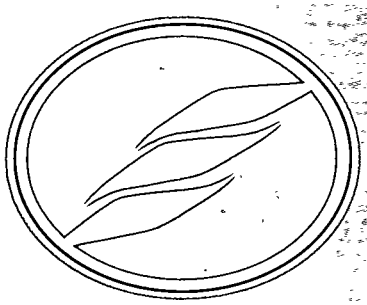
Idaho National Engineering and Environmental Laboratory



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High-Level Waste Vitrification Facility Feasibility Study

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Published August 1999

Idaho National Engineering and Environmental Laboratory
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ABSTRACT

A "Settlement Agreement" between the Department of Energy and the State of Idaho mandates that all radioactive high-level waste now stored at the Idaho Nuclear Technology and Engineering Center will be treated so that it is ready to be moved out of Idaho for disposal by a compliance date of 2035. This report investigates vitrification treatment of the high-level waste in a High-Level Waste Vitrification Facility based on the assumption that no more New Waste Calcining Facility campaigns will be conducted after June 2000. Under this option, the sodium-bearing waste remaining in the Idaho Nuclear Technology and Engineering Center Tank Farm, and newly generated liquid waste produced between now and the start of 2013, will be processed using a different option, such as a Cesium Ion Exchange Facility. The cesium-saturated waste from this other option will be sent to the Calcine Solids Storage Facilities to be mixed with existing calcine. The calcine and cesium-saturated waste will be processed in the High-Level Waste Vitrification Facility by the end of calendar year 2035. In addition, the High-Level Waste Vitrification Facility will process all newly-generated liquid waste produced between 2013 and the end of 2035. Vitrification of this waste is an acceptable treatment method for complying with the Settlement Agreement. This method involves vitrifying the waste and pouring it into stainless-steel canisters that will be ready for shipment out of Idaho to a disposal facility by 2035. These canisters will be stored at the Idaho National Engineering and Environmental Laboratory until they are sent to a national geologic repository. The operating period for vitrification treatment will be from the end of 2015 through 2035.

SUMMARY

The disposal of radioactive wastes now stored at the INEEL is currently mandated under the Settlement Agreement[1] between the U.S. Department of Energy (DOE) and the State of Idaho. Under this agreement, all high-level waste must be treated as necessary to meet the disposal criteria, and must be disposed of or put in a form that can be shipped out of Idaho for disposal by 2035. This includes all calcine in the Calcine Solids Storage Facilities (CSSF), and all of the newly generated liquid waste (NGLW) generated after the end of 2012. In addition, the Settlement Agreement requires that all of the liquid SBW remaining in the Idaho Nuclear Technologies and Engineering Center (INTEC) Tank Farm at the end of 2012 be treated by the end of 2012. This will, of necessity, include any NGLW that is mixed in with the Sodium Bearing Waste (SBW) prior to the end of 2012.

Several waste treatment options have been studied in support of a high-level waste environmental impact statement (EIS). One of these options is to treat the SBW (and any NGLW mixed with it) that is generated prior the end of 2012 in a cesium ion exchange (CsIX) facility. This facility would produce a transuranic waste that would be disposed of at the Waste Isolation Pilot Plant (WIPP), and a cesium-saturated waste that would be stored in the CSSF. This treatment would be completed by the end of 2012.

In order meet the Settlement Agreement, the calcine waste and cesium-saturated waste in the CSSF and the NGLW generated after the end of 2012 must still be treated and made ready to ship out of Idaho for disposal by 2035. One option for treating this waste is to vitrify it in a high-level waste vitrification facility (HVF). The primary product of the HVF would be borosilicate glass that would be poured into stainless-steel canisters and readied for shipment out of Idaho to a disposal facility by 2035. The vitrified borosilicate glass waste form is preferred at the present high-level waste disposal candidate site.

The objective of this study was to prepare preconceptual designs and determine the feasibility of the HVF. The design was based on a previous direct vitrification facility study completed in October 1994.[2] This study is organized into a main body and attached Appendices. The main body is primarily a summary of the more detailed work in the Appendices. Sections 1 and 2 contain the introduction and background; Section 3 provides the Mission and Justification for the HVF; Section 4 includes the design requirements and key assumptions; Sections 5 and 6 describe the facility and process by summarizing the detailed work contained in the Engineering Design Files (EDFs) in Appendix C; Section 7 briefly describes how work in the HVF is performed starting with conceptual design; Section 8 and Appendix A address the HVF life cycle cost (LCC); Section 9 and Appendix B address the HVF project schedule from start of the conceptual design through post operations decontamination and decommissioning (D&D); Section 10 addresses environmental and permitting regulations and codes and standards applicable to the HVF; Sections 11 address HVF design uncertainties determined in as a result of this study; and Section 12 includes an assessment of the readiness to proceed to conceptual design.

This study identifies a number of areas of uncertainty that may require further study. It also identifies two issues that need to be addressed before the HVF could be considered ready to proceed to conceptual design: (1) further work is needed to develop the induction melter technology within the DOE complex, and (2) work should be done to develop a dry calcine melter feed system that will achieve the required process quality to ensure that acceptable borosilicate glass will always be produced.

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Jack Prendergast—Chemical Engineer

Dan Rowley—Capitol Cost Estimates

Robert Turk—Life Cycle Cost Estimates

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ACRONYMS

AE	Architectural Engineer(ing)
AEA	Atomic Energy Act
AES	Architectural Engineering Standard
AHJ	authority having jurisdiction
ALARA	as low as reasonably achievable
CAA	Clean Air Act
CDR	conceptual design report
CRTS	calcine retrieval and transport system
CsIX	Cesium Ion Exchange
CSSF	Calcine Solids Storage Facilities
CWA	Clean Water Act
D&D	decontamination and decommissioning
DNFSB	Defense Nuclear Facility Safety Board
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
DWPF	Defense Waste Processing Facility
EDF	Engineering Design File
EMM	electromechanical manipulator
EIS	environmental impact statement
EPA	Environmental Protection Agency
ERO	emergency response organization
EUSU	electrical and utility system upgrade
FPE	fire protection engineer
GFE	government-furnished equipment
HLW	high level waste

HEPA	high efficiency particulate air
HVAC	heating, ventilating, and air conditioning
HVF	High-Level Waste Vitrification Facility
I&C	instrumentation and control
IDAPA	Idaho Administrative Procedures Act
INEEL	Idaho National Engineering and Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
ISF	interim storage facility
KD	key decision
LCC	life cycle cost
LLW	low-level waste
LMITCO	Lockheed Martin Idaho Technologies Company
MACT	maximum achievable control technology
NEPA	National Environmental Policy Act
NGLW	newly generated liquid waste
NGR	national geologic repository
NRC	Nuclear Regulatory Commission
NWCF	new waste calcining facility
OPC	other project cost
PCS	plant control system
RCRA	Resource Conservation and Recovery Act
SAR	safety analysis report
SBW	sodium bearing waste
SCR	selective catalytic reduction
SNF	spent nuclear fuel
SRS	Savannah River Site

SSCs	structures, systems, and components
TEC	total estimated cost
TPC	total project cost
TRU	transuranic
UBC	Uniform Building Code
UCS	utility control system
UPS	uninterruptible power supply
VWO	vitrified waste option

High-Level Waste Vitrification Facility Feasibility Study

1. INTRODUCTION

Treatment of high-level waste (HLW) at the Idaho Nuclear Technology and Engineering Center (INTEC) on the Idaho National Engineering and Environmental Laboratory (INEEL) is mandated under a "Settlement Agreement" between the U.S. Department of Energy (DOE) and the State of Idaho.[1] Among other requirements, the Settlement Agreement requires that this treated HLW be ready to move out of Idaho for disposal by a compliance date of 2035.

Proposed HLW treatment includes the Nonseparations Alternative Vitrified Waste Option (VWO) in which all HLW calcine, sodium bearing waste (SBW) and newly generated liquid waste (NGLW) will be in dry calcine form in the INTEC Calcine Solids Storage Facilities (CSSF). The HLW Vitrification Facility (HVF) option is based on the assumptions that no more new waste calcining facility (NWCF) campaigns will be conducted after June 2000. The SBW remaining in the INTEC Tank Farm and the NGLW produced between now the start of 2013 will be processed using another process option such as cesium removal using ion exchange columns in a cesium ion exchange (CsIX) facility. The transuranic (TRU) product resulting from this other process option will be grouted and the cesium-saturated sorbent will be sent to the CSSF to be mixed with the calcine. The calcine and cesium-saturated sorbent in the CSSF at the end of calcining, will be processed in the HVF by the end of calendar year 2035. NGLW generated between the end of 2012, when operation of the CsIX facility ends, and the end of 2015, when hot start up of the HVF begins, will have to be stored in new tankage. All NGLW produced from the end of 2012 through the end of HVF operation at the end of 2035 will be piped or shipped to the HVF for vitrification.

The HVF will blend water with calcine and cesium-saturated sorbent, to form aqueous slurries (the NGLW is liquid and requires no water addition). The aqueous solutions will be sampled and mixed with the appropriate type and amount of "glass frit" (henceforth referred to as frit) to produce a vitrified product qualified for storage in a federal repository. Batches of the mixture will then be dried, vitrified, and poured into stainless-steel canisters that will be sealed, cleaned, and transferred to an interim storage facility (ISF). The canisters will be transferred to the ISF as soon as they are produced so the transfer period will be the same as the operating life of the HVF (from the end of 2015 through 2035). The HVF design is based on modifications to the *Raytheon Direct Vitrification Option Feasibility Study Report.*[2]

2. BACKGROUND

Calcination is a treatment process that transforms liquid waste into a more stable granular solid. Past calcining activities at INTEC produced large amounts of calcine that are now stored in CSSF bins at INTEC. In addition, SBW is stored in the INTEC Tank Farm. Previous processing of liquid SBW and liquid has converted the material into calcine through a fluidized bed denitration process. The calcination process significantly reduces the volume of waste to be stored. The calcine and SBW does not meet final waste form requirements for disposal so further treatment is required before it can be sent to a repository. The process proposed in this study will treat the calcine, and NGLW by combining it with frit and other additives to produce a borosilicate glass HLW that can be disposed of in a national geologic repository (NGR).

Various possible HLW treatment alternatives are under consideration. The alternative described in this report is for vitrification of the HLW under the Nonseparations Alternative (also called the Direct Vitrification Alternative). This study is a follow-on study to the Direct Vitrified Waste Option Scoping Study[3] and the Early Vitrification Option Engineering Design Files.[4] The objective of this follow-on study is to concentrate on a facility capable of processing calcine and cesium-saturated sorbent from CsIX and NGLW.

The cesium-saturated sorbent is produced by treating the liquid SBW in a CsIX facility. The liquid SBW cannot be directly vitrified because the HVF cannot be constructed in time to treat SBW by the Settlement Agreement date of the end of 2012.

3. MISSION AND JUSTIFICATION

3.1 Program Mission/Goals

INTEC has been reprocessing spent nuclear fuel (SNF) since 1953. Originally, SNF was reprocessed to recover fissile uranium; however, changing world events have diminished the need to recover and recycle fissile uranium for that purpose. In April 1992, the DOE discontinued reprocessing SNF and shifted its focus toward continued management and dispositioning of waste accumulated from previous reprocessing activities. INTEC waste treatment activities have produced a granular solid waste calcine material from the dissolved fission products and fuel cladding material in the waste streams of the reprocessing operations. Decontamination activities at INTEC have produced liquid radioactive SBW, and on-going operations at INTEC continue to produce various types of liquid waste that contain low levels of radioactivity.

The dispositioning of radioactive wastes is now under a Settlement Agreement[1] between DOE and the State of Idaho. The Settlement Agreement requires that existing inventories of SBW and other liquid waste be treated by 2012, and that all high-level waste be dispositioned and ready to be moved out of Idaho for disposal by a compliance date of 2035. The Agreement also requires that DOE begin negotiations, with the State of Idaho, of plans and schedules for processing the waste by the end of 1999. The mission of this project is to aid in meeting the Settlement Agreement, and in the negotiation schedule for the plans and schedules for processing the waste.

A High Level Waste and Facilities Disposition Environmental Impact Statement (EIS) is currently in progress to determine a path forward for the INEEL High-Level Waste Program. The EIS will be completed by September 1999, and a Record of Decision will be made by the end of 1999.

This project will support the Program mission/goals by (a) treating all calcined waste generated at the INEEL through June 2000, (b) treating all NGLW produced at the INEEL from the end of 2015 through the end of 2035, and (c) placing treated waste into storage in a condition ready for shipment out of Idaho to a repository. This project will also support calcination of any cesium-saturated solids from processing of SBW.

The other program elements that will be in place to meet the entire Settlement Agreement are:

- A separate treatment facility to treat uncalcined SBW liquid and NGLW produced through the end of 2015
- A calcine retrieval and transport system (CRTS) to transfer calcine from the CSSF bin sets to the treatment facilities
- An ISF to store the treated waste until it can be moved out of Idaho
- Utilities to support the mission.

Project conceptual design funding should be approved because no existing treatment is available at the INEEL that can meet the requirements of the Settlement Agreement. If DOE fails to satisfy the substantive obligations or requirements agreed to in the Settlement Agreement, or fails to meet deadlines for satisfying such substantive obligations or requirements, shipments of DOE spent fuel to the INEEL will be suspended unless and until the parties agree or the Court determines that such substantive

obligations or requirements have been satisfied. According to the Settlement Agreement there are no appropriate alternatives for the waste.

Alternatives to treatment or immobilization of the wastes have been considered but none will place them in a form suitable for both shipment out of Idaho and disposal in the NGR. One alternative that may meet the Settlement Agreement would be to ship the calcine and cesium-saturated solids out of Idaho for treatment and packaging at a different facility. However, this may still require that the waste be treated so it could be shipped for disposal by 2035. It is doubtful, however, that NGLW produced between the end of 2015 and the end of 2035 could be treated at another facility because of the numerous impediments to offsite shipping of radioactive and mixed liquid wastes. Therefore, the NGLW must be treated and packaged in Idaho and made ready for shipment out of Idaho to a repository by the compliance date of 2035. This will require that a treatment facility be designed and built in Idaho.

Constructing the HVF in Idaho is the best option of those considered. If the waste is treated at an offsite facility before being shipped for disposal, an intermediate shipping cycle from INEEL to the offsite facility is required. That method could still be cost effective if proper treatment facilities already existed at the other facility. However, because the NGLW cannot be shipped offsite as a liquid, a new treatment facility is still required in Idaho. This new HVF could and should be designed to treat and package the granular calcined and cesium-saturated solids also. This would avoid the intermediate packaging, shipping, and unpacking of these granular solids.

Constructing the HVF on the INEEL is the best option at this time because it the preferred technology for HLW disposal by the NGR, and has a current proven track record at three existing production facilities that are successfully vitrifying HLW.

3.2 Project Objectives

3.2.1 Technical Objectives

The following technical objectives are established to meet applicable portions of the Settlement Agreement[1]:

1. Treat and package all INTEC calcined waste and place the packages in interim storage by 2035, in a condition in which they are ready to be moved out of Idaho for disposal.

2. Treat and package all INTEC cesium-saturated solid waste, and place the packages in interim storage by 2035, in a condition in which they are ready to be moved out of Idaho for disposal.

3. Treat and package all INTEC NGLW produced between the end of 2015 and the end of 2035 and place the packages in interim storage by 2035, in a condition in which they are ready to be moved out of Idaho for disposal.

The vitrification technology; with respect to radioactive waste, is at a relatively mature level at this time. Production facilities exist both in this country and in Europe. Technology from at least three existing production facilities apply directly to the INEEL HLW. The Savannah River Site (SRS) and the West Valley Demonstration Project are currently vitrifying HLW and pouring the glass in canisters. Both the waste and process apply directly the proposed INEEL HVF project. The French Cogema Plant is currently reprocessing SNF from several countries. Fuel reprocessing produces HLW as a byproduct. The Cogema plant contains a vitrification system that vitrifies the HLW and places it in canisters. In addition, the Hanford site is in the process of developing a vitrification facility that will treat HLW and

pour it in canisters. At least one commercial, transportable, vitrification system for treating contact-handled low-level waste (LLW) is currently operating at Oak Ridge National Laboratory. The knowledge of existing facilities, this feasibility study, and follow-on bench- and engineering-scale testing will form the basis for conceptual design of the HVF.

3.2.2 Cost Objectives

A feasibility study life cycle cost (LCC) developed for the HVF is presented in Section 8, and Appendix A, which contains the construction cost estimate that includes the cost to prepare the conceptual design, the conceptual design report, and related documentation required for Key Decision (KD) Point 1 (KD-1), approval of new start. Appendix B contains the schedule for the HVF. The cost estimate resulting from the conceptual design will be prepared at the end of the conceptual design phase, which, according to the schedule (see Appendix B) is at the end of 2008.

3.2.3 Schedule Objectives

Appendix B contains the HVF schedule as estimated in this feasibility study. Conceptual design begins at the start of 2006, and the completion of the conceptual design report (CDR) and KD-1, Approval of New Start, will be at the end of 2008.

3.3 Organization

This subsection explains the organizational involvement between KD-0, approval to begin the conceptual design review process, and KD-1, the approval of the CDR. The DOE Idaho Operations Office (DOE-ID) has overall control of the project. The Lockheed Martin Idaho Technologies Company (LMITCO) High-Level Waste Program reports to the field office and provides project direction to LMITCO Project/Construction Management. LMITCO Project/Construction Management has the responsibility for issuing the feasibility study report which occurs just before KD-0. Once KD-0 is approved, LMITCO Project/Construction Management will issue a request for proposal to an architectural engineering (AE) firm to conduct the conceptual design. Throughout the period, from KD-0 through KD-1, these organizations will maintain the lines of authority and reporting.

3.4 Risk Assessment

During the course of this study, several important areas of uncertainty arose that will need additional work during conceptual design. These include issues associated with vitrified glass quality, the pump and valve corridor, the equipment canyon, glass frit formulations, melter type, canister closure, calcine transfer, canister decontamination, and mercury amalgamation. Although the HVF design is based on using the Defense Waste Processing Facility (DWPF)-type 10-ft-long canisters, the impact of using the 15-ft Hanford vitrification canisters was also considered. Engineering Design File (EDF) EDF-HVF-F-007 (see Appendix C) explores the HVF impacts of using Hanford canisters.

4. DESIGN BASIS AND ASSUMPTIONS

4.1 Design Requirements

The following specific requirements and assumptions apply to this feasibility study:

- The HVF shall have the capability to process liquid SBW, NGLW, calcine solids, and cesium-saturated product from the CsIX options. The cesium-saturated product will be located in the CSSF bins.

- The HVF shall comply with Maximum Achievable Control Technology (MACT) rules.

- The HVF shall use induction melters for vitrification.

- The study shall refine and validate the information presented in the previous vitrification studies and verify feasibility of the option.

- The study shall provide a more extensive investigation of some of the process uncertainties to provide more support for the data.

- The basic process proposed for the HLW vitrification alternative consists of the following major steps.

  Note: This describes the process concept as it has been developed to date. This is not fixed; (the AE shall study the process including waste stabilization and packaging).

  1. Calcine retrieval, transport, and receiving.

  2. Material receiving and handling.

  3. Empty canister receipt and handling.

  4. Blending and sampling of the calcine or liquid to determine waste/frit recipes.

  5. Liquid denitration.

  6. Waste/frit mixing, sampling, and feeding.

  7. Glass forming and pouring.

  8. Welding of the canister plug in the top of the canisters.

  9. Radionuclide contamination control.

  10. Non-destructive testing,

  11. Transport of the canisters to interim storage.

  12. The product from this process shall be remote-handled HLW in a borosilicate glass form.

- The HVF shall complete operations by the end of 2035 such that all of the applicable waste will be in storage and ready to be shipped out of Idaho for disposal by that date.

- The secondary liquid waste streams produced within the HVF shall be vitrified within the HVF rather than processing it as a separate waste form (for example, a grouted waste form).

- The design shall be in accordance with DOE Orders with maintenance of status-quo interfaces with other regulatory and oversight agencies such as the Environmental Protection Agency (EPA) and the Defense Nuclear Facilities Safety Board (DNFSB). No costs shall be considered or included for Nuclear Regulatory Commission (NRC) oversight.

- The vitrified borosilicate glass product shall be packaged in containers similar or equal to the 24-in. diameter x 10-ft long vitrification canisters used at the SRS DWPF.

- The product throughput rate shall be based on operating 24 hr/d, 7 d/wk with a 75% on-stream time and a 75% operating efficiency (56% overall operating efficiency). The process shall be operated in campaigns between calcine and NGLW, with periodic maintenance turnarounds.

4.2 Initial Assumptions

The following assumptions have been made about the HVF:

- The HVF will start full production operation by the end of 2015.

- System sizing will be based on the following assumptions that (a) no more NWCF campaigns will be conducted after June 2000; (b) the SBW remaining in the Tank Farm, and the NGLW produced between now and when the vitrification process begins operation, will be processed using another process option such as the CsIX option; (c) the TRU product from this other process option will be grouted, and the dried cesium-saturated product will be transferred to CSSF bins for storage with the calcine; (d) the calcine and cesium-saturated product that is in the bins at the end of calcining and cesium-saturated product transfer will be processed in the HVF by the end of calendar year 2035.

- The anticipated volume of calcine that will be processed is 4,300 m^3 (this is not based on the NWCF High Temperature Flow Sheet). The AE will verify this volume in the study.

- The final containerized waste packages will be placed in a separate ISF until the assumed year of 2065. The ISF is not within the scope of this cost estimate.

- The final containerized waste packages will be disposed at a NGR such as Yucca Mountain. The date that that HVF will be available is not known.

- It is anticipated that new DOE facilities will fall under NRC auspices and regulations within the next 10 years. However, since no NRC regulations have been promulgated for waste treatment facilities, no additional costs will be considered for NRC regulations.

- Resource Conservation and Recovery Act (RCRA) listed wastes in the glass product will be delisted before it is placed into interim storage starting at the end of 2015.

- The throughput rate will be based on the HVF operating 24 hours/day and 7 days/week, with a 75% on-line time and a 75% operating efficiency (4928 hours per year of at the full production rate). The process will be operated in campaigns with periodic maintenance turnarounds.

- It is assumed that the processed NGLW will be placed in SRS DWPF-type canisters and will eventually be disposed of as Class B or C waste at in the NGR, in WIPP, or in a NRC-licensed near-surface LLW disposal facility. NGLW processing is estimated to generate about 12 m^3 of glass or about 16 SRS-type canisters.

- The presumed hot-start for the HVF will take place at the end of 2015.

- The CRTS and handling systems will be identical to that in EDF-WTS-003, *Regulatory Requirements for the Design, Construction and Operation of the ICPP Proposed Waste Processing Facilities*, of the Vitrified Waste Option Study Report.[3]

- The HVF will be designed to use a 2-ft diameter by 10-ft long SRS DWPF canister even if a special study recommends that the 2-ft diameter by 15-ft long Hanford vitrification canister is preferred.

- Regulatory assessments will be done by others and are not in the scope of work covered by this study.

5. FACILITY DESCRIPTION

The function of the HVF is to receive and vitrify all dry calcine, dry cesium-saturated waste from the CsIX process, and NGLW produced between the end of 2012 and the end of 2035, into road ready packages for storage in the ISF by 2035. Mercury-containing waste will be packaged and sent to an outside vendor for treatment and disposal. To accomplish this, the HVF will receive glass frit by rail, mix it with the waste, and vitrify the mixture in the four induction melters. The waste packages will consist of vitrified waste within sealed 10-ft long DWPF-type canisters (as indicated above EDF-HVF-F-007 in Appendix C explores the HVF impacts of using 15-ft long Hanford vitrification canisters).

5.1 Building Description

5.1.1 General

EDF-HVF-F-001 in Appendix C contains a detailed description of the HVF. It also contains facility drawings HVF-T-1 and HVF-A-1 through HVF-A-7, which show site, plan, and elevation views of the HVF. The HVF will be located in the northeast corner of INTEC. It will receive and vitrify dry or liquid radioactive waste, package the vitrified waste into road ready canisters, and transport the canisters to the ISF via a transfer tunnel. The HVF will be a multistory building that extends 32 ft below and 75 ft above grade, and occupies an area measuring 470 × 242 ft. The HVF is based on support of four induction melter cells, a process equipment canyon, and a pump and valve corridor. The remainder of the HVF is located around these processes and adjacent to those they support. The HVF has a concrete superstructure (3- to 4-ft-thick walls for shielding of the processes) and nonprocess areas constructed of ordinary braced steel frame systems. The area of the entire HVF's four floors is approximately 308,000 ft^2.

The HVF will be located between the east perimeter fence and Hemlock Street to the west, because of its relatively close proximity to the waste sources. Approximately 400 ft of new underground potable water, fire water, sanitary sewer, steam, and plant air lines will have to be run to the HVF. The HVF layout is based on a centrally located process cell complex of four melter cells with heavy concrete walls for shielding, and limited personnel access. EDF-VWO-007, *Fluidized Bed Blending Tank Cell Shielding Calculations*, of the Vitrified Waste Option Study Report[3] contains a calculation of the concrete shielding wall thickness necessary to reduce the maximum calcine radiation source field in the HVF to 0.10 mrem/hr or less. The melter cells will be enclosed by shielding walls with installed manipulators and shielding windows that facilitate maintenance from the operating corridors that surround the cells.

The below-grade areas of the HVF house the empty canister staging area, a canister filling and capping cell, a canister decon cell, a process liquid collection cell, the canister transfer cart loading room, the canister transfer tunnel leading to the ISF, and a heating, ventilating, and air conditioning (HVAC) exhaust equipment room. The canister filling and capping cell, decon cell, and full canister loading area and tunnel have 3 to 4-ft thick, stainless steel-lined shielding walls, ceilings, and floors. This floor occupies approximately 67,500 ft^2.

The 21-ft 0-in. level contains the upper portions of the melters cells, the process equipment canyon, the pump and valve corridor, welding cell, smear cell, equipment decon cell, equipment hands-on maintenance cell, equipment cut-up cell, equipment and loadout area, and operating corridors serving these areas. In addition, space for an analytical lab, instrument gallery, sample cells and the electrical equipment room is also located on this level. HVAC supply equipment including standby blowers and steam coils are located outside the HVF on the roof above the HVAC supply equipment room. Four

stairways provide egress, and a freight elevator provides maneuverability for equipment and materials throughout the HVF. This floor occupies approximately 65,500 ft^2.

The level 45-ft 0-in. above grade consists primarily of a large, shielded high bay (the maintenance/disassembly cell) that contains an overhead bridge crane with an electromechanical manipulator (EMM) and hatch covers over all of the ground-floor cells. The crane can remove the hatch covers and move components to and from the equipment decontamination cell and cut-up cells. Four stairways provide egress, and a freight elevator provides maneuverability for equipment and materials throughout the HVF. This floor occupies approximately 61,500 ft^2.

The process area of the HVF has a concrete superstructure extending 45 ft above grade. The cell walls will generally be 3 to 4-ft thick and support a formed cast-in-place concrete roof. The process cell walls extend to a 4-ft thick foundation 32-ft below finished grade. The operating corridor outside walls will be reinforced concrete and extend to 32-ft below finished grade. Process cells will be fully lined with stainless steel. The building superstructure containing the office and HVAC supply equipment area consists of an ordinary braced-frame system. Metal panels enclose the roof and walls. Office floors will be 6-in. reinforced concrete slab-on-grade or supported on concrete topped metal decking and structural steel framing where elevated. Grade beams and isolated column spread footings support the structural steel frame of the building. The HVF is classified as Uniform Building Code (UBC) Group H Division 7 and Group B Mixed Occupancy. The H-7 occupancy applies to buildings or portions thereof containing materials that constitute a high health hazard (the melter cells, process equipment canyon, pump and valve corridor, the maintenance area, canister filling and capping, and other cells, rooms, and areas within the shielding walls). The Group B Mixed Occupancy applies to buildings or portions thereof used for offices, laboratories, mechanical/HVAC/electrical rooms, corridors, and other rooms and areas outside the shielding walls. Details of the remote maintenance equipment philosophy and on equipment decontamination can be found in EDF-HVF-F-014 and EDF-HVF-F-015 in Appendix C.

5.1.2 Cell Descriptions

Refer to the HVF building plan and elevation drawings. The HVF is arranged into several types of segregated hot-cell areas with each area surrounded by the necessary support systems and access corridors. Each of the five types of cells are designed as follows:

As shown in the facility drawings (see Appendix C), the HVF contains eight separate production cells and four melter cells. The vertical, staggered arrangement and relationships between the filling and capping cell, the welding cell, the decontamination cell, and the smear cell is shown in two HVF building elevation views. The cells are all isolated from each other and from the rest of the HVF by positive ventilation barriers and shield hatches. Rail mounted, horizontally actuated shielding/confinement hatch covers installed over floor openings will provide positive isolation between cells and surrounding areas. This ensures that contamination will be unlikely to occur downstream of the decontamination and smear cells or to enter the transfer tunnel or ISF. The hatches are located in the clean canister storage area, canister filling and capping cell, weld cell, decontamination cell, and smear cell. The weld, decontamination, and smear cells are examples of single purpose cells. A single module exists within each cell to perform the task. The following bullets summarize cell operations:

- The pump and valve corridor holds high maintenance process equipment, (primarily for offgas treatment). An operating corridor running along the length has shield windows that allow the operators to view remote activities. An EMM and an overhead bridge crane are used to change out jumpers.

- The process equipment canyon contains mostly passive, low maintenance equipment that is expected to last the operating life of the HVF. The items are mostly tanks and vessels. These tanks and vessels will be equipped with Hanford connectors in the unexpected event that they have to be replaced. Replacement would entail removing them through the canyon hatch covers at the 45-ft elevation and into the maintenance area using the 75-ton maintenance area crane. This crane will be equipped with a special torque wrench for disengaging the Hanford connector jumpers. Some of the tanks have small lid-mounted mixer motors that can be removed and replaced using the EMM mounted on the maintenance area crane trolley.

- The four melter cells will receive, dry, and vitrify the calcine and glass frit slurry. All four cells will operate simultaneously. The cell equipment can be maintained by a combination of a master slave manipulator, a wall mounted EMM, and an in-cell overhead bridge crane. Equipment that has failed or is in need of repair will be removed through the overhead hatch by the 75-ton maintenance area crane. The offgas system is directly connected to the melters.

- The canister filling and capping cell remotely receives and lifts the empty canisters to the melter pour weir where they will be preheated (preheating promotes uniform filling and eliminates voids), and filled. While pouring the glass, gases will be continuously extracted from around the canister nozzle and routed to offgas treatment. A load cell weighs the canisters during all pouring operations to monitor the glass pour rate, and a gamma detector measures glass level. The canisters will be cooled for 24 hours in a rack, and a lid placed on the cooled canister before being moved out of the canister filling and capping cell and up into the welding cell. The cell equipment can be separated into subcomponent sections that can be removed to the overhead maintenance/disassembly cell via the welding cell using the canyon crane, after removing the cell cover.

- The canister weld-handling crane and grapple remotely lift the canister from the canister filling and capping cell. The weld cell uses a GTAW welding module to remotely weld the canister lid and to test the seal weld. The cell equipment can be separated into subcomponent sections that can be removed to the maintenance/disassembly cell above using the canyon crane after removing the cell cover.

- The outside surface of each canister will be decontaminated using either an aqueous glass frit solution or solid carbon dioxide pellet blasting system. Decontamination occurs inside a chamber isolated from the canister-handling cell. The cell equipment can be separated into subcomponent sections that can be removed to the maintenance/disassembly cell, via the welding cell, using the canyon crane after removing the cell cover.

- The canister smear cell tests for surface contamination using a remotely operated module to determine if the canister has to be returned to the decontamination cell or can be placed on the canister transport cart in the transfer tunnel and sent to the ISF. The cell equipment can be separated into subcomponent sections that can be removed to the maintenance and disassembly cell above using the canyon crane after removing the cell cover.

- The underground canister transfer tunnel will be used to transport canisters on a canister transport cart, approximately 100 ft to the ISF. The transfer tunnel will be maintained by hands-on maintenance when all canisters have been removed from the tunnel.

The maintenance area is located above the floor at the 45-ft elevation. This is a large shielded area that will contain a 75-ton bridge crane with integral overhead EMM. This crane will be used to exchange equipment through its floor hatches, and move the equipment between cells and the decontamination and cut-up cells below.

Ancillary cells include an analytical laboratory, a mercury removal cell, two sampling cells, a storage cell, a decontamination cell, an equipment cut-up cell, and crane maintenance cell areas.

5.1.3 Material Handling Equipment

The following describes the major pieces of handling equipment within the HVF. Equipment has been selected to establish an efficient handling system, while maintaining a safe working environment.

- Truck airlock bridge crane (1 ton)—The truck airlock in the northwest corner of the HVF will be equipped with a 1 ton bridge crane to off load canisters from the delivery truck and place them on the canister shuttle cart.

- Empty canister transfer cart—The canister transfer cart will be used to move empty canister from the truck airlock, located at the northwest corner of the HVF, into a storage rack in the empty canister storage area. The cart will be electrically powered.

- Clean canister storage overhead crane (1 Ton)—one-ton overhead bridge crane and its grapple will be used for moving canisters from a storage rack in the empty canister storage area and lowering them to a staging location in the north west corner of the filling and capping cell. The crane will be controlled locally using a local panel mounted in view of the crane and grapple. The crane, trolley, and hoist will be supplied with pendant control. The power to the crane will be via a festooned cable system.

- Filling and capping cell crane (3 Ton)—This remotely controlled trolley-mounted polar crane and its grapple will be used to handle all canisters in the filling and capping cell. It will move the canisters from the empty canister staging station to the melter pour station, from the pour stations to the cooling and capping station and from the cooling and capping station to the weld cell staging location. It will also be used to move equipment inside the cell and assist with maintenance. Cell equipment will be staged below the welding cell floor hatch for retrieval by the canister weld-handling crane. Hands-on maintenance will be done in the crane maintenance area located to the south of the canister filling and capping cell. The power to the crane will be via a festooned cable system.

- Canister lift mechanisms (4 total)—Four canister lift mechanisms are used in the filling and capping cell to raise and lower the canisters to the filling ports below the melters. Canister lift stations maintenance will be performed remotely. However, the lifting mechanism drive is located in an adjacent shielded room for hands-on drive maintenance. The drive system will incorporate a Serapid rigid chain linear actuator.

- Weld cell overhead polar crane (3 Ton)—This remotely controlled trolley-mounted polar crane and its grapple will be used to convey lift canisters from the canister filling and capping cell into the welding cell, load the canisters into the welding station, and lower the canisters into the decontamination cell. It will also move equipment inside the welding cell and assist with maintenance on the welding equipment. Welding cell equipment and equipment retrieved from the adjoining cells can be staged, using the canister weld handling crane, for pickup through the welding cell cover by the overhead canyon crane. Hands-on

crane maintenance will be done in the crane maintenance area south of the welding cell. The crane will be powered via a festooned cable system.

- Canister decontamination handling crane (3 Ton)—This remotely controlled trolley-mounted polar crane and its grapple will be used to move equipment and canisters inside the canister decontamination cell and assist with maintenance. Cell equipment will be staged below the smear cell floor hatch for retrieval by the smeared canister loadout crane. Hands-on maintenance will be done in the crane maintenance area located to the north of the canister decontamination cell. The power to the crane will be via a festooned cable system

- Smeared canister loadout crane (3 Ton)—This remotely controlled trolley-mounted polar crane and its grapple will be used to convey decontaminated canisters from the decontamination cell to the smear cell, and from the smear cell to the canister transport cart in the transfer tunnel. It will also move equipment inside the smear cell and assist with maintenance. Decontamination cell equipment, and equipment retrieved from the decontamination cell below can be staged, using the canister decontamination handling crane, for pickup through the decontamination cell cover by the maintenance/disassembly cell 75-ton bridge crane. Hands-on crane maintenance will be done in the crane maintenance area north of the smear cell. The power to the crane will be via a festooned cable system.

- Canister transport cart—The canister transport cart will transport filled and decontaminated canisters from the HVF, through the underground transfer tunnel, and into the ISF loading bay. The cart tracks will be located at the –20-ft level. The cart will be remotely operated from a console and viewed by CCTV. The cart will be battery powered and have two backup transport methods. Besides using its own battery pack, it can be hauled via cable system (with external drive), or retrieved via grade-level ports built into the roof of the tunnel. The cart will run on a single set of anchored tracks with its wheels totally retained by the track to eliminate the possibility of derailing. Shock absorbers will be located on each end of the track to ensure safe stopping. Hands on maintenance will be performed at the ISF maintenance area.

- Loadout area bridge monorail crane (15 Ton)—A 15-ton monorail crane will be used to load radioactive waste and discarded equipment into truck-mounted casks in the load-out area located at the south end of the HVF. This monorail will be split at the shield door between the truck airlock and the loadout area. The section in the truck airlock will be a common stationary rail-mounted overhead; the section in the loadout area will have the rail mounted onto an overhead bridge and trolley to allow the monorail to swing out of the way to permit equipment loading from above by the maintenance area 75-ton bridge crane. The monorail will be controlled by both local and remote methods. A conveniently located local panel will be mounted in clear view of the crane and hook from the shield window and remotely operated from an operators console and viewed by CCTV. The monorail, trolley, and hoist will be supplied with both a remote panel and a pendant control. The power to the crane will be via a festooned cable system.

- Maintenance area overhead bridge crane (75-ton)—The 75-ton overhead bridge crane with a span of approximately 80 ft will be used to convey equipment in and out of the cells below. A crane maintenance area will be located south of the process canyon. The crane will be remotely controlled from conveniently located remote panel that will be mounted in clear view of the crane and hook. A festooned cable system will supply crane power. Busbar power or panel is not acceptable because of the potential for corrosion.

5.2 HVAC

Details of the HVF HVAC system are contained in EDF-HVF-F-012 in Appendix C. The EDF contains the HVAC requirements, the system description, and the HVAC flow diagram. The HVAC system was designed to the requirements contained in the EDF. Sketch HV-1, the HVAC airflow diagram, is contained in the EDF. The HVF requires two ventilation confinement zones. The ventilation confinement systems, in conjunction with the physical barriers, maintain a continuous airflow pattern from areas of low potential contamination to areas of high potential contamination. The objectives of the confinement systems are to prevent the spread of radioactive and other hazardous materials to occupied areas and to minimize the release of radioactive and other hazardous materials in HVF effluents.

The primary confinement boundaries consists of the process hot cells and hot maintenance areas, which will be exhausted through two stages of high-efficiency particulate air (HEPA) filters. The secondary confinement boundary consists of the operating corridors and other building structures that surround the primary confinement. The secondary confinement boundary contains all ventilation system equipment such as HEPA filter units and exhaust fans. The non-confinement boundary consists of offices, control rooms, and support areas outside the secondary confinement boundary.

The primary and secondary confinement airflow rates are 308,000 and 184,200 cfm respectively. All primary and secondary confinement air will be exhausted to the stack through two stages of testable HEPA filter units and redundant exhaust fans. HEPA filter sets will be sized so that one bank may be closed off for change out without affecting the remainder of the units and redundant exhaust fans will be provided for each set of HEPA filters.

The control room will be provided with an independent HVAC system. Air from the room will be recirculated. Supply AHUs will have 100% redundancy. Administrative offices will be provided with an independent HVAC system. Air from these rooms will be recirculated.

The supply and exhaust fans for the hot cells can be powered from the INEEL site standby power grid. This allows the ventilation confinement to be maintained in the hot cells during a loss of offsite power. A shielded probe air monitor system will be used in the HVF exhaust stack to monitor the discharge from the ventilation system and offgas exhaust.

It is assumed that areas with large in-cell heat loads, which exceed normal nuclear ventilation capability, will have additional fan coil cooling units installed. These units will recirculate the air for cooling purposes only and will have no filtering capabilities. An example of this would be auxiliary room cooling for removing heat from the canister cooling station in the canister filling and capping cell.

5.3 Electrical

The HVF electrical requirements were established and details are contained in EDF-HVF-F-009 in Appendix C. The electrical requirements of the HVF were analyzed and determined to be 4,708 kVA connected, with a demand projected to be 4,147 kVA. The details of the analysis are shown in Tables 1 and 2 of EDF-HVF-F-009. The major loads with the HVF are the melters, HVAC equipment, and lighting. A combination of new and existing duct banks will be used to route the electrical feeders to the HVF. Electrical power at INTEC is distributed at 13.8 kV from Substation 10 through the complex. The Electrical and Utility System Upgrade (EUSU) project is currently under construction. The EUSU project will install a new 13.8 kV electrical distribution system throughout the complex. This new system will provide greater safety, additional capacity, and greater reliability.

The requirements for standby power for the HVF were analyzed and determined to be 2,656 kVA. The details of the analysis are shown in Table 3 of EDF-HVF-F-009. The EUSU project will construct a standby power plant, install new standby generators, and tie existing generators into the standby power system. Standby power will than be distributed through the complex by the new 13.8 kV distribution system. Upon completion of the EUSU project, an evaluation of the spare capacity will be performed. Because the excess capacity is not known, it will be assumed that the HVF will provide a new 2,000 kVA diesel generator and associated equipment in the standby generator plant. The Utility Control System (UCS) will control the usage of standby power.

A solid state uninterruptible power supply (UPS) with a static transfer switch will be provided. The UPS will be provided with 20-minute battery backup. Both the normal feed and the bypass feed to the UPS will be on standby power. The UPS will support voice paging/evacuation systems, the environmental monitoring system, and other critical loads.

5.4 Instrumentation and Control

EDF-HVF-F-013 in Appendix C provides the details of the instrumentation and control (I&C) estimates. The Raytheon Direct Vitrification Option Feasibility Study Report [2] baseline design was used for this I&C estimate, for I&C system requirements, and for subsequent material and installation costs. Differences between the baseline design and the HVF were used to ratio the number of instruments from the baseline design. The total number of instruments for the HVF, including instrumentation required for complying with the MACT rule, was estimated at 1,940.

Air monitors were ratioed by the area of floor space between the baseline design and the latest design (the baseline design has 70,000 ft^2 while the HVF design has 90,000 ft^2). The number of HVF process I&C measurements increases due to the increase in melter trains and cells from 3 to 4. It was estimated that the referenced report had approximately 52 measurements per melter so the total number of melter instruments were increased by the ratio 4/3. This includes the instrument bulks allowance, control and safety valves, electronic instruments, and pneumatic instruments. The process I&C measurements used in conjunction with the slurry mix, evaporation, and storage of the liquid feed will be consistent with the baseline.

A shielded probe system instead of an isokinetic sampling system will be used in the HVF exhaust stack to monitor stack effluents. The electrical estimate includes telephones, HVF public address systems, fire alarm systems, local control stations, and lighting protection systems consistent with the baseline. The process I&C system downstream of the melters will be the same as the baseline design (for example: filling, cooling, capping, smearing, welding, decontaminating, and associated canister transfer and handling equipment); therefore, the estimate is identical to the baseline estimates for these areas. The I&C for the offgas treatment system design in this report is the same as the baseline design.

The canister filling monitoring I&C cost for each melter system will be the same as in baseline design (a government-funded equipment (GFE) cost of $2 million per unit); therefore, the HVF cost for four melter systems will be $8 million. The canister leak check system I&C located in the welding cell will cost the same as the baseline design (a GFE cost of $1 million).

Additional instrumentation has been identified and added to comply with the proposed MACT rule, which includes more stringent emission limits than currently allowed for a number of pollutants. These instruments are to be used to supplement the normal stack monitors emission instrumentation.

The report titled *Feasibility Study Report for NWCF MACT Compliance Facility*, INEEL/INT-97-00992, November 1997, was the baseline design used for specifying the HVF I&C required to satisfy the MACT rule.

5.5 Fire Protection Systems and Equipment

Both DOE-ID Architectural Engineering Standard (AES) 1530 and DOE Order 5480.7A call for automatic fire suppression to be provided in all new construction; thus, fire suppression will be required in all areas, including the hot cells and interim storage areas. DOE-ID AES 1530 provides for this requirement to be waived if the variance is approved by the cognizant fire protection engineer (FPE), and if concurrence is obtained from the DOE-ID authority having jurisdiction (AHJ).

In general, all areas of the HVF require some form of automatic fire suppression. With the exceptions noted below, automatic wet-pipe sprinkler systems will be used. All "cold" areas (such as offices and corridors) will be provided with automatic wet-pipe suppression systems. Automatic water deluge suppression systems will be provided upstream of HEPA filters in all final filter plenums that have a leading face area exceeding 16 ft^2. Manual fire extinguishers will be located throughout the HVF.

Historically, some hot cells have been constructed and operated without automatic suppression or detection systems. However, based on the nature of the hazards and the cost of equipment within the HVF hot cells, it is unlikely that automatic suppression can be omitted in the hot cells. A detailed analysis of the cells should be performed during later design phases, to determine if a fire suppression should be used. All suppression systems have disadvantages, which must be considered in hot cell applications, including: potential to spread contamination via air/gas flow or water, difficulty and cost of cleanup after a discharge, and difficulties involved in maintaining confinement (negative pressure) during a fire incident and discharge of the suppression system.

Hot cells in the process area which need to be safe, or where the costs of cleanup of a water discharge will be prohibitive, will be evaluated and identified during later phases of design. These cells will be provided with either limited water or gaseous extinguishing systems; the choice will be made considering both the technical merits and the costs of the systems for the specific cells involved. The system currently recommended is a limited water sprinkler system. This recommendation was based on technical advantages (such as least impact on overall design and on probable lowest cost for the system).

5.6 Fire Detection and Alarm Systems

Automatic detection systems are a required part of redundant fire protection systems, as defined by DOE Order 5480.7A, and will be provided throughout the HVF. DOE Order 6430.1A requires redundant and automatic detection systems to process confinement systems. The need for automatic detection systems elsewhere will be determined by the cognizant FPE with concurrence by the DOE AHJ. The alarm and detection system will be compatible with the existing on-Site alarm and detection system, and will be arranged to automatically notify the CFA fire department of all alarm conditions at the HVF.

With the exception of the Interim Storage Areas, automatic and manual detection will be provided in all areas of the HVF, including the various hot cells. Alarms will sound locally (at the protected building) at a facility main fire alarm control panel. Smoke detection will be provided in all cold areas, such as administrative areas, office areas, and operating corridors. Areas where the ambient conditions may not be suitable for smoke detection, such as equipment rooms, will be provided with rate-of-rise thermal detection systems.

