION DISTRIBUTION PANEL	501	1 EA	0	0	0	0	1000	6000	400	7400
310010.1600100	REF. CASE 2A 252027.1661606 30X FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION SWITCH GEAR	501	1 EA	0	0	0	0	48000	160000	12800	220800
310010.1600105	REF. CASE 2A 252027.1661701 30X FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION LOAD CENTERS	501	1 EA	0	0	0	0	41000	135000	10850	186850
310010.1600110	REF. CASE 2A 252027.1661702 30X FIELD LAB & MATL INSTALL STANDBY ELECT DISTRIBUTION HCC	501	1 EA	0	0	0	0	1000	6000	400	7400
310010.1600115	REF. CASE 2A 252027.1661703 30X FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY DISTRIBUTION PANEL	501	1 EA	0	0	0	0	5000	15000	1250	21250
310010.1600120	REF. CASE 2A 252027.1661801 30X FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY OTHER PANELS	501	1 EA	0	0	0	0	48000	164000	13000	225000
310010.1600125	REF. CASE 2A 252027.1661802 30X FIELD LAB & MATL INSTALL UNINTERRUPTIBLE POWER SUPPLY BATTERIES	501	1 EA	0	0	0	0	12000	41000	3250	56250
310010.1600130	REF. CASE 2A 252027.1661803 30X FIELD LAB & MATL INSTALL DC BATTERY CONTROL	501	1 EA	0	0	0	0	18000	59000	4750	81750
	REF. CASE 2A 252027.1661901 30X FIELD LAB & MATL INSTALL										

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** TEST - INTERACTIVE ESTIMATING **
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5MT/D JOULE HEATED MELTER -- S T U D Y
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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
310010.1600135	DC BATTERY CHARGER REF. CASE 2A 252027.1661902 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	3000	10000	800	13800
310010.1600140	DC DISTRIBUTION PANEL REF. CASE 2A 252027.1661903 30% FIELD LAB & MATL INSTALL	501	1 EA	0	0	0	0	1000	3000	250	4250
310010.1600150	COMPRESSED AIR NO INFORMATION ALLOW \$100K USE 50% INSTALLATION	501	1 LOT	0	0	0	0	50000	100000	10000	160000
310010.1600152	ALLOW 300' POLE LINE ALLOW 2EA POLES \$500/EA 300' X 2WIRES X.5/LF=\$300 ALLOW 4MEN 24MH/EA. @ \$32/HR	501	1 LOT	0	0	0	0	5000	0	500	5500
310010.1600160	STEAM ALLOWANCE (15,000#/HR) PH QUOTE FOR OIL FIRED BOILR ALLOW 50% INSTALLATION	501	1 LOT	0	0	0	0	50000	100000	10000	160000
310010.1600210	INSTRUMENTATION ALLOW 25% OF EQUIP. COSTS. \$7,925,672 X 25% =	501	1 LOT	0	0	0	0	1980000	0	198000	2178000
<hr/>											
SUBTOTAL	ELECTRICAL			0	0	0		2,587,036		327,004	
	SALES TAX 7.80 %						0		1,366,000		4,280,040
	OH&P (ON HARKUPS ONLY)						0		106548		106548
										5327	5327
<hr/>											
TOTAL	COST CODE 50116 WBS 310010 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0		2,587,036		332,331	
							0		1,472,548		4,391,915
<hr/>											
TOTAL WBS 310010	PROCESS FACILITY			0	0	0		4,150,286		488,657	
							0		1,472,548		6,111,491

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	HANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
411000	CONSTRUCTION MANAGEMENT										
411000.00	TECHNICAL SERVICES										
411000.0000001	CONSTRUCTION MANAGEMENT 10% OF DIRECTS	000	1 LOT	0	0	0	0	1395000	0	0	1395000
SUBTOTAL	TECHNICAL SERVICES			0	0	0	0	1,395,000	0	0	1,395,000
TOTAL	COST CODE 00000 WBS 411000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0	0	0	0	1,395,000	0	0	1,395,000
TOTAL WBS 411000	CONSTRUCTION MANAGEMENT			0	0	0	0	1,395,000	0	0	1,395,000

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS
511000	PROJECT MANAGEMENT										
511000.00	TECHNICAL SERVICES										
511000.0000001	PROJECT MANAGEMENT 10% OF DIRECTS, ENGINEERING & CONSTRUCTION MANAGEMENT.	000	1 LOT	0	0	0	0	2093000	0	0	2093000

SUBTOTAL	TECHNICAL SERVICES			0		0		2,093,000	0	0	

					0		0		0		2,093,000

TOTAL	COST CODE 00000 WBS 511000 (ESCALATION 0.00% - CONTINGENCY 50.00 %)			0		0		2,093,000	0	0	

					0		0		0		2,093,000

TOTAL WBS 511000	PROJECT MANAGEMENT			0		0		2,093,000	0	0	

					0		0		0		2,093,000

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ACCOUNT NUMBER	DESCRIPTION	COST CODE	QUANTITY	MANHOURS	LABOR	EQUIP USAGE	MATERIAL	SUB- CONTRACT	EQUIP- MENT	OH&P / B & I	TOTAL DOLLARS	

REPORT TOTAL				800		25,600	0	14,139,286	4,042	7,925,671	929,216	23,023,816