Smoke detection will be provided in HVAC ducts as required by the Uniform Building Code and related Codes, and by National Fire Protection Association Standards. Thermal detection will be provided upstream of final HEPA filters, as required by DOE Orders, and the DOE *Fire Protection Resource Manual.*

Thermal detectors have been used successfully in hot cells, and are currently recommended for the HVF because they can be arranged to be tested remotely (testing is not a concern), and it may be possible to arrange the detectors so failed detectors can be replaced from outside the hot cell; such a design is "standard" on glovebox enclosures at some facilities.

An "incipient" fire detection system, such as a "VESDA" system, will be considered for the hot cells as an alternative to standard thermal detection because (a) this is an air sampling system that can be arranged to sample air at various levels and locations throughout the hot cells; therefore, increasing the likelihood of detecting products of combustion at an earlier stage; (b) the air sampled by the system is potentially contaminated and therefore it must be returned to the cell or exhausted through another HEPA filter (air-handler unit components of this system will also potentially be contaminated); and (c) maintenance of such a system could be a significant problem in areas that are highly radioactive.

5.7 Utility Control System and Fiber-optic cable

EDF-HVF-F-011 in Appendix C provides details of the HVF utilities. The existing UCS fiber-optic cable loop at INTEC consists of six dedicated fibers in a 36-fiber, fiber-optic cable. Three loops of fiber-optic cable encircle the INTEC site and control and monitor the UCS, the fire alarm system, the voice paging and public address system, the criticality alarms, and local area network (LAN) systems. To connect the HVF into these systems one of the loops must have all 36 fibers cut and the loop expanded to include HVF. All above systems must be tested to ensure proper functioning before reactivation.

The UCS controls the main and tie breakers of all load centers at INTEC, while the plant control system (PCS) controls the main and tie breakers on the downstream motor control center and power centers. In addition, the PCS controls the starting and stopping of all loads in the facility/building. The UCS and PCS combined allow load shedding of unimportant loads from the electrical system, thus limiting and controlling the standby load requirements at INTEC.

The HVF and ISF will be located directly over the top of an existing ductbank that extends from the coal fired steam generation plant into the fuel processing restoration facility area (north-south running ductbank). The ductbank and the fiber-optic cable will be rerouted around the east side of the ISF. The fiber optic loop will occur in an existing manhole. New fiber-optic cable and ductbank will be routed to the HVF from this location. Rerouting of existing fiber-optic cable or ductbank is not required in this option.

5.8 HVF Staffing

The HVF will require a total staff of 171. Support personnel will include two managers and four engineers. The HVF will also require eight supervisors, eight administrative support personnel 21 technicians, 68 operators, and 60 maintenance personnel. These numbers were derived by scaling (based on increased complexity and floor space) personnel numbers established in a previous Vitrification Study.[3]

5.9 Strategic Materials

The strategic and critical materials list from the Stockpile Report to the Congress[5] was reviewed with respect to materials and processes to be included in the HVF. It was determined that no materials in that list will be used in the HVF.

6. HVF PROCESS DESCRIPTION

6.1 Empty Canister Handling

Drawing HVF-M-01 (see EDF-HVF-F-010 in Appendix C) shows the process flow for the empty canisters from the truck airlock loading dock to the canister filling station in the canister filling and capping cell. Each canister lifting crane referred to in this section will be equipped with a SRS DWPF Canister Grapple (an existing SRS design). Empty canisters will be delivered by trucks that enter the truck airlock near the northwest corner of the HVF. Canisters will be removed from the truck by an empty canister crane, and placed on the HLW canister transfer cart. The cart will be moved into the clean canister storage room. The clean canister storage room crane will lower the canisters through a floor hatch and into the canister staging area at the 32-ft level. The filling and capping cell crane will move the canister into the filling and capping cell and place it on one of the four canister lift stations below the melters. The canister lift station will raise the canister to the filling position and mate it with the canister filling bellows assembly. The bellows assembly will seal to the mouth of the canister, and glass pouring will begin.

6.2 Vitrification Process

Detailed process descriptions, process flow sheets, and related material balances are given in EDF-HVF-F-002 and EDF-HVF-F-004 in Appendix C. The vitrification process includes feed material, grinding equipment, blending equipment, spray dryers, four induction melters, and an offgas treatment system.

The system is capable of processing either calcine or NGLW. Calcine is delivered pneumatically to the HVF from the CSSF bins by the CRTS. Sketch HVF-P-01 in EDF-HVF-F-004 (Appendix C) shows this system. The active components of the CRTS (the calcine delivery cyclone, sintered metal filter, primary HEPA filter, primary blower, air cooler, balancing HEPA filter and balancing blower) are all located within the HVF. However, the costs for the CRTs components are captured in the CRTS cost estimate and are not contained in the HVF estimate.

The calcine is stored in a calcine-receiving vessel that holds enough for 8 days of production. From there, the calcine is transferred pneumatically to a calcine weigh vessel that feeds the calcine grinders. Details of the calcine grinders are provided in EDF-HVF-F-005 in Appendix C. The calcine is ground so that it can be more easily blended and mixed. The grinder will feed calcine, by gravity, into one of the three mixing vessels. Calcine samples are taken from the mixing tanks prior to frit being added to the mix tank. NGLW is stored in a 10,000-gallon tank and vitrified in a single short campaign each year. The calcine mix tanks are also used to prepare the NGLW for treatment.

Melter feed material is prepared as water slurry. This approach is consistent with the feed systems used at other DOE vitrification plants, including the DWPF and the Transportable Vitrification system. The mixing tanks each hold approximately two days of feed material for the entire HVF. Having three tanks allows time to characterize and certify the feed material before it is fed to the melters.

Once the calcine fed in to a mixing tank has been characterized, the appropriate type and quantity of frit is added, along with the proper amount of water. Sketch HVF-P-01 in EDF-HVF-F-004 (Appendix C) shows the glass frit delivery system. Three separate types of glass frit chemistry are delivered to the HVF by rail hopper car. Each frit formulation is gravity fed from the hopper car into one of three dedicated subgrade storage cells. Frit is transferred from each storage cell to one of three dedicated storage silos by means of three separate auger and bucket conveyor systems. These systems are

located outside and to the north of the HVF. Glass frit is then fed, by a second set of three auger and bucked conveyors, from the silos to one of three dedicated frit weigh tanks inside the HVF. The mixture of frit, calcine, and water is agitated and sampled again to complete the certification process. Once the contents of a mixing tank have been certified, the entire content of the tank is transferred to an agitated feed tank. Another batch of feed material can then be added to the empty mixing tank.

From the feed tanks, slurry is fed to the spray drying system associated with each of the four induction melters (see EDF-HVF-F-006 in Appendix C details). The spray dryers are discussed in detail in EDF-HVF-F-004 in Appendix C. The spray dryers remove about 95% of the water in the slurry and then the dried solids are stored in day tanks for feeding to a melter. The water is removed to increase the glass making capacity of each melter. If slurry were fed directly to a melter, the rate of glass output would be reduced to about half that when dry feed is used. Water is added to the mix tank when calcine is being processed to facilitate blending and to allow operators to obtain representative samples of feed material for certification. In the HVF, the product glass is certified as suitable for disposal based on the composition of the feed material. Throughout an entire operating year, no more than a few samples of actual product glass will be taken. This approach to waste certification is the same as that used at the DWPF.

6.3 Full Canister Handling

Drawing HVF-M-01 (see EDF-HVF-F-010 in Appendix C) shows the process flow for the filled canisters from the canister filling station in the filling and capping cell to the canister in place on the transport cart in the transfer tunnel in preparation for transport to the ISF. Each canister lifting crane referred to in this section will be equipped with a SRS DWPF Canister Grapple (an existing SRS design). After the canister is filled with glass in the filling station, it will be lowered, removed from the lift station by the filling and capping cell crane and transported to the canister cooling and capping station. After the canister cools for 24 hours, its lid is set in place by the canister capping manipulator. It will then be removed from the cooling station by the filling and capping cell crane and be transported to a station below the north welding cell floor hatch. The welding cell crane will lift the canister through the welding cell floor hatch and place it in the welding station. The lid will be welded in place by the remote GTAW module. A remote leak check module will be used to test and qualify the weld. The welding cell crane will then lower the welded canister through the welding cell south floor hatch, and place it in the decon cell. The decon cell crane will lift the canister and position it in the decontamination spray chamber. The crane also raises, lowers, and rotates the canister in the spray chamber for complete coverage by the spray nozzles. The decontamination process will use either solid carbon dioxide pellets or slurried glass frit under high velocity to remove oxide and contamination from the canisters. If carbon dioxide pellets are used, approximately 100 scfm of carbon dioxide vapor will be removed by the decontamination room HVAC exhaust. The decon cell crane will then place the canister at a station below the smear cell north floor hatch. This hatch is also located in the decon cell ceiling. The smear cell crane will lift the canister into the smear cell and place it into the smear station. After the canister is monitored for residual contamination by a smear monitor, the smear cell crane will either return the canister to the decon cell through the north floor hatch (if it needs further decontamination), or it will lower the canister through the south smear cell floor hatch and onto transport cart in the transfer tunnel. The transport cart will then move the canister approximately 100 ft to the ISF.

6.4 Offgas System

EDF-HVF-F-004 in Appendix C describes details of the HVF offgas system and presents key assumptions on which the offgas system is based. This offgas system collects and treats offgas from the melters and the melter pour-spout area. The only secondary waste streams produced by the offgas system

are a treated vapor that will be exhausted to the atmosphere, and a solidified mercury stream which may de disposed of as LLW or may be sent to an outside vendor for final treatment. The EDF also includes the offgas system process flow diagrams HVF-P-01, -02, and -03. The offgas system incorporates the following unit operations/steps: offgas collection, offgas flow control, offgas cooling, hydrogen fluoride removal via dry scrubbing with lime, fines removal baghouse, mercury removal and treatment, HEPA filtration, NOx removal via selective catalytic reduction with NH-3 reaction and treated gas blower discharge to atmosphere. The process description for the feasibility of meeting MACT for the HLW-Vitrification offgas is presented in the EDF. This process has a design basis for treating the HVF offgas by use of proven and demonstrated technology where available and applicable.

In addition to the offgas system, melter feed dryer systems are also required and are described in the EDF. The dryer systems are needed in order to provide an adequately dried waste feed stream to the induction melters. One spray dryer will be located in each melter cell to reduce the water at 60 wt% in the slurry feed to approximately 5 wt% water.

As can be seen on Sketch HVF-P-02, the induction heated vitrification melters offgas is collected by a header. Air in-leakage will occur since the melters are maintained under vacuum to provide positive assurance that the melters do not leak to the exterior. Fifty scfm of air will be inducted into each melter which is operating at approximately 1150° C and 9.5 psia. The first treatment step of the collected and flow controlled offgas is the removal of hydrogen fluoride as can be seen on process flow diagram HVF-P-03. A dry scrubber is used.

The offgas exits a fabric filter baghouse at a controlled temperature of between 150 and 200° C as depicted on Sketch HVF-P-03. Next, the gas is mixed with the tank and vessel gas from the HVF process via a temperature-controlled vent gas heat exchanger. This achieves a mixed gas feed temperature of 120° C. The mixed gas then enters an activated charcoal bed where the mercury in the offgas is adsorbed to meet the MACT limit. The charcoal will periodically be removed and sent to a vendor for mercury removal and disposal. As can be seen on offgas process Sketch HVF-P-03, the HEPA filtration of the offgas occurs after the mercury removal via adsorption and on the feed stream for the NOx removal by Selective Catalytic Reduction (SCR). This removes residual fine particulate matter as either entrained activated charcoal or fine particulate that have passed through the baghouse in the dry scrubbing system. The incoming tank vent air will also be HEPA filtered.

The gas leaving the HEPA filter enters the SCR unit to reduce the NOx emission from the HVF offgas and also any residual carbon monoxide or any trace amounts of hydrocarbons present to comply with MACT. In the SCR process, NOx emissions are reduced by injecting a chemical reagent such as ammonia into the gas which passes through a catalyst. An induced draft blower takes treated gas suction from the effluent stream from the SCR NOx removal step as depicted on process Sketch HVF-P-03 and discharges the gas to the atmosphere. The blower will have an installed spare to ensure MACT compliance.

7. METHOD OF PERFORMANCE

7.1 Design, Procurement, and Construction

Conceptual design will most likely be accomplished by LMITCO Engineering personnel, whereas title design might be subcontracted to an AE firm. Any long-lead components will be provided as GFE. Procurement contracts for these items will be placed during the Title Design phase, if necessary, to ensure the equipment is available during the construction window identified in Appendix B. Fabrication and installation of equipment will be accomplished by competitively bid fixed-priced construction contracts. Standard components will be procured during the construction work period by the Subcontractor. Force account workers might perform demonstration and installation/modification work inside the NWCF.

7.2 Work Breakdown Structure

Figure 1 shows the work breakdown structure for the HVF feasibility study.

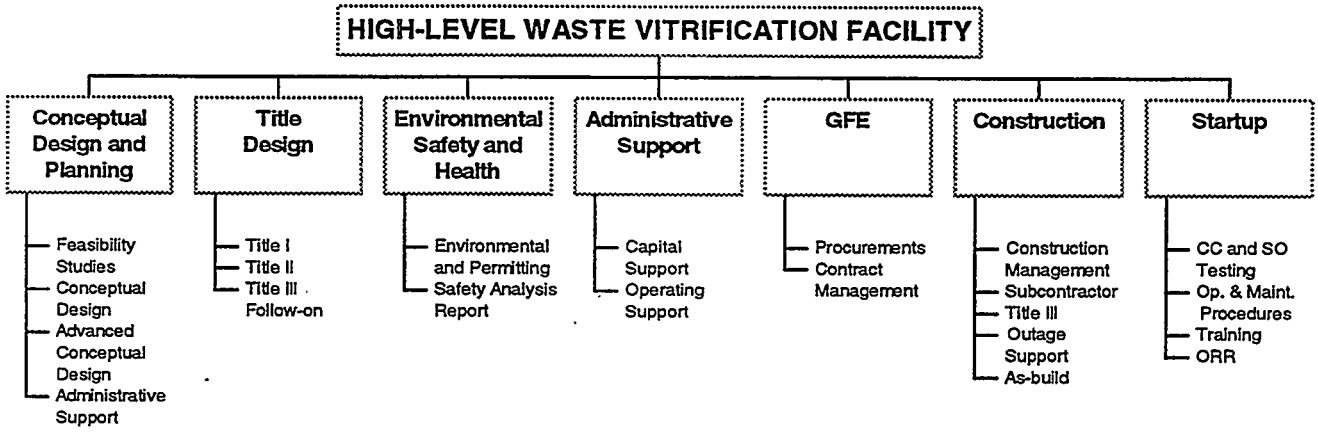


Figure 1. Work breakdown structure for the HVF feasibility study.

7.3 Facility Decommissioning

A Decontamination and Decommissioning (D&D) plan will be written and in place before start of operations. The estimated cost to perform the D&D work is summarized in Section 8. Detailed and LCC estimates are contained in Appendix A.

If Scenario 2 is selected, the existing NWCF D&D Plan will be revised to reflect the modifications and additions generated by this project.

8. ESTIMATED COST

The capital cost, also called total project cost (TPC), was estimated for the HVF. This estimate is divided into total estimated costs (TECs) and other project costs (OPCs). TECs include the title designs, project management (during title design and construction periods), construction and construction management, inspection, general and administrative costs, procurement, GFE, and all applicable escalation and contingency for the title design and construction periods. OPCs include conceptual designs, project management (during the conceptual and startup periods), environmental documentation, operations, support, final testing, and startup. To reflect the expected impact of inflation, the estimates are escalated to the future at a rate prescribed by *The Departmental Price Change Index Fiscal Year 2000 Guidance—Anticipated Economic Escalation Rates, DOE Construction Projects and Operating Expenses*, January 1998 update.

An LCC analysis was also performed. The LCC analysis estimates costs for preoperation, operation, and postoperation activities. LCC postoperation activities comprise D&D. The LCC analysis assume a 35-year period (2006-2040) since this is the estimated time required to complete all anticipated HVF project and remediation activities. A discounted LCC analysis assumes a constant-dollar basis, discounted at 5.10 % per the Office of Management and Budget Circular A-94. For the preoperations portion of the cost analyses, the TPC estimates were used. Details of the LCC analysis is included in Appendix A and summarized in Table 1.

Table 1. Cost estimates for the HVF.

Cost category	Cost (K$)
Preoperations	
Total Estimated Cost (TEC)	$900,380
Other Project Cost (OPC)	$181,300
Total Project Cost (TPC=TEC+OPC)	$1,081,680
Discounted TPC	$585,044
Operations (with escalation & contingency)	$3,203,946
Discounted Operations	$853,592
Post Operations (D&D)	$328,002
Discounted Post Operations	$47,125
Total Cost (unescalated, not discounted)	$1,814,611
Total Cost (escalated, not discounted)	$ 4,613,628
Discounted Total Cost	$ 1,478,851

9. PROJECT SCHEDULE

The project design, construction, operation, and D&D schedule is illustrated in Appendix B. The schedule starts at the beginning of 2006 with conceptual design and project management and ends the last day of 2040 with D&D. The 4 year construction schedule starts at the beginning of 2011 and ends the last day of 2014. Testing occurs for 2 years in 2014 and 2015, with startup occurring at the beginning of 2016. The operation period starts at the beginning of 2016 and ends the last day of 2035, and D&D starts at the beginning of 2036 and ends the last day of 2040.

10. REQUIREMENTS AND ASSESSMENTS

10.1 Radiological

10.1.1 General

Radionuclides in the waste pose radiological hazards. The waste contains both transuranics and fission products. At various stages in the treatment, the waste have the form of dry granular calcine, wet calcine (slurried with water), dry calcine dust, dry cesium-saturated particulate (from the CsIX option), wet cesium-saturated particulate (slurried with water), and liquid NGLW. The dry calcine may be mixed with the dry cesium-saturated particulate, and aqueous slurries may contain both forms. The radiation hazards consist of ionizing radiation exposure and contamination exposure. Protection against these exposures requires the use of significant biological shielding in all areas where the wastes are handled or treated, and at least a double ventilation confinement system to control contamination.

A double confinement structure is defined as a series of physical barriers that, together with the ventilation system, minimizes the potential for release of radioactive material into work areas and the environment under normal and abnormal conditions. Radioactive materials are separated from the ambient environment by at least two barriers and from an operator by at least one barrier.

The ventilation system is designed to ensure airflow is from less contaminated areas to more confinement areas. The primary confinement is maintained at a negative pressure relative to the secondary confinement and the secondary confinement is maintained at a negative pressure relative to the environment. The ventilation exhaust of both the primary and secondary confinement areas is filtered by DOP-testable, redundant, HEPA filters.

The radiological contamination will be contained within the primary and secondary confinement areas. This will be accomplished using radiological control work practices. These radiological work practices will maintain the radiological contamination in the secondary confinement within established limits by periodic decontamination using a centralized decontamination solution dispensing system, stainless steel-lined primary confinement areas, and airlocks for the ingress and egress of equipment and personnel in the confinement areas.

The HVF is designed to handle the same basic type of waste as the VWO.[3] Therefore, the shielding thickness established for the VWO design will also be used for the HVF design.

10.2 Environmental

This subsection lists current regulatory sources that apply to the design, construction, and operation of the proposed HVF at the INEEL. The HVF will be used to vitrify mixed HLW, cesium-saturated waste, and NGLW, all of which contain both radioactive and RCRA hazardous constituents. Consequently, managing the wastes and HVF will be subject to the requirements of both the EPA and the Atomic Energy Act (AEA). The requirements for radioactive waste management developed under the AEA are conducted in accordance with the DOE standards. The principal governing sources for the regulations and codes presented here are the EPA, IDAHO Laws and regulations, DOE, DOE-ID, National Environmental Policy Act (NEPA), and other applicable standards and codes.

It is assumed that the waste resulting from the HVF will be delisted through the up front exclusions of the EPA before being transported to the interim storage facilities, and disposed of at a NGR. The EPA

delisting criteria and processes for preparing a delisting petition are contained in *Petitions to Delist Hazardous Wastes: A Guidance Manual,* Second Edition, P1393-169365, March 1993.

The HVF must be managed in accordance with the EPA RCRA requirements. The requirements are defined in 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities" and in 40 CFR 270, "EPA Administered Permit Programs: the Hazardous Waste Permit Program." The State of Idaho adopted the Federal RCRA regulations, pursuant to the Idaho Hazardous Waste Management Act of 1983. The regulations are administered under the Idaho Administrative Procedures Act (IDAPA) 16.01.05. Additional applicable RCRA regulations include 40 CFR 264.18, "Location Standards," 40 CFR 262.34 (subpart of 40 CFR 262—IDAPA 16.01.05.006), "Accumulation Time," and 40 CFR 268.50 (subpart of 40 CFR 268—IDAPA 16.01.05.011), "Prohibitions on Storage of Restricted Wastes."

EPA has established radiation protection standards in 40 CFR 191, "Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level Waste and Transuranic Waste." The standards apply to (a) Radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel or HLW or TRU waste at any facility regulated by the NRC or by Agreement States, to the extent that such management and storage operations are not subject to the provisions of 40 CFR 190, "Environmental Radiation Protection Standards for Nuclear Power Operations"; and (b) Radiation doses received by members of the public as a result of the management and storage of spent nuclear fuel or HLW or TRU waste at any disposal facility that is operated by the DOE and that is not regulated by the NRC or by Agreement States.

40 CFR 270 establishes the requirements for obtaining permits (Part A and part B). The permit application covers all aspects of the design, construction, operation, monitoring, and maintenance of the HVF. The requirements for Part A permit application are given in 40 CFR 270.13, and for Part B Permit application are given in 40 CFR 270.14 through 29.

Clean Air Act (CAA) air permits are addressed by:

- 40 CFR 50
- 40 CFR 52
- 40 CFR 60
- 40 CFR 61
- 40 CFR 62
- 40 CFR 63
- 40 CFR 70
- 40 CFR 77
- 40 CFR 124.

The Clean Water Act (CWA) "Wastewater Effluent Discharges and Drinking Water Permit" is covered under 40 CFR 122, "National Pollution Discharge Elimination System and Wastewater Land Application Permits."

The Idaho standards for air and water pollution control and for releases into the environment are applicable to the design, construction, and operations of the HVF. The standards are based on the federal requirements established by the CAA, the CWA, and the RCRA. The requirements are provided here as reference materials.

- Idaho Code 39-44, "Hazardous Waste Management Act"
- IDAPA 16.01.05, "Rules and Standards for Hazardous Waste"
- IDAPA 16.01.01, "Rules for the Control of Air Pollution in Idaho"
- IDAPA 16.01.01.161, "Toxic Substances"
- IDAPA 16.01.01.210, "Demonstration of Reconstruction Compliance with Toxic Standards"
- IDAPA 16.01.01.575, "Air Quality Standards and Area Classification"
- IDAPA 16.01.01.650, "Rules for Control of Fugitive Dust"
- IDAPA 16.01.09, "Idaho Radiation Control Rules"
- Idaho Code 39-36, "Water Quality Act"
- IDAPA 16.01.02, "Water Quality Standard's and Wastewater Treatment"
- IDAPA 16.01.08.500, "Design Standards for Public Drinking water Systems"
- IDAPA 16.01.08.551, "Construction Requirement for Public Water Systems"
- IDAPA 16.01.08, "Idaho Rules for Public Drinking Water Systems"
- IDAPA 16.01.17, "Wastewater Land Application Permit Regulations"

DOE requires that the planning, design, construction, and operations of DOE facilities be performed in a manner that will satisfy all applicable federal, state, and local environmental, safety and health laws and regulations, and the DOE criteria. The following DOE and DOE-ID standards apply to this study:

- DOE order 5820.2A, "Radioactive Waste Management" requires that the development of large scale waste treatment facility be supported by the appropriate documentation such as NEPA documentation, construction design report including projected waste throughputs, and treatment methods, construction and operating cost estimates, and Safety Analysis Report (SAR).
- The new HVF shall be doubly contained. Where required, ventilation and filtration systems shall be provided to maintain radionuclide releases within the guidelines specified in DOE Order 5481.1B, "Safety Analysis and Review System," DOE Order 5480.23, "Nuclear

Safety Analysis Report," and other applicable orders discussed in this section. Ventilation systems shall be provided where the possibility exists for generating flammable and explosive mixtures of gases (e.g., hydrogen or organic).

- Nuclear criticality safety considerations and controls shall be evaluated for normal operations and, before any significant operational changes are made, to protect against an uncontrolled nuclear criticality incident. Each facility shall use remote maintenance features and other appropriate techniques to minimize personnel radiation exposure in accordance with DOE Order 5481.1B, "Environment, Safety, and Health Program for Department of Energy Operations," DOE Order 5480.23, and DOE Order 5480.24, "Nuclear Criticality Safety."

- Monitoring, surveillance, and leak detection capability shall be incorporated in the engineering systems (e.g., liquid level sensing devices and alarms for high-level waste liquid systems) to provide rapid identification of failed containment, and measurement of abnormal temperatures. As a minimum, temperature, pressure, radioactivity in ventilation exhaust, and liquid effluent streams associated with HVF, shall be monitored. Where the possibility exists for the generation of flammable and explosive mixtures of gases, monitoring shall be conducted.

- Training and qualification standards shall be developed and an up-to-date record of training status shall be maintained. Worker safety training must comply with the requirements of DOE Order 5480.113 and applicable Orders. Quality Assurance consistent with DOE Order 5700.6C, "Quality Assurance," shall be conducted in accordance with applicable requirements of the American National Standards Institute and other applicable codes.

- Compliance with DOE Order 6430.1A, "General Design Criteria" is mandatory under the current LMITCO contract. DOE-ID Notice 430.1A, "Life Cycle Asset Management-ID expectations," requires that for facilities under the purview of the DNFSB, the DOE Order 6430.1A remains effective until 10 CFR 830.340, "Maintenance Management," and DOE O 420.1, "Facility Safety," are finalized and incorporated into the LMITCO contract. Division 13, Section 1300, "General Requirements," and Section 1324, "Radioactive Solid Waste Facilities," address general and specific design criteria. Also, Section 0900-99.0, "Nonreactor Nuclear Facilities," contains additional criteria relevant to HVF design. All of these criteria provide minimally acceptable requirements for the HVF design.

Additional applicable local building codes and design requirements that are not covered in the order are provided in the DOE-ID, AES. The following is a list of some of the applicable standards and codes included in the AE documents:

- ICB0 UBC, "Uniform Building Code," latest edition

- ICBO UFC, "Uniform Fire Code," latest edition

- 29 CFR 1910, "Occupational Safety and Health Standards"

- 29 CFR 1926, "Safety and Health Regulations for Construction"

- ADAAG, "Americans with Disabilities Act—Accessibility Guidelines"

- ASCE-4-86, "Seismic Analysis of Safety-Related Nuclear Structures"

- ASCE-7-93, "Minimum Design Loads for Buildings and Structures"
- DOE-STD-93, "Natural Phenomena Hazard Performance Categorization"
- DOE-STD- 1020-94, "Natural Phenomena Hazard Design and Evaluation Criteria for Department of Energy Facilities"
- DOE-STD-1021-93, "Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components"

DOE Order 5400.5, "Radiation Protection of the Public and the Environment" Chapter II, "Requirements for Radiation Protection of the Public and the Environment," specifies that exposure of members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem. The 100 mrem limit is the sum of the effective dose equivalent from exposure to radiation sources external to the body during the year plus the committed effective dose equivalent from radionuclides taken into the body (radioactive decay inside the body) during the year. Exposure of members of the public to radioactive materials released to the atmosphere as a consequence of routine DOE activities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem annually.

DOE Order 5480.4, "Environmental Protection, Safety, and Health Protection Standards" must be followed during HVF design, construction, operation, modification, and decommissioning. This Order requires compliance with the Occupational Safety and Health Administration (OSHA) standards including 29 CFR 1910, 29 CFR 1915, 29 CFR 1918, 29 CFR 1926, and 29 CFR 1928.

DOE Order 5480.19, "Conduct of Operations Requirements for DOE Facilities," contains requirements and guidelines for departmental elements to use in developing directives, plans, and/or procedures related to the conduct of operations at DOE facilities. The implementation of these requirements and guidelines should result in improved quality and uniformity of operations. The guidance for conduct of operations at DOE facilities is contained in the attachments of this Order. It is based on well-developed industrial operations practices. The guidelines are written to be flexible, so that they encompass the range from large, permanent DOE test or production facilities to small research or testing facilities. These guidelines form a compendium of good practices and describe key elements of programs that support operations at DOE facilities. Their implementation should result in a high level of performance and therefore contribute to safe and reliable operation. These guidelines include a number of elements such as operations policies, monitoring of operating performance, accountability, management, training, planning for safety, shift routines and operating practices, control area activities, communications (emergency communications systems, public address system, contracting operators, radios, and oral instructions and informational communications), control of on-shift training, investigation of abnormal events, notifications, control of equipment and system status (equipment and system alignments, equipment locking and tagging, alarm status, required reading, and equipment and piping labeling.

DOE Order 5480.23, "Nuclear Safety Analysis Reports," establishes requirements for DOE-owned nuclear facilities and operations, and for contractors responsible for the design, construction, operation, decontamination, or decommissioning of nuclear facilities to develop safety analyses that establish and evaluate the adequacy of the safety bases of the facilities. The SAR that is required by this Order documents the results of the safety analysis.

DOE Order 5480.28, "Natural Phenomena Hazard Mitigation," must be used in conjunction with the general design criteria in DOE Order 6430.1A and other departmental design criteria as applicable.

DOE Order 5480.28 requires that facilities structures, systems, and components (SSCs) be designed and constructed to withstand the effects of natural phenomena hazards. An objective for all SSCs is to prevent loss of structural integrity endangering life safety. An additional objective for selected SSCs or site activities is to prevent loss of capability to perform functions consistent with: (1) importance to safety for workers and the public; (2) impact on the environment; (3) repair/replacement costs; or (4) programmatic mission.

DOE Order 5700.6C, "Quality Assurance," applies to the work performed by all Departmental Elements and management and operating contractors as provided by law and/or contract and as implemented by the Department's Contracting Officer. If conflicts between this and other Departmental Orders exist, the quality assurance requirements of DOE 5700.6C take precedent. Work licensed by the NRC or a NRC Agreement State and subject to the quality assurance requirements of that agency are excluded from this Order. Other DOE orders that apply include:

- DOE Order 5480.113, "Environment, Safety, and Health Program for Department of Energy Operations"
- DOE Order 5480.9A, "Construction Projects Safety and Health Management"
- DOE Order 5480.10, "Contractor Industrial Hygiene Program"
- DOE-ID 437.A, "Physical Security Information (Firearms, Bomb threat, INEEL Traffic Citations, and Controlled Substances)"

Other applicable codes and standards include:

- 10 CFR 1021, "National Environmental Policy Act Implementing Procedures"
- *Uniform Building Code*, ICBO UBC, "International Conference of Building Officials"
- American Institute of Steel Construction
- American Welding Society Standards
- American Concrete Institute
- *DOE-ID Welding Procedure Specification Manual*
- DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques, for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*
- DOE-STD-3007-93, *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities*
- DOE-STD-3009-94, *Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports*
- *INEL Radiological Control Manual*
- 10 CFR 835, "Occupational Radiation Protection, DOE Order 5480.11 has been canceled and replaced by 10 CFR 83 5."

- *Uniform Fire Code*, ICBO UFC, "Western Fire Chiefs Association and International conference of Building Officials"
- 929 CFR 1910, "Occupational Safety and Health Standards"
- 29 CFR 1926, "Safety and Health Regulations for Construction"
- ADAAG, *Americans with Disabilities Act (ADA)—Accessibility Guidelines*
- ASCE-4-86, *Seismic Analysis of Safety-Related Nuclear Structures*
- ASCE-7-93, *Minimum Design Loads for Buildings and Structures*
- DOE-STD-93, *Natural Phenomena Hazard Performance Categorization*
- DOE-STD-1020-94, *Natural Phenomena Hazard Design and Evaluation Criteria for Department of Energy Facilities*
- DOE-STD- 1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components*
- National Fire Protection Association (NFPA)
- *Uniform Building Code*, Section 505 (e)
- DOE Order 5480.7A, "Fire Protection"
- DOE-STD-1020-94(CH-1) *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*

In addition, to the above requirements, EDF-WTS-003, *Regulatory Requirements for the Design, Construction and Operation of the ICPP Proposed Waste Processing Processes, of the Vitrified Waste Option Study Report*,[3] provides an excellent reference containing regulations and permitting activities that apply to the HVF.

The cesium-saturated sorbent from the CsIX option will contain enough TRU and Cs radionuclides that it will exceed Class C LLW limits and will exhibit many of the characteristics of HLW. At this time, waste that exceeds Class C limits is only suitable for disposal in an NGR. The relatively small volume of sorbent will be transferred to the CSSF bins and reside there with existing calcine. When the sorbent is pneumatically transferred to the HVF in the CRTS, it may become mixed with calcine in which case it cannot be vitrified separately. Even if it could be vitrified separately, the glass produced would fill only about 40 DWPF-type canisters. These canisters would be classified as greater-than-Class C, LLW and could be disposed of at WIPP. This will still be an option if WIPP will accept, and is able to handle, the SRS-type canisters. Otherwise these 40 canisters should be able to be disposed of at the NGR along with the other 13,460 vitrification canisters that will be produced in the HVF.

10.3 Quality

Appropriate quality program documentation will be generated and followed as necessary to confirm proper design, construction, and operation of the HVF. A rigorous quality assurance sampling

process upstream of the melter will verify the glass form before it is made. This is necessary because the HVF has no means of reprocessing canisters that contain glass that does not meet specifications. This same method is used in the SRS DWPF. It is assumed that DOE-ID will continue to implement the quality assurance program described in DOE-RW-0-333P, *Quality Assurance Requirements and Description*, and will apply it to this effort as well.

10.4 Safety

10.4.1 Facility Hazard Category and Performance Category

Facility hazard and performance categories are discussed in Subsection 5.1, "Building Description."

10.4.2 Industrial Safety

The basic approach to worker safety for the HVF is the incorporation of standard engineering and administrative controls to separate the worker from physical, chemical, and radiation hazards. The LMITCO Health and Safety Program includes aggressive goals with respect to as low as reasonably achievable (ALARA) for radiation hazards and lost time worker injury rates for industrial workers. These goals are most effectively attained by physical separation of workers from the hazards associated with the processes contained within the project buildings.

10.4.2.1 Construction Hazards. Construction hazards for this project are typical for most construction sites. For example, heavy equipment produces physical hazards of striking objects, crushing of hands or feet, and head injuries. Construction Subcontractors shall be required to comply with 10 CFR 1926, "Occupational Safety and Health for Construction" and monitored to ensure compliance.

10.4.2.2 Systems Safety. Manual and remote modes of system operation will allow standard physical lockout of either mode to ensure that operators do not initiate actions that could injure workers performing maintenance, repair, or troubleshooting tasks inside hazardous areas. Equipment and procedures to ensure safe shutdown of the different process systems will be developed as appropriate for the hazards associated with the system. Systems that may have high radiation fields will have remote repair or maintenance capabilities. The remote maintenance philosophy and equipment decontamination philosophies are contained in EDF-HVF-F-014 and EDF-HVF-F-015 respectively (Appendix C).

10.4.2.3 Equipment Safety. Equipment will comply with 10 CFR 1910, "Occupational Safety and Health Standards for General Industry." For example, equipment will be provided with guards, lockout/tagout features, operation and maintenance documentation, and any other items necessary to ensure safe operation of the equipment. Long-lived equipment will be contained in the equipment canyon and be accessible from the shielded highbay area above the canyon. The equipment in the canyon will be removable via Hanford connectors. Shorted lived equipment will be contained in the pump and valve corridor with special provisions for rapid changeout. Equipment in the melter cells will be accessible with the use of remote manipulators, wall mounted EMMs, and the highbay crane and its overhead EMM.

10.4.2.4 Personnel Safety. In general, workers will be physically separated from most hazardous systems by primary confinement cells, canyons, and the equipment corridors that have shielding walls, viewing windows, and remote handling equipment. These area are kept at a negative pressure with respect to that areas that surround them so air will always flow from areas of lower contamination to areas of higher contamination. All equipment pass-out and pass-in areas are controlled by vestibules or areas of lesser contamination. All primary zone areas are surrounded by secondary operating corridors that are

normally non-contaminated but may become contaminated. The Zone II areas are held at a negative pressure with respect to the ambient.

Administrative procedures will allow workers access to some systems for maintenance or repair of equipment. Entries to cells and shielded corridors are viewed as hazardous and non-routine and will require the use of safety permits. A Radiation Work Permit will address radiological hazards. Personnel safety will be maintained by:

- Following administrative and procedural controls for entry into confinement areas
- Incorporating engineering controls into the design for systems and equipment
- Using personnel monitoring equipment
- Using video monitoring inside confinement areas
- Using lockout/tagout of remote controls and manual controls when working on equipment or systems
- Using emergency procedures to initiate worker response to chemical spills/reactions, fires, and other emergencies
- Using the buddy system when working inside confinement structures or other hazardous areas.

10.4.2.5 Emergency Preparedness. Operations for this project will coordinate emergency preparedness planning with the INTEC Emergency Response Organization (ERO). The INTEC ERO will handle site emergencies. Access for emergency vehicles and personnel will be provided as part of the project design.

11. UNCERTAINTIES AND RECOMMENDED RESOLUTIONS

During the course of this study, several important areas of uncertainty arose. Additional work is needed during conceptual design of these uncertainties. They include issues associated with: vitrified glass quality, the pump and valve corridor, the equipment canyon, glass frit formulations, melter type, canister closure, calcine transfer, canister decontamination, the potential use of Hanford vitrification canisters, and mercury amalgamation. These topics are discussed in this section.

11.1 Vitrified Glass Quality Issues

The most important technical issue associated with vitrification is ensuring that all the glass produced meet requirements for shipping and disposal at the NGR. HVF has no provisions for storing or recycling canisters containing glass that does not meet specifications; therefore, the process must be qualified. Samples of the waste feed will be taken in two areas to ensure that acceptable glass product is produced. Each calcine batch is first sampled and analyzed to determine its representative chemistry. The calcine bins contain a variety of materials, including sodium, alumina, and zirconia calcines and dolomite and fluorapatite (from startup). To the extent possible, calcine will be blended. Development work and modeling done to date indicate that concentrations of alumina calcine in excess of 25% result in low waste loading in glass, and this situation will be avoided. Although the alumina calcine will be purposely batched with other types of calcine, the actual chemistry of the final batch will not be known until the samples of the batch are analyzed. In order to ensure that the samples are representative of the entire batch, the batch must be thoroughly blended before the sample is taken. The amount, and type of glass frit that must be mixed with the batch to produce an acceptable glass is then determined from the chemistry of the sample and the amount of calcine in the batch. The most reliable method of blending was chosen to gain the highest confidence that the samples will be representative. This method involves adding water to the dry calcine waste in the batch tank so that an aqueous slurry is produced. When the batch slurry is kept in an agitated state, the different types of calcine solids have a high probability of remaining homogeneously suspended and can be easily sampled. Three calcine grinders have also been included in the process system to reduce the size of the calcine particles and promote better homogeneity of the slurry. EDF-HVF-F-005 in Appendix C provides details on the proposed calcine grinders. It was determined that blending and sampling dry powders may produce less reliable samples, which will also be more difficult to obtain.

In addition to proper mixing, an effective feed certification program requires a statistically valid sampling procedure. Samples must be representative of the blended waste and feed materials.

As a result of the analysis, a specific amount of one of three glass frit formulations will be selected to be mixed into the slurry. After the frit is added to the slurry, the entire batch will be agitated to ensure homogeneity, and a second sample will be taken. This sample will be analyzed to ensure that the entire batch has a chemistry that will produce acceptable vitrified glass. In order to ensure that the melter will operate properly, most of the slurry water will be evaporated from a sub-batch of known composition before it is fed, in its entirety, into the melter.

The main disadvantage with this method is that approximately 9,600 liters of water must be added and then evaporated each day. The water is filtered and recycled, but the energy required to dry the waste is in excess of 500 MW/hr/yr. One spray dryer is located in each melter cell. These spray dryers are large and have active components that add to size and maintenance requirements in the melter cell. Although extra equipment and complexity has been added to the system to produce the aqueous solution with calcine, the HVF must be able to handle liquid feed in any case. This is because it must also be able to vitrify the NGLW which, of course, in already a liquid. The NGLW represents a small fraction of the

waste to be vitrified, but HVF must be designed to handle this liquid regardless of whether the calcine is handled dry or in a slurry.

A decision is still pending as to whether the calcine should be slurried or handled dry. During conceptual design acceptable designs for ensuring adequate blending, mixing, and obtaining representative samples should be sought. If such methods can be found, then they should be incorporated into the design instead of the slurried calcine methods incorporated in this study.

11.2 Pump and Valve Corridor

In the existing design, failed contaminated jumpers must be moved through the crane maintenance area at the south end of the P&V corridor before being placed in the decontamination room. The INTEC Fuel Processing Restoration facility is designed this way. The crane maintenance area requires manned entry but it may become contaminated when the jumpers are routed through the area. This problem should be considered further during conceptual design of the HVF.. One solution would be to exchange locations of the crane maintenance area and the decon area. This would allow decontamination of the jumpers before they entered the crane maintenance area, thus eliminating the contamination problem.

11.3 Equipment Canyon

The equipment canyon in this study is open along its entire length and not compartmentalized with shielding walls. This means that if manned entry is ever required, the entire canyon must be drained of waste and decontaminated to reduce the radiation levels. Since this is not practical, Hanford connectors are recommended for any systems that may require removal during the life of the plant. The conceptual design process should determine if intermittent shield walls are needed to eliminate the Hanford connectors. The canyon approach must minimize the use of active components; however, some of the slurry tanks have top mounted mixer motors that may have to be changed. These can be designed for relative ease of removal and replacement using the bridge crane and EMM located in the maintenance area above the canyon roof hatches.

11.4 Glass Frit Formulations

The batch calcine and glass frit formulations used in this report were primarily based on preliminary crucible studies with alumina, zirconia, and SBW waste calcine. In addition, some estimates were made using the GLASSFORM mathematical model. The waste loading values have not been optimized. Because of the expected high cost to dispose of the canisters, a slight increase in waste loading can have a very significant impact on overall cost. The number of frit formulations (presently three) has been reduced from the six required in the VWO report.[3] Further study, including technology development, should be done during conceptual design to ensure that the formulations will produce proper glass and a reasonable number of canisters.

11.5 Melter Evaluation

The selection of a melter design is a subject that deserves a separate technical evaluation. This report is based on induction melters, but, the VWO report[3] was based on the joule heated melter design, which is the only type now in use in the DOE complex. Induction melters are small, relatively simple, and can be changed out quite rapidly. However, they have smaller capacities than joule heated units which means that multiple induction melters will have to be operated in parallel. While the "hot wall" units currently used in Europe have a limited operating lifetime (3,000—5,000 hours), the "cold crucible" induction melters are expected to have significantly longer life. The induction melter requires a relatively

dry feed stream because it is not a cold cap melter; therefore, a separate dryer is needed. The joule melter operates with a cold cap and therefore, a wet feed stream may be fed directly into the melter instead of predrying. Although both melters appear feasible for the INEEL HLW, joule heated melters are currently preferred within the DOE complex.

Further studies should be conducted during conceptual design to select the overall best melter type considering cost, operations, change out, maintenance, dismantling, and disposal. A specific study should compare the purchase prices, operating costs, and disposal costs of joule heated melters with induction melters.

11.6 Operation Simulation

The proposed HVF manufacturing process is very complex. It is based on the design and approximate throughput rates used in the *Raytheon Direct Vitrification Option Feasibility Study Report.*[2] However, in order to determine operations and throughput bottlenecks and to refine the design, a manufacturing simulation model should be developed during conceptual design. Software packages such as ARENA® and SIMAN/Cinema® can evaluate operating scenarios and generate animated sequences describing proposed procedures. Problems can then be identified and corrected early in the design process. The model should determine if an average of 10,600 lb of glass frit/day can be received by rail and conveyed to the silos and receiving tanks.

11.7 Canister Closure

This study retained the sealing, leak checking, and welding processes of the baseline HVF design *Raytheon Direct Vitrification Option Feasibility Study Report.*[2] The SRS DWPF process uses a temporary plug, a 125-ton press, and a 230,000-amp resistance welder. It is not clear if the baseline design lid and lid-weld method (gas tungsten arc welding) will meet settlement agreement requirement to allow cask to be moved out of Idaho. If not, the DWPF method could be used in the VWO vitrification facility, but the equipment and facility changes would be costly.

In addition, if 100% volumetric weld inspection were to be required, a new remote, ultrasonic inspection station may need to be added; however, the associated cost increase is expected to be a very small percentage of the total HVF cost.

11.8 Canister Opening

The SRS DWPF canister has a relatively small neck opening through which the glass is poured. The Hanford glass canister, on the other hand, has a relatively large opening. During some operations at the DWPF, glass has migrated beyond the periphery of the canister neck, and poured onto the exterior canister body. A study should be conducted to determine the appropriate size of the HVF canister neck and opening to allow proper pouring.

11.9 Calcine Transfer

Without an intermediate transfer station, the CRTS system may not be able to reliably deliver calcine to the position sited for the HVF in this report. During conceptual design, a study should be made for siting the HVF and its ISF to the west or southwest of its present location so a single stage CRTS delivery system can be used.

11.10 Canister Decontamination

Two methods for decontaminating the filled vitrification canisters exist in the DOE complex. The DWPF uses an aqueous slurry of glass frit, and the West Valley Demonstration Project uses an acid bath followed by a neutralizer bath. The feasibility of both of these methods has been demonstrated. The design in this study is set up with a spray booth for either the aqueous glass frit slurry method or carbon dioxide pellet blasting. The feasibility of the latter method to remove the oxide coating produced on the canister during glass pouring and cooling has not been demonstrated. The baseline design on which this report is based (Raytheon Direct Vitrification Option) used the glass frit slurry blast. If the HVF uses a slurried melter feed it can easily recycle the used glass frit decon slurry back into melter feed system. However, if a dry calcine/glass frit system is selected, the slurried glass frit decon solution may not be compatible. It appears that West Valley personnel were considering carbon dioxide pellet blasting at one time. The conceptual design should finalize the canister decontamination method to be used in the HVF.

11.11 Use of the Hanford Vitrification Canister

The initial requirements for this study dictated that the HVF would be based on using a 10-ft long by 2-ft diameter DWPF-type vitrification canister, the preferred canister at the NGR may be the 15-ft long by 2-ft diameter Hanford canister. The conceptual design should settle on the appropriate canister and make appropriate changes to the design presented in this study if the longer canister is selected. This would entail a deeper basement and taller grade-level cells for handling the longer canister. Canisters could also be handled horizontally in all operations except glass pouring. The 15-ft canister would increase the HVF construction costs but, because only two-thirds as many canisters would have to be handled, it could reduce the operating costs as well as offsite transportation and disposal costs. Unlike the DWPF canisters, the Hanford canisters have not been used in production. Therefore, added development costs may be incurred by using the Hanford canisters in the HVF.

11.12 Mercury Retorting

A study should be conducted to determine if mercury retorting should be performed on a continuous or an annual batch-mode basis. Project and life cycle costs should be compared to arrive at the most cost effective design (see EDF-HVF-F-004, Section 2.5 for details).

12. RECOMMENDATION ON THE READINESS TO PROCEED INTO CONCEPTUAL DESIGN

The maturity of the HVF technology is, in general, estimated to be high (between the Engineering Development and the Implementation stage). The canister handling systems have been used at the French Cogema plant, and similar systems have been used within the DOE complex. The P&V corridor, equipment canyon, and the hot cell and remote maintenance systems have all been used successively within the DOE complex for many years.

The maturity of joule heated vitrification melters for treating liquid waste streams is considered to be high within the DOE complex. However, there is no such experience or precedence in the complex with regards to cold crucible induction melters specified in the HVF. It is felt that the HVF induction melters and associated equipment and systems will not be ready to proceed to conceptual design until significant developed work is done within the DOE complex, or until adequate knowledge can be obtained on their operations from foreign countries in which they are in routine use.

It is absolutely necessary to achieve adequate quality control of the melter feed and feed sampling systems to ensure that no unacceptable glass formulations will ever enter the melters. The melter feed and sampling systems can operate either dry or as a liquid slurry. The highest confidence of proper quality control can be achieved by slurry systems because they can more easily maintain the mixtures and samples in a suspended, homogenous state. Therefore the liquid slurry system was used in the design of the HVF to achieve the highest degree of melter feed quality assurance. It is felt that the liquid feed systems in the HVF design are ready to proceed to conceptual design from a technological standpoint. It is recommended, however, that further work be done to develop dry calcine feed systems that can meet the melter feed quality assurance requirements. If this can be done, it will save on equipment and operations costs associated with continuously adding water to the calcine and then removing it just prior to vitrification.

13. REFERENCES

1. Consent Order and Settlement Agreement Between DOE and the State of Idaho Regarding Spent Fuel and Nuclear Waste Issues, October 17, 1995.

2. Raytheon Engineers and Constructors, Inc. Western Operations, *Idaho Chemical Processing Plant Waste Immobilization Facility Direct Vitrification Option Feasibility Study Report*, MS528.163, October 25, 1994.

3. Lopez, D. A., and Kimmitt, R.R., *Vitrified Waste Option Study Report*, INEEL/EXT-01389, February 1998.

4. EDFs Related to HLW EIS Projects for Vitrifying SBW and Calcine (P88) and Calcine Blending and Vitrification (P60), April 1998

5. Stockpile Report to the Congress—Fiscal Year 1996.

Appendix A

Life cycle Cost Estimate

LOCKHEED MARTIN

Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date:	June 30, 1999		
To:	D. A. Lopez	MS 3765	6-9020
From:	D. A. Rowley DR	MS 3655	6-2978
Subject:	COST ESTIMATES – HIGH LEVEL WASTE VITRIFICATION FACILITY (4 OPTIONS) – DAR-35-99		

Transmitted herewith are the four (4) planning cost estimate options for the above referenced project as follows:

Estimate #2499-1 Option #1 – Total Estimated Cost (TEC) escalated to year 2015.
Estimate #2499-1 Option #2 – TEC not escalated (using present day costs).
Estimate #2499-1 Option #3 – Other Project Costs (OPC) escalated to year 2015.
Estimate #2499-1 Option #4 – OPC not escalated (using present day costs).

Estimates #2499-1 Option #1 and #2499-1 Option #2 include costs for engineering and design (Title I and II), quality assurance, project management, construction management, construction (direct and indirect costs), procurement, escalation, Lockheed Martin G & A and PIF allowances, management reserve, and contingency.

Estimates #2499-1 Option #3 and #2499-1 Option #4 are for Other Project Costs only.

Estimate #2499-1 Option #1 (TEC) is.....$900,380,000.
Estimate #2499-1 Option #2 (TEC) is.....$646,120,000.
Estimate #2499-1 Option #3 (OPC) is.....$181,300,000.
Estimate #2499-1 Option #4 (OPC) is.....$150,860,000.

Please refer to the attached detail, Recapitulation and Summary sheets for cost breakdowns, descriptions, and cost estimating basis.

If you have any questions or comments please contact me at 526-2978 or e-mail "drowley".

DAR

Attachments

cc: Estimate File #2499-1
D. A. Rowley File BDR/KLS

Lockheed Martin Idaho Technologies Company

COST ESTIMATE SUPPORT DATA RECAPITULATION

Project Title: High Level Waste Vitrification Facility
Estimator: D. A. Rowley
Date: June 30, 1999
Estimate Type: Planning
File: 2499-1
Approved By: BOR/KLS

I. **SCOPE OF WORK:** *Brief description of the proposed project.*

The project work scope includes erection of a new vitrification facility at the INTEC facility. The new facility is multiple level with the main level having a footprint of 113,740 square feet. Four cost estimates have been prepared as follows:
2499-1 Option #1 – Total Estimated Cost (TEC) escalated to year 2015.
2499-1 Option #2 – TEC with no escalation.
2499-1 Option #3 – Other Project Costs (OPC) escalated to year 2015.
2499-1 Option #4 – OPC with no escalation.

II. **BASIS OF THE ESTIMATE:** *Drawings, Design Report, Engineers Notes and/or other documentation upon which the estimate is originated.*

The estimate is based on the following:
A. Preliminary drawings dated 2/9/99.
B. Engineering Design Files (EDF's) for instrumentation and controls, electrical, HVAC, and canister flow diagram.
C. Equipment list provided by R. R. Kimmett.
D. Equipment list provided by D. A. Lopez.
E. Discussions held with D. A. Lopez and R. R. Kimmett.

III. **ASSUMPTIONS:** *Conditions statements accepted or supposed true without proof of demonstration. An assumption has a direct impact on total estimated cost.*

A. Assume no radiological or hazardous contamination will be encountered during project construction.
B. Assume no rock removal shall be required during excavation.
C. Assume the associated transfer tunnel shall be by others and is not included in this project cost.
D. Assume all process areas will require decontaminable coatings on all floors, walls, and ceilings.
E. Assume all equipment and construction materials shall be provided by subcontractors – no government furnished equipment (GFE) is included.

III. **ASSUMPTIONS:** *(Continued)*

F. Assume the project shall be issued as a single subcontract with the construction period shall beginning in year 2010 and last for four (4) years (2010 – 2014).
G. Assume the design effort shall begin in year 2007 and continue for three (3) years.
H. Assume systems operations (S.O.) testing shall begin in year 2013 and continue for two (2) years.
I. Assume the facility hot start-up shall be in year 2015.
J. Assume the procurement cost for this project shall be 1% in lieu of the standard 3% (per R. D. Adams).
K. Assume process development cost to be $25M. The multi-function pilot plant to be a separate facility with separate funding.

IV. **CONTINGENCY GUIDELINE IMPLEMENTATION:** *The percentage used for contingency as determined by the contingency allowance guidelines can be altered to reflect the type of construction and conditions that may impact the total estimated cost.*

A contingency analysis has been prepared to assess project risks. Contingency range for this project has been calculated to range from 44.08% to 45.75% for the construction estimates and from 37.33% to 37.77% for OPC estimates. Items of possible risk considered for this calculation are:

A. Potential for encountering radiological or hazardous materials contamination during excavation.
B. Potential for substantial design changes.
C. Potential for process development cost to exceed $25M.
D. Potential for procurement costs to exceed 1%.
E. Potential for uncommon special materials to be used for process equipment fabrication due to the anticipated high radiation levels known to exist in the calcine material.
F. Potential for technology changes prior to the start of construction.
G. Potential for stricter acceptance / qualifications standards. (Per D. A. Lopez / B. A. Staples)

V. OTHER COMMENTS/CONCERNS SPECIFIC TO THE ESTIMATE

A. Costs from the Detailed Cost Estimate sheets are direct costs for material, labor, equipment, and special subcontracts. Costs for corresponding divisions on the Cost Estimate Summary sheet include all applicable indirect costs (overhead, profit, commission on subcontracts, sales tax, and bond).

Indirect costs include:

Consumables & Small Tools – 3% Of Labor Cost.
Construction Equipment (Cranes & Etc.) – 10% Of Labor Cost.
NQA-1 Quality Requirements – 25% Of Material Cost.
DOE / RW / 0333P Quality Standards – 10% Of Material Cost.
Subcontractor Procurement Cost – 1% Of Equipment & Material Cost.
Material & Equip. Overhead & Profit – 5% Of Material & Equip. Cost.
Subcontractor Overhead & Profit – 10% Of "Other 1" Column.
Bond – 2% Of All Subcontractor Costs.
Labor Indirect Costs – Overhead & Profit – 50% Of Labor Cost.

B. Costs for each activity represent present day costs escalated to the appropriate activity midpoint.

C. Subcontractor labor costs reflect INEEL Site Jurisdictional Agreement craft labor rates.

D. Costs for Lockheed Martin General and Administrative allowance (G & A) and Performance Incentive Factor (PIF) have been included in this estimate. These allowances have been calculated over a four (4) year construction schedule.

Lockheed Martin Idaho Technologies Co.

Rev. 6-96

COST ESTIMATE SUMMARY

OJECT NAME: HLW - Vitrification Facility
Option #1 - TEC - Escalated
CATION 1: INTEC
QUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. #1
PREPARED BY: D. A. Rowley
REPORT NAME: Cost Estimate Summary

DATE: 30-Jun-1999
TIME: 13:04:25
CHECKED BY: SNW
APPR'D BY: BDC/HKS

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
.1	ENGINEERING, DESIGN AND INSPECTION			>> $96,954,000
1.1.1	DESIGN ENGINEERING TITLE I & II	57,200,000	19,448,000	76,648,000
1.1.2	QUALITY ASSURANCE	14,300,000	6,006,000	20,306,000
.2	MANAGEMENT COSTS			>> $97,468,800
1.2.1	PROJECT MANAGEMENT	40,040,000	16,816,800	56,856,800
1.2.2	CONSTRUCTION MANAGEMENT	28,600,000	12,012,000	40,612,000
.3	CONSTRUCTION			>> $406,125,498
1.3.1	GENERAL CONDITIONS	6,819,843	2,864,334	9,684,177
1.3.2	SITEWORK	4,243,649	1,782,333	6,025,982
1.3.3	CONCRETE	42,206,274	17,726,635	59,932,909
1.3.5	METALS	20,342,996	8,544,058	28,887,054
1.3.7	THERMAL & MOISTURE PROTECTION	2,200,626	924,263	3,124,889
1.3.8	DOORS & WINDOWS	2,370,235	995,499	3,365,734
1.3.9	FINISHES	2,655,632	1,115,365	3,770,997
1.3.10	SPECIALTIES	2,287,640	960,809	3,248,449
1.3.11	EQUIPMENT	85,641,147	35,969,282	121,610,429
1.3.12	FURNISHINGS	2,229,554	936,413	3,165,967
1.3.14	CONVEYING SYSTEMS	224,400	94,248	318,648
1.3.15	MECHANICAL	76,895,774	32,296,225	109,191,999
1.3.16	ELECTRICAL	37,886,101	15,912,163	53,798,264
.5	G&A/PIF			>> $20,321,745
1.5.1	G&A/PIF ADDER	14,311,088	6,010,657	20,321,745
1.5.2	PROCUREMENT FEES	2,860,039	1,201,216	>> $4,061,255
	SUBTOTAL INCLUDING ESCALATION	443,314,998	181,616,300	>> $624,931,298
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> $43,050,850
	CONTINGENCY			>> $232,397,852
	TOTAL ESTIMATED COST			>> $900,380,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= *24.00%*

CONTINGENCY= *44.08%*

Lockheed Martin Idaho Technologies Co.

Rev 6-98

DETAILED COST ESTIMATE SHEET

PROJECT NAME: HLW - Vitrification Facility
Option #1 - TEC - Escalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO.: 2499-1 Opt. #1
PREPARED BY: D. A. Rowley

DATE 30-Jun-1999
TIME: 13:04:29
REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.1.1	DESIGN ENGINEERING TITLE I & II											
	DESIGN ENGINEERING TITLE I & II S/T						0					
1.1.1.1	TITLE DESIGN Title Design - 20% Of Construction Cost	1	Lot		LMITCO	0.000					*,***,***	57,200,000
	TITLE DESIGN S/T						0				$*,***,***	$57,200,000
1.1.2	QUALITY ASSURANCE											
	QUALITY ASSURANCE S/T						0					
1.1.2.1	QUALITY ASSURANCE Quality Assurance - 5% Of Construction Cost	1	Lot		LMITCO	0.000					*,***,***	14,300,000
	QUALITY ASSURANCE S/T						0				$*,***,***	$14,300,000
1.2.1	PROJECT MANAGEMENT											
	PROJECT MANAGEMENT S/T						0					

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.2.1.1	**PM DURING DESIGN AND CONSTRUCTION** Project Management During Design And Construction - 14% Of Construction Cost	1	Lot		*LMITCO*	0.000					*,***,***	40,040,000
	PM DURING DESIGN AND CONSTRUCTION S/T						0				$*,***,***	$40,040,000
1.2.2	**CONSTRUCTION MANAGEMENT**											
	CONSTRUCTION MANAGEMENT S/T						0					
1.2.2.1	**CONSTRUCTION MANAGEMENT AND SUPPORT** Construction Management @ 10% Of Construction Cost	1	Lot		*LMITCO*	0.000					*,***,***	28,600,000
	CONSTRUCTION MANAGEMENT AND SUPPORT S/T						0				$*,***,***	$28,600,000
1.3.1	**GENERAL CONDITIONS**											
	GENERAL CONDITIONS S/T						0					
1.3.1.1	**TRAINING AND SUPERVISION** Training @ 2% Of Const. Hours	1	allow		PIPE *GEN*	25400.0	25,400	934,466				934,466
	Supervision - 5 men 4 years	1	allow		PIPE *GEN*	41600.0	41,600	1,530,464				1,530,464
	TRAINING AND SUPERVISION S/T						67,000	$2,464,930				$2,464,930

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.1.2	**EQUIPMENT SUPPORT**											
	Crane Support - Full Time - 4 Years	1	Lot		EQHV GEN	8320.00	8,320	262,496	1,500,000			1,762,496
	Oiler - Full Time - 4 Years	1	Lot		EQOL GEN	8320.00	8,320	270,733				270,733
	EQUIPMENT SUPPORT S/T						16,640	$533,229	$1,500,000			$2,033,229
1.3.2	**SITEWORK**											
	SITEWORK S/T						0					
1.3.2.1	**EXCAVATION AND BACKFILL**											
	Structural Excavation	180,000	cuyd		GEN	0.000					1,404,000	1,404,000
	Structural Backfill	50,000	cuyd		GEN	0.000					607,000	607,000
	Asphalt and landscaping	1	allow		GEN	0.000					500,000	500,000
	Construction barriers	1	allow		GEN	0.000					5,200	5,200
	Clear & Grub	150,000	Sf		LABR GEN	0.004	600	17,424	37,500			54,924
	Haul & Dump	130,000	Cy		TRHV GEN	0.065	8,450	263,133	208,000			471,133
	Excavation & Backfill For Stack	30	Cy		LABR GEN	0.350	11	305	75			380
	EXCAVATION AND BACKFILL S/T						9,061	$280,862	$245,575		$2,516,200	$3,042,637
1.3.2.2	**SITEWORK - UTILITIES**											
	Plumbing Utility To Building	200	Lf	12.00	PLUM GEN	2.000	400	15,704		2,400		18,104

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.2.2	**SITEWORK - UTILITIES**											
	Process Pipe Utility To Building	200	Lf	200.00	PIPE GEN	5.000	1,000	36,790		40,000		76,790
	Fire Water To Building	200	Lf	50.00	SPRI GEN	3.000	600	21,684		10,000		31,684
	Electrical Service To Building	1	Lot	200,000.00	ELEC GEN	700.000	700	23,317		200,000		223,317
	Excavation & Backfill For Utilities	2,275	Cy		LABR GEN	0.700	1,593	46,246	22,750			68,996
	SITEWORK - UTILITIES S/T						4,293	$143,741	$22,750	$252,400		$418,891
1.3.3	**CONCRETE**											
	CONCRETE S/T						0					
1.3.3.1	**FOOTINGS**											
Memo:	Facility Footings Total concrete qty. Includes footings, mats, walls, and slabs. Prices are averages for all concrete configurations.	2,000	cuyd		GEN	0.000					1,200,000	1,200,000
	FOOTINGS S/T						0				$1,200,000	$1,200,000
1.3.3.2	**CONCRETE - SLABS**											
	Concrete - Basement Floor	7,500	Cy		LABR GEN	0.000					3,000,000	3,000,000
	Concrete - Main Floor	9,740	Cy		LABR GEN	0.000					5,844,000	5,844,000
	Concrete - 45' Level	6,930	Cy		GEN	0.000					4,158,000	4,158,000
	Concrete - Roof Deck	4,460	Cy		GEN	0.000					2,676,000	2,676,000
	CONCRETE - SLABS S/T						0				$*,***,***	$15,678,000

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.3.3	**CONCRETE - WALLS**											
	Concrete Walls - Basement	12,460	Cy		GEN	0.000					7,476,000	7,476,000
	Concrete Walls - 1st Floor	15,830	Cy		GEN	0.000					9,498,000	9,498,000
	Concrete Walls - 45' Level	6,150	Cy		GEN	0.000					3,690,000	3,690,000
	Concrete Hatch Allowance	250	Lf		GEN	0.000					75,000	75,000
	CONCRETE - WALLS S/T						0				$*,***,***	$20,739,000
1.3.5	**METALS**											
	METALS S/T						0					
1.3.5.1	**STRUCTURAL STEEL, LINER PLATE, CRANE RAILS & MISC. METALS**											
	Struct. Steel, Line Plate, Crane Rails and Misc. Metals	3,000	Ton		GEN	0.000					*,***,***	14,280,000
	STRUCTURAL STEEL, LINER PLATE, CRANE RAILS & MISC. METALS S/T						0				$*,***,***	$14,280,000
1.3.5.2	**METAL DECK**											
	Metal Decking	396,000	Sf		GEN	0.000					990,000	990,000
	Metal Deck Pan - For Concrete Roof	60,160	Sf		GEN	0.000					150,400	150,400
	METAL DECK S/T						0				$1,140,400	$1,140,400

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.5.3	**METALS - STACK** ***CARBON STEEL, 10' DIA., 108' TALL STACK***											
	Excavation And Concrete	1	ls		CARP GEN	0.000					15,000	15,000
	Fab Stack	155,094	lbs		SHEE GEN	0.000					162,849	162,849
	Paint Stack	1	subcon		PAIN GEN	0.000					40,716	40,716
	Stack Installation	1	job		IRON GEN	640.000	640	23,558	4,000			27,558
	Stack Shielded Probe	1	ea	500,000.00	PIPE GEN	120.000	120	4,415		500,000		504,415
	METALS - STACK S/T						760	$27,973	$4,000	$500,000	$218,565	$750,538
1.3.5.4	**METALS - MISCELLANEOUS**											
	Metal Roof	53,580	Sf	5.00	LABR GEN	0.060	3,215	93,358		267,900		361,258
	Metal Siding	106,800	Sf	4.25	LABR GEN	0.060	6,408	186,088		453,900		639,988
	Metal Soffets & Trim	1	Lot	15,000.00	LABR GEN	600.000	600	17,424		15,000		32,424
	Building Entrance Awnings	9	Ea	1,500.00	IRON GEN	10.000	90	3,313		13,500		16,813
	Awning For Truck Unloading Station	1,200	Sf	9.00	IRON GEN	0.100	120	4,417		10,800		15,217
	Stairwell, Stringer, Steel, Concrete Fill Pan	4	Plc	20,000.00	LABR GEN	600.000	2,400	69,696		80,000		149,696
	METALS - MISCELLANEOUS S/T						12,833	$374,296		$841,100		$1,215,396
1.3.7	**THERMAL & MOISTURE PROTECTION**											

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.7	**THERMAL & MOISTURE PROTECTION**											
	THERMAL & MOISTURE PROTECTION S/T						0					
1.3.7.1	**INSULATION** Pipe, Tank and Duct Insulation	113,740	Sf		GEN	0.000					568,700	568,700
	Roof Insulation	113,740	Sf	1.10	LABR GEN	0.050	5,687	165,150		125,114		290,264
	Wall Insulation - 4" Thick	152,400	Sf	0.85	LABR GEN	0.040	6,096	177,028		129,540		306,568
	Foundation Insulation - UG	4,800	Sf	0.60	LABR GEN	0.040	192	5,576		2,880		8,456
	INSULATION S/T						11,975	$347,754		$257,534	$568,700	$1,173,988
1.3.7.2	**ROOFING** Roof Membrane PIB W/ Asphalt Base - 75' Level	60,160	Sf	4.00	LABR GEN	0.060	3,610	104,823		240,640		345,463
	ROOFING S/T						3,610	$104,823		$240,640		$345,463
1.3.8	**DOORS & WINDOWS**											
	DOORS & WINDOWS S/T						0					
1.3.8.1	**DOORS** Roll Back Hatch Cover	4	Ea	29,000.00	IRON GEN	100.000	400	14,724		116,000		130,724
	Roll-Up Door	2	Ea	5,000.00	CARP GEN	20.000	40	1,334		10,000		11,334

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.8.1	**DOORS**											
	Roll up Shield Door	2	Ea	216,000.00	IRON GEN	200.000	400	14,724		432,000		446,724
	Small Shielding Door	6	Ea	50,000.00	LABR GEN	400.000	2,400	69,696		300,000		369,696
	Medium Shielding Door	1	Ea	60,000.00	LABR GEN	500.000	500	14,520		60,000		74,520
	Large Shielding Door	1	Ea	75,000.00	LABR GEN	600.000	600	17,424		75,000		92,424
	Air Lock Doors - Single	2	Ea	5,000.00	IRON GEN	20.000	40	1,472		10,000		11,472
	Air Lock Doors - Double	9	Ea	10,000.00	IRON GEN	40.000	360	13,252		90,000		103,252
	Single Personnel Doors - Interior	45	Ea	1,500.00	CARP GEN	10.000	450	15,012		67,500		82,512
	Single Personnel Doors - Exterior	3	Ea	2,000.00	CARP GEN	10.000	30	1,001		6,000		7,001
	Double Personnel Doors - Interior	29	Ea	3,000.00	CARP GEN	20.000	580	19,349		87,000		106,349
	Double Personnel Doors - Exterior	13	Ea	4,000.00	CARP GEN	20.000	260	8,674		52,000		60,674
	DOORS S/T						6,060	$191,182		$1,305,500		$1,496,682
1.3.9	**FINISHES**											
	FINISHES S/T						0					
1.3.9.1	**PAINTING**											
	Floor Finish - Epoxy	268,610	Sf		GEN	0.000					402,915	402,915
	Wall Finish - Epoxy	589,200	Sf		GEN	0.000					1,178,400	1,178,400
	Ceiling Finish - Epoxy	268,610	Sf		GEN	0.000					537,220	537,220

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.9.1	PAINTING Wall Finish - Latex	27,000	Sf		GEN	0.000					16,200	16,200
	PAINTING S/T						0				$2,134,735	$2,134,735
1.3.9.2	FINISHES - GYP BOARD WALLS Metal Studs - Interior Walls - 3-5/8" - 16" O.C. (All)	15,600	Sf	0.23	CARP GEN	0.020	312	10,408		3,588		13,996
	Gypsum Board - 5/8" - Standard (Taped & Finished)	27,000	Sf	0.28	CARP GEN	0.018	486	16,213		7,560		23,773
	FINISHES - GYP BOARD WALLS S/T						798	$26,621		$11,148		$37,769
1.3.9.3	FINISHES - MISCELLANEOUS Acoustical Suspended Ceiling - 1st Floor	8,170	Sf	0.95	LABR GEN	0.020	163	4,745		7,762		12,507
	Ceramic Tile	2,740	Sf	3.45	CARP GEN	0.080	219	7,313		9,453		16,766
	Carpet - Office Area	800	Sy	23.10	LABR GEN	0.200	160	4,646		18,480		23,126
	Misc. Finishes	1	Lot		GEN	0.000					100,000	100,000
	FINISHES - MISCELLANEOUS S/T						543	$16,704		$35,695	$100,000	$152,399
1.3.10	SPECIALTIES											
	SPECIALTIES S/T						0					

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.10.1	**STORAGE RACKS**											
	Empty Canister Storage Rack	1	ea	15,000.00	IRON *GEN*	80.000	80	2,945		15,000		17,945
	STORAGE RACKS S/T						80	$2,945		$15,000		$17,945
1.3.10.3	**K-PLUGS**											
	K-Plugs	230	ea	5,000.00	LABR *GEN*	40.000	9,200	267,168		1,150,000		1,417,168
	K-PLUGS S/T						9,200	$267,168		$1,150,000		$1,417,168
1.3.11	**EQUIPMENT**											
	EQUIPMENT S/T						0					
1.3.11.1	**PROCESS EQUIPMENT**											
Memo:	(*) HWL Feasibility Study Process Equipment List											
	Provided By R. R. Kimmett. Frit Storage Silo - 20,000 Gal - CS	3	Ea	24,000.00	IRON *GEN*	100.000	300	11,043		72,000		83,043
	Frit Weigh Vessel - 1,000 Gal - CS	3	Ea	86,000.00	IRON *GEN*	60.000	180	6,626		258,000		264,626
	Glass Melter - Inconel 600	4	Ea	500,000.00	IRON *GEN*	300.000	1,200	44,172		2,000,000		2,044,172
	Calcine Receiving Tank - 7,000 Gal - SST	1	Ea	100,000.00	PIPE *GEN*	150.000	150	5,519		100,000		105,519
	Blending Cyclone - SST - 2' x 4'	1	Ea	15,500.00	IRON *GEN*	40.000	40	1,472		15,500		16,972
	Sintered Metal Filter - SST - 2' x 4'	4	Ea	38,000.00	PIPE *GEN*	40.000	160	5,886		152,000		157,886
	Calcine Fines Collection Tank - SST - 2' x 4'	1	Ea	2,000.00	PIPE *GEN*	20.000	20	736		2,000		2,736

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.1	**PROCESS EQUIPMENT**											
	Calcine Feed Cyclone - SST - 2' x 4'	3	Ea	15,500.00	IRON GEN	20.000	60	2,209		46,500		48,709
	Calcine Blending Blower - 4,000 scfm - SST	1	Ea	86,000.00	SHEE GEN	40.000	40	1,386		86,000		87,386
	HEPA Filter - 2' x 2' - SST	16	Ea	250.00	SHEE GEN	0.500	8	277		4,000		4,277
	HEPA Filter Housing	2	Ea	250,000.00	SHEE GEN	200.000	400	13,864		500,000		513,864
	Calcine Blending ID Blower - 4,000 scfm - SST	1	Ea	16,500.00	SHEE GEN	40.000	40	1,386		16,500		17,886
	Calcine Load Fan - 4,000 scfm - SST	1	Ea	16,500.00	SHEE GEN	40.000	40	1,386		16,500		17,886
	Mix Tank - 8,000 Gal - Inconel 600	3	Ea	60,000.00	PIPE GEN	40.000	120	4,415		180,000		184,415
	Feed Tank - 8,000 Gal - Inconel 600	2	Ea	60,000.00	PIPE GEN	40.000	80	2,943		120,000		122,943
	NGLW Storage Tank - 10,000 Gal - Inconel 600	1	Ea	80,000.00	PIPE GEN	50.000	50	1,840		80,000		81,840
	Water Collection Tank - 9,000 Gal - Inconel 600	1	Ea	80,000.00	PIPE GEN	50.000	50	1,840		80,000		81,840
	Mix Tank Transfer Pump - 100 gpm - 10 hp - Inconel 600	3	Ea	5,000.00	PIPE GEN	8.000	24	883		15,000		15,883
	Feed Tank Delivery Pump - 150 gpm - 20 hhp - Inconel 600	2	Ea	8,000.00	PIPE GEN	8.000	16	589		16,000		16,589
	NGWL Transfer Pump - 100 gpm - 10 hp - Inconel 600	1	Ea	5,000.00	PIPE GEN	8.000	8	294		5,000		5,294
	Water Transfer Pump - 100 gpm - 10 hp - Inconel 600	1	Ea	5,000.00	PIPE GEN	8.000	8	294		5,000		5,294
	Mix Tank Agitator - 10 hp - Inconel 600	3	Ea	30,000.00	PIPE GEN	40.000	120	4,415		90,000		94,415

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.1	**PROCESS EQUIPMENT**											
	Feed Tank Agitator - 10 hp - Inconel 600	2	Ea	30,000.00	PIPE GEN	40.000	80	2,943		60,000		62,943
	NGWL Tank Agitator - 15 hp - Inconel 600	1	Ea	45,000.00	PIPE GEN	60.000	60	2,207		45,000		47,207
	Rail To Silo Frit Conveyor - 20 hp - CS	3	Ea	86,300.00	IRON GEN	240.000	720	26,503		258,900		285,403
	Frit Silo To Weigh Vessel Conveyor - 20 hp - CS	3	Ea	10,000.00	IRON GEN	40.000	120	4,417		30,000		34,417
	Calcine Weigh Vessel To Mix Tanks - SST	3	Ea	86,000.00	PIPE GEN	40.000	120	4,415		258,000		262,415
	Decon Solution Mix Tank - 1,500 Gal - SST	1	Ea	15,000.00	PIPE GEN	20.000	20	736		15,000		15,736
	Spent Decon Solution Collection Tank - 1,500 Gal - SST	1	Ea	15,000.00	PIPE GEN	20.000	20	736		15,000		15,736
	Cooling Water Recirculation Tank - 1,500 Gal - SST	2	Ea	15,000.00	PIPE GEN	20.000	40	1,472		30,000		31,472
	Water Conditoning Additive Tank - 100 Gal - SST	1	Ea	8,000.00	PIPE GEN	8.000	8	294		8,000		8,294
	Cooling Water Heat Exchanger - 1.2M BTU/hr - 5' Dia x 8' - SST	2	Ea	65,000.00	PIPE GEN	40.000	80	2,943		130,000		132,943
	Decon Solution Transfer Pump - 25 gpm - 1 hp - SST	2	Ea	5,000.00	PIPE GEN	10.000	20	736		10,000		10,736
	Cooling Water Recirc. Pump - 150 gpm - 5 hp - SST	2	Ea	10,000.00	PIPE GEN	20.000	40	1,472		20,000		21,472

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.1	**PROCESS EQUIPMENT**											
	Slurry Sampling Recirc. Pump - 5 gpm - 1 hp - Inconel 600	3	Ea	5,000.00	PIPE GEN	4.000	12	441		15,000		15,441
	Water Conditioning Agitator - 1 hp - SST	1	Ea	10,000.00	PIPE GEN	20.000	20	736		10,000		10,736
	Decon Solution Agitator - 5 hp - SST	2	Ea	20,000.00	PIPE GEN	40.000	80	2,943		40,000		42,943
Memo:	(*) Spray Dryer System - SST Spray dryer system to include spray dryer,	4	Ea	334,000.00	PIPE GEN	250.000	1,000	36,790		1,336,000		1,372,790
	heater, primary cyclones, recycle blower, condenser, and secondary cyclone.											
	Dried Solids Feed Hoppers - 28 cf - SST	8	Ea	8,000.00	SHEE GEN	20.000	160	5,546		64,000		69,546
	Conveyor Blower - 1,000 scfm - 1 hp - SST	4	Ea	15,000.00	SHEE GEN	8.000	32	1,109		60,000		61,109
Memo:	(*) Dry Additive Process (Scrubber) System - CS System includes lime feed equipment, gas mixer,	1	Ea	250,000.00	PIPE GEN	400.000	400	14,716		250,000		264,716
	gas cooler, dry reactor, bah house, gas heater, and blowers.											
Memo:	(*)Blower - 500 scfm - 1 hp - CS Blower returns fines to calcine receiving tank.	1	Ea	10,000.00	SHEE GEN	8.000	8	277		10,000		10,277
	Granular Activated Carbon Column - 42,000 lbs Carbon - 10' Dia x 30' - CS	2	Ea	52,000.00	PIPE GEN	240.000	480	17,659		104,000		121,659
	Selectively Catalyzed Reduction Reactor - 1,500 cfm - CS	1	Ea	150,000.00	PIPE GEN	120.000	120	4,415		150,000		154,415
	Anhydrous Ammonia Storage Vessel - 500 Gal - CS	1	Ea	30,000.00	PIPE GEN	40.000	40	1,472		30,000		31,472
	Off-Gas HEPA Filters	4	Ea	250.00	SHEE GEN	0.500	2	69		1,000		1,069

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.1	**PROCESS EQUIPMENT**											
	HEPA Filter Housing	1	Ea	150,000.00	SHEE GEN	150.000	150	5,199		150,000		155,199
	PROCESS EQUIPMENT S/T						6,946	$253,721		$6,959,900		$7,213,621
1.3.11.2	**CRANES**											
Memo:	(*) Crane and lifting equipment list per D. A. Lopez.											
	Truck Airlock Bridge Crane - 1 Ton	1	ea	25,000.00	IRON GEN	100.000	100	3,681		25,000		28,681
	Clean Canister Storage O.H. Crane - 1 Ton	1	ea	25,000.00	IRON GEN	100.000	100	3,681		25,000		28,681
	Filling And Capping Cell Crane - 3 Ton	1	Ea	30,000.00	IRON GEN	150.000	150	5,522		30,000		35,522
	Weld Cell O.H. Polar Crane - 3 Ton	1	Ea	50,000.00	IRON GEN	200.000	200	7,362		50,000		57,362
	Canister Decontamination Handling Crane - 3 Ton	1	Ea	50,000.00	IRON GEN	200.000	200	7,362		50,000		57,362
	Smeared Canister Loadout Crane - 3 Ton	1	Ea	50,000.00	IRON GEN	200.000	200	7,362		50,000		57,362
	Loadout Area Bridge Monorail Crane - 15 Ton	1	Ea	500,000.00	IRON GEN	300.000	300	11,043		500,000		511,043
	Maintenance Area O.H. Bridge Crane - 75 Ton	1	Ea	***,***.**	IRON GEN	600.000	600	22,086		1,000,000		1,022,086
	Pump & Valve Corridor Bridge Crane - 2 Ton	1	Ea	15,000.00	IRON GEN	100.000	100	3,681		15,000		18,681
	Melter Cell Bridge Crane - 3 Ton	1	Ea	50,000.00	IRON GEN	200.000	200	7,362		50,000		57,362
	CRANES S/T						2,150	$79,142		$1,795,000		$1,874,142

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.3	MATERIAL HANDLING EQUIPMENT (*)											
Memo:	Material list provided by D. A. Lopez.											
	Empty Canister Transfer Cart	1	Ea	40,000.00	IRON GEN	20.000	20	736		40,000		40,736
	Canister Lift Mechanisms	4	Ea	20,000.00	IRON GEN	100.000	400	14,724		80,000		94,724
	Canister Transport Cart - Remote Operated	1	Ea	50,000.00	IRON GEN	250.000	250	9,203		50,000		59,203
	Maintenance Area Overhead PAR	1	Ea	***,***.**	IRON GEN	400.000	400	14,724		1,000,000		1,014,724
	Pump & Valve Corridor Wall-Mounted PAR	1	Ea	80,000.00	IRON GEN	80.000	80	2,945		80,000		82,945
	Melter Cell Wall-Mounted PAR	4	Ea	80,000.00	IRON GEN	80.000	320	11,779		320,000		331,779
	Master-Slave Manipulators	55	Pr	65,000.00	MILL GEN	250.000	13,750	430,100		3,575,000		4,005,100
	Glass Frit Auger Conveyors	6	Ea	20,000.00	MILL GEN	200.000	1,200	37,536		120,000		157,536
	Glass Frit Bucket Conveyors	6	Ea	20,000.00	MILL GEN	200.000	1,200	37,536		120,000		157,536
	Transfer Ports	1	Ea	10,000.00	LABR GEN	150.000	150	4,356		10,000		14,356
	Tool Drop	3	Ea	10,000.00	LABR GEN	150.000	450	13,068		30,000		43,068
	MATERIAL HANDLING EQUIPMENT S/T						18,220	$576,707		$5,425,000		$6,001,707
1.3.11.3.1	ADDITIONAL EQUIPMENT (*)											
Memo:	Material list provided by D. A. Lopez.											
	Frit Receipt System @ Rail Spur	1	Lot	86,300.00	LABR GEN	240.000	240	6,970		86,300		93,270
	Canister Heater	4	Ea	103,000.00	ELEC GEN	100.000	400	13,324		412,000		425,324
	CO2 System	1	Ea	175,000.00	PIPE GEN	100.000	100	3,679		175,000		178,679
	Canister Lifting Mechanism	4	Ea	257,500.00	LABR GEN	200.000	800	23,232		1,030,000		1,053,232
	Canister Sealing Manipulator	1	Ea	120,000.00	MILL GEN	80.000	80	2,502		120,000		122,502

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.3.1	**ADDITIONAL EQUIPMENT**											
	Canyon Equipment For Decon Process	1	Lot	150,000.00	MILL GEN	120.000	120	3,754		150,000		153,754
	Decon Solution Pumping Station	1	Lot	50,000.00	PIPE GEN	120.000	120	4,415		50,000		54,415
	Decon Cell Equipment	1	Lot	515,000.00	PIPE GEN	400.000	400	14,716		515,000		529,716
	Decon / Disassembly Equipment - Turntable Manipulator, Tools, w/ Rack, Etc	2	Plc	500,000.00	MILL GEN	240.000	480	15,014		1,000,000		1,015,014
	Smear Monitor	1	Plc	515,000.00	MILL GEN	100.000	100	3,128		515,000		518,128
	Smear Station Module	1	Ea		GEN	0.000					42,000	42,000
	Cameras	40	Ea	3,000.00	ELEC GEN	24.000	960	31,978		120,000		151,978
	Filter Change-Out Unit	1	Plc	1,500.00	SHEE GEN	40.000	40	1,386		1,500		2,886
	Weld Station Module	1	Plc	103,000.00	MILL GEN	200.000	200	6,256		103,000		109,256
	Canister Fill Monitoring	2	Plc		GEN	0.000					8,240,000	8,240,000
	Technical Waste Cutting Module	1	Plc	515,000.00	MILL GEN	100.000	100	3,128		515,000		518,128
	Technical Waste Weld Module	1	Plc	515,000.00	MILL GEN	100.000	100	3,128		515,000		518,128
	Canister Welder Leak Check Module	1	Plc	***,***.**	MILL GEN	100.000	100	3,128		1,030,000		1,033,128
	Miscellaneous Equipment	1	Lot	***,***.**	MILL GEN	300.000	300	9,384		1,000,000		1,009,384
	Mock-Up Facility	6,000	Sf	1,700.00	GEN	0.000				*,***,***		10,200,000
	Crane Support	1	Lot		GEN	0.000					100,000	100,000
	Calcine Grinders	3	Ea	30,000.00	MILL GEN	120.000	360	11,261		90,000		101,261
	ADDITIONAL EQUIPMENT S/T						5,000	$160,383		$*,***,***	$8,382,000	$26,170,183

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.11.4	MISC. EQUIPMENT Shielding Windows	76	Ea	184,000.00	LABR GEN	200.000	15,200	441,408		*,***,***		14,425,408
	Cooling & Capping Station	1	Ea	80,000.00	LABR GEN	600.000	600	17,424		80,000		97,424
	Decon Booth	1	Ea	***,***.**	LABR GEN	500.000	500	14,520		1,000,000		1,014,520
	Canister Hatch	5	Ea	40,000.00	LABR GEN	200.000	1,000	29,040		200,000		229,040
	MISC. EQUIPMENT S/T						17,300	$502,392		$*,***,***		$15,766,392
1.3.12	FURNISHINGS											
	FURNISHINGS S/T						0					
1.3.12.1	INTERIOR FURNISHINGS Interior partitions and furnishings	1	ls		GEN	0.000					1,918,125	1,918,125
	Office Furnishings	9	Ea		GEN	0.000					54,000	54,000
	Rest Room Furnishings	1	Lot		GEN	0.000					15,000	15,000
	INTERIOR FURNISHINGS S/T						0				$1,987,125	$1,987,125
1.3.14	CONVEYING SYSTEMS											
	CONVEYING SYSTEMS S/T						0					
1.3.14.1	ELEVATOR Elevator	1	ea		GEN	0.000					200,000	200,000

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.14.1	**ELEVATOR**											
	ELEVATOR S/T						0				$200,000	$200,000
1.3.15	**MECHANICAL**											
	MECHANICAL S/T						0					
1.3.15.1	**HVAC**											
	Building HVAC - Process Area	140,000	Sf		GEN	0.000					2,800,000	2,800,000
	Building HVAC - Non-Process Area	138,000	Sf		GEN	0.000					828,000	828,000
	HEPA Filter - 2' x 2' - SST	1,200	Ea	250.00	SHEE GEN	0.500	600	20,796		300,000		320,796
	HEPA Filter Housing	36	Ea	250,000.00	SHEE GEN	200.000	7,200	249,552		9,000,000		9,249,552
	Steam Coils	4	Ea	60,000.00	SHEE GEN	80.000	320	11,091		240,000		251,091
	SST Supply Plenums - 12'x12'	22	Ea	5,000.00	SHEE GEN	120.000	2,640	91,502		110,000		201,502
	Blower	15	Ea	5,000.00	SHEE GEN	40.000	600	20,796		75,000		95,796
	HVAC S/T						11,360	$393,738		$9,725,000	$3,628,000	$13,746,738
1.3.15.2	**PIPING**											
	Piping - Process Area	140,000	Sf	50.00	PIPE GEN	4.000	560,000	20,602,400		7,000,000		27,602,400
	Piping - Non-Process Area	138,000	Sf	8.00	PIPE GEN	0.500	69,000	2,538,510		1,104,000		3,642,510
	Plumbing	21	Fixt	1,500.00	PLUM GEN	12.000	252	9,894		31,500		41,394
	PIPING S/T						629,252	$23,150,804		$8,135,500		$31,286,304

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.15.3	**FIRE PROTECTION**											
	Fire Supression - Process Area	140,000	Sf	2.00	SPRI GEN	0.300	42,000	1,517,880	175,000	280,000		1,972,880
	Fire Suppression - Non-Process Area	138,000	Sf	1.50	SPRI GEN	0.050	6,900	249,366	96,600	207,000		552,966
	FIRE PROTECTION S/T						48,900	$1,767,246	$271,600	$487,000		$2,525,846
1.3.16	**ELECTRICAL**											
	ELECTRICAL S/T						0					
1.3.16.1	**FACILITY ELECTRICAL**											
	Switchgear	1	Lot	800,000.00	ELEC GEN	30000.0	30,000	999,300		800,000		1,799,300
	Lighting - Production Non-Process	62,000	Sf	3.00	ELEC GEN	0.067	4,154	138,370		186,000		324,370
	Lighting - Administration	8,000	Sf	4.00	ELEC GEN	0.090	720	23,983		32,000		55,983
	Lighting - Blower	68,000	Sf	3.00	ELEC GEN	0.067	4,556	151,760		204,000		355,760
	Lighting - Building Exterior	1	Lot	5,000.00	ELEC GEN	200.000	200	6,662		5,000		11,662
	High Intensity Lighting - Process Areas	140,000	Sf	10.00	ELEC GEN	0.250	35,000	1,165,850		1,400,000		2,565,850
	Raceways & Enclosures - Process Areas	140,000	Sf	4.50	ELEC GEN	0.250	35,000	1,165,850		630,000		1,795,850
	Raceways & Enclosures - All Non-Process	138,000	Sf	4.50	ELEC GEN	0.140	19,320	643,549		621,000		1,264,549
	Conductors & Grounding	278,000	Sf	4.00	ELEC GEN	0.150	41,700	1,389,027		1,112,000		2,501,027
	UPS Allowance	1	Lot		GEN	0.000					15,000	15,000

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.16.1	**FACILITY ELECTRICAL**											
	Wiring Devices	278,000	Sf	1.50	ELEC *GEN*	0.050	13,900	463,009		417,000		880,009
	FACILITY ELECTRICAL S/T						184,550	$6,147,361		$5,407,000	$15,000	$11,569,361
1.3.16.2	**INSTRUMENTATION AND CONTROLS**											
	Instrumentation & Controls - Process Areas	140,000	Sf	25.00	ELEC *GEN*	0.500	70,000	2,331,700		3,500,000		5,831,700
	Instrumentation & Controls - Non-Process Areas	138,000	Sf	10.00	ELEC *GEN*	0.120	16,560	551,614		1,380,000		1,931,614
	Additional Controls - MACT Rule	1	Lot		*GEN*	0.000					1,500,000	1,500,000
	INSTRUMENTATION AND CONTROLS S/T						86,560	$2,883,314		$4,880,000	$1,500,000	$9,263,314
1.3.16.3	**COMMUNICATIONS & SECURITY**											
	Communication System	278,000	Sf	1.00	ELEC *GEN*	0.030	8,340	277,805		278,000		555,805
	Security System	278,000	Sf	4.00	ELEC *GEN*	0.080	22,240	740,814		1,112,000		1,852,814
	CC Testing	278,000	Sf		ELEC *GEN*	0.033	9,174	305,586				305,586
	COMMUNICATIONS & SECURITY S/T						39,754	$1,324,206		$1,390,000		$2,714,206
1.5.1	**G&A/PIF ADDER**											
00701000	G&A - Year 1	1	Lot		*LMITCO*	0.000					135,000	135,000
	G&A - Year 2	1	Lot		*LMITCO*	0.000					135,000	135,000
	G&A - Year 3	1	Lot		*LMITCO*	0.000					135,000	135,000
	G&A - Year 4	1	Lot		*LMITCO*	0.000					135,000	135,000

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.5.1	G&A/PIF ADDER											
	Procurement On G&A	1	Lot		LMITCO	0.000					772,210	772,210
	PIF - Year 1	1	Lot		LMITCO	0.000					3,217,544	3,217,544
	PIF - Year 2	1	Lot		LMITCO	0.000					3,217,544	3,217,544
	PIF - Year 3	1	Lot		LMITCO	0.000					3,217,544	3,217,544
	PIF - Year 4	1	Lot		LMITCO	0.000					3,217,544	3,217,544
	Procurement On PIF	1	Lot		LMITCO	0.000					128,702	128,702
	G&A/PIF ADDER S/T						0				$*,***,***	$14,311,088
	PROJECT SUBTOTAL						1,192,843	$42,021,239	$2,043,925	$81,705,217	$228,738,813	$354,509,193

Lockheed Martin Idaho Technologies Co.

Rev. 6-96

COST ESTIMATE SUMMARY

PROJECT NAME: HLW - Vitrification Facility
Option #2 - TEC - Unescalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. #2
PREPARED BY: D. A. Rowley
REPORT NAME: Cost Estimate Summary

DATE: 30-Jun-1999
TIME: 13:16:53
CHECKED BY: SNW
APPR'D BY: BOR/KLS

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	ENGINEERING, DESIGN AND INSPECTION			>> $71,500,000
1.1.1	DESIGN ENGINEERING TITLE I & II	57,200,000	0	57,200,000
1.1.2	QUALITY ASSURANCE	14,300,000	0	14,300,000
1.2	MANAGEMENT COSTS			>> $68,640,000
1.2.1	PROJECT MANAGEMENT	40,040,000	0	40,040,000
1.2.2	CONSTRUCTION MANAGEMENT	28,600,000	0	28,600,000
1.3	CONSTRUCTION			>> $286,003,871
1.3.1	GENERAL CONDITIONS	6,819,843	0	6,819,843
1.3.2	SITEWORK	4,243,649	0	4,243,649
1.3.3	CONCRETE	42,206,274	0	42,206,274
1.3.5	METALS	20,342,996	0	20,342,996
1.3.7	THERMAL & MOISTURE PROTECTION	2,200,626	0	2,200,626
1.3.8	DOORS & WINDOWS	2,370,235	0	2,370,235
1.3.9	FINISHES	2,655,632	0	2,655,632
1.3.10	SPECIALTIES	2,287,640	0	2,287,640
1.3.11	EQUIPMENT	85,641,147	0	85,641,147
1.3.12	FURNISHINGS	2,229,554	0	2,229,554
1.3.14	CONVEYING SYSTEMS	224,400	0	224,400
1.3.15	MECHANICAL	76,895,774	0	76,895,774
1.3.16	ELECTRICAL	37,886,101	0	37,886,101
1.5	G&A/PIF			>> $14,311,088
1.5.1	G&A/PIF ADDER	14,311,088	0	14,311,088
1.5.2	PROCUREMENT FEES	2,860,039	0	>> $2,860,039
	SUBTOTAL INCLUDING ESCALATION	443,314,998	0	>> $443,314,998
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> $30,317,500
	CONTINGENCY			>> $172,487,502
	TOTAL ESTIMATED COST			>> $646,120,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= *25.00%*

CONTINGENCY= *45.75%*

Lockheed Martin Idaho Technologies Co.
Rev. 6-96

COST ESTIMATE SUMMARY

ROJECT NAME: HLW - Vitrification Facility
Option #3 - OPC - Escalated
OCATION 1: INTEC
EQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. 3
PREPARED BY: D. A. Rowley
REPORT NAME: Cost Estimate Summary

DATE: 30-Jun-1999
TIME: 13:30:07
CHECKED BY: JMW
APPR'D BY: BRR/KS

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	CONCEPTUAL DESIGN			>> $19,483,600
1.1.1	CONCEPTUAL DESIGN	14,540,000	4,943,600	19,483,600
1.2	MANAGEMENT COSTS			>> $58,646,000
1.2.1	PROJECT MANAGEMENT & PROCESS	41,300,000	17,346,000	58,646,000
1.3	PERMITTING			>> $5,005,781
1.3.1	PERMITTING	3,525,198	1,480,583	5,005,781
1.4	SO TEST & STARTUP			>> $48,463,824
1.4.1	SO TEST & STARTUP	50,483,150	(2,019,326)	48,463,824
1.5.2	PROCUREMENT FEES	0	0	>> $0
	SUBTOTAL INCLUDING ESCALATION	109,848,348	21,750,857	>> $131,599,205
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> $0
	CONTINGENCY			>> $49,700,795
	TOTAL ESTIMATED COST			>> $181,300,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= *36.00%*

CONTINGENCY= *37.77%*

Lockheed Martin Idaho Technologies Co.

Rev 6-96

DETAILED COST ESTIMATE SHEET

PROJECT NAME: HLW - Vitrification Facility
Option #3 - OPC - Escalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO.: 2499-1 Opt. 3
PREPARED BY: D. A. Rowley

DATE 30-Jun-1999
TIME: 13:30:08
REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.1.1 00109000	CONCEPTUAL DESIGN Design - 5% Of TCC	1	Lot		LMITCO	0.000					*,***,***	14,300,000
	A-E Procurement	1	Lot		LMITCO	0.000					240,000	240,000
	CONCEPTUAL DESIGN S/T						0				$*,***,***	$14,540,000
1.2.1	PROJECT MANAGEMENT & PROCESS DEVELOPMENT ACDC / SOW, CPDS,, PEP, DC / SOW & Reviews - 5% Of TCC	1	Lot		LMITCO	0.000					*,***,***	14,300,000
	Process Development	1	Lot		LMITCO	0.000					*,***,***	25,000,000
Memo:	(*) The previously estimated cost for process development (VCO - Estimate #2418) was $75M, $50M of which was to partially fund a new Multi-Function Pilot Plant (MFPP). However, it has been determined that none of the cost of the new MFPP will be absorbed by this facility. A separate project (P133) has been identified to construct the new MFPP.											
	PROJECT MANAGEMENT & PROCESS DEVELOPMENT S/T						0				$*,***,***	$39,300,000
1.2.1.1	SAFETY REVIEWS PSAR & SAR	1	Lot		LMITCO	0.000		2,000,000				2,000,000
	SAFETY REVIEWS S/T						0	$2,000,000				$2,000,000
1.3.1	PERMITTING Siting Agreement	1	Lot		Z-4170 LMITCO	640.000	640	46,694				46,694

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.1	**PERMITTING**											
	HWMA / RCRA Permit	1	Lot		Z-4170 LMITCO	6800.00	6,800	496,128				496,128
	Permit To Construct	1	Lot		Z-4170 LMITCO	3600.00	3,600	262,656				262,656
	CWA, Storm Water, Historical, Other Reg. Compliance	1	Lot		Z-4170 LMITCO	2000.00	2,000	145,920				145,920
	P.E. Certification	1	Lot		LMITCO	0.000					40,000	40,000
	Health & Safety Issues	1	Lot		LMITCO	0.000					1,200,000	1,200,000
	Quality Reviews	1	Lot		LMITCO	0.000					500,000	500,000
	Trial Burn / Waste Feed Analysis	1	Lot		LMITCO	0.000					833,800	833,800
	PERMITTING S/T						13,040	$951,398			$2,573,800	$3,525,198
1.4.1	**SO TEST & STARTUP**											
	ORR	1	Lot		LMITCO	0.000					2,000,000	2,000,000
	SO Test & Training @ 3% Of TEC	1	Lot		LMITCO	0.000					*,***,***	19,383,600
	Trial Burn Test & Analysis	1	Lot	75,000.00	LMITCO	0.000		2,400,000		75,000	776,000	3,251,000
	SO TEST & STARTUP S/T						0	$2,400,000		$75,000	$*,***,***	$24,634,600
1.4.1.1	**PROJECT SUPPORT FOR STARTUP** Support During Design, Construction, And Startup - 4% Of TEC	1	Lot		LMITCO	0.000					*,***,***	25,844,800

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.4.1.1	PROJECT SUPPORT FOR STARTUP											
	PROJECT SUPPORT FOR STARTUP S/T						0				$*,***,***	$25,844,800
	PROJECT SUBTOTAL						13,040	$5,351,398	$0	$75,000	$104,418,200	$109,844,598

Lockheed Martin Idaho Technologies Co.

CONTINGENCY ANALYSIS

PROJECT NAME: HLW - Vitrification Facility
Option #3 - OPC - Escalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. 3
PREPARED BY: D. A. Rowley

DATE: 30-Jun-1999
TIME: 13:30:41

REPORT NAME: Contingency Analysis

PROBABLE % VARIATION									PROJECT CONTINGENCY		SUMMARY
WBS Element	Cost Estimate Element	Total Cost w/o Contingency	% Total Cost	Prob. % Var. From Est. -	Prob. % Var. From Est. +	Wt. % of Prob. -	Wt. % of Prob. +	Contingency	%	Cost	Total Cost by Element
1.1.1	CONCEPTUAL DESIGN	14,540,000	11.05	15	40	1.66	4.42	3.812%	10.09%	5,015,475	19,555,475
1.2.1	PROJECT MANAGEMENT & PROCESS	41,300,000	31.38	15	40	4.71	12.55	10.827%	28.66%	14,246,157	55,546,157
1.3.1	PERMITTING	3,525,198	2.68	10	50	0.27	1.34	1.179%	3.12%	1,550,832	5,076,030
1.4.1	SO TEST & STARTUP	50,483,150	38.36	5	45	1.92	17.26	15.345%	40.62%	20,189,940	70,673,090
1.5.2	PROCUREMENT FEES	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
	ESCALATION	21,750,857	16.53	5	45	0.83	7.44	6.611%	17.50%	8,698,391	30,449,248
	SUBTOTAL	131,599,205	100.00					37.773%			
	CALCULATED CONTINGENCY	49,709,490									
	RESULTANT TEC	181,308,695									
	ROUNDED TEC	181,300,000									
	PROJECT CONTINGENCY	49,700,795						37.77%			
	MANAGEMENT RESERVE	0									
	CONTINGENCY	49,700,795									
	TOTAL ESTIMATED COST	181,300,000								49,700,795	181,300,000

CONFIDENCE LEVEL AND ASSUMED RISKS:
The Lockheed Martin Idaho Technologies Co. Cost Estimate Contingency Analysis Model is based on the applied contingency and the assumptions upon which the estimate was predicated. The model is applied with a suggested risk level of 18% and a level of confidence of 90% the estimate will fall within the bid range. The Contingency Analysis is based on a weighted average to provide a 90 % probability of underrun and a 10% probability of overrun.

CONTINGENCY ANALYSIS GUIDE BY TYPE OF ESTIMATE
Guidelines established by DOE/FM 50, Cost Estimating Guide, Vol. 6, Cost Guide, and as presented in the INEL Cost Estimating Guide.

PLANNING	20% – 30%
Experimental/Special Conditions	Up to 50%
Conceptual	15% – 25%
Experimental/Special Conditions	Up to 40%
TITLE I	10% – 20%
TITLE II	5% – 15%
TITLE II/AFC	Market Conditions

Lockheed Martin Idaho Technologies Co.
Rev. 6-96

COST ESTIMATE SUMMARY

ROJECT NAME: HLW - Vitrification Facility
Option #4 - OPC - Unescalated
OCATION 1: INTEC
EQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. #4
PREPARED BY: D. A. Rowley
REPORT NAME: Cost Estimate Summary

DATE: 30-Jun-1999
TIME: 13:31:39
CHECKED BY: JNW
APPR'D BY: BAR/KLS

WBS Element	Cost Estimate Element	Total Unescalated	Escalation	Total Incl Escalation
1.1	CONCEPTUAL DESIGN			>> $14,540,000
1.1.1	CONCEPTUAL DESIGN	14,540,000	0	14,540,000
1.2	MANAGEMENT COSTS			>> $41,300,000
1.2.1	PROJECT MANAGEMENT & PROCESS	41,300,000	0	41,300,000
1.3	PERMITTING			>> $3,525,198
1.3.1	PERMITTING	3,525,198	0	3,525,198
1.4	SO TEST & STARTUP			>> $50,483,150
1.4.1	SO TEST & STARTUP	50,483,150	0	50,483,150
1.5.2	PROCUREMENT FEES	0	0	>> $0
	SUBTOTAL INCLUDING ESCALATION	109,848,348	0	>> $109,848,348
	PROJECT CONTINGENCY			
	MANAGEMENT RESERVE			>> $0
	CONTINGENCY			>> $41,011,652
	TOTAL ESTIMATED COST			>> $150,860,000

PROJECT COST PARAMETERS

EDI AS A % OF CONST. + GFE= *27.00%*

CONTINGENCY= *37.33%*

Lockheed Martin Idaho Technologies Co.

Rev 6-96

DETAILED COST ESTIMATE SHEET

PROJECT NAME: HLW - Vitrification Facility
Option #4 - OPC - Unescalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO.: 2499-1 Opt. #4
PREPARED BY: D. A. Rowley

DATE 30-Jun-1999
TIME: 13:31:42
REPORT NAME: Detail Cost Estimate Sheet

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.1.1	**CONCEPTUAL DESIGN**											
00109000	Design - 5% Of TCC	1	Lot		LMITCO	0.000					*,***,***	14,300,000
	A-E Procurement	1	Lot		LMITCO	0.000					240,000	240,000
	CONCEPTUAL DESIGN S/T						0				$*,***,***	$14,540,000
1.2.1	**PROJECT MANAGEMENT & PROCESS DEVELOPMENT**											
	ACDC / SOW, CPDS,, PEP, DC / SOW & Reviews - 5% Of TCC	1	Lot		LMITCO	0.000					*,***,***	14,300,000
	Process Development	1	Lot		LMITCO	0.000					*,***,***	25,000,000
Memo:	(*) The previously estimated cost for process development (VCO - Estimate #2418) was $75M, $50M of which was to partially fund a new Multi-Function Pilot Plant (MFPP). However, it has been determined that none of the cost of the new MFPP will be absorbed by this facility. A separate project (P133) has been identified to construct the new MFPP.											
	PROJECT MANAGEMENT & PROCESS DEVELOPMENT S/T						0				$*,***,***	$39,300,000
1.2.1.1	**SAFETY REVIEWS**											
	PSAR & SAR	1	Lot		LMITCO	0.000		2,000,000				2,000,000
	SAFETY REVIEWS S/T						0	$2,000,000				$2,000,000
1.3.1	**PERMITTING**											
	Siting Agreement	1	Lot		Z-4170 LMITCO	640.000	640	46,694				46,694

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.3.1	**PERMITTING**											
	HWMA / RCRA Permit	1	Lot		Z-4170 *LMITCO*	6800.00	6,800	496,128				496,128
	Permit To Construct	1	Lot		Z-4170 *LMITCO*	3600.00	3,600	262,656				262,656
	CWA, Storm Water, Historical, Other Reg. Compliance	1	Lot		Z-4170 *LMITCO*	2000.00	2,000	145,920				145,920
	P.E. Certification	1	Lot		*LMITCO*	0.000					40,000	40,000
	Health & Safety Issues	1	Lot		*LMITCO*	0.000					1,200,000	1,200,000
	Quality Reviews	1	Lot		*LMITCO*	0.000					500,000	500,000
	Trial Burn / Waste Feed Analysis	1	Lot		*LMITCO*	0.000					833,800	833,800
	PERMITTING S/T						13,040	$951,398			$2,573,800	$3,525,198
1.4.1	**SO TEST & STARTUP**											
	ORR	1	Lot		*LMITCO*	0.000					2,000,000	2,000,000
	SO Test & Training @ 3% Of TEC	1	Lot		*LMITCO*	0.000					*,***,***	19,383,600
	Trial Burn Test & Analysis	1	Lot	75,000.00	*LMITCO*	0.000		2,400,000		75,000	776,000	3,251,000
	SO TEST & STARTUP S/T						0	$2,400,000		$75,000	$*,***,***	$24,634,600
1.4.1.1	**PROJECT SUPPORT FOR STARTUP** Support During Design, Construction, And Startup - 4% Of TEC	1	Lot		*LMITCO*	0.000					*,***,***	25,844,800

CODE	DESCRIPTION	QTY	UOM	MATL UNIT COST	CREW SUB	UNIT LAB HOURS	TOTAL LAB HRS	LABOR	CONST. EQUIP.	MAT'L	S/C (OTHER 1)	TOTAL COST
1.4.1.1	PROJECT SUPPORT FOR STARTUP											
	PROJECT SUPPORT FOR STARTUP S/T						0				$*,***,***	$25,844,800
	PROJECT SUBTOTAL						13,040	$5,351,398	$0	$75,000	$104,418,200	$109,844,598

Lockheed Martin Idaho Technologies Co. **CONTINGENCY ANALYSIS**

PROJECT NAME: HLW - Vitrification Facility
Option #4 - OPC - Unescalated
LOCATION 1: INTEC
REQUESTOR: D. A. Lopez

TYPE OF ESTIMATE: Planning
PROJECT NO: 2499-1 Opt. #4
PREPARED BY: D. A. Rowley

DATE: 30-Jun-1999
TIME: 13:31:54

REPORT NAME: Contingency Analysis

PROBABLE % VARIATION									PROJECT CONTINGENCY		SUMMARY
WBS Element	Cost Estimate Element	Total Cost w/o Contingency	% Total Cost	Prob. % Var. From Est. -	Prob. % Var. From Est. +	Wt. % of Prob. -	Wt. % of Prob. +	Contingency	%	Cost	Total Cost by Element
1.1.1	CONCEPTUAL DESIGN	14,540,000	13.24	15	40	1.99	5.29	4.567%	12.23%	5,016,605	19,556,605
1.2.1	PROJECT MANAGEMENT & PROCESS	41,300,000	37.60	15	40	5.64	15.04	12.971%	34.74%	14,249,367	55,549,367
1.3.1	PERMITTING	3,525,198	3.21	10	50	0.32	1.60	1.412%	3.78%	1,551,182	5,076,380
1.4.1	SO TEST & STARTUP	50,483,150	45.96	5	45	2.30	20.68	18.383%	49.24%	20,194,489	70,677,639
1.5.2	PROCUREMENT FEES	0	0.00	0	0	0.00	0.00	0.000%	0.00%	0	0
	ESCALATION	0	0.00	0	0	0.00	0.00	0.000%	0.00%	9	9
	SUBTOTAL	109,848,348	100.00					37.333%			
	CALCULATED CONTINGENCY	41,009,147									
	RESULTANT TEC	150,857,495									
	ROUNDED TEC	150,860,000									
	PROJECT CONTINGENCY	41,011,652						37.33%			
	MANAGEMENT RESERVE	0									
	CONTINGENCY	41,011,652									
	TOTAL ESTIMATED COST	150,860,000								41,011,652	150,860,000

CONFIDENCE LEVEL AND ASSUMED RISKS:
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TITLE I	10% – 20%
TITLE II	5% – 15%
TITLE II/AFC	Market Conditions

G & A and PIF Worksheet

Project: High Level Waste Vitrification Facility

Estimate No.: 2499

Estimator: D. A. Rowley

Date: 3/2/99

Total Construction Cost	$ 286,003,873
Construction Procurement Fee - 1%	$ 2,860,039

Construction Cost

Construction Cost - Year 1	$ 71,500,968	25% Of TCC		
Construction Cost - Year 2	$ 71,500,968	25% Of TCC		
Construction Cost - Year 3	$ 71,500,968	25% Of TCC		
Construction Cost - Year 4	$ 71,500,968	25% Of TCC		
Subtotal	$ 286,003,873		$	286,003,873

G & A @ 27% With A $500,000 Construction Ceiling ($135,000)

		G & A	Amount	
Construction Cost - Year 1	$ 71,500,968	27%	$ 135,000	
Construction Cost - Year 2	$ 71,500,968	27%	$ 135,000	
Construction Cost - Year 3	$ 71,500,968	27%	$ 135,000	
Construction Cost - Year 4	$ 71,500,968	27%	$ 135,000	
Procurement Cost	$ 2,860,039	27%	$ 772,210	
Subtotal			$ 1,312,210	$ 1,312,210

Performance Incentive Factor (PIF) @ 4.5% - No Ceiling

		PIF		
Construction Cost - Year 1	$ 71,500,968	4.5%	$ 3,217,544	
Construction Cost - Year 2	$ 71,500,968	4.5%	$ 3,217,544	
Construction Cost - Year 3	$ 71,500,968	4.5%	$ 3,217,544	
Construction Cost - Year 4	$ 71,500,968	4.5%	$ 3,217,544	
Procurement Cost	$ 2,860,039	4.5%	$ 128,702	
Subtotal			$ 12,998,876	$ 12,998,876

Total Adders $	$ 14,311,086
Total Cost	$ 300,314,959
Total Adder %	5%

LOCKHEED MARTIN

Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date:	March 11, 1999		
To:	D. A. Lopez	MS 3765	6-9020
From:	R. J. Turk	MS 3875	6-3611
Subject:	ECONOMIC AND LIFE CYCLE ANALYSIS CONDUCTED HLW VITRIFICATION WASTE FACILITY-RJT-09-99		

Purpose:

As requested an Economic and Life-Cycle Cost (LCC) has been conducted to evaluate the HLW VITRIFICATION WASTE FACILITY. This facility will accept all raw calcined waste, including SWB calcined waste form ICPP Bin Sets, vitrify and cast it into a SRSDWPF-Type Glass Canisters (GC). The GC's will be sent to an Interim Storage Facility (ISF) until transport to final disposition.

This economic analysis is based on information provided by S. E. Gifford, S. L. Alstad, R. R. Kimmitt and other team members. D. A. Rawley provided cost estimates. D. A. Lopez provided process personnel modeling.

Methodology:

The Economic Evaluation assumed a 35-year period, (2006-2040) since this is the estimated time required to complete all of the anticipated remediation activities. The LCC identifies evaluated the initial development, construction, operation and post-operating costs over the life-cycle. A discounted LCC analysis assumes a constant-dollar basis, discounted at 5.10% annually per the Office of Management and Budget (OMB) Circular A-94. All costs are conservatively discounted assuming the end-of-year convention.

Assumptions:

The scope of work and requirements of all related activities are vague at this time. Facility and processing costs were developed from historical cost. Closure cost generated form work associated with DD&D work at the INEEL. The LCC analysis was generated to match cost estimating cost tructure. These costs include Permitting, Direct and Indirect Construction; G&A,

Procurement Fee, Engineering, Inspection, Project Management, Construction Management, Escalation and Contingency costs.

The design period is assumed to be accomplished in six years with construction completed in five years. The operational period for this facility was assumed to be twenty years, followed by five years of post-operations activities. Due to this project's lack of complexity and relative cleanliness this analysis assumed a decommissioning cost equal to 20% of the engineering design cost, decontamination costs equal to 5% of total pre-operation cost, and demolition costs equal to 8% of total pre-operation cost. Utility costs were calculated assuming a .082 $/kWh. Per your direction, procurement costs for Gc's Canisters at $10,000 each, Materials for blending costs (borosilica glass frit) $4.40/kg. Transportation and Laboratory costs were assumed to been captured in other studies and therefore not included.

Results:

The HLW VITRIFICATION WASTE FACILITY has a Discounted LCC of $ 1.5 billion.

Attachments:

cc: R. J. Turk File

HLW VITRIFICATION FACILITY Life-Cycle Cost (LCC) Analysis (ALL COST X1000)					fical year counting year Escalation Factor	2006 7 1.209	2007 8 1.242	2008 9 1.277	2009 10 1.313	2010 11 1.350	2011 12 1.387	2012 13 1.426	2013 14 1.466	2014 15 1.507	2015 16 1.550
Other Project Cost (OPC)															
OPC unescalated															
Conceptual Design, Project Mgt, & Permitting						14,841	14,841	14,841	14,841						
Testing and Start-up														25,242	25,242
Total OPC (unescalated)						14,841	14,841	14,841	14,841	0	0	0	0	25,242	25,242
plus escalation of						2,939	2,939	2,939	2,939	0	0	0	0	4,998	4,998
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						6,715	6,715	6,715	6,715	0	0	0	0	11,421	11,421
Total OPC including escalation, mgt reserve, & contingency						24,495	24,495	24,495	24,495	0	0	0	0	41,660	41,660
Total Estimated Cost (TEC)															
TEC unescalated															
Title Design, Inspection									35,750	35,750					
Project mgt									6,117	6,673	6,673	6,673	6,673	6,673	556
Construction Mgt										5,244	5,720	5,720	5,720	5,720	476
Construction, Equip, GSA & Procurement											75,794	75,794	75,794	75,794	
Total TEC (unescalated)						0	0	0	41,867	47,667	88,187	88,187	88,187	88,187	1,032
plus escalation of						0	0	0	17,152	19,628	36,128	36,128	36,128	36,128	423
plus management reserve of						0	0	0	4,066	4,629	8,564	8,564	8,564	8,564	100
plus contingency of						0	0	0	21,948	24,988	46,230	46,230	46,230	46,230	541
Total TEC including escalation, mgt reserve, contingency						0	0	0	85,033	96,812	179,109	179,109	179,109	179,109	2,097
Total Project Cost (TPC)															
TPC unescalated						14,841	14,841	14,841	56,709	47,667	88,187	88,187	88,187	113,429	26,274
plus escalation of						2,939	2,939	2,939	20,091	19,628	36,128	36,128	36,128	41,126	5,421
plus management reserve of						0	0	0	4,066	4,629	8,564	8,564	8,564	8,564	100
plus contingency of						6,715	6,715	6,715	28,663	24,988	46,230	46,230	46,230	57,651	11,962
Total TPC including esc, mgt res, contingency						24,495	24,495	24,495	109,528	96,812	179,109	179,109	179,109	220,770	43,757
discount factor @ OMB discount rate of		6.00%		for escalated costs		1.407	1.477	1.551	1.629	1.710	1.796	1.886	1.980	2.079	2.183
Discounted Annual Cost						$17,406	$16,579	$15,790	$67,241	$56,604	$99,735	$94,966	$90,482	$106,194	$20,046
Operations	2080 hr-shift/yr.														
Operations/Process Facility	171														
Managers		2	FTE @	$125	/hr.										
Engineers		4	FTE @	$100	/hr.										
Other Tech.		21	FTE @	$85	/hr.										
Supervisors		8	FTE @	$85	/hr.										
Administration/Support		8	FTE @	$65	/hr.										
Operators		68	FTE @	$65	/hr.										
Maintenance		60	FTE @	$65	/hr.										
Utilities		32,396,000	kWh/yr	$0.062	$/kwh										
Maintenance of Equipment		8.00%	of	232,734	Rq'd maint										
Consumables		966,697	kg/yr@	$4.40	$/kg										
Disposal		22	M^3/yr	$3,250	$/drum										
Procurement		675	units/Yr	$10,000	Each										
Steam Usage		50,000,000	lb/yr	$0.02	$/lb										
Operations subtotal (unescalated)						0	0	0	0	0	0	0	0	0	0
plus Escalation						0	0	0	0	0	0	0	0	0	0
plus Operations Contingency @		30.0%				0	0	0	0	0	0	0	0	0	0
Total Operations (w/ escalation & contingency)						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of		5.10%		for escalated costs		1.417	1.489	1.565	1.644	1.728	1.816	1.909	2.006	2.109	2.216
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Post Operations															
Decommission		20.00%	of	Engineering costs											
Decontamination		5.00%	of	Pre-operation Costs											
Demolition		8.00%	of	Pre-operation Costs											
Post-Operations Subtotal (unescalated)						0	0	0	0	0	0	0	0	0	0
plus Escalation						0	0	0	0	0	0	0	0	0	0
plus Post-Operations Contingency @		30.0%				0	0	0	0	0	0	0	0	0	0
Total Post-Operations (w/ escalation & contingency)						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of		5.10%		for escalated costs		1.417	1.489	1.565	1.644	1.728	1.816	1.909	2.006	2.109	2.216
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Cost (unescalated)						14,841	14,841	14,841	56,709	47,667	88,187	88,187	88,187	113,429	26,274
Cumulative Total LCC (unescalated)						14,841	29,683	44,524	101,233	148,900	237,087	325,274	413,461	526,889	553,163
Total Cost (w/ escalation, mgt reserve, & contingency)						24,495	24,495	24,495	109,528	96,812	179,109	179,109	179,109	220,770	43,757
Cumulative Total LCC (escalated)						24,495	48,990	73,486	183,013	279,825	458,935	638,044	817,154	1,037,923	1,081,680
discount factor @ OMB discount rate of		5.10%		for escalated costs		1.417	1.489	1.565	1.644	1.728	1.816	1.909	2.006	2.109	2.216
Discounted Annual Cost						$17,292	$16,453	$15,655	$66,604	$56,014	$98,602	$93,817	$89,265	$104,688	$19,743
Cumulative Discounted LCC						$17,292	$33,746	$49,401	$116,005	$172,019	$270,621	$364,438	$453,703	$558,392	$578,134

DRAFT

HLW VITRIFICATION FACILITY
Life-Cycle Cost (LCC) Analysis
(ALL COST X1000)

DRAFT

					fiscal year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
					counting year	17	18	19	20	21	22	23	24	25	26
					Escalation Factor	1.593	1.638	1.683	1.730	1.779	1.829	1.880	1.933	1.987	2.042
Other Project Cost (OPC)															
OPC unescalated															
Conceptual Design, Project Mgt, & Permitting															
Testing and Start-up															
Total OPC (unescalated)						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total OPC including escalation, mgt reserve, & contingency						0	0	0	0	0	0	0	0	0	0
Total Estimated Cost (TEC)															
TEC unescalated															
Title Design, Inspection															
Project mgt															
Construction Mgt															
Construction, Equip, G&A & Procurement															
Total TEC (unescalated)						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total TEC including escalation, mgt reserve, contingency						0	0	0	0	0	0	0	0	0	0
Total Project Cost (TPC)															
TPC unescalated						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total TPC including esc, mgt res, contingency						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of	5.00%		for escalated costs			2.292	2.407	2.527	2.653	2.786	2.925	3.072	3.225	3.386	3.556
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations	2080 hr-shift/yr.														
Operations/Process Facility	171														
Managers	2	FTE @	$125	/hr.		520	520	520	520	520	520	520	520	520	520
Engineers	4	FTE @	$108	/hr.		899	899	899	899	899	899	899	899	899	899
Other Tech.	21	FTE @	$85	/hr.		3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713
Supervisors	8	FTE @	$85	/hr.		1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414
Administration/Support	8	FTE @	$65	/hr.		1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082
Operators	68	FTE @	$65	/hr.		9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194
Maintenance	60	FTE @	$65	/hr.		8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112
Utilities	32,396,000	kWh/yr	$0.082	$/kwh		2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669
Maintenance of Equipment	8.00%	of	232,734	Rq'd maint		18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619
Consumables	966,697	kg/yr @	$4.40	$/kg		4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253
Disposal	22	M^3/yr	$3,250	$/drum		533	533	533	533	533	533	533	533	533	533
Procurement	675	units/Yr	$10,000	Each		6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755
Steam Usage	50,000,000	lb/yr	$0.02	$/lb		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Operations subtotal (unescalated)						58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762
plus Escalation						34,840	37,461	40,156	42,925	45,772	48,699	51,708	54,801	57,981	61,250
plus Operations Contingency @	30.0%					28,081	28,867	29,676	30,508	31,360	32,238	33,141	34,069	35,023	36,003
Total Operations (w/ escalation & contingency)						121,683	125,090	128,592	132,193	135,894	139,699	143,611	147,632	151,766	156,016
discount factor @ OMB discount rate of	5.10%		for escalated costs			2.329	2.448	2.573	2.704	2.842	2.987	3.140	3.300	3.468	3.645
Discounted Annual Cost						$52,237	$51,094	$49,976	$48,883	$47,813	$46,766	$45,743	$44,742	$43,763	$42,805
Post Operations															
Decommission	20.00%	of	Engineering costs												
Decontamination	5.00%	of	Pre-operation Costs												
Demolition	9.00%	of	Pre-operation Costs												
Post-Operations Subtotal (unescalated)						0	0	0	0	0	0	0	0	0	0
plus Escalation						0	0	0	0	0	0	0	0	0	0
plus Post-Operations Contingency @	30.0%					0	0	0	0	0	0	0	0	0	0
Total Post-Operations (w/ escalation & contingency)						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of	5.10%		for escalated costs			2.329	2.448	2.573	2.704	2.842	2.987	3.140	3.300	3.468	3.645
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Cost (unescalated)						58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762
Cumulative Total LCC (unescalated)						611,925	670,687	729,449	788,211	846,973	905,734	964,496	1,023,258	1,082,020	1,140,782
Total Cost (w/ escalation, mgt reserve, & contingency)						121,683	125,090	128,592	132,193	135,894	139,699	143,611	147,632	151,766	156,016
Cumulative Total LCC (escalated)						1,203,369	1,328,452	1,457,045	1,589,237	1,725,132	1,864,831	2,008,442	2,156,074	2,307,839	2,463,854
discount factor @ OMB discount rate of	5.10%		for escalated costs			2.329	2.448	2.573	2.704	2.842	2.987	3.140	3.300	3.468	3.645
Discounted Annual Cost						$52,237	$51,094	$49,976	$48,883	$47,813	$46,766	$45,743	$44,742	$43,763	$42,805
Cumulative Discounted LCC						$630,372	$681,466	$731,442	$780,325	$828,137	$874,904	$920,647	$965,389	$1,009,152	$1,051,957

HLW VITRIFICATION FACILITY Life-Cycle Cost (LCC) Analysis (ALL COST X1000)					fiscal year counting year Escalation Factor	2026 27 2.100	2027 28 2.158	2028 29 2.219	2029 30 2.281	2030 31 2.345	2031 32 2.410	2032 33 2.478	2033 34 2.547	2034 35 2.619	2035 36 2.692
Other Project Cost (OPC)															
OPC unescalated															
Conceptual Design, Project Mgt, & Permitting															
Testing and Start-up															
Total OPC (unescalated)						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total OPC including escalation, mgt reserve, & contingency						0	0	0	0	0	0	0	0	0	0
Total Estimated Cost (TEC)															
TEC unescalated															
Title Design, Inspection															
Project mgt															
Construction Mgt															
Construction, Equip, G&A & Procurement															
Total TEC (unescalated)						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total TEC including escalation, mgt reserve, contingency						0	0	0	0	0	0	0	0	0	0
Total Project Cost (TPC)															
TPC unescalated						0	0	0	0	0	0	0	0	0	0
plus escalation of						0	0	0	0	0	0	0	0	0	0
plus management reserve of						0	0	0	0	0	0	0	0	0	0
plus contingency of						0	0	0	0	0	0	0	0	0	0
Total TPC including esc, mgt res, contingency						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of	5.00%	for escalated costs				3.733	3.920	4.116	4.322	4.538	4.765	5.003	5.253	5.516	5.792
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operations	2080 hr-shift/yr.														
Operations/Process Facility	171														
Managers	2	FTE @	$125	/hr.		520	520	520	520	520	520	520	520	520	520
Engineers	4	FTE @	$108	/hr.		899	899	899	899	899	899	899	899	899	899
Other Tech.	21	FTE @	$86	/hr.		3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713	3,713
Supervisors	8	FTE @	$85	/hr.		1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414	1,414
Administration/Support	8	FTE @	$65	/hr.		1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062
Operators	68	FTE @	$65	/hr.		9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194	9,194
Maintenance	60	FTE @	$65	/hr.		8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112	8,112
Utilities	32,396,000	kWh/yr	$0.082	$/kwh		2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669	2,669
Maintenance of Equipment	8.00%	of	232,734	Rq'd maint		18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619	18,619
Consumables	966,697	kg/yr@	$4.40	$/kg		4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253
Disposal	22	M^3/yr	$3,250	$/drum		533	533	533	533	533	533	533	533	533	533
Procurement	875	units/Yr	$10,000	Each		6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755	6,755
Steam Usage	50,000,000	lb/yr	$0.02	$/lb		1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Operations subtotal (unescalated)						58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762
plus Escalation						64,610	66,064	71,616	75,266	79,019	82,977	86,843	90,920	95,111	99,419
plus Operations Contingency @	30.0%					37,012	38,048	39,113	40,208	41,334	42,492	43,681	44,904	46,162	47,454
Total Operations (w/ escalation & contingency)						160,385	164,874	169,491	174,236	179,115	184,130	189,286	194,586	200,034	205,635
discount factor @ OMB discount rate of	5.10%	for escalated costs				3.831	4.028	4.231	4.447	4.674	4.912	5.163	5.426	5.703	5.994
Discounted Annual Cost						$41,868	$40,952	$40,056	$39,179	$38,322	$37,483	$36,663	$35,861	$35,076	$34,308
Post Operations															
Decommission	20.00%	of	Engineering costs												
Decontamination	5.00%	of	Pre-operation Costs												
Demolition	8.00%	of	Pre-operation Costs												
Post-Operations Subtotal (unescalated)						0	0	0	0	0	0	0	0	0	0
plus Escalation						0	0	0	0	0	0	0	0	0	0
plus Post-Operations Contingency @	30.0%					0	0	0	0	0	0	0	0	0	0
Total Post-Operations (w/ escalation & contingency)						0	0	0	0	0	0	0	0	0	0
discount factor @ OMB discount rate of	5.10%	for escalated costs				3.831	4.028	4.231	4.447	4.674	4.912	5.163	5.426	5.703	5.994
Discounted Annual Cost						$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total Cost (unescalated)						58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762	58,762
Cumulative Total LCC (unescalated)						1,199,544	1,258,306	1,317,067	1,375,829	1,434,591	1,493,353	1,552,115	1,610,876	1,669,638	1,728,400
Total Cost (w/ escalation, mgt reserve, & contingency)						160,385	164,874	169,491	174,236	179,115	184,130	189,286	194,586	200,034	205,635
Cumulative Total LCC (escalated)						2,624,238	2,789,112	2,958,603	3,132,839	3,311,954	3,496,084	3,685,370	3,879,956	4,079,991	4,285,626
discount factor @ OMB discount rate of	5.10%	for escalated costs				3.831	4.028	4.231	4.447	4.674	4.912	5.163	5.426	5.703	5.994
Discounted Annual Cost						$41,868	$40,952	$40,056	$39,179	$38,322	$37,483	$36,663	$35,861	$35,076	$34,308
Cumulative Discounted LCC						$1,093,825	$1,134,777	$1,174,833	$1,214,013	$1,252,335	$1,289,818	$1,326,481	$1,362,342	$1,397,418	$1,431,726

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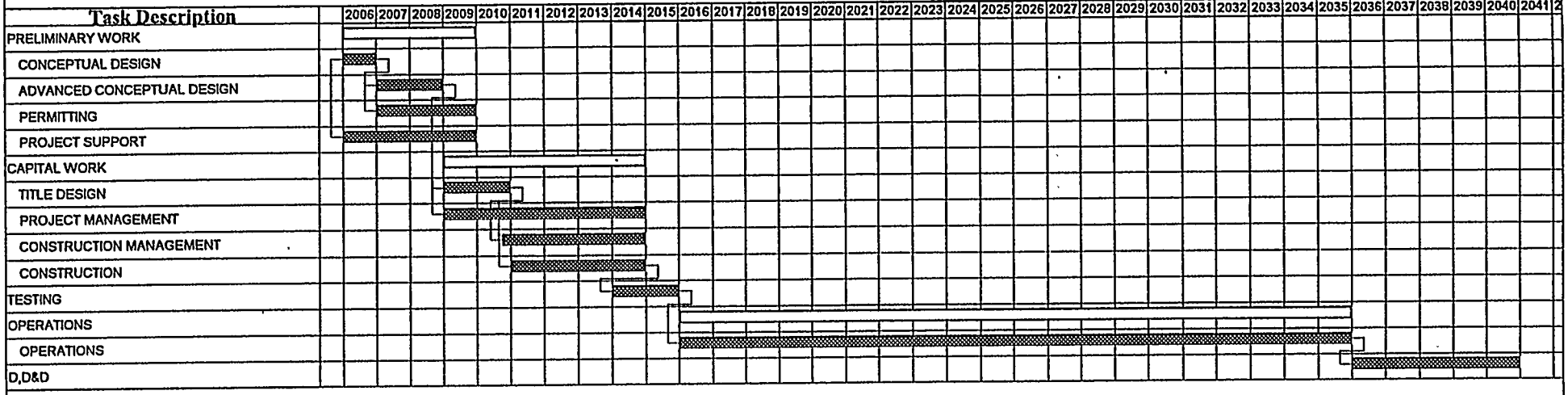
HLW VITRIFICATION FACILITY Life-Cycle Cost (LCC) Analysis (ALL COST X1000)					fical year counting year Escalation Factor	2036 37 2.787	2037 38 2.845	2038 39 2.924	2039 40 3.006	2040 41 3.090	Total Cost
Other Project Cost (OPC)											
OPC unescalated											
Conceptual Design, Project Mgt, & Permitting											$59,365
Testing and Start-up											$50,483
Total OPC (unescalated)						0	0	0	0	0	$109,848
plus escalation of						0	0	0	0	0	$21,751
plus management reserve of						0	0	0	0	0	$0
plus contingency of						0	0	0	0	0	$49,701
Total OPC including escalation, mgt reserve, & contingency						0	0	0	0	0	$181,300
Total Estimated Cost (TEC)											
TEC unescalated											
Title Design, Inspection											$71,600
Project mgt											$40,040
Construction Mgt											$28,600
Construction, Equip, G&A & Procurement											$303,175
Total TEC (unescalated)						0	0	0	0	0	$443,315
plus escalation of						0	0	0	0	0	$181,616
plus management reserve of						0	0	0	0	0	$43,051
plus contingency of						0	0	0	0	0	$232,398
Total TEC including escalation, mgt reserve, contingency						0	0	0	0	0	$900,380
Total Project Cost (TPC)											
TPC unescalated						0	0	0	0	0	$553,163
plus escalation of						0	0	0	0	0	$203,367
plus management reserve of						0	0	0	0	0	$43,051
plus contingency of						0	0	0	0	0	$282,099
Total TPC including esc, mgt res, contingency						0	0	0	0	0	$1,081,680
discount factor @ OMB discount rate of		5.00%		for escalated costs		6.081	6.385	6.706	7.040	7.392	
Discounted Annual Cost						$0	$0	$0	$0	$0	$585,044
Operations	2080 hr-shift/yr.										
Operations/Process Facility	171										
Managers		2	FTE @	$125	/hr.						$10,400
Engineers		4	FTE @	$108	/hr.						$17,971
Other Tech.		21	FTE @	$85	/hr.						$74,256
Supervisors		8	FTE @	$85	/hr.						$28,288
Administration/Support		8	FTE @	$85	/hr.						$21,632
Operators		68	FTE @	$85	/hr.						$183,872
Maintenance		60	FTE @	$85	/hr.						$162,240
Utilities		32,396,000	kWh/yr	$0.092	$/kwh						$53,389
Maintenance of Equipment		8.00%	of	232,734	Rq'd maint						$372,375
Consumables		966,697	kg/yr@	$4.40	$/kg						$95,069
Disposal		22	M^3/yr	$3,250	$/drum						$10,655
Procurement		675	units/Yr	$10,000	Each						$135,090
Steam Usage		50,000,000	lb/yr	$0.02	$/lb						$20,000
Operations subtotal (unescalated)						0	0	0	0	0	$1,176,237
plus Escalation						0	0	0	0	0	$1,289,337
plus Operations Contingency @		30.0%				0	0	0	0	0	$739,372
Total Operations (w/ escalation & contingency)						0	0	0	0	0	$3,203,946
discount factor @ OMB discount rate of		5.10%		for escalated costs		6.299	6.621	6.958	7.313	7.686	
Discounted Annual Cost						$0	$0	$0	$0	$0	$963,592
Post Operations											
Decommission		20.00%	of	Engineering costs		2,860	2,860	2,860	2,860	2,860	$14,300
Decontamination		5.00%	of	Pre-operation Costs		5,532	5,532	5,532	5,532	5,532	$27,658
Demolition		8.00%	of	Pre-operation Costs		8,851	8,851	8,851	8,851	8,851	$44,253
Post-Operations Subtotal (unescalated)						17,242	17,242	17,242	17,242	17,242	$86,211
plus Escalation						30,472	31,000	33,181	34,503	36,044	$166,099
plus Post-Operations Contingency @		30.0%				14,314	14,716	15,127	15,551	15,986	$75,693
Total Post-Operations (w/ escalation & contingency)						62,028	63,765	65,550	67,396	69,273	$328,002
discount factor @ OMB discount rate of		5.10%		for escalated costs		6.299	6.621	6.958	7.313	7.686	
Discounted Annual Cost						$9,847	$9,631	$9,420	$9,214	$9,013	$47,125
Total Cost (unescalated)						17,242	17,242	17,242	17,242	17,242	$1,614,611
Cumulative Total LCC (unescalated)						1,745,642	1,762,885	1,780,127	1,797,369	1,814,611	
Total Cost (w/ escalation, mgt reserve, & contingency)						62,028	63,765	65,550	67,396	69,273	$4,613,628
Cumulative Total LCC (escalated)						4,347,654	4,411,419	4,478,970	4,644,366	4,613,628	
discount factor @ OMB discount rate of		5.10%		for escalated costs		6.299	6.621	6.958	7.313	7.686	
Discounted Annual Cost						$9,847	$9,631	$9,420	$9,214	$9,013	$1,478,851
Cumulative Discounted LCC						$1,441,573	$1,451,204	$1,460,624	$1,469,839	$1,478,851	

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Appendix B

Schedule

HLW VITRIFICATION FACILITY



Default

Complete | Complete Milestone | Remaining | Remaining Milestone | Free Float | Total Float (+) | Total Float (-) | Delay | Non-Resource | Baseline 1

Critical

Remaining | Remaining Milestone

Parent

Remaining | Remaining Milestone

HLW VITRIFICATION FACILITY

Task Description	Duration	Schedule Start	Schedule Finish
PRELIMINARY WORK	1044d	01/02/06	12/31/09
CONCEPTUAL DESIGN	261d	01/02/06	01/01/07
ADVANCED CONCEPTUAL DESIGN	523d	01/02/07	01/01/09
PERMITTING	783d	01/02/07	12/31/09
PROJECT SUPPORT	1044d	01/02/06	12/31/09
CAPITAL WORK	1566d	01/02/09	01/02/15
TITLE DESIGN	521d	01/02/09	12/31/10
PROJECT MANAGEMENT	1566d	01/02/09	01/02/15
CONSTRUCTION MANAGEMENT	1109d	10/04/10	01/01/15
CONSTRUCTION	1044d	01/03/11	01/01/15
TESTING	523d	01/02/14	01/04/16
OPERATIONS	5215d	01/05/16	12/31/35
OPERATIONS	5215d	01/05/16	12/31/35
D,D&D	1305d	01/01/36	12/31/40

Appendix C

Engineering Design Files

Appendix C

Engineering Design Files

The engineering design files (EDFs) prepared for this study are listed below and included in this appendix:

EDF Serial Number	EDF Title
EDF-HVF-F-001	AE Facility Design
EDF-HVF-F-002	Process Calculations
EDF-HVF-F-003	Deleted (content included in EDF-HVF-F-002)
EDF-HVF-F-004	Offgas Treatment System
EDF-HVF-F-005	Calcine Grinding
EDF-HVF-F-006	Induction Melting
EDF-HVF-F-007	Fifteen Foot (15-ft) Canister Evaluation
EDF-HVF-F-008	Sampling Study
EDF-HVF-F-009	Electrical Study
EDF-HVF-F-010	Canister Flow Diagram
EDF-HVF-F-011	Utilities Study
EDF-HVF-F-012	HVAC Study
EDF-HVF-F-013	Instrumentation and Control
EDF-HVF-F-014	Remote Maintenance and Equipment Sizing
EDF-HVF-F-015	Cell Equipment Decontamination

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task Non-Separations Alternative

3. Subtask High Level Waste Vitrification Facility

4. Title: A/E Facility Design

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

This EDF contains a description of the HLW Vitrification Facility (HVF) for Vitrifying calcine, cesium-saturated sorbent from the CsIX process, and NGLW as an option to satisfy the Settlement agreement between DOE and the State of Idaho.

The Vitrification Facility is to receive and vitrify dry or liquid HLW, package the vitrified waste into road ready canisters, and transport the canisters to the storage facility via a transfer tunnel. The HVF will be located in the northeast corner of INTEC.

The Vitrification Facility will be a multistory building that extends 32 ft. below and 75 ft. above grade, and occupies an area measuring 470 ft. x 242 ft. The facility is based around four melter cells, a process equipment canyon, and a pump and valve corridor. The remainder of the facility is located around these processes and adjacent to those they support. The facility has a concrete superstructure (3 to 4 ft. thick walls for shielding of the processes) and nonprocess areas constructed of ordinary braced steel frame systems.

See the attached written description and sketches HVF-T-1 and HVF-A-1 through A-7.

6. Distribution (complete package): D. J. Harrell MS 3211; B. R. Helm MS 3765, V. L. Jacobson MS 3211; WTP EIS Studies Library; Project File.

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	T. A. Langenwalter	Tracy Langenwalter	2-3-99
Independent Verification	R	P.W. BRAGASSA	Pat Bragassa	2-3-99
Requestor	A	D. A. Lopez	D A Lopez	3-20-99

1.0 Vitrification Facility Description

The function of the HVF is to receive dry calcine solid HLW from the CSSF and NGLW, vitrify the waste, package the vitrified waste into road ready canisters, and transport these canisters to the disposal facility via a transfer tunnel. Mercury-containing waste will be packaged and transported to a mixed LLW disposal facility. To accomplish this the HVF will receive glass frit by rail, mix it with the HLW, and vitrify the mixture in one of four induction melters. The molten glass will be poured into 2-ft diameter x 10-ft long DWPF-type canisters. The area of the entire facility's four floors is approximately 308,000 square feet.

Verbal input from SRS DWPF personnel is documented in EDF-VWO-003.[1] This information was carefully considered in developing the HVF design presented in this report.

1.1 Site Description

The Vitrification Facility will be located in the northeast corner of the INTEC between the east perimeter fence and Hemlock Street to the west, because of the close proximity to the waste sources. The facility will be sited on an environmentally controlled area (ECA-CPP-26), which it is assumed, will be released for construction.

Existing site soils consist of poorly graded, gravely and sandy alluvial deposits ranging from 35 to 40 ft deep that overlay a 8-ft thick clay layer which rests on a massive basalt bedrock formation. Groundwater is not located above the basalt elevation.

The floor elevation at grade will be higher that the 100-yr flood elevation (4916.5 ft. per INTEC datum) in accordance with RCRA requirements or the INTEC probable maximum flood elevation. The 0'-0" floor elevation will be at 4917.0 ft. minimum. The lowest floor level elevation was chosen to minimize excavation of existing bedrock.

The facility was sited for delivery, service, and emergency vehicle accessibility. Site roads connect to existing streets and have adequate maneuvering area for delivery trucks.

1.2 Underground Utilities

The HVF is located in the north-east corner of INTEC as shown on Sketch T-1(attached). Underground utility lines exist in the vicinity of the facility but new tie-in lines will have to be added to the existing lines. The average length of these lines is estimated to be 400 ft. The underground utilities include: potable water, fire water, sanitary sewer, steam, and plant air.

1.3 Fences, Roads, and Railroads

The HVF and ISF will be enclosed by a fence with gates for access roads and railroad crossings. The fence will be a chain-link security fence, typical of that around the perimeter of the INTEC complex. Parking will be provided for approximately 30 site vehicles with head-bolt heaters.

1.4 Facility Layout

The HVF will be a multistory building that extends 32 ft below and 75 ft above grade, and has a footprint occupying an area measuring 470 ft x 242 ft. The HVF floor plans and cross sections are shown on Drawings HVF-A- 1

through A-6. It will be designed to house the equipment and operations for nonseparations processing of CSSF and NGLW waste while providing essential features for safe and efficient operation and maintenance.

The HVF layout is based on a centrally located process cell complex of four melter cells with heavy concrete walls for shielding, and limited personnel access. EDF-VWO-007,[1] Fluidized Bed Blending Tank Cell Shielding Calculations, contains a calculation of the concrete shielding wall thickness necessary to reduce the maximum calcine radiation source field in the HVF to 0.10 mrem/hr or less. The melter cells will house equipment that presents a high radiation hazard but requires minimal maintenance. The melter cells will be enclosed by shielding walls with installed manipulators and shielding windows that facilitate maintenance from the operating corridors that surround these process areas.

The Process Equipment Canyon contains equipment, vessels, etc, that need minimum access for maintenance. The Canyon also has heavy concrete walls for shielding. The Canyon is adjacent to the melter cells, spans most of the length of the building, and is accessed from concrete ceiling hatches using the bride crane in the maintenance area above. The pump and valve corridor contains valves, jumpers, and other equipment that requires some maintenance. The pump and valve corridor also has heavy concrete walls for shielding and is adjacent to the Process Equipment Canyon. Pump and valve corridor equipment can be remotely maintained or replaced using the PaR and/or the bridge crane located in the corridor.

The periphery of the facility contains office space, change rooms, support areas, truck and equipment delivery and loading areas, and nonradioactive operation areas.

1.4.1 Below Grade Features. The below grade areas of the HVF house the 32-ft high empty canister lowering bay, the canister filling and capping cell, the decon cell, a full canister storage/staging area, a liquid collection cell, and a large HVAC exhaust equipment room. The canister filling and capping cell, decon cell, and full canister storage/staging area contain 3-ft thick, decontaminable shielding walls, ceilings, and floors. Two liquid collection tanks will be located within a cell on this level for firewater or decon liquid solution. Four stairways and a freight elevator, located near the northwest comer, will provide for personnel egress and equipment loading throughout the building. This floor is approximately 67,500 square feet in area.

1.4.2 Above Grade Features. Level 0-ft 0-in. contains the four vitrification melter cells and their operating corridors, the process equipment canyon, the pump and valve corridor, smear cell, weld cell, equipment decon/pre-decon/hands-on cells, clean canister storage area, remote maintenance cell, equipment cut-up cell and its operating corridor, decon solution makeup room, decon solution distribution equipment room, and the equipment loadout area. Three 13-ft diameter by 20-ft tall glass frit silos and a 10-ft diameter exhaust stack will be located outside at grade level, east of the facility. Administrative areas, including offices, control rooms, restroom/change room space, mechanical and electrical equipment rooms, and a truck airlock will be located on the west side of the facility. The large HVAC supply equipment room will be located on the east side of the facility adjacent to the process cells to facilitate filtering close to the contamination source. Four stairways provide egress, and a freight elevator, a truck loading bay, and an equipment loadout bay provide maneuverability for equipment and raw materials throughout the facility. Airlocks will be provided at the entrance to the personnel corridors between the process cells, at the interface between the office and operating the corridor, and directly between the operating corridor and the change rooms. Equipment airlocks will be provided in the loading bays for canister and freight delivery trucks. This floor is approximately 113,500 square feet in area.

The level 21-ft 0-in. above grade contains the upper portions of the melters cells, the process equipment canyon, the pump and valve corridor, smear cell, welding cell, equipment decon/pre-decon/hands-on cells, and loadout area. Space for an analytical lab, instrument gallery, sample cells and the electrical equipment room are also located on this level. HVAC supply equipment including standby blowers and steam coils are located outside the facility on the roof

above the HVAC supply equipment room. Four stairways provide egress, and a freight elevator provides maneuverability for equipment and materials throughout the facility. This floor is approximately 65,500 square feet in area.

The level 45-ft 0-in. above grade consists primarily of a large, shielded high bay (the maintenance/disassembly cell) that contains a 75-ton overhead bridge crane and hatch covers to all process cells, the process equipment canyon, and the pump and valve corridor below. The crane can lift, set aside, and replace all removable cell covers. After cell cover removal, the crane can move components to and from the equipment decontamination cell and remote maintenance cell through the cell covers on the level at 21-ft 0-in. Conveyer systems will transport glass frit from the outdoor silos to frit weigh tanks located in the corridor, and from there to the mix tanks in the process equipment canyon that serves the melter cells. Four stairways provide egress, and a freight elevator provides maneuverability for equipment and materials throughout the facility. This floor is approximately 61,500 square feet in area.

1.5 Structural Features

The process area of this facility has a concrete superstructure extending 45 ft above grade. The cell walls will generally be 3 to 4-ft thick and support a formed cast-in-place concrete roof. The process cell walls extend to a 4-ft thick foundation 32-ft below finished grade. The operating corridor outside walls will be reinforced concrete and extend to 32-ft below finished grade.

Process cells have 1/4-in. thick stainless steel floors and 1/8-in. thick wall liner plates that extend the full height of the cell walls. The tops of all cells at the 45 ft elevation, as shown in Drawing A-5, will be covered by stepped, 4-ft thick, concrete plug-type hatch covers that can be removed by the 75-ton bridge crane to completely expose the equipment below.

The building superstructure containing the office and HVAC supply equipment area consists of an ordinary braced-frame system. Metal panels enclose the roof and walls. Office floors will be 6-in. reinforced concrete slab-on-grade or supported on concrete topped metal decking and structural steel framing where elevated. Grade beams and isolated column spread footings support the structural steel frame of the building.

1.6 Occupancy Classification

The HLW Vitrification Facility is classified as a UBC Group H Division 7 and Group B Mixed Occupancy. The H-7 occupancy applies to buildings or portions thereof containing materials that constitute a high health hazard. This area includes the central core of the facility contained within the shielding walls on all floors (the melter cells, process equipment canyon, pump and valve corridor, the maintenance area, canister filling and capping, and other cells, rooms, and areas within the shielding walls).

The Group B Mixed occupancy applies to buildings or portions thereof used for offices, laboratories, etc., that are not classified as Group H for hazardous materials. This area includes the above grade portion of the building that is outside of the shielding walls (the office/administrative area, mechanical/ HVAC/electrical rooms, corridors, and other rooms and areas outside the shielding walls). According to UBC Table 3-13, the required separation between H-7 and B occupancies is one hour per.

1.7 Construction Type

The HVF construction type classification is UBC Type II-F.P. Allowable floor area for B occupancy is unlimited if auto sprinklered per section 505.2. Allowable area for H-7 occupancy Type II-F.P. is 39,900 ft^2. If auto sprinklered

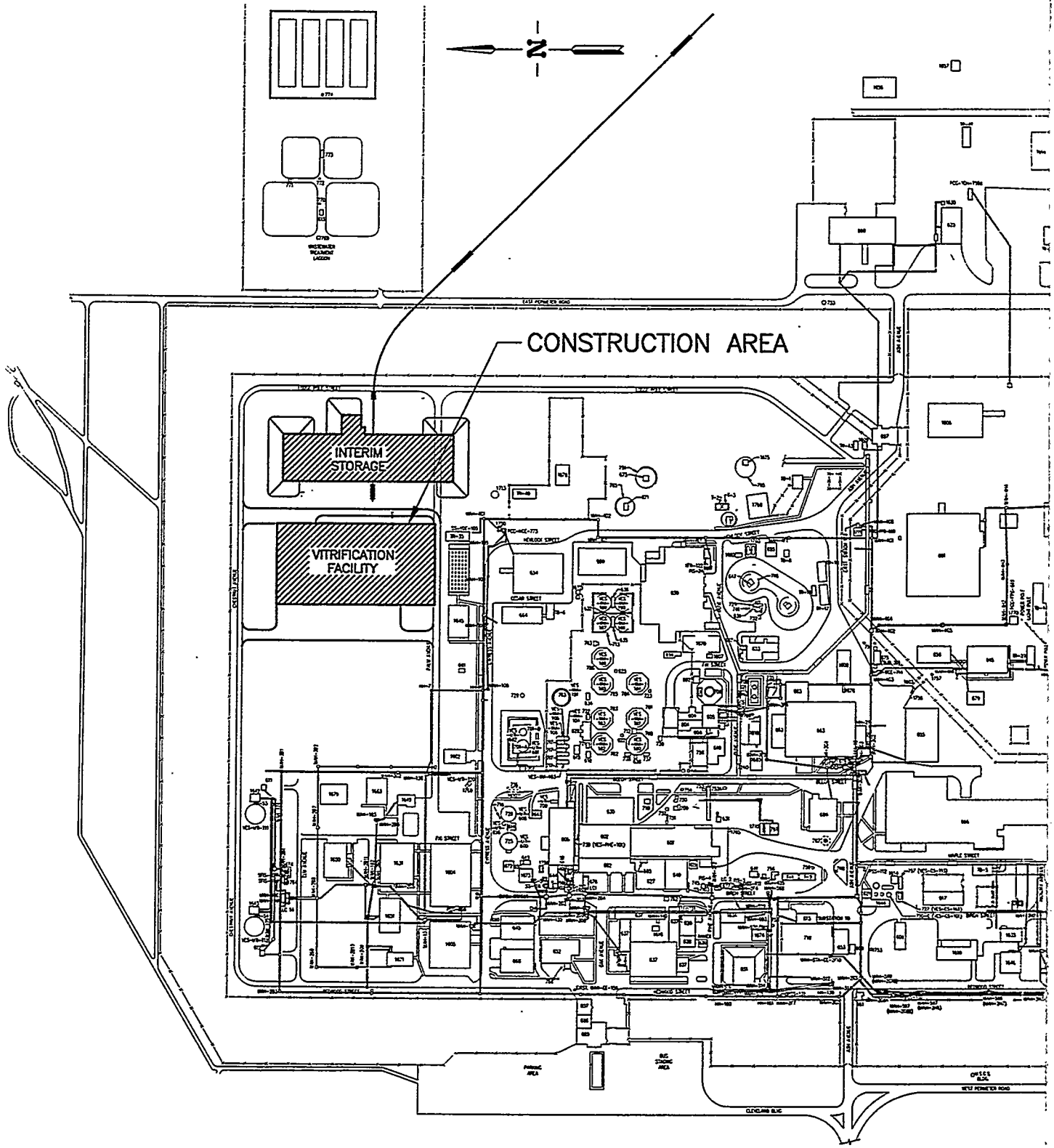
throughout, twice the area is allowed or 79,800 ft^2 per section 505.3. The HLW Vitrification Facility has 71,000 ft^2 of building area requiring Type II-F.P. with auto sprinklers to gain the necessary allowable area.

Occupancy H-7 Type II-F.P. construction requires exterior bearing walls to be four hour fire rated, interior bearing walls to be two hour, permanent partition to be one hour, and structural frame, floors and ceilings to be one hour. Because of the nature of the facility, most separation walls are concrete and will meet the required fire rating. Doors will need to be fire rated. In the cells, shielding doors and shielding windows will need to be fire rated. One-hour separation walls will be required for mixed occupancies, between the Type B and H-7 occupancies per Table 3B.

Further investigation or testing will be required to verify that shielding doors and windows between the H-7 and B occupancies will meet fire rating requirements. Shielding windows have been tested at INTEC previously and were found to be acceptable for use in fire rated walls.

Reference:

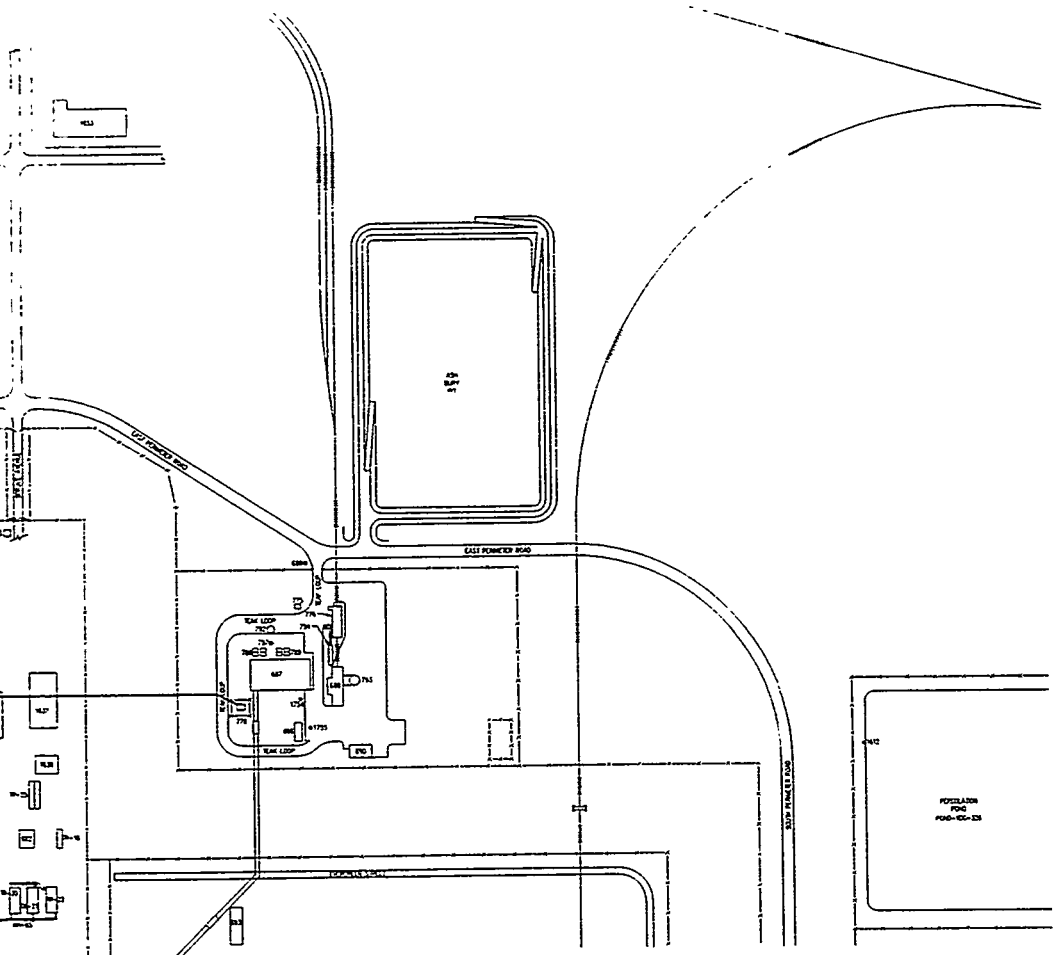
1 Lopez, D.A., and Kimmitt, R.R., Vitrified Waste Option Study Report, INEEL/EXT-01389, February 1998.



SITE PLAN

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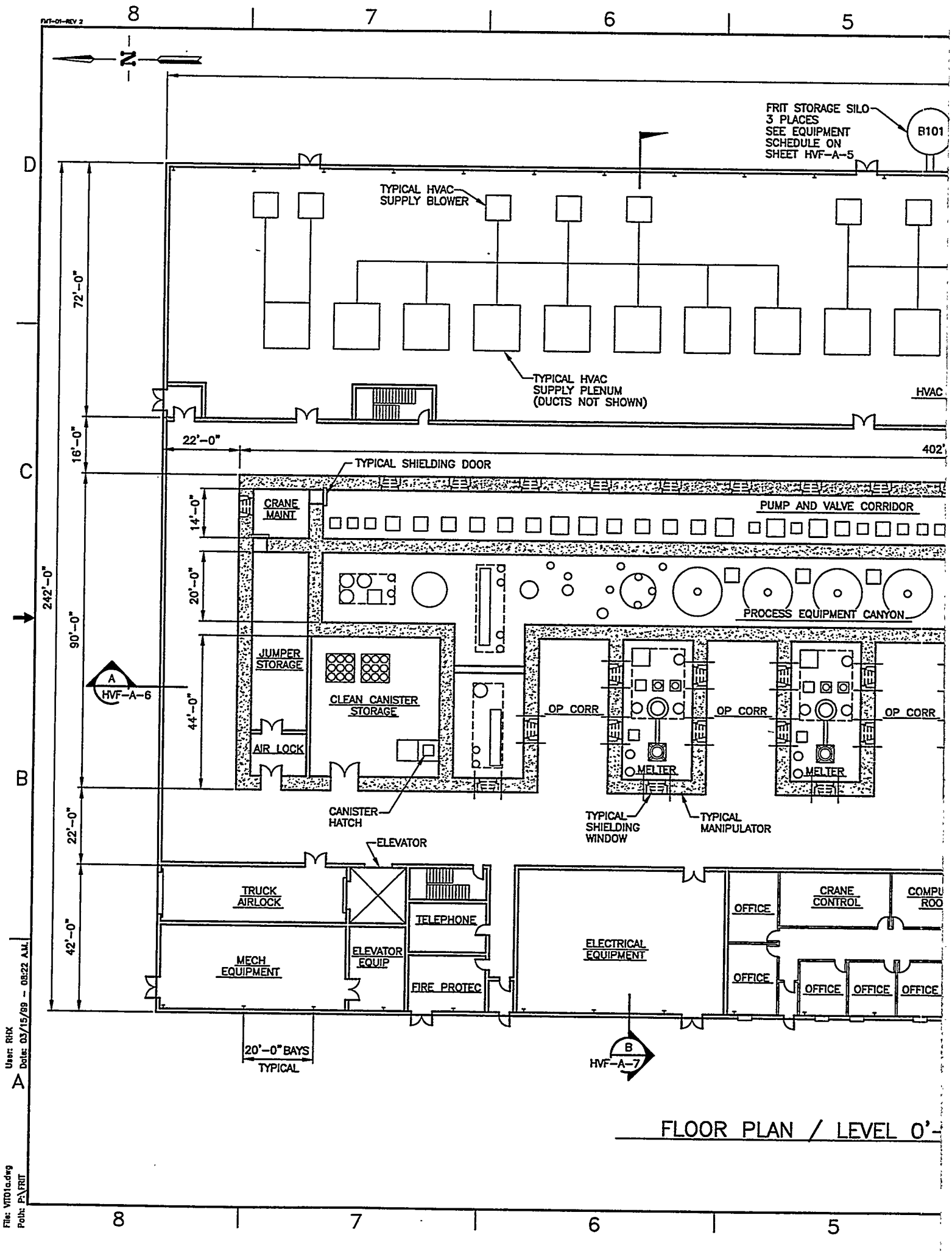
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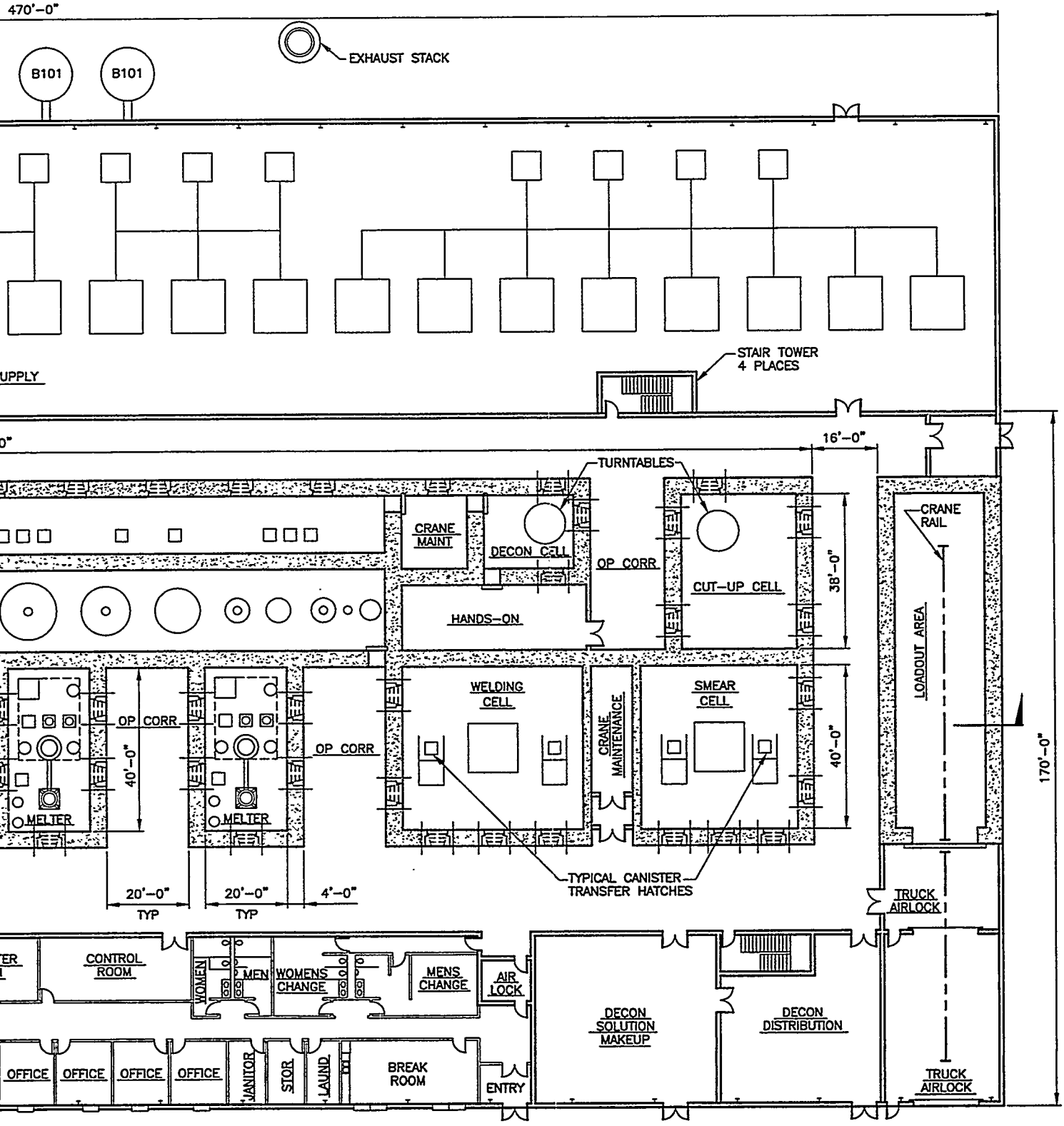
DRAWING INDEX

PAGE NO.	DWG NO.	A-E DWG NO.	REV	DRAWING TITLE
		HVF-T-1		SITE PLAN AND DRAWING INDEX
		HVF-A-1		FLOOR PLAN AT LEVEL 0'-0"
		HVF-A-2		FLOOR PLAN AT LEVEL +21-0"
		HVF-A-3		FLOOR PLAN AT LEVEL +45'-0"
		HVF-A-4		FLOOR PLAN AT LEVEL -32'-0"
		HVF-A-5		PARTIAL PLAN AND EQUIPMENT SCHEDULE
		HVF-A-6		BUILDING SECTION
		HVF-A-7		BUILDING SECTION

FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
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	DRAWN: D. BRONSON	
	PROJECT NO.	
	SPEC CODE	
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QUALITY LEVEL: 3	EFFECTIVE DATE:	SCALE: 1"=200.0'; SHEET HVF-T-1


FRIT STORAGE SILO
3 PLACES
SEE EQUIPMENT
SCHEDULE ON
SHEET HVF-A-5
B101
TYPICAL HVAC
SUPPLY BLOWER
TYPICAL HVAC
SUPPLY PLENUM
(DUCTS NOT SHOWN)
HVAC
72'-0"
16'-0"
22'-0"
402'
TYPICAL SHIELDING DOOR
CRANE
MAINT
PUMP AND VALVE CORRIDOR
14'-0"
20'-0"
PROCESS EQUIPMENT CANYON
242'-0"
90'-0"
JUMPER
STORAGE
CLEAN CANISTER
STORAGE
A
HVF-A-6
44'-0"
AIR LOCK
OP CORR
OP CORR
OP CORR
MELTER
MELTER
CANISTER
HATCH
TYPICAL
SHIELDING
WINDOW
TYPICAL
MANIPULATOR
22'-0"
ELEVATOR
TRUCK
AIRLOCK
TELEPHONE
OFFICE
CRANE
CONTROL
COMPU
ROO
42'-0"
MECH
EQUIPMENT
ELEVATOR
EQUIP
FIRE PROTEC
ELECTRICAL
EQUIPMENT
OFFICE
OFFICE
OFFICE
OFFICE
OFFICE
20'-0" BAYS
TYPICAL
B
HVF-A-7
FLOOR PLAN / LEVEL 0'-
8
7
6
5
D
C
B
A
N
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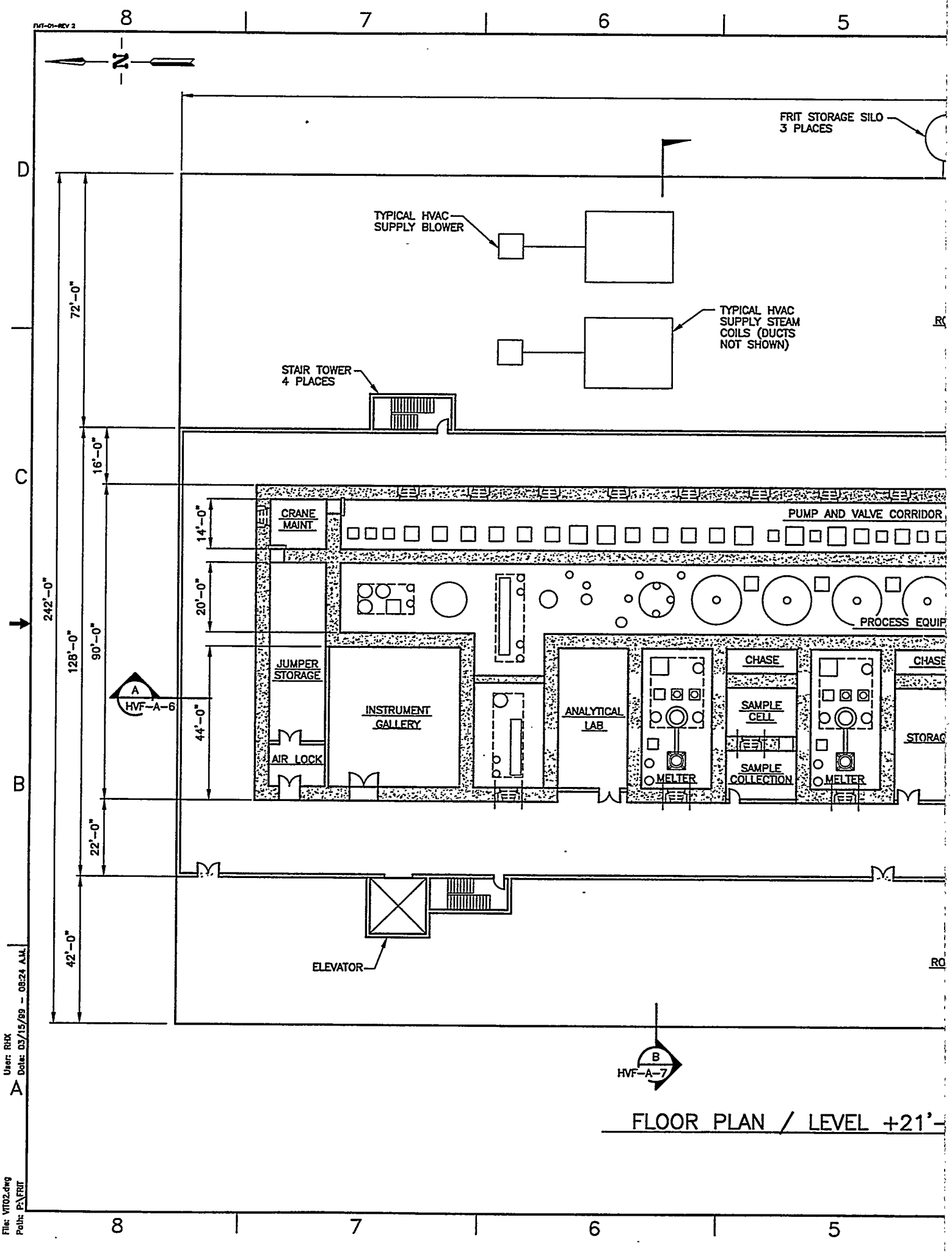
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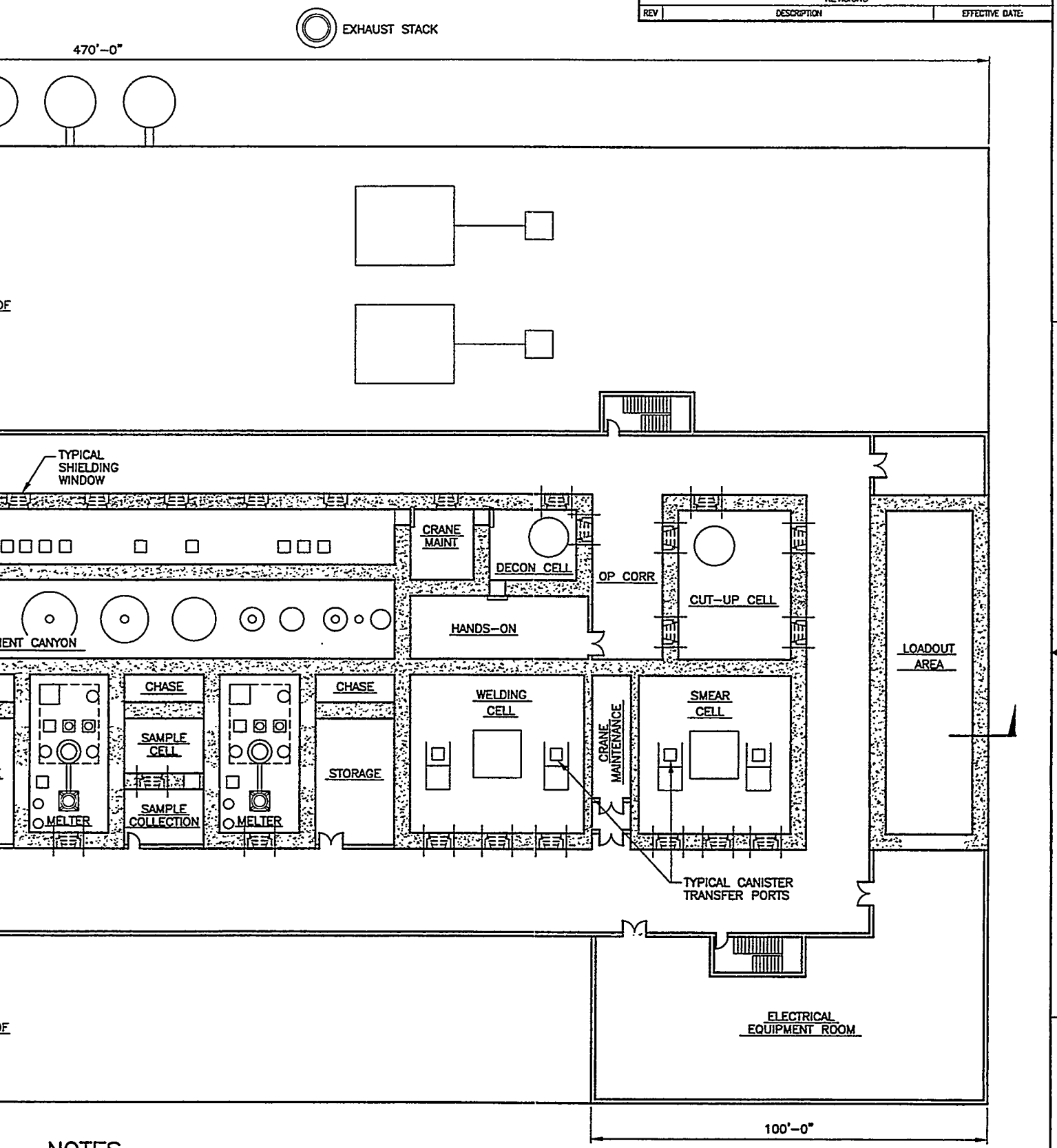
NOTES

1. FOR EQUIPMENT LABELS AND DESCRIPTIONS, IN PUMP AND VALVE CORRIDOR, PROCESS EQUIPMENT CANYON, AND MELTER CELLS, SEE SHEET HVF-A-5.

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	DESIGN: T. LANGENWALTER	
	DRAWN: D. BRONSON	
	PROJECT NO.	
	SPEC CODE	
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE D; CAGE CODE 01MF3; INDEX CODE NUMBER AREA 200 TYPE OL 00 DISC 530; DWG-; REV
QUALITY LEVEL: 3	EFFECTIVE DATE:	SCALE: 1/16"=1'-0"; SHEET HVF-A-1


8
7
6
5
D
C
B
A
N
FRIT STORAGE SILO
3 PLACES
TYPICAL HVAC
SUPPLY BLOWER
TYPICAL HVAC
SUPPLY STEAM
COILS (DUCTS
NOT SHOWN)
STAIR TOWER
4 PLACES
72'-0"
16'-0"
14'-0"
20'-0"
44'-0"
22'-0"
42'-0"
90'-0"
128'-0"
242'-0"
CRANE
MAINT
PUMP AND VALVE CORRIDOR
PROCESS EQUIP
JUMPER
STORAGE
INSTRUMENT
GALLERY
AIR LOCK
ANALYTICAL
LAB
CHASE
SAMPLE
CELL
SAMPLE
COLLECTION
MELTER
MELTER
CHASE
STORAG
A
HVF-A-6
ELEVATOR
B
HVF-A-7
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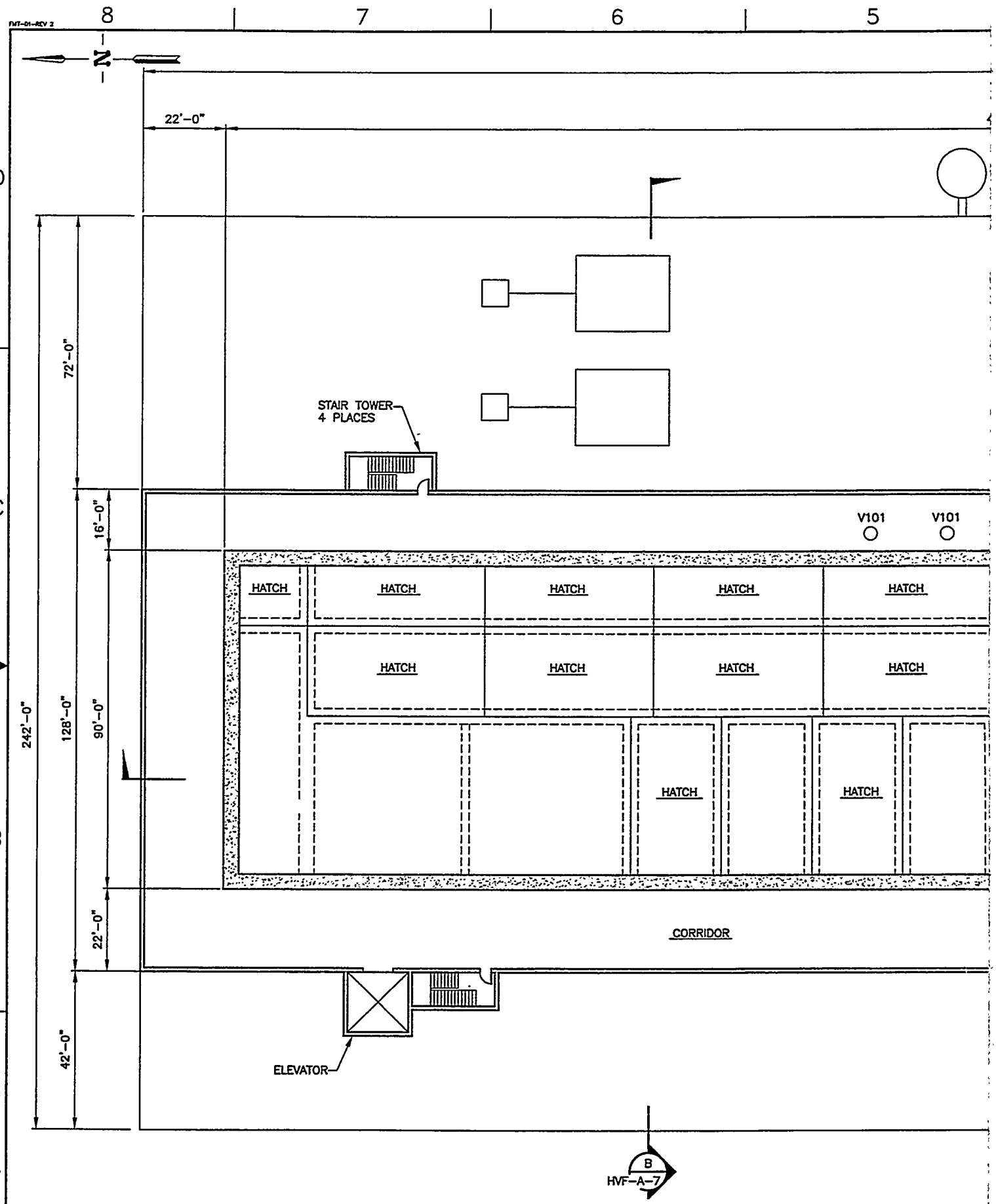
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	DRAWN: D. BRONSON	
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FLOOR PLAN / LEVEL

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470'-0"

EXHAUST STACK

8'-0"

30'-0"

FRIT STORAGE SILO 3 PLACES

TYPICAL HVAC SUPPLY BLOWER

ROOF

TYPICAL HVAC SUPPLY STEAM COILS (DUCTS NOT SHOWN)

V101 FRIT WEIGH TANK 3 PLACES

STORAGE

AIR LOCK

HATCH

BRIDGE CRANE MAINTENANCE

A HVF-A-6

STORAGE

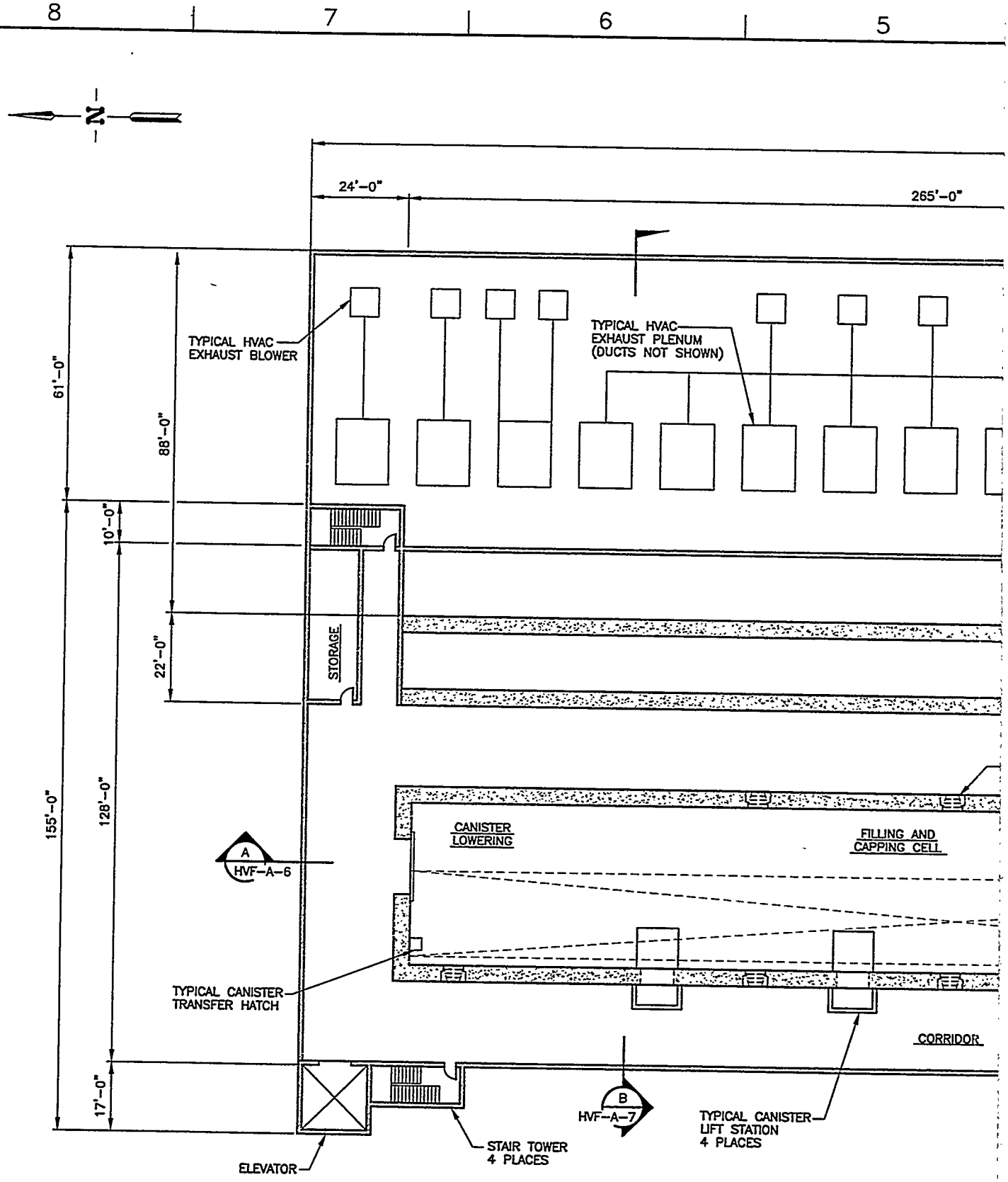
AIR LOCK

ROOF

ROOF

+45'-0"

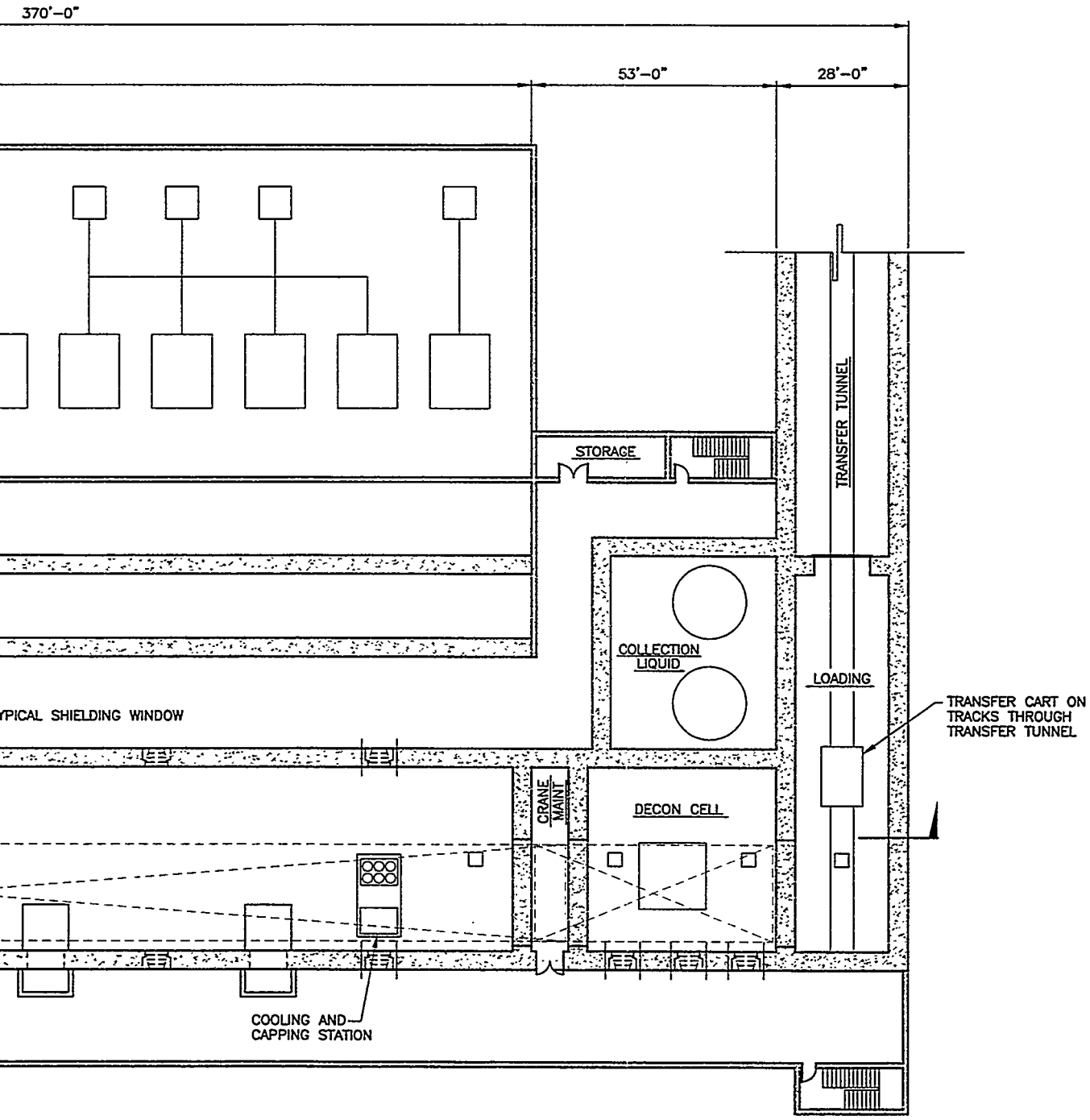
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	DRAWN: D. BRONSON	
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FLOOR PLAN / LEVEL

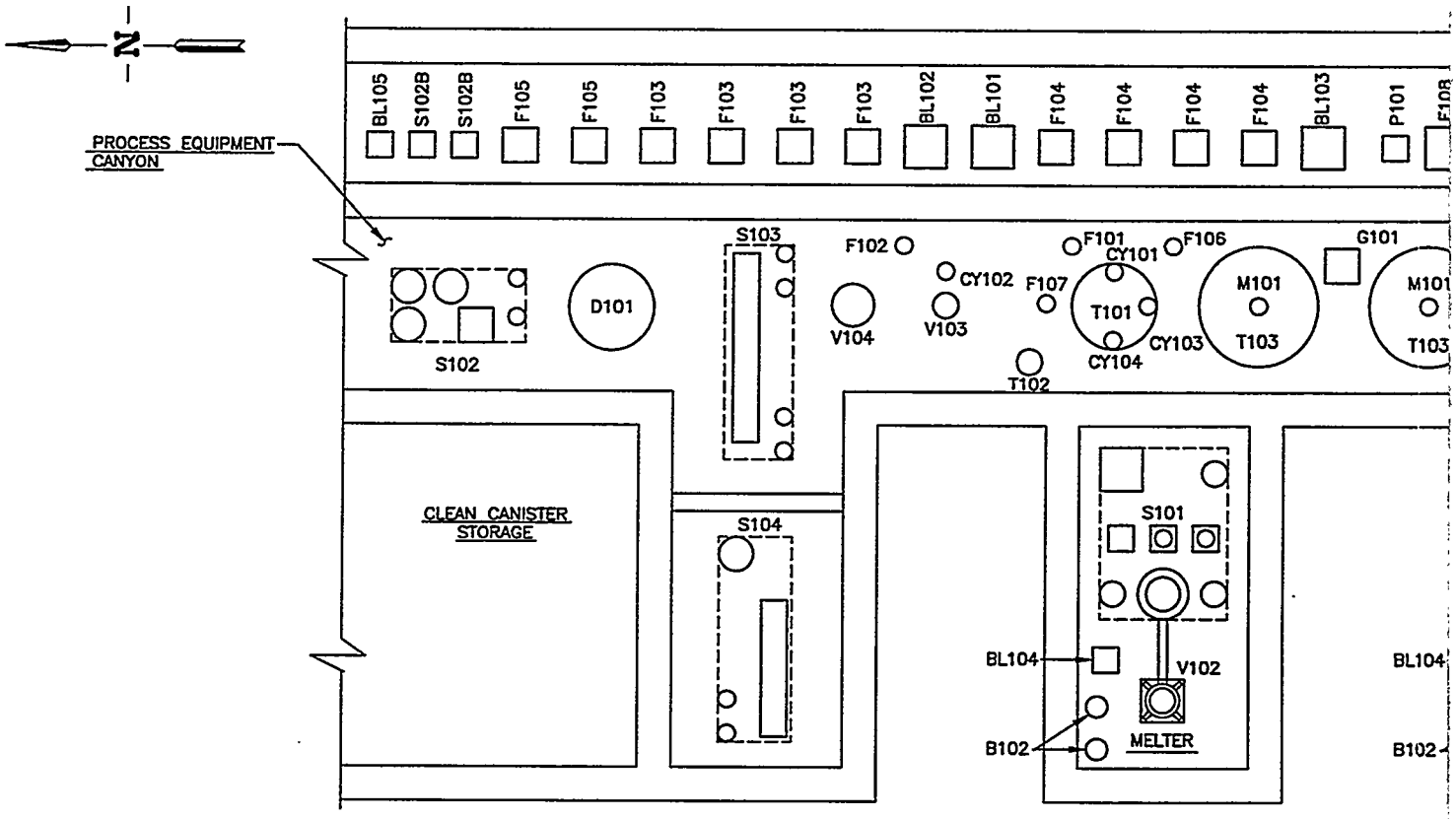
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-32'-0"

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	DESIGN: T. LANGENWALTER	
	DRAWN: D. BRONSON	
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	SPEC CODE	
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, SL, ORG 00 530; DWG-; REV
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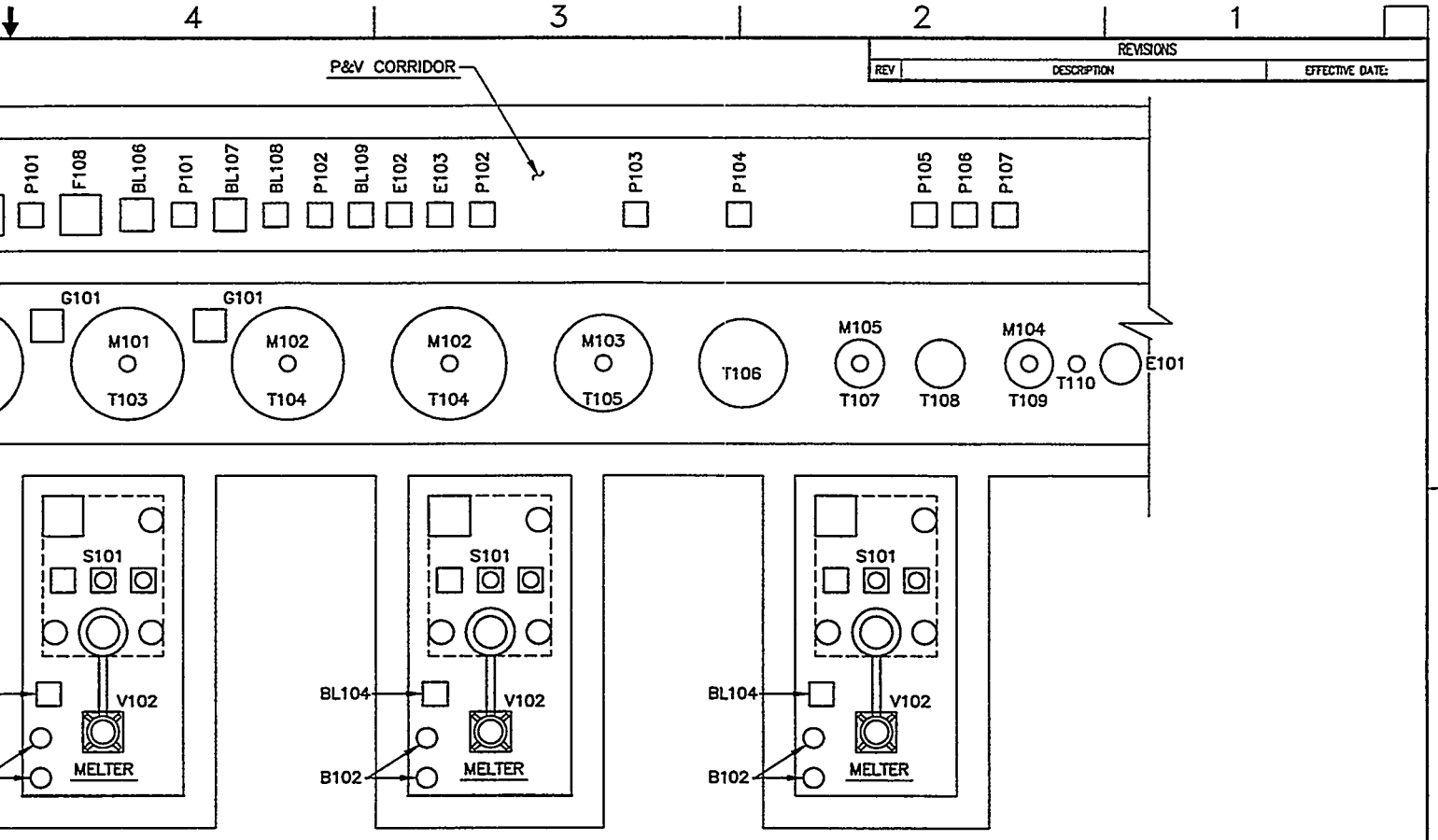


PART

EQUIPMENT SCHEDULE

EQ. LABEL	DESCRIPTION	EQ. LABEL	DESCRIPTION
B101	FRIT SILO STORAGE	P101	MIX TANK TRANSFER PUMP
B102	DRIED SOLIDS FEED HOPPER	P102	FEED TANK DELIVERY PUMP
BL101	CALCINE BLENDING BLOWER	P103	NGLW TRANSFER PUMP
BL102	CALCINE BLENDING ID FAN	P104	WATER TRANSFER PUMP
BL103	CALCINE BLENDING ID FAN	P105	COOLING SOLUTION TRANSFER PUMP
BL104	CONVEYOR BLOWER	P106	COOLING WATER RECIRCULATION PU
BL105	BLOWER	P107	SLURRY SAMPLING RECIRCULATION
BL106	RETRIEVAL BLOWER	S101	SPRAY DRYER SYSTEM
BL107	RETRIEVAL BLOWER	S102	DRY ADDITIVE PROCESS SCRUBBER
BL108	BALANCING BLOWER	S102B	DRY ADDITIVE BLOWERS
BL109	BALANCING BLOWER	S103	SELECTIVELY CATALYZED REDUCTION
CO101	RAIL TO SILO FRIT CONVEYOR	S104	MERCURY RECOVERY SYSTEM
CO102	FRIT SILO TO WEIGHT VESSEL CONVEYOR	T101	CALCINE RECEIVING TANK
CO103	FRIT WEIGH VESSEL TO MIX TANK CONVEYOR	T102	CALCINE FINES COLLECTION TANK
CO104	CALCINE WEIGH VESSEL TO MIX TANKS	T103	MIX TANK
CY101	BLENDING CYCLONE	T104	FEED TANK
CY102	CALCINE FEED CYCLONE	T105	NGLW STORAGE TANK
D101	GRANULAR ACTIVATED CARBON COLUMN	T106	WATER COLLECTION TANK
E101	COOLING WATER HEAT EXCHANGER	T107	DECON SOLUTION MIX TANK
E102	RETRIEVAL AIR COOLER	T108	SPENT DECON SOLUTION COLLECTIO
E103	RETRIEVAL AIR COOLER	T109	COOLING WATER RECIRCULATION TAN
F101	SINTERED METAL FILTER	T110	WATER CONDITIONING ADDITIVE TANK
F102	SINTERED METAL FILTER	V101	FRIT WEIGH TANK
F103	HEPA FILTER	V102	GLASS MELTER
F104	HEPA FILTER	V103	CALCINE WEIGH VESSEL
F105	OFF-GAS HEPA FILTER	V104	ANHYDROUS AMMONIA STORAGE VES
F106	RETRIEVAL SINTERED METAL FILTER		
F107	RETRIEVAL SINTERED METAL FILTER		
F108	RETRIEVAL HEPA FILTER		
G101	CALCINE GRINDER		
M101	MIX TANK AGITATOR		
M102	FEED TANK AGITATOR		
M103	NGLW TANK AGITATOR		
M104	WATER CONDITIONING AGITATOR		
M105	DECON SOLUTION AGITATOR		

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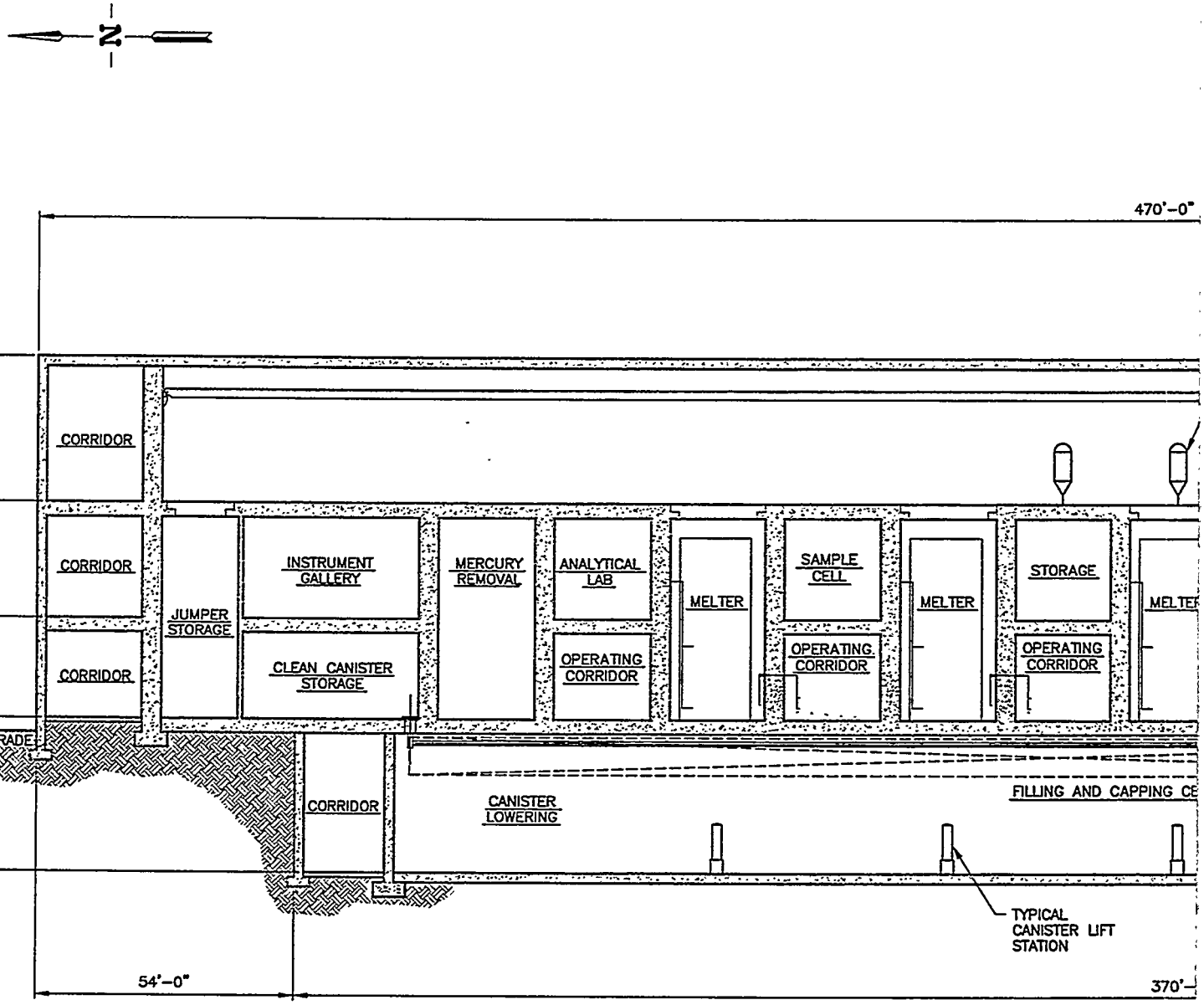
REVISIONS

REV	DESCRIPTION	EFFECTIVE DATE:

AL PLAN

P
UMP
YSTEM
REACTOR
TANK
EL

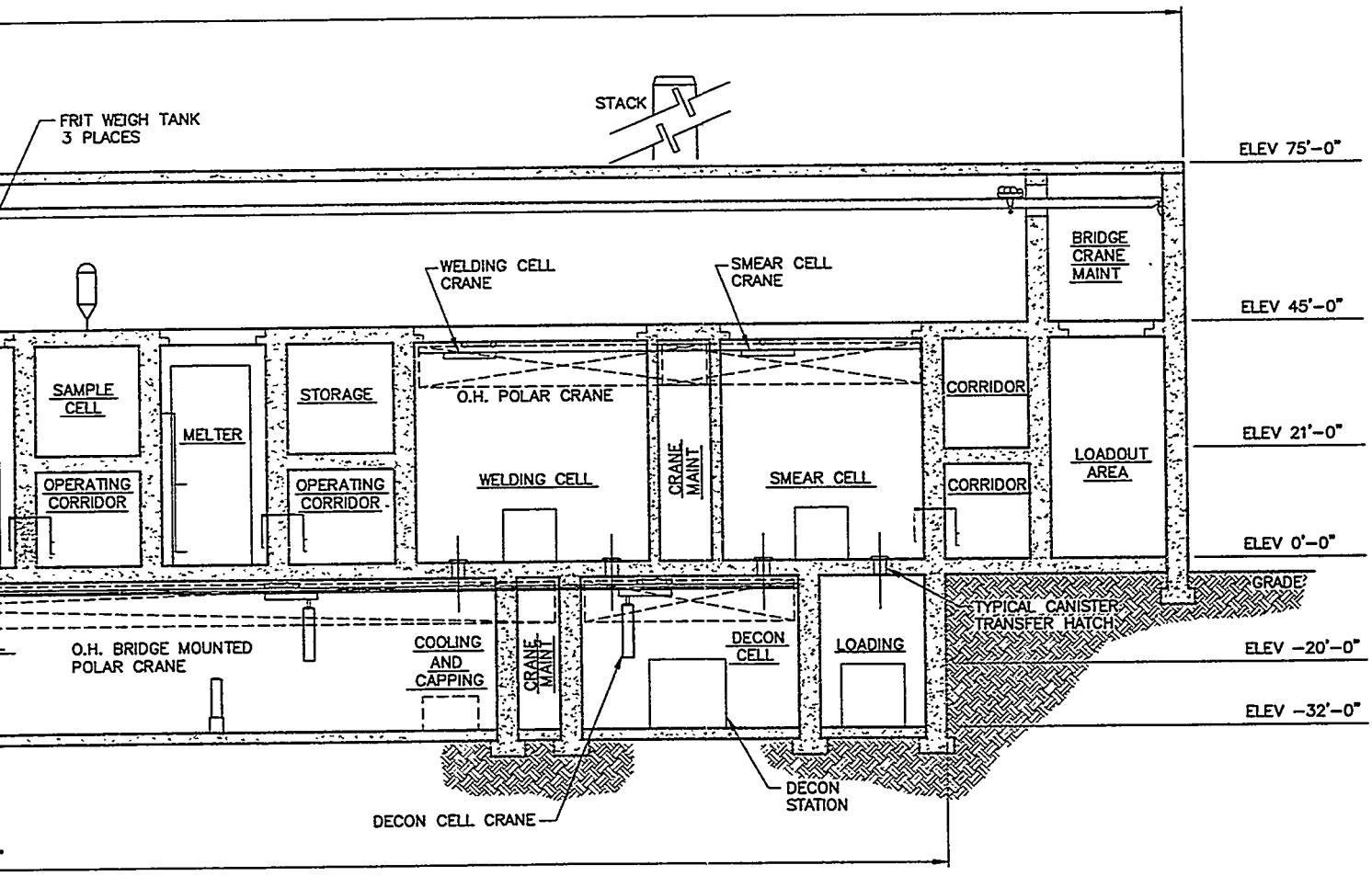
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	DESIGN: T. LANGENWALTER	
	DRAWN: D. BRONSON	
	PROJECT NO.	
	SPEC CODE	
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, Q, ORG 00 530; DWG-; REV
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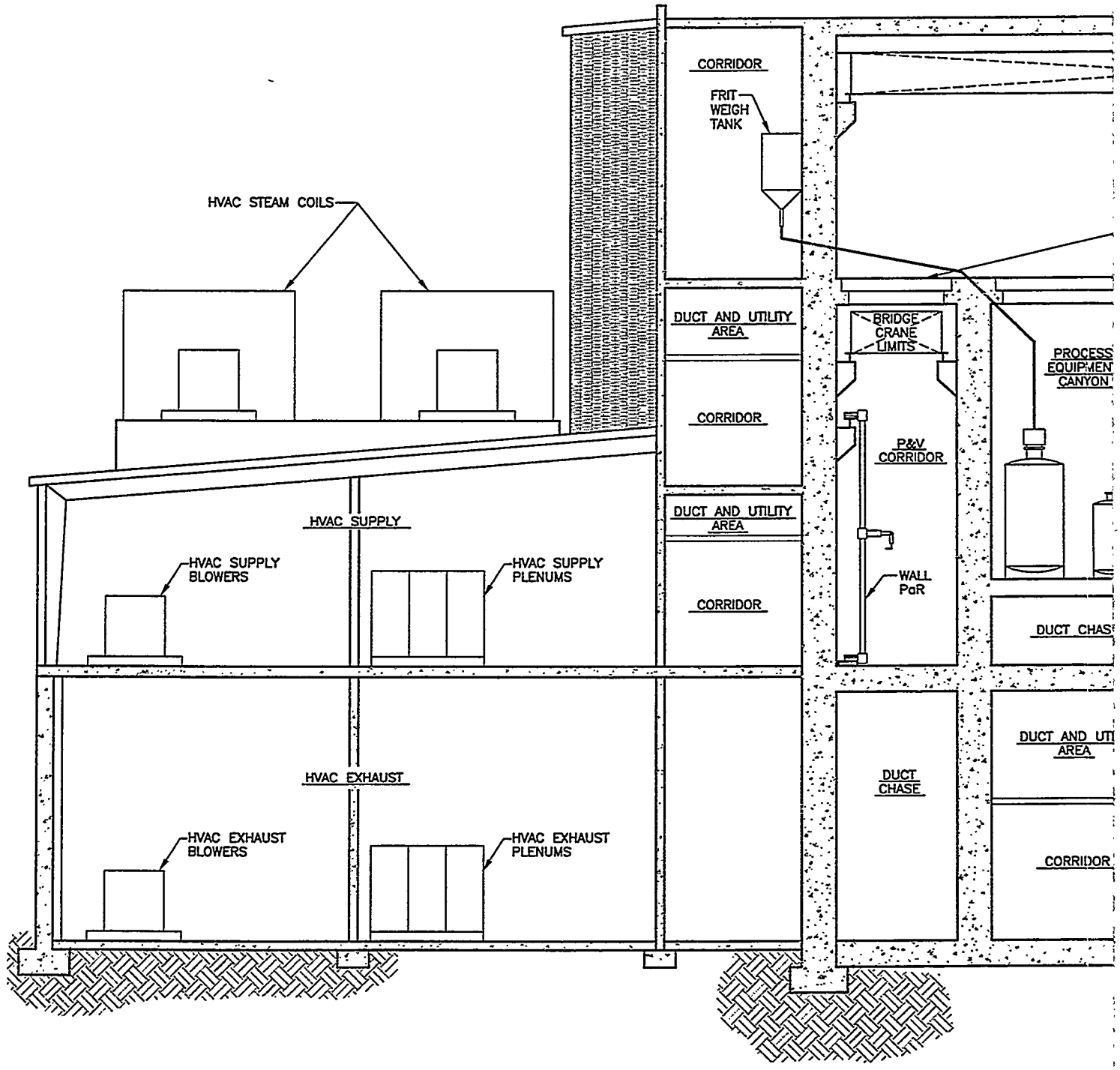
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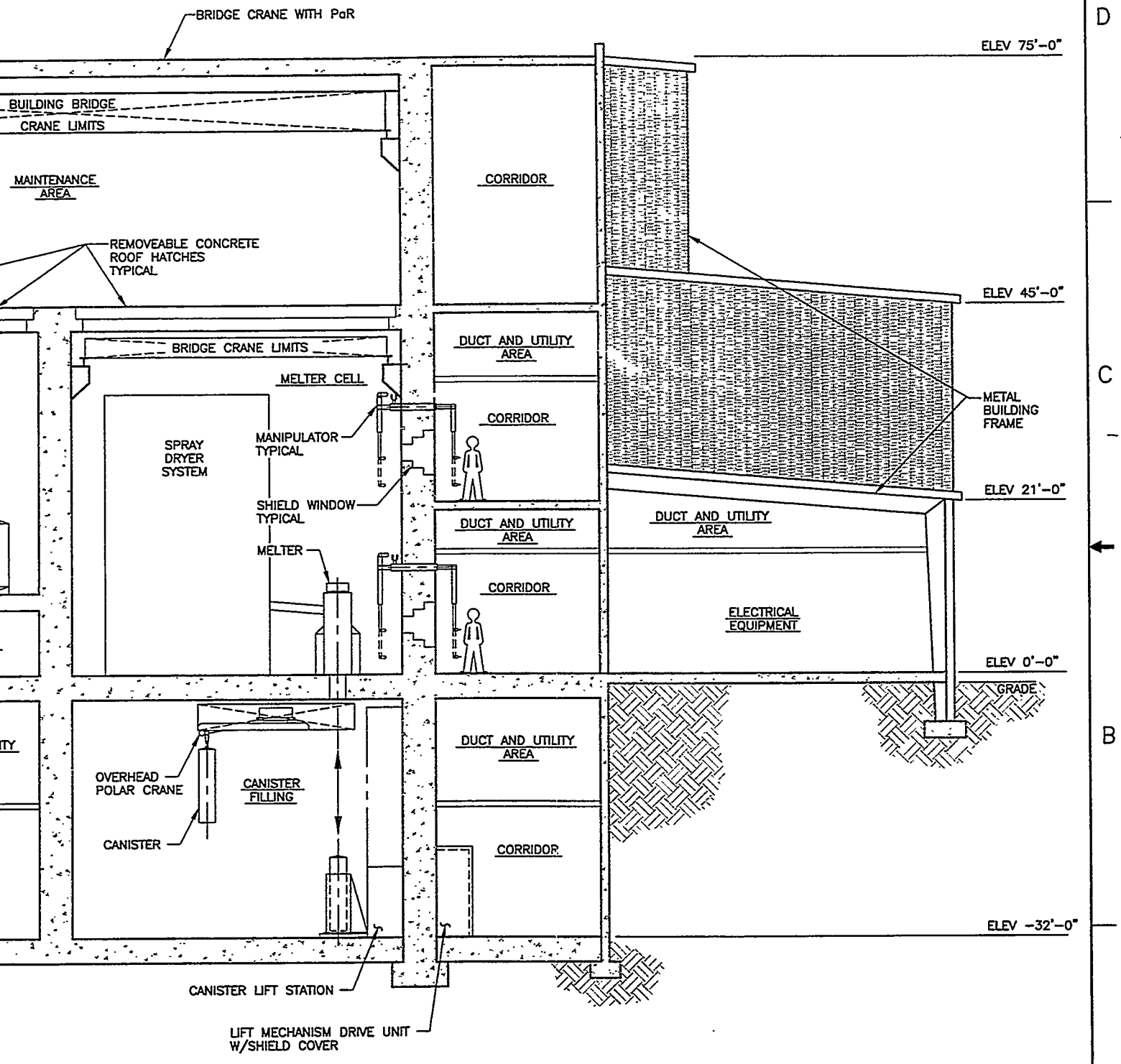


FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
SCALE: 1/16" = 1'-0"	REQUESTER:	INTEC WASTE TREATMENT FACILITY VITRIFIED WASTE OPTION HLW–VITRIFICATION FACILITY BUILDING SECTION
	DESIGN: T. LANGENWALTER	
	DRAWN: D. BRONSON	
	PROJECT NO.	
	SPEC CODE	
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 100, TYPE, SI, ORG 00 530; DWG–; REV
QUALITY LEVEL: 3	EFFECTIVE DATE:	SCALE: 1/16"=1'-0"; SHEET HVF–A–6


CORRIDOR
FRIT WEIGH TANK
HVAC STEAM COILS
DUCT AND UTILITY AREA
BRIDGE CRANE LIMITS
PROCESS EQUIPMEN CANYON
CORRIDOR
P&V CORRIDOR
DUCT AND UTILITY AREA
HVAC SUPPLY
HVAC SUPPLY BLOWERS
HVAC SUPPLY PLENUMS
WALL PaR
CORRIDOR
DUCT CHAS
DUCT AND UTI AREA
DUCT CHASE
HVAC EXHAUST
HVAC EXHAUST BLOWERS
HVAC EXHAUST PLENUMS
CORRIDOR

SECTIO

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



N B TYPICAL

FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
	REQUESTER:	INTEC WASTE TREATMENT FACILITY VITRIFIED WASTE OPTION HLW VITRIFICATION FACILITY BUILDING SECTION
SCALE: 1/8" = 1'-0"	DESIGN: T. LANGENWALTER	
	DRAWN: D. BRONSON	
	PROJECT NO.	
	SPEC CODE	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, CL, ORG 00 530; DWG-; REV
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	
QUALITY LEVEL: 3	EFFECTIVE DATE:	SCALE: 1/8"=1'-0"; SHEET HVF-A-7

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task Non-Separations Alternative

3. Subtask High Level Waste Vitrification Facility

4. Title: Process Calculations

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

This high level waste vitrification feasibility study is based on the use of cold crucible induction-heated melters. While this type of equipment is not in regular production use in this country or in Europe, it has been in pilot-scale development for over a decade in France. The approach is actually an extrapolation of the hot-wall induction design that has been in operation in production facilities in France since 1978.

The facility is intended to process about 151,000 liters of wastewater and about 4,465 cubic meters of calcine and inorganic ion exchange media over a 20-year operating life.

The calcine volume used in this revision of the EDF includes an assumed 150 cubic meter increase in calcine volume to be vitrified. The increase accounts for the operation of the calciner between April, 1999 and June, 2000. The attached material balances have been modified to account for the increase.

The process design is based on conservative design bases and assumptions. The feed system involves slurrying both calcine and liquid waste with frit. A water slurry feed system is the type used at the Defense Waste Processing Facility for feed certification, and it is used in this study because it represents a proven approach to waste certification. The capacities used in throughput calculations are based on the performance of the French hot-wall melters, even though development work has shown that cold crucible melters of similar size are capable of higher throughput. Finally, a relatively low waste loading of calcine in the product glass is assumed. Mathematical modeling indicates that borosilicate glass loaded with 30% calcine should be achievable at a melt temperature of 1,150°C, a value of about 25% was used in material balance calculations. This lower value was chosen because very little development data exist to demonstrate borosilicate glass performance with calcine.

The main advantages of the cold crucible design over the joule-heated melter is the relative ease of changeout when the melter fails. Induction melters are relatively small devices, usually less than 3 feet in diameter and 3-4 feet high. This compares with joule heated melters for radioactive use that are 12-15 feet in diameter and 15-20 feet high. In addition, the cold crucible design allows for a long operating life (at least several years) compared to the 1 year operating life typical of hot-wall induction melters.

6. Distribution (complete package): D.J. Harrell MS 3211, B.R. Helms MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File
Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	R. R. Kimmitt	R. R. Kimmitt	7/30/99
Independent Verification	R	C. M. Barnes	C M Barnes	7/30/99
Requestor	A	D. A. Lopez	D A Lopez	7/30/99

1. Design Requirements
   1.1 The waste to be processed include:
      (a) Newly generated liquid waste produced between 2016 and 2035. The estimated total is 151,000 liters.
      (b) Calcine totaling 4,465 cubic meters
      (c) Spent inorganic ion exchange media from CsIX process, totaling about 10 cubic meters
   1.2 The system is intended to process the entire volume of calcine in 20 years, from the beginning of 2016 to the end of 2035. The system will process calcine for 180 days per year, 24 hours per day. The liquid waste will be campaigned separately during one additional week per year.
   1.3 The vitrification system is based on the use of four (4) cold crucible induction melters operating in parallel. This design allows operation at very high temperatures if necessary (~1,400 °C). However, the melters in this study are intended to operate at 1,150 °C. The throughput for each of the melters is 3 metric tons per day of glass per square meter of melter cross sectional area. This is based on the performance of similar units operated by COGEMA in France.
   1.4 Waste will be drawn from 1 or 2 bins to fill a calcine receiving hopper.
   1.5 Feed material will be prepared on a batch basis in one of three mix tanks. All waste will be prepared as a water slurry to facilitate characterization and certification.
   1.6 Melters will be electrically heated. The power requirements will be equivalent to 2.5MWh per short ton of glass produced.

2. Assumptions
   2.1 Analytical data will be available when needed. It is assumed that data on a given sample can be obtained within 2 days.
   2.2 As many as three frit formulations will be needed to process all of the waste.
   2.3 Approximately 800 scfm of air will be pulled into the headspace of the melters.
   2.4 Calcine waste loading in process glass will be about 25 wt %.

3. Process description
   This study describes the use of induction melters for directly vitrifying calcine and liquid high activity waste. The materials will be processed in separate campaigns. All waste will be combined with frit in the melters to form a borosilicate glass suitable for disposal in the National Geologic Repository[1]. The melters will be operated in batch mode, and glass will be drained directly into stainless steel canisters suitable for disposal.

[1] Waste Acceptance Systems Requirements Document

3.1 Feed Preparation

Calcine will be delivered to the vitrification facility by a pneumatic system that is outside the scope of this EDF[2]. The calcine will be stored in a tank in the facility. The tank can hold enough calcine for up to 8 days of operation. Waste from up to two separate bin sets can be combined in one delivery. Pneumatic systems are included with the storage tank to provide some initial blending of dry calcine and for transferring the calcine to a small weigh vessel. From the weigh vessel, the dry calcine will be weighed and delivered by gravity to one of 3 mix tanks, where it will be combined with water and frit. Each mix tank holds feed material for two days of facility operation. Once dry calcine is fed to a mix tank, water is added, and the resulting slurry is agitated and sampled. Complete blending of the calcine in the receiving tank cannot be guaranteed; therefore, characterization of the calcine in each batch of feed is performed on the calcine in the mix tanks. Once the composition of the calcine is known, the correct amount of the proper frit formulation can be added. This final feed mixture is agitated and sampled for certification. Once the contents of a mix tank have been certified, the entire contents can be transferred to one of two feed tanks. This allows another batch of feed material to be prepared in that mix tank.

Frit is transferred from a silo to a day hopper by conveyor. Each frit composition has a separate silo and weigh vessel. This eliminates the possibility of mixing different frit formulas. The frit is weighed and fed by gravity into the mixing vessels in the same manner as the calcine.

Three mix tanks and two feed tanks are used in the feed system. Each vessel holds enough slurry for two days of facility operation. With this arrangement of tanks, it is highly unlikely that the system would run out of fully certified feed material, even if re-characterization is needed for some batches.

Since newly generated liquid waste is processed in a single campaign each year, a vessel large enough to hold all the liquid waste for a year is provided in the facility. This is an agitated vessel, so representative samples of the raw waste can be obtained from this tank. Once characterized, liquid waste is pumped into a mix tank and frit is added. At this point, the liquid waste slurry is managed in the same way as the calcine slurry.

The feed material is pumped from the feed tanks to a spray drier system. Each of the 4 melters has its own spray drier and dried feed collection hoppers. These units are described in more detail in EDF-HVF-F-004.

3.2 Melter Operation

The melters are water-cooled induction melters similar to those that have been developed in France[3]. The throughput value of 3.03 metric tons per day per square meter is based on the performance of the COGEMA hot wall units currently used in production. Each melter is operated in batch mode. Initially, a load of dried feed is added to the melter, and electric

[2] EDF-WTS-002, "Retrieve Calcine from CSSF's and Deliver it to the Waste Treatment Facility", 01/29/98
[3] ICPP Radioactive Waste HLW Immobilization Treatment Technologies: Numatec Comments and Recommendations, January, 1995

resistance heat is used to begin the melting process. Once the mixture is capable of conducting electricity, current is applied to the induction coils surrounding the melter. This induces a secondary current in the glass, which heats the material to 1,150°C. The nature of the induced current facilitates rapid mixing of the melt by natural circulation. After 6-8 hours of processing, the melt is poured into a canister through a standpipe in the bottom of the melter. Since the standpipe is above the bottom of the melter, a "heel" of molten glass is left. This facilitates the application of induction heating when the next batch of dried feed material is added to the melter. Total cycle time for each melter (load, melt, drain) is expected to be about 13 hours.

3.3 Off-Gas Management
This part of the process is described in EDF-HVF-F-004.

4. Process Flow Diagrams
Process flow diagrams showing the feed and melter systems are included in EDF-HVF-F-004.

5. Calculations

5.1 Feed Material Chemistry and Glass Production Material Balances
Material balances for glass production from liquid waste and from calcine are included below. Three alternatives are shown for processing calcine: zirconia calcine alone, 75% zirconia calcine blended with 25% alumina calcine, and 75% sodium-based calcine blended with 25% alumina calcine. Mathematical modeling has indicated that waste loading in the product glass can be maximized if the alumina calcine is not processed separately, but instead combined with other types of calcine in the ratios shown here[4]. The modeling work indicated that calcine waste loadings of 30% could be achieved. However, this study assumed a calcine waste loading in glass of only about 25% for conservatism. Modeling also shows that liquid waste loading can be as high as 50%, on a dry solids basis[5].

5.2 Melter Throughput and Sizing
The melter capacity values used are based on extrapolation data from the 55-cm hot wall melters that are in current operation in France (Reference 3, Section 2). COGEMA has done pilot scale work with larger melters, up to 120 cm in diameter. Based on this information, the extrapolation to production melters with diameters of 86 cm is considered reasonable. The calculations are shown below.

6. Issues and Uncertainties

6.1 Dry Feed vs. Slurry Feed
Slurry feeding of calcine and frit was selected for this study because of the relatively high probability of achieving good mixing relative to dry mixing of these materials. One significant

[4] Letter, K. Vinjamuri to R. Kimmitt, "Vitrification of Calcine", dated 4/22/98
[5] Letter, K. Vinjamuri to R. Kimmitt, " Direct Vitrification of Sodium-bearing Waste", dated 3/19/98

concern is associated with the difference in density between the calcine and frit. Bulk specific gravity of the former is about 1.4 on average, while frit has a specific gravity closer to 2.5. In a slurry mixing environment, these materials can be engineered to have similar settling velocities, and, hence, similar mixing characteristics. For example, applying the stokes settling equation[6], it can be shown that frit with a particle size range between 80 and 100 microns (0.08 to 0.10 millimeters) has the same settling velocity as calcine with a particle size range between 150 and 180 microns. This settling velocity is about 1.5 feet per minute, well within the range suitable for solids blending[7]. The frit can be ordered from the vendor with the desired particle size distribution. A calcine grinder is included in the system design to produce calcine with the required particle size distribution.

It has not been concluded that the use of slurry is the only way to achieve proper mixing of feed materials for waste certification. However, it is believed that more development work will be needed to demonstrate adequate dry mixing than will be required to demonstrate adequate slurry mixing.

One disadvantage of slurry mixing is the need to remove the water prior to feeding material to the melters. Although development work has been done in France on slurry feeding of induction melters, the production units that have been used for the past 20 years have been fed dry solids directly from a calciner. Because of this the addition of drying systems immediately upstream of the melters was considered necessary. This results in a relatively complex waste feed system compared to the dry feed method, but one that is essentially the same as the design that has been used by the French for 2 decades.

6.2 Settling of Slurry During Pumping

The vitrification facility is large, and the potential exists to settle solids out of suspension as it is pumped from the feed tanks to the dryers. This is a legitimate concern and it is being addressed in the design in several ways. First, each melter will be fed by a separate loop from the feed tanks. This will reduce the distances over which slurry must be pumped. Second, the feed pumping systems include powerful pumps, capable of maintaining the slurry velocity at about 15 feet per second. This will reduce the potential for settling. Finally, equipment is included to flush the feed lines when the they are shut down.

6.3 Number of Melters and Their Capacities

The throughput value used in this study is based on the capacities demonstrated for the "hot wall" melters already in operation. It is recognized that cold crucible melters currently in development have demonstrated higher capacities (Reference 3). However, it must be pointed out that no cold crucible melters are in routine operation in production facilities in France. COGEMA still relies on the hot wall design, even after 10 years of development work on the cold crucible design. Since this is a feasibility study, there has been an emphasis on the adoption of proven techniques instead of methods and equipment still in development.

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[6] Weber, W. J., Jr., Physicochemical Processes for Water Quality Control, Wiley-Interscience, New York, 1972, p. 114
[7] Perry, J. H., ed, Chemical Engineers' Handbook, 4th ed., McGraw-Hill, New York, 1963, p. 19-12

The selection of the cold crucible design itself introduces some uncertainty into the project. Since this equipment has been in testing for about a decade in France and elsewhere, it is considered an acceptable design risk. In addition, the cold crucible design offers the potential for extremely long operating life compared to the proven hot wall induction melter. The hot-wall units last only 4,000 to 6,000 hours in operation before they must be replaced. However, the replacement of an induction melter is a straight-forward process compared to removal of a joule-heated unit. The French have reduced it to a 2-3 day exercise. Decontamination and decommissioning is also easier because of the melters small size and relative simplicity of design.

If induction melters are ultimately selected for processing high level waste from INTEC, a substantial development program will have to be undertaken to demonstrate their performance and reliability.

6.4 Pre-blending of Calcine with Frit

It has been suggested that calcine and frit need not be pre-blended before feeding these materials to the melters. In theory, these materials will be adequately mixed and will produce acceptable glass if only they are fed to the melters in the proper proportions. However, there are several arguments against using this method until it can be demonstrated in a development program. First, the induction melters are much smaller than their joule-heated counterparts, and the residence time of the melt is much lower. Even though induction melters generate more vigorous convection mixing than the joule heated units, intimate mixing of calcine and frit before they are fed gives an additional margin of assurance that a proper melt composition. Of course, extending the residence time of the melt would have the same effect. Development work would be required to validate this method of feeding waste. The feed system for this study is based on the techniques proven effective at the Defense Waste Processing Facility.

Assumed Composition of Newly Generated Liquid Waste, 2016-2035														
Source	Capacity, liters	Mass, kgrams	H+, g/l	NO3, g/l	Al, g/l	B, g/l	Cd, g/l	Ca, g/l	Cl, g/l	Cr, g/l	F, g/l	Fe, g/l	Pb, g/l	Mn, g/l
New Generation (2016 - 2035)	150,594	195,772	2.49	399.65	17.44	0.24	0.35	2.69	0.72	0.06	1.3	1.09	0.06	0.2
Source	Capacity, liters	Hg, g/l	Mo, g/l	Ni, g/l	PO4, g/l	K, g/l	Na, g/l	SO4, g/l	Zr, g/l	UDS, g/l	U, mg/l	H2O, g/l		
New Generation (2016 - 2035)	150,594	0.05	0.02	0.04	0.15	8.22	32.2	3.41	0.24	4.47				
Source	Capacity, liters	Mass, kg	H+, kg	NO3, kg	Al, kg	B, kg	Cd, kg	Ca, kg	Cl, kg	Cr, kg	F, kg	Fe, kg	Pb, kg	Mn, kg
Newly Generated (2016-2035)	150,594	195,772	375	60,185	2,626	36	53	405	108	9	196	164	9	30
Source	Capacity, liters	Hg, kg	Mo, kg	Ni, kg	PO4, kg	K, kg	Na, kg	SO4, kg	Zr, kg	SS, kg	U, kg	H2O, kg	Total Solids, kg	Total Mass, kg
New Gen Waste (2016 - 2035)	150,594	8	3	6	23	1,238	4,849	514	36	673	-	124,226	71,546	195,772

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Fate of Liquid Waste Chemical Species in the Melter**												
2													
3	This spreadsheet takes the bulk chemical composition of liquid waste and converts it to oxides and gas												
4	The results of these calculations are used in the other worksheet in this file												
5	The daily rate is based on a total of 100 days of operation with liquids (5 days/yr for 20 years)												
6	Species in Liquid	Mass, lbs	MW	Lb-Moles of Species	Product	MW of Product	Lb-moles of Product	Lbs of Product	Lbs of Product per Day	Lb-moles of O2 in Original Species	Lb-Moles O2 in Product	Moles O2 Released During Vitrification	Lbs O2 Released During Vitrification
7													
8	H	825	1	825	H2O	18	383	6,896	68.96	-	192	(192)	(6,129)
9	NO3	132,407	62	2,136	NO2	46	1,068	49,119	491.19	1,602	1,068	534	17,085
10					NO	30	1,068	32,034	320.34	1,602	534	1,068	34,169
11	Al	5,778	27	214	Al2O3	102	107	10,914	109.14	-	160	(160)	(5,136)
12	B	80	10.8	7	B2O3	69.6	4	256	2.56	-	6	(6)	(177)
13	Cd	116	112.4	1	CdO	128.4	1	132	1.32	-	1	(1)	(17)
14	Ca	891	40.1	22	CaO	56.1	22	1,247	12.47	-	11	(11)	(356)
15	Cl	239	35.5	7	HCl	36.5	7	245	2.45	-	-	-	-
16	Cr	20	52	0	Cr2O3	152	0	29	0.29	-	0	(0)	(9)
17	F	431	19	23	HF	20	23	453	4.53	-	-	-	-
18	Fe	361	55.8	6	Fe2O3	159.6	3	516	5.16	-	5	(5)	(155)
19	UDS (Assume CaF2)	1,481	78.1	19	CaF2	78.1	19	1,481	14.81	-	-	-	-
20	Pb	20	207.2	0	PbO	223.2	0	21	0.21	-	0	(0)	(2)
21	Mn	66	54.9	1	MnO2	86.9	1	105	1.05	-	1	(1)	(39)
22	Hg	17	200.6	0	Hg	200.6	0	17	0.17	-	-	-	-
23	H2O	273,298	18	15,183	H2O	18	15,183	273,298	2,732.98	7,592	7,592	-	-
24	Mo	7	95.9	0	MoO3	143.9	0	10	0.10	-	0.10	(0)	(3)
25	Ni	13	58.7	0	NiO	74.7	0	17	0.17	-	0.11	(0)	(4)
26	PO4	50	95	1	P2O5	270	0	71	0.71	1.05	0.65	0	13
27	K	2,723	39.1	70	K2O	94.2	35	3,281	32.81	-	17.41	(17)	(557)
28	Na	10,668	23	464	Na2O	62	232	14,379	143.79	-	115.96	(116)	(3,711)
29	SO4	1,130	96.1	12	SO2	64.1	12	754	7.54	23.51	12	12	376
30	U	-	238	-	U3O8	842	-	-	-	-	-	-	-
31	Zr	80	91.2	1	ZrO2	123.2	1	107	1.07	-	1	(1)	(28)
32													
33	Total, lb	430,699						395,381	3,954	10,820	9,716	1,104	35,321
34	Total, kg	195,772											

Feed Rate, lbs. per day dry solids	326		Fraction of solids from liquid waste in product	0.50							
Total Feed Rate, lbs. per day Frit + Liquid Waste	4,633	This assumed a processing campaign of 5 days for liquid waste once each year.									
Waste Composition	wt. %	lbs. per day	Additive Composition	wt%	lbs. per day	Glass Composition	wt.%	lbs. per day	Off-Gas Composition	wt%	lbs. per day
			Mass of Frit Added		326						
Al2O3	33.51%	109				Al2O3	16.75%	109	NO2	12.34%	491
Al2(SO4)3	0.00%	-				Al2(SO4)3	0.00%	-	H2O	70.38%	2,802
AlPO4	0.00%	-				AlPO4	0.00%	-	HF	0.11%	5
B2O3	0.79%	3	B2O3	20%	65	B2O3	10.40%	68	HCl	0.06%	2
CaCO3	0.00%	-				CaCO3	0.00%	-	Hg	0.00%	0
CaF2	4.55%	15				CaF2	2.27%	15	SO2	0.19%	8
CaO	3.83%	12				CaO	1.91%	12	O2	8.87%	353
Ca3(PO4)2	0.00%	-				Ca3(PO4)2	0.00%	-	NO	8.05%	320
CdO	0.41%	1				CdO	0.20%	1			
Cr2O3	0.09%	0				Cr2O3	0.04%	0			
CuO	0.00%	-				CuO	0.00%	-			
Fe2O3	1.59%	5				Fe2O3	0.79%	5			
Gd2O3	0.00%	-				Gd2O3	0.00%	-			
H2O	0.00%	-				H2O	0.00%				
H3BO3	0.00%	-				H3BO3	0.00%	-			
HgO	0.00%	-				HgO	0.00%	-			
KAlO2	0.00%	-				KAlO2	0.00%	-			
K2O	10.07%	33				K2O	5.03%	33			
K2SO4	0.00%	-				K2SO4	0.00%	-			
Li2O	0.00%	-				Li2O	0.00%	-			
Li2CO3	0.00%	-				Li2CO3	0.00%	-			
MgO	0.00%	-				MgO	0.00%	-			
MgCO3	0.00%	-				MgCO3	0.00%	-			
MnO	0.32%	1				MnO	0.16%	1			
MoO3	0.03%	0				MoO3	0.02%	0			
Na2O	44.15%	144				Na2O	22.06%	144			
NaAlO2	0.00%	-				NaAlO2	0.00%	-			
NaCl	0.00%	-				NaCl	0.00%	-			
Na2CO3	0.00%	-				Na2CO3	0.00%	-			
Na2B4O7	0.00%	-				Na2B4O7	0.00%	-			
NaF	0.00%	-				NaF	0.00%	-			
NaNO3	0.00%	-				NaNO3	0.00%	-			
Na3(PO4)2	0.00%	-				Na3(PO4)2	0.00%	-			
Na2SO4	0.00%	-				Na2SO4	0.00%	-			
Nb2O5	0.00%	-				Nb2O5	0.00%	-			
NiO	0.05%	0				NiO	0.03%	0			
P2O5	0.22%	1				P2O5	0.11%	1			
PbO	0.07%	0				PbO	0.03%	0			
SiO2	0.00%	-	SiO2	80%	261	SiO2	40.02%	261			
SnO2	0.00%	-				SnO2	0.00%	-			
U3O8	0.00%	-				UO2	0.00%	-			
ZrO2	0.33%	1				ZrO2	0.16%	1			
Total	100%	326	Total	100%	326	Total	100.00%	652		100%	3,981

100 % Zr Calcine

Feed Rate, lbs. per day Dry Calcine	3,551		Fraction of Calcine in Product	0.255											
Feed Rate, lbs. Per day, Calcine + Frit Slurry	35,252														
Calcine Composition	wt. %	lbs. per day	Frit Composition	wt%	lbs. per day				Product Composition	wt.%	lbs. per day		Off-Gas Composition	wt. %	lbs. per day
			Mass of Frit Used	100%	10,550	Mass of Slurry Water, lbs./day	21,151								
Al2O3	13.7	486							Al2O3	3.49%	486		O2	0.09%	19
Al2(SO4)3	0	-							Al2(SO4)3	0.00%	-		CO2	0.00%	-
AlPO4	0	-							AlPO4	0.00%	-		H2O	99.40%	21,204
B2O3	2.35	83	B2O3	18.0%	1,899				B2O3	14.24%	1,982		Hg	0.01%	2
CaCO3	0	-							CaCO3	0.00%	-		NO2	0.51%	108
CaF2	45	1,598							CaF2	11.48%	1,598		SO2	0.00%	-
CaO	13.41	476							CaO	3.42%	476				
Ca3(PO4)2	0	-							Ca3(PO4)2	0.00%	-				
CdO	0	-							CdO	0.00%	-				
Cr2O3	0.38	13							Cr2O3	0.10%	13				
CuO	0	-	CuO	0.0%	-				CuO	0.00%	-				
Fe2O3	0.53	19							Fe2O3	0.14%	19				
Gd2O3	0.01	0							Gd2O3	0.00%	0				
H2O	1.5	53				H2O	21,151		H2O	0.00%					
H3BO3	0	-							H3BO3	0.00%	-				
HgO	0.05	2							HgO	0.00%	-				
KAlO2	0.8	28							KAlO2	0.20%	28				
K2O	0	-							K2O	0.00%	-				
K2SO4	0	-							K2SO4	0.00%	-				
Li2O	0	-	Li2O	5.0%	528				Li2O	3.79%	528				
Li2CO3	0	-							Li2CO3	0.00%	-				
MgO	0	-							MgO	0.00%	-				
MgCO3	0	-							MgCO3	0.00%	-				
MnO	0	-							MnO	0.00%	-				
MoO3	0	-							MoO3	0.00%	-				
Na2O	0	-	Na2O	17.0%	1,794				Na2O	13.41%	1,866				
NaAlO2	1.09	39							NaAlO2	0.28%	39				
NaCl	0	-							NaCl	0.00%	-				
Na2CO3	0	-							Na2CO3	0.00%	-				
Na2B4O7	0	-							Na2B4O7	0.00%	-				
NaF	0	-							NaF	0.00%	-				
NaNO3	5.61	199							NaNO3	0.00%	-				
Na3(PO4)2	0	-							Na3(PO4)2	0.00%	-				
Na2SO4	0	-							Na2SO4	0.00%	-				
Nb2O5	0	-							Nb2O5	0.00%	-				
NiO	0	-							NiO	0.00%	-				
P2O5	0	-							P2O5	0.00%	-				
PbO	0	-							PbO	0.00%	-				
SiO2	0	-	SiO2	60.0%	6,330				SiO2	45.48%	6,330				
SnO2	0.22	8							SnO2	0.06%	8				
UO2	0	-							UO2	0.00%	-				
ZrO2	15.35	545							ZrO2	3.92%	545				
Total	100.00	3,551	Total	100.0%	10,550	Total	21,151		Total	100.00%	13,919		Total	100%	21,333
Generation of CO2															
from MgCO3		-													
from Na2CO3		-													
from CaCO3		-													
from Li2CO3		-													
Total CO2		-													

Calcine Composition	wt. %	lbs. per day	Frit Composition	wt%	lbs. per day			Product Composition	wt.%	lbs. per day	Off-Gas Composition	wt. %	lbs. per day
			Mass of Frit Used	100%	10,550	Mass of Slurry Water, lbs./day	21,151						
Generation of O2													
from HgO		0											
from Na2SO4		-											
from NaNO3		19											
from K2SO4		-											
from Al2(SO4)3		-											
Total O2		19											
Generation of NO2													
from NaNO3		108											
Generation of SO2													
from Na2SO4		-											
from Al2(SO4)3		-											
from K2SO4		-											
Total SO2		-											
Generation of Hg													
from HgO		2											
Generation of H2O													
from H3BO3		-											
Chemical Reactions													
MgCO3 -> MgO + CO2 [300 - 600 C]													
Na2CO3 -> Na2O + CO2 [about 850 C]													
Na2B4O7 -> Na2O + 2B2O3													
Li2CO3 -> Li2O + CO2 [about 1310 C]													
CaCO3 -> CaO + CO2 [400 - 900 C]													
Na2SO4 -> Na2O + SO2 + 0.5O2 [900 - 1200 C]													
Al2(SO4)3 -> Al2O3 + 3SO2 + 1.5O2 [about 770 C]													
K2SO4 -> K2O + SO2 + 0.5O2 [<500 C]													
2NaNO3 -> Na2O + 2NO2 + 0.5O2 [about 380 C]													
2Na3PO4 -> 3Na2O + P2O5 [<300 C]													
2H3BO3 -> B2O3 + 3H2O [greater than 300 C]													
Notes:													
1. Calcine composition is from Garcia, R., "Waste Inventories/Characterization Study (Draft)", May 1, 1997, Table 3f, page 25.													
2. Additive composition based on Frit # 127. See Staples, B.A., et.al., "Properties of Formula 127 Glass Prepared with Radioactive Zirconia Calcine", ENICO-1120, 9/82, page 4.													
3. Amount of frit used is based on upper limit of 33.3% waste loading. See Cole, H.S., et. al., "Properties of Vitrified ICPP Zirconia Calcine", ENICO-1038, 7/80, page iv.													

75 % Zr Calcine with 25 % Al Calcine

Feed Rate, lbs. per day	3,551		Fraction of Calcine in Product	0.254										
Total Feed Rate, lbs/day (Calcine + Frit + Water)	35,502													
Calcine Composition	wt. %	lbs. per day	Frit Composition	wt%	lbs. per day			Product Composition	wt.%	lbs. per day	Off-Gas Composition	wt. %	lbs. per day	
			Mass of Frit Used	100%	10,650	Mass of Water Slurry, lbs/day	21,301							
Al2O3	31.95	1,134						Al2O3	8.16%	1,141	O2	0.10%	23	
Al2(SO4)3	0.59	21						Al2(SO4)3	0.00%	-	CO2	0.00%	-	
AlPO4	0.03	1						AlPO4	0.01%	1	H2O	99.25%	21,354	
B2O3	1.93	69	B2O3	18.0%	1,917			B2O3	14.20%	1,986	Hg	0.12%	26	
CaCO3	0	-						CaCO3	0.00%	-	NO2	0.46%	100	
CaF2	33.75	1,198						CaF2	8.57%	1,198	SO2	0.06%	12	
CaO	10.06	357						CaO	2.55%	357				
Ca3(PO4)2	0	-						Ca3(PO4)2	0.00%	-				
CdO	0	-						CdO	0.00%	-				
Cr2O3	0.29	10						Cr2O3	0.07%	10				
CuO	0	-	CuO	0.0%	-			CuO	0.00%	-				
Fe2O3	0.45	16						Fe2O3	0.11%	16				
Gd2O3	0.01	0						Gd2O3	0.00%	0				
H2O	1.5	53				H2O	21,301	H2O	0.00%					
H3BO3	0	-						H3BO3	0.00%	-				
HgO	0.8	28						HgO	0.00%	-				
KAlO2	0.6	21						KAlO2	0.15%	21				
K2O	0	-						K2O	0.01%	1				
K2SO4	0.04	1						K2SO4	0.00%	-				
Li2O	0	-	Li2O	5.0%	533			Li2O	3.81%	533				
Li2CO3	0	-						Li2CO3	0.00%	-				
MgO	0	-						MgO	0.00%	-				
MgCO3	0	-						MgCO3	0.00%	-				
MnO	0	-						MnO	0.00%	-				
MoO3	0	-						MoO3	0.00%	-				
Na2O	0	-	Na2O	17.0%	1,811			Na2O	13.47%	1,884				
NaAlO2	0.82	29						NaAlO2	0.21%	29				
NaCl	0	-						NaCl	0.00%	-				
Na2CO3	0	-						Na2CO3	0.00%	-				
Na2B4O7	0	-						Na2B4O7	0.00%	-				
NaF	0	-						NaF	0.00%	-				
NaNO3	5.19	184						NaNO3	0.00%	-				
Na3(PO4)2	0.33	12						Na3(PO4)2	0.00%	-				
Na2SO4	0	-						Na2SO4	0.00%	-				
Nb2O5	0	-						Nb2O5	0.00%	-				
NiO	0	-						NiO	0.00%	-				
P2O5	0	-			-			P2O5	0.04%	5				
PbO	0	-						PbO	0.00%	-				
SiO2	0	-	SiO2	60.0%	6,390			SiO2	45.69%	6,390				
SnO2	0.17	6						SnO2	0.04%	6				
TiO2	0		TiO2	0.0%	-			TiO2	0.00%	-				
UO2	0							UO2	0.00%	-				
ZrO2	11.51	409						ZrO2	2.92%	409				
Total	100.0	3,551	Total	100.0%	10,650	Total	21,301	Total	100.00%	13,987	Total	100%	21,515	
Generation of CO2														
from MgCO3		-												
from Na2CO3		-												
from CaCO3		-												

Calcine Composition	wt. %	lbs. per day	Frit Composition	wt%	lbs. per day			Product Composition	wt.%	lbs. per day	Off-Gas Composition	wt. %	lbs. per day
from LI2CO3		-											
Total CO2		-											
Generation of O2													
from HgO		2											
from Na2SO4		-											
from NaNO3		17											
from K2SO4		0											
from Al2(SO4)3		3											
Total O2		23											
Generation of NO2													
from NaNO3		100											
Generation of SO2													
from Na2SO4		-											
from Al2(SO4)3		12											
from K2SO4		1											
Total SO2		12											
Generation of Hg													
from HgO		26											
Generation of H2O													
from H3BO3		-											
Chemical Reactions													
MgCO3 -> MgO + CO2 [300 - 600 C]													
Na2CO3 -> Na2O + CO2 [about 850 C]													
Na2B4O7 -> Na2O + 2B2O3													
LI2CO3 -> LI2O + CO2 [about 1310 C]													
CaCO3 -> CaO + CO2 [400 - 900 C]													
Na2SO4 -> Na2O + SO2 + 0.5O2 [900 - 1200 C]													
Al2(SO4)3 -> Al2O3 + 3SO2 + 1.5O2 [about 770 C]													
K2SO4 -> K2O + SO2 + 0.5O2 [<500 C]													
2NaNO3 -> Na2O + 2NO2 + 0.5O2 [about 380 C]													
2Na3PO4 -> 3Na2O + P2O5 [<300 C]													
2H3BO3 -> B2O3 + 3H2O [greater than 300 C]													
Notes:													
1. Calcine composition is from Garcia, R., "Waste Inventories/Characterization Study (Draft)", May 1, 1997, Table 3f, page 25.													
2. Additive and product composition based on Frit # 283. See Brotzman, J.R., "Vitrification of High-level Alumina Nuclear Waste", ENICO-1040, 6/80, Page 9.													
3. Amount of frit used is based on 23% waste loading. See Brotzman, page 9.													

75 % SBW Calcine with 25 % Al Calcine

Feed Rate, lbs. per day	3,551		Fraction of Calcine in Product	0.256										
Total Feed Rate, lbs/day (Calcine + Frit + Water)	35,627													
Calcine Composition	wt. %	lbs. per day	Additive Composition	wt%	lbs. per day			Product Composition	wt.%	lbs. per day		Off-Gas Composition	wt. %	lbs. per day
			Mass of Frit Added		10,700	Mass of Slurry Water, lbs/day	21,376							
Al2O3	33.53	1,190.65						Al2O3	8.57%	1,191		O2	0.21%	45
Al2(SO4)3	0.59	20.95						Al2(SO4)3	0.00%	-		CO2	0.00%	-
AlPO4	0.03	1.07						AlPO4	0.01%	1		H2O	98.62%	21,429
B2O3	1.87	66.40	B2O3	18%	1,926			B2O3	14.34%	1,992		Hg	0.14%	30
CaCO3	0	-						CaCO3	0.00%	-		NO2	0.79%	171
CaF2	31.38	1,114.21						CaF2	8.02%	1,114		SO2	0.24%	53
CaO	6.65	236.12						CaO	1.70%	236				
Ca3(PO4)2	0.01	0.36						Ca3(PO4)2	0.00%	0				
CdO	1.88	66.75						CdO	0.48%	67				
Cr2O3	0.09	3.20						Cr2O3	0.02%	3				
CuO	0	-						CuO	0.00%	-				
Fe2O3	0.48	17.04						Fe2O3	0.12%	17				
Gd2O3	0	-						Gd2O3	0.00%	-				
H2O	1.5	53.26						H2O	0.00%					
H3BO3	0	-						H3BO3	0.00%	-				
HgO	0.9	31.96						HgO	0.00%	-				
KAlO2	0	-						KAlO2	0.00%	-				
K2O	0	-						K2O	0.19%	26				
K2SO4	1.37	48.64						K2SO4	0.00%	-				
Li2O	0	-	Li2O	5%	535			Li2O	3.85%	535				
Li2CO3	0	-						Li2CO3	0.00%	-				
MgO	0	-						MgO	0.00%	-				
MgCO3	0	-						MgCO3	0.00%	-				
MnO	0.02	0.71						MnO	0.01%	1				
MoO3	0	-						MoO3	0.00%	-				
Na2O	0	-	Na2O	17%	1,819			Na2O	14.13%	1,964				
NaAlO2	0.65	23.08						NaAlO2	0.17%	23				
NaCl	0	-						NaCl	0.00%	-				
Na2CO3	0	-						Na2CO3	0.00%	-				
Na2B4O7	0	-						Na2B4O7	0.00%	-				
NaF	0	-						NaF	0.00%	-				
NaNO3	8.91	316.37						NaNO3	0.00%	-				
Na3(PO4)2	0.33	11.72						Na3(PO4)2	0.00%	-				
Na2SO4	1.47	52.20						Na2SO4	0.00%	-				
Nb2O5	0.2	7.10						Nb2O5	0.05%	7				
NiO	0.01	0.36						NiO	0.00%	0				
P2O5	0	-						P2O5	0.04%	5				
PbO	0	-						PbO	0.00%	-				
SiO2	0	-	SiO2	60%	6,420			SiO2	46.21%	6,420				
SnO2	0.11	3.91						SnO2	0.03%	4				
UO2	0.01	0.36						UO2	0.00%	0				
ZrO2	8.04	285.48						ZrO2	2.05%	285				
Total	100.03	3,552	Total	100%	10,700			Total	100.00%	13,893		Total	100%	21,729
Generation of CO2														
from MgCO3		-												
from Na2CO3		-												

Calcine Composition	wt. %	lbs. per day	Additive Composition	wt%	lbs. per day	Product Composition	wt.%	lbs. per day	Off-Gas Composition	wt. %	lbs. per day
from CaCO3		-									
from Li2CO3		-									
Total CO2		-									
Generation of O2											
from HgO		2									
from Na2SO4		6									
from NaNO3		29.78									
from K2SO4		4									
from Al2(SO4)3		3									
Total O2		45									
Generation of NO2											
from NaNO3		171									
Generation of SO2											
from Na2SO4		24									
from Al2(SO4)3		12									
from K2SO4		18									
Total SO2		53									
Generation of Hg											
from HgO		30									
Generation of H2O											
from H3BO3		-									
Chemical Reactions											
MgCO3 -> MgO + CO2 [300 - 600 C]											
Na2CO3 -> Na2O + CO2 [about 850 C]											
Na2B4O7 -> Na2O + 2B2O3											
Li2CO3 -> Li2O + CO2 [about 1310 C]											
CaCO3 -> CaO + CO2 [400 - 900 C]											
Na2SO4 -> Na2O + SO2 + 0.5O2 [900 - 1200 C]											
Al2(SO4)3 -> Al2O3 + 3SO2 + 1.5O2 [about 770 C]											
K2SO4 -> K2O + SO2 + 0.5O2 [<500 C]											
2NaNO3 -> Na2O + 2NO2 + 0.5O2 [about 380 C]											
2Na3PO4 -> 3Na2O + P2O5 [<300 C]											
2H3BO3 -> B2O3 + 3H2O [greater than 300 C]											
Notes:											
1. Calcine composition is from Garcia, R., "Waste Inventories/Characterization Study (Draft)", May 1, 1997, Table 3f, page 25.Bin Set 5											
2. Additive and product compositions based on Vinjamuri, K., "Glass waste Forms for the Na-Bearing High Activity Waste Fractions", INEL-95/0214, June, 1995, Tables 6 & 7.											

Induction Melter Design Parameters

Melter Diameter, m	Melter Crossectional Area, m^2	Melter Length, m	Volume, m^3	Throughput, lbs/hr	Throughtput, m^3/hr	Throughput, lbs/day	Throughput, meteric tons/day-m^2	Residence Time, hrs.	Required Facility Throughput, lbs/day	Number of Parallel Melters Required
0.55	0.24	0.70	0.17	66	0.012	1,584	3.03	13.88	13,900	8.78
1.00	0.79	0.70	0.55	218	0.040	5,236	3.03	13.88	13,900	2.65
0.82	0.53	0.70	0.37	147	0.027	3,521	3.03	13.88	13,900	3.95

Notes:

1. The 0.55 meter melters are the ones currently in use in the production facility at Marcoule, France.
2. The data on the 1.00 meter unit are based on development work in France.
3. We chose the 0.82 meter size as the basis for our design.
4. Note that the throughput in metric tons per day per square meter of surface area is 3 - 6 times the value obtainable with joule-heated melters. These melters have high output for their size. The problem is that the laws of physics (induced currents) limit the practical size.

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task Non-Separations Alternative

3. Subtask High-Level Waste Vitrification Facility

4. Title: Offgas Treatment System

5. Summary:

The process description for the feasibility of meeting MACT for the HLW-Vitrification offgas was developed and is presented in basic engineering format documentation. This process has a design basis for treating the HLW-Vitrification off gas by use of proven and demonstrated technology where available and applicable. Documentation, up to and including vendor literature and cost estimates, is provided for this process description. Where alternative technologies are compared for making a feasible selection, the rationale for making the selection is provided. The process description is presented schematically on process flow diagrams (PFDs) which are discussed in Sections 1 and 2 of the attached report. Mass balances are shown on the PFDs that were derived from process simulation modeling using the ASPEN Plus model and a corresponding data base of physical properties from HSC Chemistry for Windows (v.,2.03) which contains data for more than 7,600 compounds for gas, solid, liquid and aqueous phases. The offgas treatment process is based upon a number of key assumptions which are presented in Section 3 of the attached report. The process consists of the following unit operations/steps: offgas collection, off gas flow control, offgas cooling, HF removal via dry scrubbing with lime, fines removal baghouse, Hg removal via GAC/S adsorption, Hg recovery/GAC treatment, HEPA filtration, NOx removal via Selective Catalytic Reduction (SCR) with NH-3 reaction and treated gas blower discharge to atmosphere

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	W. J. Prendergast	W. J. Prendergast	7-27-99
Independent Verification	R	R. R. Kimmitt	R. R. Kimmitt	7/29/99
Requestor	A	D. A. Lopez	D. A. Lopez	7/30/99

1.0 INTRODUCTION

An assessment of the feasibility of controlling the High Level Waste Vitrification (HLW-Vit) offgas to comply with the maximum achievable control technology (MACT) limits was performed. This assessment required that an off gas composition and an offgas flowrate be estimated from three sources of offgas generation. Since these three sources are expected to exist in the HLW-Vit process (See PFDs HVF-P-01, HVF-P-02, and HVF-P-03 as listed below) it was necessary to determine a reasonable design basis for the flow and composition from each source. The primary source of the offgas is generated from air leakage into the induction-heated vitrification melters; during the vitrification melting operation. These melters operate under a moderate vacuum of approximately 42 to 69 inches of water column which induces or promotes air inleakage through all the vessel nozzle flanges.. The second source of the offgas is to be generated from all tanks and process vessels during the normal operating venting due to heating and filling. These vents are collected and ducted into the offgas treatment system to comply with MACT. The third source of the offgas generation is air emissions from the pneumatic conveying of the dried waste mix into feed hoppers mounted above the vitrification melters. This third source is assumed to be a very small air stream with very little contaminants present and has therefore been neglected for this feasibility study. An important premise of this design is the use of a totally enclosed circulation loop of gas for the vitrifier feed slurry drying. This drying is accomplished by the use of spray dryers and the closed loop gas stream is an option proposed by an equipment manufacturer, Swenson Process Equipment. An equivalent dryer manufacturer could be selected. The HLW-Vit Off gas process description for the feasibility study is based upon a vitrification waste mixture made up of 9.8 wt. % calcine, 30.2 wt. % frit and 60 wt. % water. The calcine type that is the basis for the feasibility study off gas is a solid calcine consisting of 75 wt % zirconium calcine and 25 wt % aluminum calcine (Reference 1). Process simulation using ASPEN Plus modeling was performed for this feasibility study and mass and energy balances were generated to support the process description (Reference 13). The process simulation was used to assist in the development of an integrated process for MACT compliance. Based upon the level of detail needed and the deliverable timing, this effort is not a detailed design effort. This effort is intended to provide the basic engineering identification of a feasible treatment process based on best available technologies that comply with the MACT criteria.

The HLW-Vit Offgas process description is integrated into the overall HLW-Vit process flow on three process flow diagrams as follows:

PFD sheet number HVF-P-01; HLW Vitrification-G lass Frit & HLW Vitrification Calcine Process Flow Diagram (Attachment no. 1)

PFD sheet number HVF-P-02; HLW Vitrification Waste Feed and Vitrification Process Flow Diagram (Attachment no. 2)

PFD sheet number HVF-P-03; HLW-Vitrification- Offgas Process Flow Diagram (Attachment no. 3)

Note: The simulated process flow material balance presented shows stream properties and compositions consistent with the process flow diagrams cited above. (Attachment no. 4)

2.0 PROCESS DESCRIPTION

The HLW-It offgas treatment system identified by this feasibility study to meet the MACT compliance criteria consists of the following process steps:

- Closed loop Spray Drying,

- Collection of vitrification melter offgas,
- Dry scrubbing system for HF removal,
- Mercury removal by granular activated carbon (GAC/S) adsorption,
- On-site mercury retorting and GAC/S treatment,

2.1 Closed Loop Spray Drying

The sixty (60) weight percent slurry melter feed stream is dried to a feed moisture content of approximately five (5) weight percent in a spray dryer as manufactured by Swenson Process Equipment Inc., or equivalent. The design basis for this dryer is to process a liquid-slurry feed to a dry solid using a proven and reliable technology. The other important design basis is to minimize or eliminate the generation of offgas for subsequent treatment to comply with MACT. Several dryer types were considered for this application. A vacuum rotary dryer was sized and was found to be very large due to poor overall heat transfer. These dryers are normally used where a solid is fed to the dryer. Alternatively, an evaporator is employed up-stream of the rotary dryer. The vacuum rotary dryer could also be expected to result in the segregation of coarse and fine particle sizes as the solids being dried slowly tumbled down the length of the kiln barrel. A reputable dryer manufacturer was sought that could provide assistance in selecting a dryer type from the large number of available technologies. Swenson Process Equipment Inc. was selected since they currently manufacture sixteen (16) different dryer types for over one hundred (100) different product types.

Swenson recommended a Spray Dryer System for this application and provided a budget proposal (Attachment no. 5) for the requirement of four (4) spray dryer systems to provide needed flexibility for the four (4) induction heated vitrification melters.

Note: The budget proposal calls out drying to 0.5 wt. % rather than the 5 wt. % specified which provides a fairly large safety factor on the dryer size of 4'-6" diameter by 30' straight side length. The straight side length can reasonably be shortened by approximately 6 feet to compensate for this difference. The equipment cost may not change proportionately since this is a small spray dryer per discussion with Swenson on this issue.

The budget proposal, as requested, provides breakout costs for both an open and closed-loop system for the drying medium, heated air stream. The cost breakout, however, does not include all of the necessary equipment to collect Condensate from the four dryer systems prior to introducing it into the slurry feed tanks. The cost justification and process requirements strongly indicate that a closed loop system is preferable to an open loop process that would add 3,500 acfm for each dryer system or 14,000 acfm to the offgas treatment system. The off gas system feasibility study then is based upon the use of a closed loop recirculating air stream for each dryer and the use of spray dryers.

The operation of the spray dryer is relatively simple as described in the Swenson literature. The 60 weight percent (60 % water) slurry to be dried is pumped via a high-pressure pump and then sprayed into the drying chamber in the form of droplets that are closely contacted by a co-current heated air stream. In the dryer, sufficient residence time is provided to dry the slurry into well dispersed solid particles. The dried solid particles are then separated from the gas by means of a primary cyclone and a baghouse that are arranged in a series orientation. Next, the offgas from the baghouse which contains water of evaporation is cooled, cyclonically-separated in a secondary cyclone and the condensate is collected for recycle to the slurry feed tank for certification formulation as required. The solid from the primary cyclone and the baghouse is collected

and pneumatically conveyed to the melter feed hoppers. The gas from the secondary cyclone is then reheated under temperature control and recirculated as co-current heated air into the spray dryer as the drying media.

2.2 Collection of Vitrification Melter Offgas

As can be seen on the process flow diagram (HVF-P-02, Attachment no. 2), the induction heated vitrification melters off gas is collected into a collection duct header which is flow controlled and vacuum controlled to ensure a constant flowrate to the offgas treatment system. Air in-leakage will occur since the melters are maintained under vacuum to provide positive assurance that the melters do not leak to the exterior. It is assumed that fifty (50) SCFM at standard temperature and pressure (60 degrees F and 14.7 psia) leaks into each melter which is operating at approximately 2100 degrees F and 9.5 psia.

Note: Attachment no. 2 shows the offgas pressure from the vitrification melters to be 11.9 psia which is depicting the pressure after or downstream of a let-down pressure control valve which is not shown on the process flow diagram. The upstream pressure is controlled at approximately 9.5 psia to ensure a constant controlled pressure on the melters that is independent of the off gas treatment system pressure drop.

Another source of potential off gas is the pneumatic conveying air (not shown) that is introduced into the dried solids conveying line for transfer of the feed solids from the dryer system to the elevated melter feed hoppers.

Note: This dried solids conveying requirement is believed to be a good application for a dense-phase conveying system (manufacturer, Cyclonaire or equivalent) that will provide for minimum air usage. It is premised that the conveying air for this requirement will be a closed loop air system with a cyclonic separator to remove particulates from the air discharge from the feed hoppers. The solid particulates will be recovered and returned to the feed hoppers and the gas will recirculate back to the blower suction. This level of detail is not depicted on the process flow diagram as it is a detailed design that goes beyond this feasibility study.

Since the size of the offgas air stream for the dried solids conveying requirement is expected to be small, it has not been included in this feasibility study as an additional treatment requirement. A controlled flowrate, as depicted on the process flow diagram (HVF-P-02), at a reasonably constant pressure is necessary to ensure optimal removal efficiency through each process step in the offgas treatment system to comply with MACT. Any significant flow variations to the offgas treatment system can result in surging flow or oscillating flow through the removal process and result in reduced removal efficiencies.

2.3 Dry Scrubbing System for HF Removal

The first treatment step of the collected and flow controlled off gas is the removal of hydrogen fluoride (HF) as can be seen on process flow diagram (HVF-P-03, Attachment no. 3). A scrubbing system for the HF removal from the off gas was evaluated first as a wet spray scrubber and then as a dry scrubber. The dry scrubber was identified as the preferred type of scrubber for two reasons. First, a wet scrubber would bring the offgas stream to a condition approaching saturation and second, the wet scrubber would be severely limited in downturn off gas temperature feed conditions. Since downturn feed temperature to the offgas treatment system is highly likely to occur, it was judged that a dry scrubber system should require much less corrosion maintenance. The wet scrubber, for the reasons cited, would always be more vulnerable to dew point corrosion and/or water condensation in the piping and equipment which could promote the generation of a secondary waste stream that would need to be treated or alternatively returned to the slurry feed tank. Returning any stream to the slurry feed tank is not a good alternative since this tank must be closely controlled for feed certification purposes.

A dry scrubbing system using dry, primarily CaO, was discussed with a major lime manufacturer, the Dravo Lime Co.. Dravo recommended a dry scrubbing technology offered by Amerex Industries, Inc. and their subsidiary company, Interel Environmental Technologies, Inc.. This technology is referred to as the Interel Dry Additive Process (IDAP) and is licensed by Luhr Staubtechnik of Germany. The discussion with Dravo Lime Company's Mr. Tony Licata is included for reference here (Attachment no. 6). The original proposed mixture of dry lime and activated carbon, called "Sorbalit" by Dravo Lime will not be used since it would result in a difficult secondary waste stream including both Hg adsorbed on carbon and CaF2 which would pose significant handling and disposal issues.

Dry lime only is added in this dry scrubbing system and essentially 99.9 % of the HF and no mercury is expected to be removed in this step. The waste stream of reacted lime, CaF2 and a trace quantity of CaO (less than 5 wt % unreacted lime) will be collected and reintroduced into the slurry feed tank on a certifiable and controlled feed basis. The chemistry for the calcium oxide reacting with hydrogen fluoride is shown in the following equation:

$$CaO(solid) + 2HF(gas) = CaF2(solid) + H20(gas)$$

The technology consists of several process steps integrated into a package system for promoting a high usage efficiency of the dry lime additive for contacting and reaction with the hydrogen fluoride present.

The dry scrubber was evaluated for cost impact on both an open loop spray dryer which has a flowrate of 7958 acfm at 355 degrees F and a closed loop spray dryer which has 1213 acfm at 2167 degrees F. The lower flow, higher temperature case employs the IDAP-111 process which recirculates cooled offgas for temperature control in a novel method whereas the higher flow and lower temperature case employs the IDAP-111 process which does not require gas cooling and therefore it does not require gas recirculation for temperature control. Budget proposals were requested for both cases and the IDAP-111 was selected because the equipment cost is only marginally more and resulted in a much reduced gas flow to the offgas treatment processing steps downstream of the HF removal process. The Amerex-Interel IDAP proposals and process schematics are included here. (Attachment no. 7)

The IDAP-111 process mixes the high temperature offgas at 2167 degrees F with a recirculated exhaust gas at 300 degrees F to maintain a temperature below 900 degrees F after mixing. The gas then enters a self cleaning air-cooled heat exchanger where it is cooled to 300 degrees F. Hydrated lime is added upstream of the heat exchanger via Interel supplied lime feed and injection system. The gas temperature of 900 degrees F for this process is based upon the use of carbon steel construction that has 900 degrees F as a maximum design operating temperature. The gas then enters a two-pass reactor/gas-solid contactor with dust conditioning drum where recirculated dust and lime is re-entrained into the gas prior to entering a fabric-filter baghouse. A HF removal efficiency of 99 percent or greater is promised by the Interel proposal.

Note: The offgas temperature of 2167 degrees F is an assumed temperature from air in-leakage that flows from the vitrification melters. This is the maximum temperature the gas can leave the melters, and is a design basis number which is conservatively high for determining the gas mixing requirement for IDAP-111.

2.4 Mercury Removal by Granular Activated Carbon (GAC/S) Adsorption

The offgas exits the fabric filter baghouse at a controlled temperature of between 300 and 400 degrees F as depicted on the process flow diagram. (HVF-P-03, Attachment no. 3) Next, the gas is mixed with the tank and vessel vents from the HLW-Vit process via a temperature controlled vent gas heat exchanger to achieve a mixed gas feed temperature of 250 degrees F to a GAC/S bed where the mercury in the offgas is adsorbed to

meet the MACT limit. Previous work carried out at the INEEL on the identification of promising and demonstrated commercial technology for the removal of mercury from a gas stream was referenced (See reference no. 2, 3 & 4) for this feasibility study. Adsorption of mercury on activated carbon whose adsorption capacity for mercury is increased by impregnation with a material that chemically reacts with, and holds the mercury, is currently identified as a leading technology for mercury removal from a gas stream to comply with MACT. The choice of impregnation material is dictated by the composition of the fluid and the sizing of adsorption equipment is determined by the flow rate of the fluid stream and the desired life of the adsorbent.

NUCON International, Inc. manufactures and markets a sulfur-impregnated activated carbon named, "MERSORB" which significantly increases the mercury adsorption and holding capacity by the formation of mercury sulfide. Mercury sulfide is a more thermally stable compound than elemental mercury or mercury oxide. In general, activated carbon manufacturers indicate that mercury removal efficiencies improve with increasing offgas temperatures until volatilization of the impregnated sulfur occurs. The MERSORB adsorbent was used in this feasibility study because it is claimed by NUCON to have a minimal sulfur loss up to 390 degrees F. This adsorbent has been used successfully at offgas temperatures as high as 250 degrees F.

The mercury removal process equipment was rough-sized for the feasibility study using MERSORB adsorption sizing criteria in the NUCON International Inc. design bulletin. (Reference 5). This sizing was based upon an offgas flowrate of 1268 acfm at 250 degrees F with a mercury content of 1.22 lb/hr. An adsorption bed break-through at 70 percent of the adsorption capacity of the MERSORB of 0.20 lb Hg/lb MERSORB was assumed. Two adsorption beds in a series orientation were specified with breakthrough monitoring between beds. The MERSORB usage was calculated to be 42,000 lb/yr and two, 10 feet diameter by 30 feet long beds were determined to be needed with a bed changeout requirement on an annual basis. NUCON (Joe Enneking) was requested to validate the sizing and to comment on the mercury recovery from MERSORB options recognizing both the hazards and the expense of off-site treatment of this waste which would be considered a mixed waste. NUCON validated the rough sizing and MERSORB usage rate. (Attachment no. 8). NUCON also responded to our request for information and/or their recommendations for treating options of the MERSORB after it has reached the maximum adsorption capacity for mercury and is removed from service. Joe Enneking with NUCON provided the contacts for two representative and capable companies that are believed to have the needed experience to perform on-site mercury removal and either regeneration or thermal destruction of the GAC/S-MERSORB. (Reference 6).

2.5 On-Site Mercury Retorting and GAC/S Recovery

A waste stream of impregnated activated carbon with adsorbed mercury present is generated at the rate of approximately 110 lb/day when the offgas treatment is in full operation. The generation-frequency of the waste Hg-containing stream requiring handling for mercury retorting and sulfide-impregnated granular activated carbon (GAC/S) regeneration or destruction is currently based on a yearly change-out requirement of the GAC/S adsorption bed at break-through Hg loading. The generation cycle of this waste is dependent upon several factors; the most important of which is whether the waste treatment of the GAC/S is performed on-site or off-site. The waste stream retorting and GAC/S treatment process may be carried out on an almost continuous basis, in which case, the process becomes very small and the treatment operating cost increases or alternatively, the waste treatment can be carried out on an annual basis which makes the waste treatment process larger and drives the operating cost down. In either case, the size of the Hg removal adsorption bed size is impacted.

Note: If a detailed design were to be performed, a trade-off study should be carried out to determine the lowest overall project cost or life-cycle cost to arrive at the most cost-effective design.

In this study, it is assumed that on-site treatment will be carried out and that the GAC/S waste generation cycle is one generation of 42,000 lb of MERSORB or equivalent per year in a lump sum generation quantity. The feasibility of on-site generation is believed to be possible and probably cost justified based upon the responses received from two companies that were recommended by NUCON International, Inc.. The two companies that claim to have on-site GAC/S treatment capability and have provided responses to this feasibility study are SepraDyne Corporation (Attachment no. 9) and Mercury Recovery Services (Attachment no. 10). Both companies have commercial experience for mercury retorting/recovery and granular activated carbon with mercury impregnant (MERSORB or equivalent) treatment using unique thermal desorption processes. Sepradyne Corp. recovers the GAC/S by a reduced temperature thermal desorption carried out under vacuum while Mercury Recovery Services thermally destroys the GAC/S after first retorting the mercury. Both companies reference some mixed waste experience and both claim to have had their technologies identified as Best Demonstrated Available Technology (BDAT) by the EPA and/or the DOE. The cost for either of these technologies is comparable but if SepraDyne's claims are proven true they promise to have a very high regeneration/recovery rate for the GAC/S and therefore offer a substantial reduction in operating costs of approximately $189k/yr for GAC/S usage or replacement cost. The capital equipment costs are very comparable for the two processes based on "verbal only" cost estimates of $150k for SepraDyne and $225k for Mercury Recovery services.

Note: It is assumed that the recovered mercury will be amalgamated for final disposal and that a commercial facility exists for the amalgamation of the mercury mixed waste generated.

2.6 HEPA Filtration

As can be seen on the off gas process flow diagram (HVF-P-03), the HEPA filtration of the offgas occurs after the Hg removal via adsorption and on the feed stream for the NOx removal by Selective Catalytic Reduction (SCR) to remove residual fine particulate matter as either entrained GAC or fine particulates that have passed through the baghouse in the dry scrubbing system. For purposes of this study, the rad contend in the offgas stream will be reduced to acceptable levels by the HEPA filtration train. HEPA filtration has also been identified for the incoming tank vents that are mixed with the off gas before the Hg removal via adsorption. These units are 2 x 2 x 1-ft (Model GG-F) and 2 x 2 x 2.5-ft V(Model GN-F) respectively for the SCR feed stream and the tank vents stream. These HEPA filtration units will have 304 stainless steel frames and have high capacity filter elements by Flanders or equivalent.

2.7 NOx Removal by Selective Catalytic Reduction

The gas leaving the HEPA filter enters the Selective Catalytic Reduction (SCR) unit to reduce the NOx emission from the HLW-Vit offgas and also any residual carbon monoxide or any trace amounts of hydrocarbons present to comply with MACT. In the SCR process, NOx emissions are reduced by injecting a chemical reagent such as ammonia into the gas which passes through a catalyst. The catalyst promotes and ensures efficient chemical reaction between the ammonia and the NOx to produce nitrogen and water which are subsequently released to the atmosphere. The SCR operates over a wide range of temperatures from 400 degrees F to 1,100 degrees F depending on the catalyst type used. A 400 degree F catalyst type is the one which is depicted in this feasibility study. The gas enters the SCR and is heated with an electrical heater from 250 to 400 degrees F. The ammonia can either be anhydrous (dry) or aqueous. Since the usage of ammonia is very small for this application, because the amount of NOx is determined to be very small from the ASPEN Plus simulation, anhydrous ammonia is assumed to be used by use of cylinder gas in Chemically Pure (CP) grade under flow control. The ammonia is injected in by flow control to the heated gas based upon feedback from a continuous emissions monitoring system (CEMS). The gas/ammonia mixture is piped to an ammonia injection grid located in the duct ahead of the catalyst bed. The grid design provides uniform distribution of the

ammonia into the gas. The gas mixture then passes through the SCR catalyst where NOx is reduced. NOx removal efficiencies are typically 90% or higher. The size of this SCR is estimated to be the same as was specified/estimated by CSM for the NWCF MACT compliance feasibility study, INEEL/INT-97-00992. This application had an approximate footprint (plan view) size of 8' by 25'. CSM is a well known supplier of air pollution control equipment for NOx, CO, and VOC control. (Reference 2, Vol. 1, Appendix E)

2.8 Vacuum Pressure Control by System Blower

An induced draft blower takes treated gas suction from the effluent stream from the SCR NOx removal step as depicted on the process flow diagram (HVF-P-03, Attachment 3) and discharges the gas to the atmosphere. This blower will supply the system pressure drop on the offgas treatment system and maintain a constant vacuum condition on the vitrification melters during vitrification processing. The blower turndown will not be significant because the offgas system design will have a controlled gas flow via make-up air addition as shown on the process flow diagram (HVF-P-02, Attachment 2). The blower is estimated to have a design differential head of approximately 3.0 psi or 83 inches of water gauge for a flowrate of 1500 acfm at 400 degrees F. The blower should have an installed spare to ensure MACT compliance.

3.0 DESIGN BASIS AND KEY ASSUMPTIONS

1. The following flowrates are assumed from respective sources and become the basis for the offgas design basis for flow and approximate composition:

Vessel(s)	Air In-Flow (all in SCFM)	Temperature (F)
T-701 A,B	150 CFM	70
B-701	100 CFM	70
Mix Tanks (3)	100 CFM	70
Slurry Feed Tanks (2)	100 CFM	70
Water Collection Tank	50 CFM	70
Melter Vents	200 CFM	2,100

2. It is assumed that the vitrification melter slurry feed has a closed-loop circulating air stream as the drying media to minimize the offgas flow to the treatment process. This closed loop system is discussed in the description for the spray dryer description, Section 2.1 and can be designed/supplied by the dryer manufacturer referenced.

3. It is assumed that the granular activated carbon, impregnated with sulfide (GAC/S), is treated on-site for mercury retorting and that one of the identified companies will treat the GAC/S on-site for either destruction or regeneration based upon overall cost and proven capabilities.

4. It is assumed that 150 psig steam is available for adding heat to the closed loop air stream referenced for the spray dryer for drying the vitrification melter feed slurry.

5. It is assumed that anhydrous ammonia will be used for the Selective Catalytic Reduction unit for NOx removal as identified in Section 2.7.

6. It is assumed that the pneumatic conveying system for transfer of the dried solid mixture from the dryer baghouse to the vitrification feed hoppers will require a very small air flowrate that for the purposes of this feasibility study can be neglected from the offgas treatment requirement.

7. It is assumed that the dry scrubbing system for HF removal will employ a recirculation heating gas stream during periods when the off gas treatment system is down for routine maintenance to ensure/protect against dew point corrosion of the carbon steel system as proposed by the manufacturer, Amerex Industries, Inc..

8. It is assumed that the offgas temperature from the vitrification melters will be 2167 degrees F at about 12.9 psia (2100 F @ 11.9 psia) to provide for a conservative design basis.

9. It is assumed that the dry scrubber system will be fabricated from carbon steel

10. It is assumed that the GAC/S (MERSORB or equivalent) adsorption beds will be designed for horizontal beds rather than vertical beds. It is assumed that this decision will be justified based upon a trade-off study comparing differential vessel installation cost with differential offgas blower operating cost. Basis of comparison is 10 ft dia. x 30 ft overall horizontal vessels versus 10 ft dia. x 20 ft overall vertical vessels and 8 in. H_20 versus 40 in. H_20 differential pressure required for horizontal versus vertical tanks respectively.

11. The design basis for the offgas treatment system is the vitrification melter feed basis of using a calcine blend made-up of 75% zirconia and 25% aluminum calcine as described in reference.

12. It is assumed that the solid waste from the dry scrubbing system can be returned to the slurry feed tank on a carefully controlled basis. This waste stream is very small and could be stored as a solid powder as collected from the baghouse blowdown.

13. It is assumed that the spray dryer condensate can be returned to the slurry feed tank on a carefully controlled basis. A condensate collection tank has been identified to collect this condensate on the process flow diagram.
14. It. is assumed that a commercial service company exists to amalgamate the mercury that has been retorted from the GAC/S. SepraDyne has stated that they have worked with a mercury amalgamation company to treat mercury recovered from their process. The company name to be supplied by SepraDyne.

15. It is assumed that the calcine and Frit that is in the waste mixture slurry that is fed to the spray dryer has a particle size range of 50 to 100 microns. This range was specified to Swenson Process Equipment' Inc. for their dryer design estimate basis.

16. The design basis uses the ASPEN Plus process flow simulation code to calculate the material and energy balances for the HLW-Vit offgas treatment system

17. It is assumed that the following equilibria calculations by the ASPEN Plus code are applicable in describing the simulated process. The compositional distribution in the melter was determined by assuming that the components in the calcine-frit mixture achieve equilibrium concentrations at the melter temperature of 2100 degrees F. This assumption is made, in part, because rate constants describing mass transfer and reaction kinetics are unknown. Such an assumption is generally considered valid at high temperatures.

HSC Chemistry for Windows (v. 2.03), which contains data for more than 7,600 compounds including gases, liquids, solids, ions, and aqueous phase constituents, was used to calculate the equilibrium concentrations in the gas and melt phases. The software calculates equilibrium concentrations for different reactions and are

based on the principle that chemical equilibria have been achieved when the Gibbs free energy for all specified reactions has been minimized. This information was incorporated in the ASPEN Plus simulation to complete material and energy balance equations.

4.0 REFERENCES

1. R. R. Kimmitt, 1998, "HLW-Vit, Feasibility Study Design Basis". 75% Zr-25%Al Calcine; Slurry Feed Mixture spreadsheet with calcine, frit, and vitrified product compositions.

2. John K. Rawlins, "Feasibility Study Report for NWCF MACT Compliance Facility", Nov., 1997

3. Soelberg, Anderson, Raivo, "Offgas System Equipment and Design for Mixed Waste Treatment", August 14, 1996

4. WERF MACT Feasibility Study Team, "WERF MACT Feasibility Study Report', Nov., 1998

5. "Design & Performance Characteristics of MERSORB Mercury Adsorbents in Liquids and Gases" NUCON International, Inc., Bulletin No. 11 B28-R1 - 10/97

6. Jack Prendergast, "Memo of Telephone Conversation; to Joe Enneking of NUCON Int'l. , 12/2/98, Mercury removal using NUCON's MERSORB re system sizing and recommendations for disposal.

7. "LIME; Handling Application and Storage" Handbook by National Lime Association, Bul. 13

8. "Environmental Product Profiles", INTEREL Dry Additive Process (IDAP), by National Environmental Technology Applications Corporation (NETAC), Jan., 1993

9. Thomas E. Weyand, Casimir J. Koshinski, "Removal and Recovery of Mercury from Mixed Wastes", June, 1996, Air & Waste Management Association

10. Randy Aulbaugh, Greg Hawk, "High Vacuum Rotary Kiln for the Removal of Mercury from Air Pollution Control Scrubber Waste", SepraDyne Corporation

11. Randy Aulbaugh, Greg Hawk, "High Vacuum Rotating Retort for the Removal of Mercury from CHLOR-ALKALI Plant Wastewater Treatment Sludge, Thermall Corporation

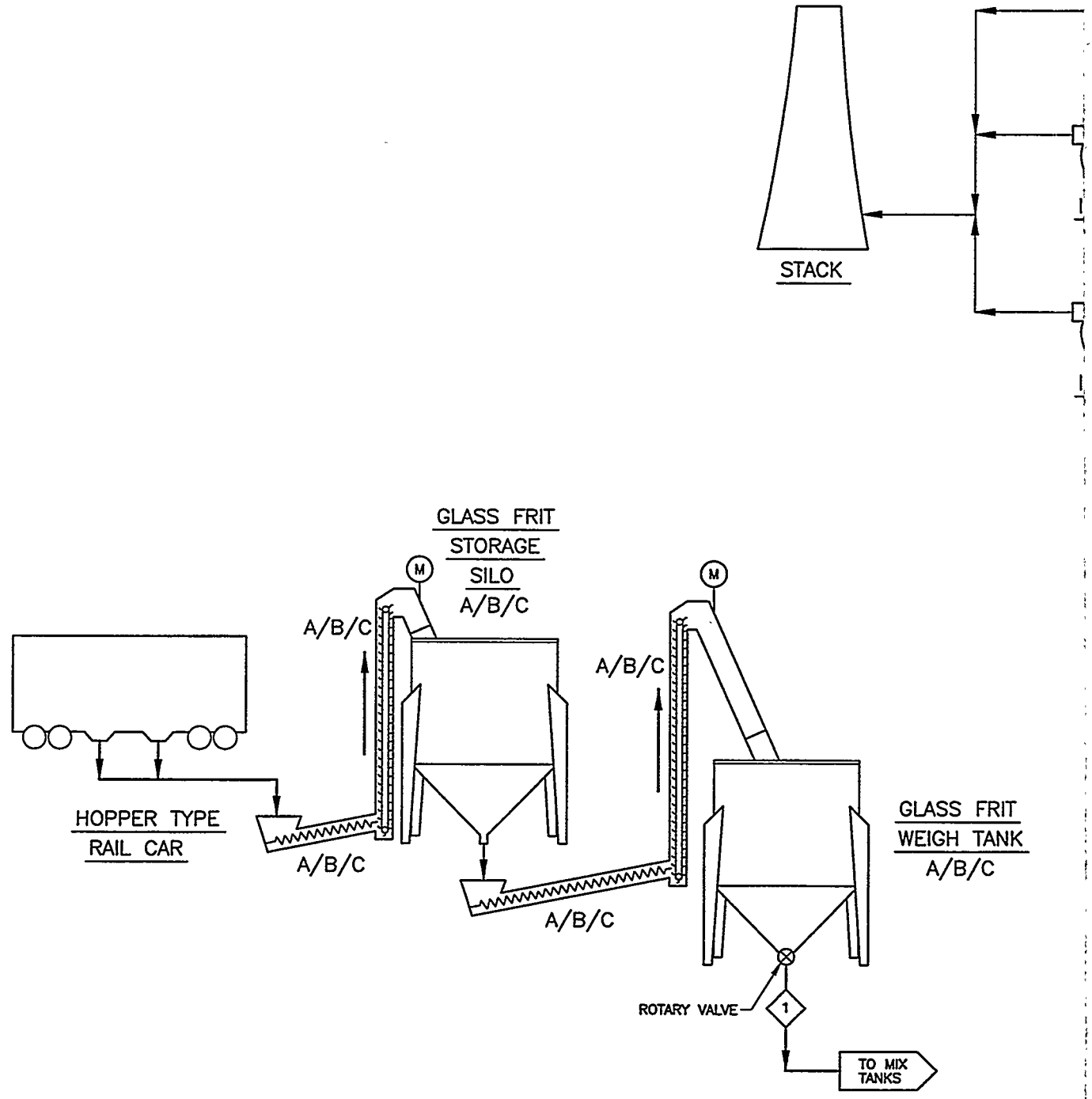
12. Michael V. Rose, Thomas E. Weyand, Casimir J. Koshinski, "Mercury Cleanup: The Commercial Application of a New Mercury Removal/Recovery Technology", REMEDIATION, Volume 5, Number 3, Summer, 1995

13. Kevin Liekhus, "ASPEN PLUS Simulation and Modeling Support Work for HLW-Vitrification Offgas Process Description", December, 1998

5.0 INDEX OF ATTACHMENTS

1. Process Flow Diagram, HVF-P-01, Glass Frit Process Flow and Calcine Process Flow
2. Process Flow Diagram, HVF-P-02, Waste Feed and Vitrification Process Flow
3. Process Flow Diagram, HVF-P-03, Offgas Process Flow
4. ASPEN PLUS Simulation Process Flow Material Balance Streams; Composition and Properties
5. Budgetary Proposal by Swenson Process Equipment, Inc. for Spray Dryers of Calcine and Frit, dated November 25, 1998
6. Memorandum of Telephone Conversation, Subject; "Potential Application of Dravo Lime's SORBALIT re faxed Request for HF and Hg Removal Requirements per MACT Implementation", dated September 29,1998
7. Budgetary Proposals by Amerex Industries, Inc. for Interel Dry Additive Processes, IDAP-111 and IDAP-1 for HF Removal dated November 25,1998
8. Evaluation of Mercury Removal Beds Design per HLW-Vit Criteria as Validated by Joe Enneking of NUCON International Inc., dated December 2, 1998
9. Budgetary Cost Estimate for Contaminated Carbon (MERSORB) Cleanup Services for Raduce System by SepraDyne Corporation, dated December 10, 1998
10. Letter presenting a fact sheet for "Summary of Technology for the Removal and Recovery of Mercury from Soils, Solid Wastes and Industrial Process Streams" by Mercury Recovery Services, Inc., dated December 3,1998

Attachment 1

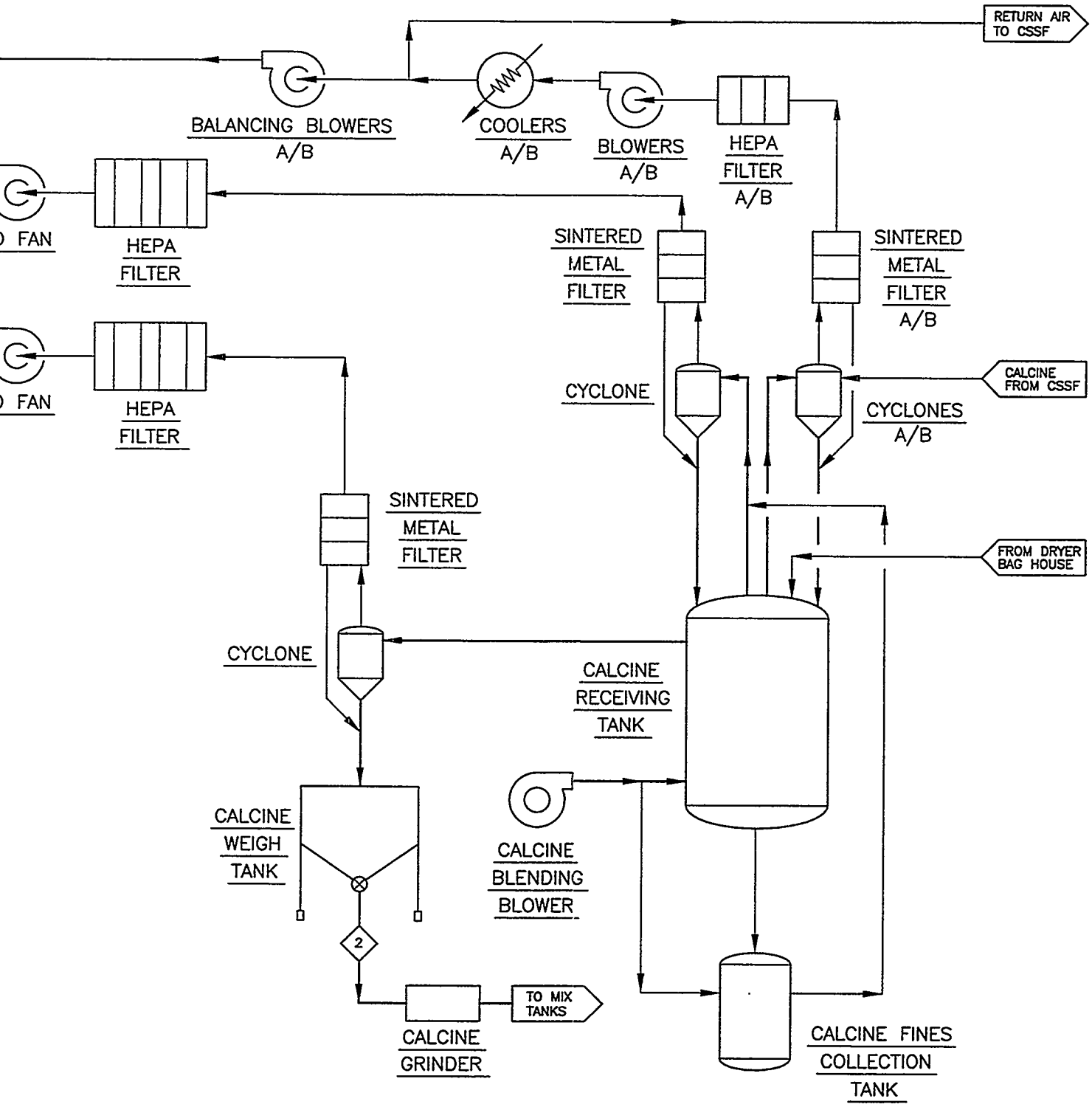


HLW VITRIFICATION – GLASS FRIT PROCESS FLOW DIAGRAM

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MATERIAL	F
FLOW LBS/HR (TYP)	4

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REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

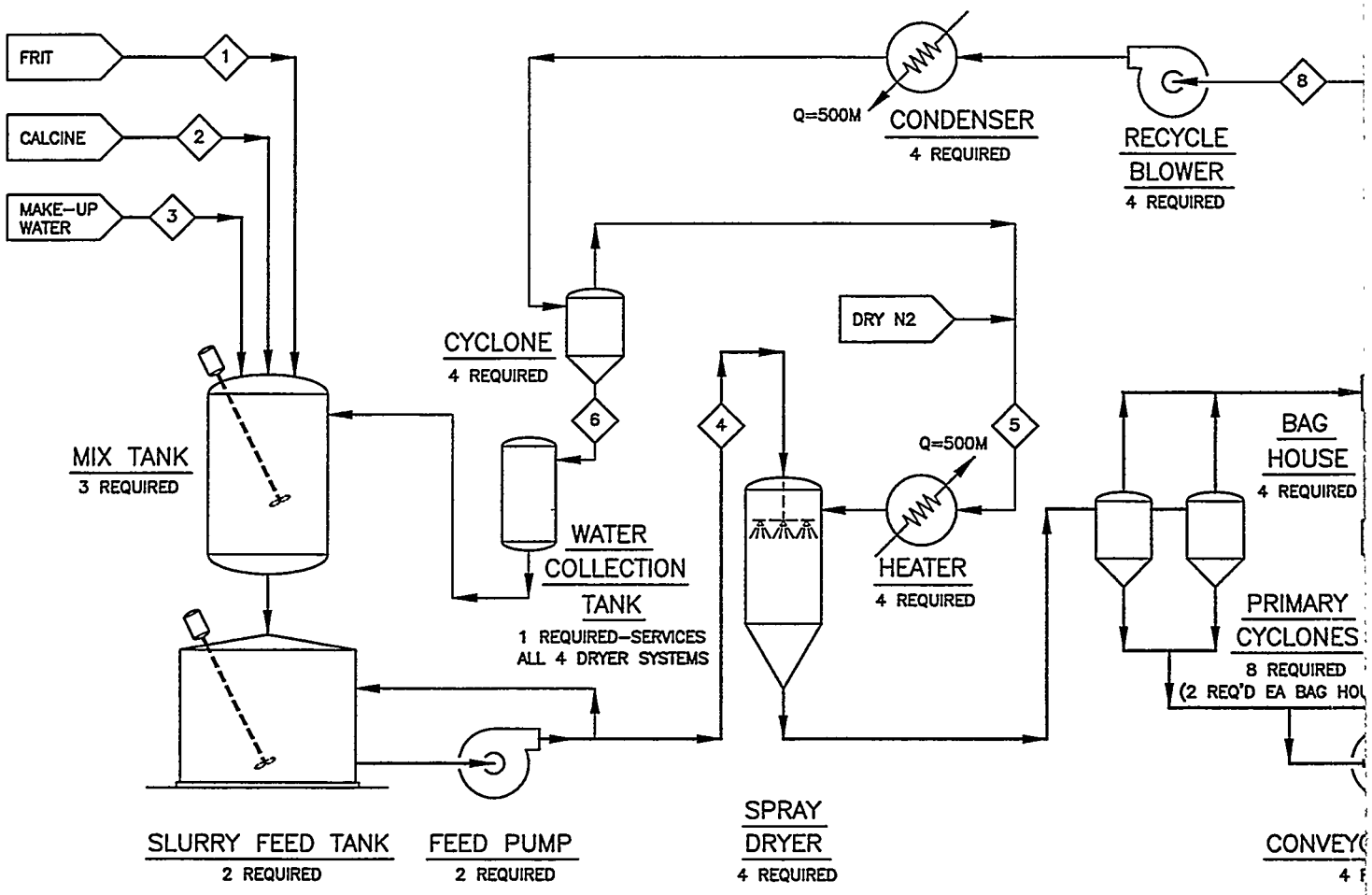


HLW VITRIFICATION – CALCINE PROCESS FLOW DIAGRAM

LE	
	2
IT	CALCINE
4	144

SUBCONTRACT NO.	LOCKHEED MARTIN
REQUESTER: DA LOPEZ	INTEC WASTE TREATMENT FACILITY VITRIFICATION WASTE OPTION HLW VITRIFICATION FACILITY PROCESS FLOW DIAGRAMS
DESIGN: RR KIMMITT	
DRAWN: RM HALL	
PROJECT NO.	
SPEC CODE	
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, SEQ 24 530; DWG-; REV
EFFECTIVE DATE:	SCALE: NONE; SHEET HVF-P-01

Attachment 2



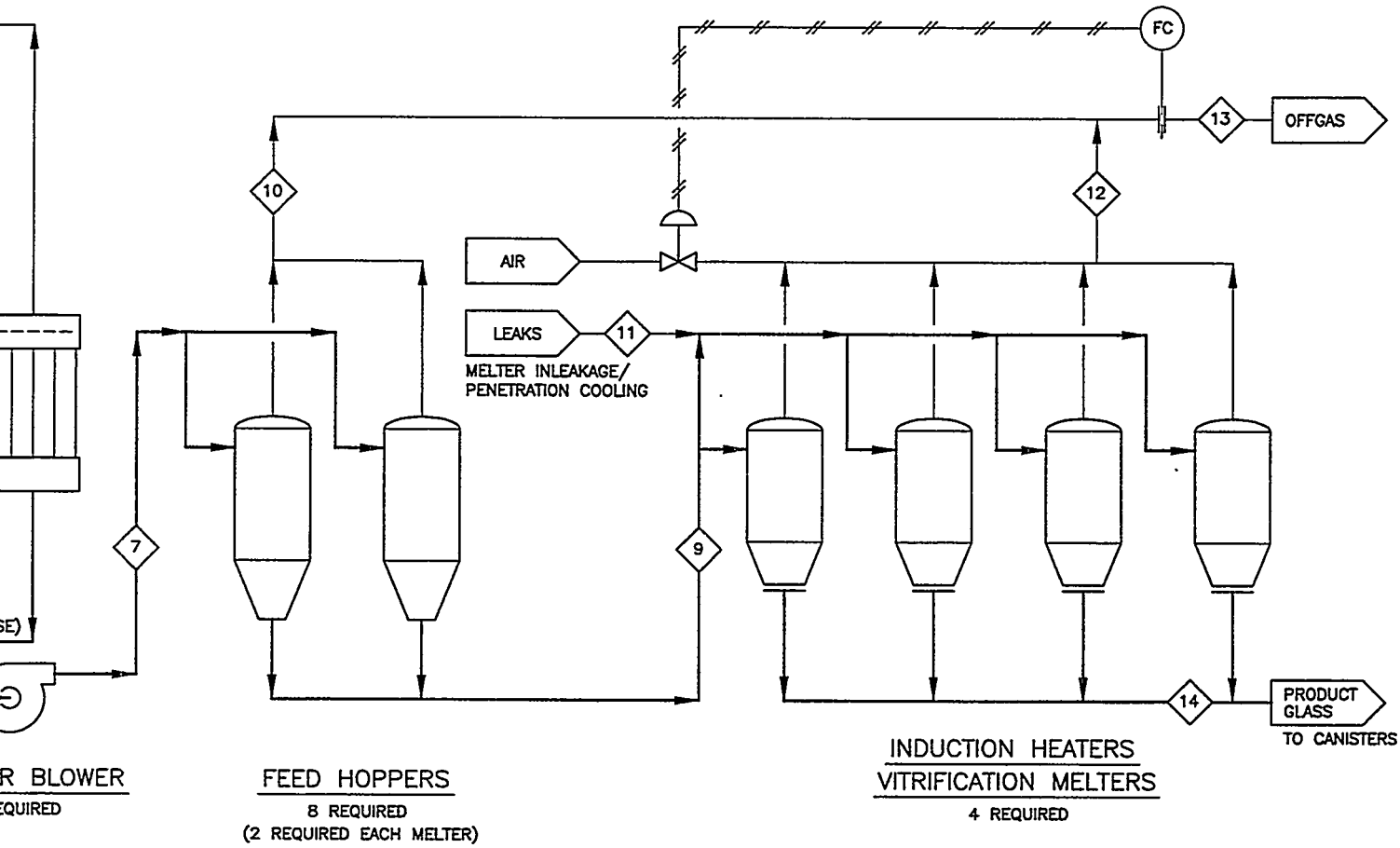
HLW VITRIFICATION – WASTE FE

MATERIAL BALANCE TABLE: 75% Zr/25% Al CALCINE

STREAM NO.	1	2	3	4	5	6	7	8	
CALCINE		143.9		143.9			143.9		14
FRIT	443.7			443.7			443.7		44
H20			31.2	881.4	113.6	850.2	31.2	963.8	3
N2					13,634.1			13,634.1	
O2					4,139.8			4,139.8	
HF									
NO									
NO2									
HG									
SIO2 (SLAG)									
OTHER SLAG COMPONENTS									
TOTAL LBS/HR	443.7	143.9	31.2	1,469.0	17,887.6	850.2	618.8	18,737.7	61
(ACTUAL) FT3/MIN					4,635			5,973	
TEMPERATURE °F	70	70	70	70	40	40	103.9	133.9	10
PRESSURE PSIA	12.2	12.2	12.2	12.0	12.0	12.0	11.9	11.9	1

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REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE



ED AND VITRIFICATION FLOW DIAGRAM

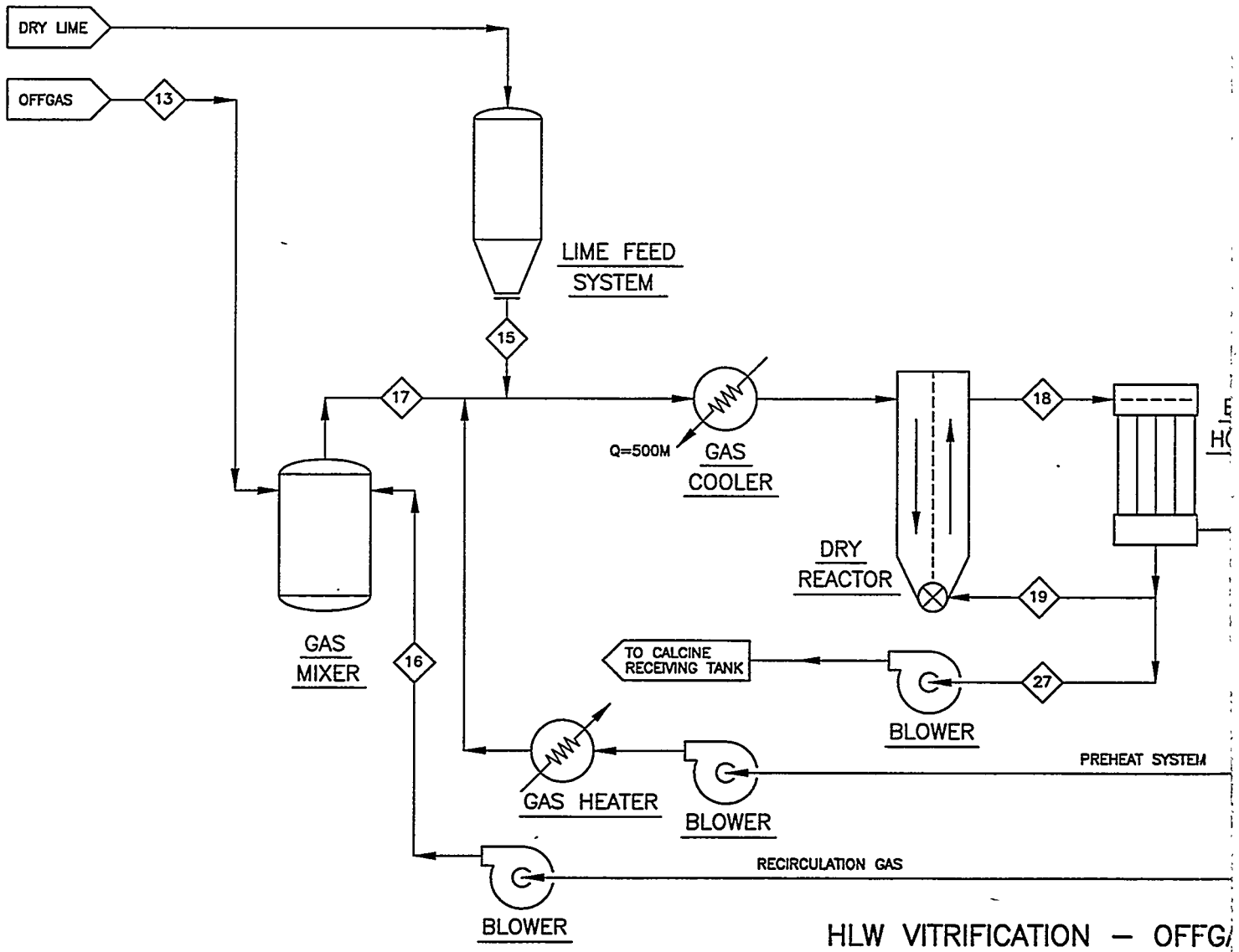
NOTES

1. ALL FLOWS SHOWN ARE TOTAL OF FOUR (4) FEED SYSTEMS TO MELTERS.

W FRIT					
9	10	11	12	13	14
.9					
.7					
.2	(FUTURE)		31.2	31.2	
		695.2	696.1	696.1	
		211.1	214.4	214.4	
					268.2
					313.2
.8		906.3	941.7	941.7	581.4
		240	1,282	1,214	
.9	70	70	2,100	2,168	2,100
9	12.5	12.4	11.9	12.9	11.9

SUBCONTRACT NO.	LOCKHEED MARTIN
REQUESTER: DA LOPEZ	INTEC
DESIGN: WJ PRENDERGAST	WASTE TREATMENT FACILITY
DRAWN: RM HALL	VITRIFICATION WASTE OPTION
PROJECT NO.	HLW VITRIFICATION FACILITY
SPEC CODE	WASTE FEED AND VITRIFICATION FLOW DIAGRAM
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, CL, ORG 24 530; DWG-; REV
EFFECTIVE DATE:	SCALE: NONE; SHEET HVF-P-02

Attachment 3



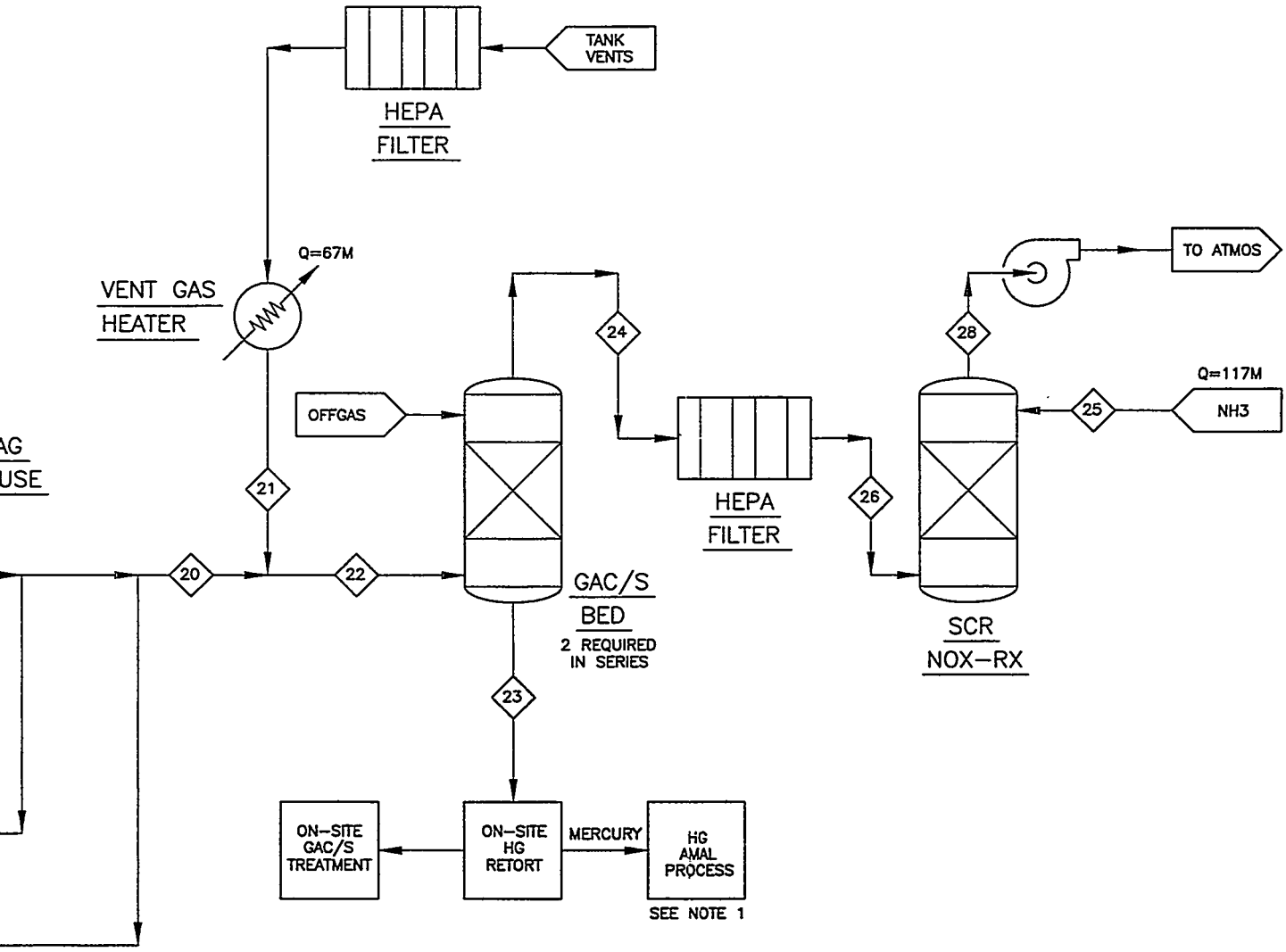
HLW VITRIFICATION – OFFG

MATERIAL BALANCE TABLE: 75% Zr/25% Al CALCINE

STREAM NO.	15	16	17	18	19	20	21	22	
H2O		92.1	123.3	123.3		31.3		31.3	
SIO2									
N2		2,052.2	2,748.6	2,777.4	26.7	697.2	1804.7	2,501.8	
O2		632.1	846.5	855.4	8.2	214.7	214.7	762.7	
HF		TRACE	TRACE	TRACE		TRACE		TRACE	
NO		2.47	3.31	3.31		0.84		0.84	
NO2		0.02	0.03	0.03		0.007		0.007	
HG		3.60	4.82	4.82		1.22		1.22	1
LIME – (SOL)	0.0042				0.002				
CAF2 – (SOL)					0.102				
NH3									
TOTAL LBS/HR	0.0042	2,782.8	3,726.5	3,764.5	35.0	945.3	2,352.6	3,297.9	1
(ACTUAL) FT3/MIN		1,248	2,559	1,731	16.0	446	773.8	1,268	
TEMPERATURE °F	70	428	900	400	411	400	187.6	250	2
PRESSURE PSIA	12.2	12.5	12.5	11.8	11.8	11.5	12.2	11.5	1

User: RHX
Date: 12/14/98 – 10:20 A.M.
File: hlw--p-03.dwg
Path: P:\FRIT

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



S PROCESS FLOW DIAGRAM

W FRIT					
3	24	25	26	27	28
	31.3		31.3		32.0
	2,501.8		2,501.8	1.072	2,502.6
	762.7		762.7	0.330	762.4
	TRACE		TRACE		TRACE
	0.84		0.84		0.084
	0.007		0.007		0.0007
2	1.2E–6		1.2E–6		1.2E–6
				TRACE	
				0.004	
		0.480			0.0024
2	3,296.6	0.480	3,296.6	1.406	3,297.1
	1,268		1,302.9	0.6	1,339.9
0	250	70	250	400	400
5	11.2	12.2	10.9	11.5	10.9

NOTES

1. MERCURY AMALGAMATION PROCESS BY OTHERS (ASSUME COMMERCIAL SERVICE).

SUBCONTRACT NO.	LOCKHEED MARTIN
REQUESTER: DA LOPEZ	INTEC
DESIGN: WJ PRENDERGAST	WASTE TREATMENT FACILITY
DRAWN: RM HALL	VITRIFICATION WASTE OPTION
PROJECT NO.	HLW VITRIFICATION FACILITY
SPEC CODE	OFFGAS PROCESS FLOW DIAGRAM
FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, CL 24, ORG 530; DWG– ; REV
EFFECTIVE DATE:	SCALE: NONE; SHEET HVF–P–03

Attachment 4

Stream Number	1	2	3	4
Mass Flow LB/HR				
H2O	0.000000	0.000000	31.183100	881.372900
SIO2	0.000000	268.231900	0.000000	268.231900
N2	0.000000	0.000000	0.000000	0.014494
O2	0.000000	0.000000	0.000000	0.008990
HF	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000
HG	0.000000	0.000000	0.000000	0.000000
HGO	0.000000	0.000000	0.000000	0.000000
HGO-S	1.315997	0.000000	0.000000	1.315997
CAF2-S	50.490190	0.000000	0.000000	50.490190
LIME-S	0.000000	0.000000	0.000000	0.000000
NH3	0.000000	0.000000	0.000000	0.000000
AL2O3	48.103290	0.000000	0.000000	48.103290
CAO	15.088750	0.000000	0.000000	15.088750
NAF	0.000000	0.000000	0.000000	0.000000
B2O3	2.826928	77.814500	0.000000	80.641430
NA2O	0.000000	75.319290	0.000000	75.319290
LI2O	0.000000	22.336350	0.000000	22.336350
NAALO2	1.212338	0.000000	0.000000	1.212338
NANO3	7.747268	0.000000	0.000000	7.747268
ZRO2	17.110720	0.000000	0.000000	17.110720
Mass Frac				
H2O	0.000000	0.000000	1.000000	0.599984
SIO2	0.000000	0.604532	0.000000	0.182596
N2	0.000000	0.000000	0.000000	9.866890E-06
O2	0.000000	0.000000	0.000000	6.119780E-06
HF	0.000000	0.000000	0.000000	0.000000
NO	0.000000	0.000000	0.000000	0.000000
NO2	0.000000	0.000000	0.000000	0.000000
HG	0.000000	0.000000	0.000000	0.000000
HGO	0.000000	0.000000	0.000000	0.000000
HGO-S	0.009146	0.000000	0.000000	8.958490E-04
CAF2-S	0.350881	0.000000	0.000000	0.034371
LIME-S	0.000000	0.000000	0.000000	0.000000
NH3	0.000000	0.000000	0.000000	0.000000
AL2O3	0.334293	0.000000	0.000000	0.032746
CAO	0.104859	0.000000	0.000000	0.010271
NAF	0.000000	0.000000	0.000000	0.000000
B2O3	0.019646	0.175376	0.000000	0.054896
NA2O	0.000000	0.169752	0.000000	0.051273
LI2O	0.000000	0.050341	0.000000	0.015205
NAALO2	0.008425	0.000000	0.000000	8.252850E-04
NANO3	0.053840	0.000000	0.000000	0.005274
ZRO2	0.118911	0.000000	0.000000	0.011648
Total Flow LB/HR	143.895500	443.702100	31.183100	1468.994000
Total Flow CUFT/HR	0.689147	2.973016	27.726760	787.371000
MASSVFRA	0.000000	0.000000	0.000000	7.518120E-07
MASSSFRA	1.000000	1.000000	0.000000	0.400000
Density LB/CUFT	208.802200	149.243100	1.124657	1.865695
Temperature F	85.000000	85.000000	85.000000	46.788370
Pressure PSI	12.200000	12.200000	12.200000	12.000000
Density LBMOL/CUF	2.436374	2.537726		2.520087
Density LB/CUFT	208.802200	149.243100		160.542200
Average MW	85.702010	58.809770		63.705040

5	6	7	8	11
113.605300	850.189800	31.182220	963.796000	0.000000
0.000000	0.000000	268.231900	0.000000	0.000000
13634.090000	0.014496	2.796690E-04	13634.100000	695.210500
4139.845000	0.008991	1.607810E-04	4139.854000	211.093600
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	1.315997	0.000000	0.000000
0.000000	0.000000	50.490190	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	48.103290	0.000000	0.000000
0.000000	0.000000	15.088750	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	80.641430	0.000000	0.000000
0.000000	0.000000	75.319290	0.000000	0.000000
0.000000	0.000000	22.336350	0.000000	0.000000
0.000000	0.000000	1.212338	0.000000	0.000000
0.000000	0.000000	7.747268	0.000000	0.000000
0.000000	0.000000	17.110720	0.000000	0.000000
0.006351	0.999972	0.050393	0.051436	0.000000
0.000000	0.000000	0.433485	0.000000	0.000000
0.762212	1.704980E-05	4.519680E-07	0.727628	0.767083
0.231437	1.057490E-05	2.598350E-07	0.220937	0.232917
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.002127	0.000000	0.000000
0.000000	0.000000	0.081596	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.077739	0.000000	0.000000
0.000000	0.000000	0.024385	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.130323	0.000000	0.000000
0.000000	0.000000	0.121722	0.000000	0.000000
0.000000	0.000000	0.036097	0.000000	0.000000
0.000000	0.000000	0.001959	0.000000	0.000000
0.000000	0.000000	0.012520	0.000000	0.000000
0.000000	0.000000	0.027652	0.000000	0.000000
17887.540000	850.213200	618.780200	18737.750000	906.304200
2.781080E+05	755.967300	31.389410	3.584070E+05	14400.000000
1.000000	0.000000	0.000000	1.000000	1.000000
0.000000	0.000000	0.949606	0.000000	0.000000
0.064319	1.124669	19.713030	0.052281	0.062938
40.000000	40.000000	103.851900	133.896200	70.000000
12.000000	12.000000	11.900000	11.900000	12.400000
		2.517946		
		160.405800		
		63.705040		

12	13	14	15	16
31.181250	31.181250	0.000000	0.000000	92.087790
0.000000	0.000000	268.231900	0.000000	0.000000
696.094200	696.094200	0.000000	0.000000	2052.488000
214.385100	214.385100	0.000000	0.000000	632.130900
0.002141	0.002141	0.000000	0.000000	3.244300E-05
0.837771	0.837771	0.000000	0.000000	2.474043
0.007361	0.007361	0.000000	0.000000	0.021738
1.218785	1.218785	0.000000	0.000000	3.599224
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.004024	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	51.353440	0.000000	0.000000
0.000000	0.000000	54.302170	0.000000	0.000000
0.000000	0.000000	80.641430	0.000000	0.000000
0.000000	0.000000	8.825708	0.000000	0.000000
0.000000	0.000000	22.336350	0.000000	0.000000
0.000000	0.000000	78.556050	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	17.110720	0.000000	0.000000
0.033041	0.033041	0.000000	0.000000	0.033092
0.000000	0.000000	0.461389	0.000000	0.000000
0.737602	0.737602	0.000000	0.000000	0.737562
0.227169	0.227169	0.000000	0.000000	0.227156
2.268330E-06	2.268330E-06	0.000000	0.000000	1.165840E-08
8.877270E-04	8.877270E-04	0.000000	0.000000	8.890480E-04
7.799810E-06	7.799810E-06	0.000000	0.000000	7.811420E-06
0.001291	0.001291	0.000000	0.000000	0.001293
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.088334	0.000000	0.000000
0.000000	0.000000	0.093406	0.000000	0.000000
0.000000	0.000000	0.138712	0.000000	0.000000
0.000000	0.000000	0.015181	0.000000	0.000000
0.000000	0.000000	0.038421	0.000000	0.000000
0.000000	0.000000	0.135125	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.029432	0.000000	0.000000
943.726600	943.726600	581.357800	0.004024	2782.801000
76897.600000	72809.950000	3.712879	2.754640E-05	74863.810000
1.000000	1.000000	0.000000	0.000000	1.000000
0.000000	0.000000	1.000000	1.000000	0.000000
0.012273	0.012962	156.578700	146.081900	0.037172
2100.000000	2167.600000	2100.000000	70.000000	428.013600
11.900000	12.900000	11.900000	12.200000	12.500000
		2.644500	1.971611	
		156.578700	146.081900	
		59.209210	74.092680	

17	18	19	20	21
123.269000	123.366100	0.000000	31.280220	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
2748.582000	2777.447000	26.702540	697.185300	1804.651000
846.515900	855.406100	8.223925	214.721100	547.963900
0.002173	0.002173	0.000000	1.102020E-05	0.000000
3.311815	3.314422	0.000000	0.840379	0.000000
0.029099	0.029121	0.000000	0.007384	0.000000
4.818008	4.821802	0.000000	1.222578	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.102286	0.102334	0.000000	0.000000
0.000000	0.006034	0.002010	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.033079	0.032771	0.000000	0.033092	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.737572	0.737801	0.762259	0.737562	0.767083
0.227159	0.227230	0.234763	0.227156	0.232917
5.831490E-07	5.772770E-07	0.000000	1.165840E-08	0.000000
8.887130E-04	8.804430E-04	0.000000	8.890480E-04	0.000000
7.808480E-06	7.735810E-06	0.000000	7.811420E-06	0.000000
0.001293	0.001281	0.000000	0.001293	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	2.717130E-05	0.002921	0.000000	0.000000
0.000000	1.602890E-06	5.737120E-05	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
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0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
3726.528000	3764.495000	35.030810	945.257000	2352.615000
1.535560E+05	1.038860E+05	958.501600	26770.400000	49251.920000
1.000000	0.999971	0.997021	1.000000	1.000000
0.000000	2.877420E-05	0.002979	0.000000	0.000000
0.024268	0.036237	0.036547	0.035310	0.047767
900.000300	400.099900	411.207500	400.058400	187.570100
12.500000	11.800000	11.800000	11.500000	11.500000
	2.350960	2.397668		
	183.002900	187.003900		
	77.841750	77.994060		

22	23	24	25	26
31.280220	0.000000	31.280220	0.000000	31.280220
0.000000	0.000000	0.000000	0.000000	0.000000
2501.836000	0.000000	2501.836000	0.000000	2501.836000
762.685100	0.000000	762.685100	0.000000	762.685100
1.102020E-05	0.000000	1.102020E-05	0.000000	1.102020E-05
0.840379	0.000000	0.840379	0.000000	0.840379
0.007384	0.000000	0.007384	0.000000	0.007384
1.222578	1.222577	1.222580E-06	0.000000	1.222580E-06
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.479706	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.009485	0.000000	0.009488	0.000000	0.009488
0.000000	0.000000	0.000000	0.000000	0.000000
0.758621	0.000000	0.758903	0.000000	0.758903
0.231266	0.000000	0.231352	0.000000	0.231352
3.341600E-09	0.000000	3.342840E-09	0.000000	3.342840E-09
2.548250E-04	0.000000	2.549190E-04	0.000000	2.549190E-04
2.238960E-06	0.000000	2.239790E-06	0.000000	2.239790E-06
3.707170E-04	1.000000	3.708500E-10	0.000000	3.708500E-10
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	1.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.000000	0.000000	0.000000	0.000000	0.000000
3297.872000	1.222577	3296.649000	0.479706	3296.649000
76100.420000	0.097631	76096.380000	13.123470	78134.640000
1.000000	0.000000	1.000000	1.000000	1.000000
0.000000	0.000000	0.000000	0.000000	0.000000
0.043336	12.522420	0.043322	0.036553	0.042192
250.000200	250.000200	250.000200	70.000000	249.999800
11.500000	11.500000	11.500000	12.200000	11.200000

27	28
0.000000	32.037570
0.000000	0.000000
1.071931	2502.583000
0.330136	762.420300
0.000000	1.102020E-05
0.000000	0.084038
0.000000	7.383790E-04
0.000000	1.222580E-06
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0.000000	0.000000
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0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.009717
0.000000	0.000000
0.762259	0.759019
0.234763	0.231238
0.000000	3.342350E-09
0.000000	2.548820E-05
0.000000	2.239460E-07
0.000000	3.708000E-10
0.000000	0.000000
0.000000	0.000000
0.002921	0.000000
5.737120E-05	0.000000
0.000000	7.274610E-07
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
0.000000	0.000000
1.406256	3297.129000
38.975830	97284.520000
0.997021	1.000000
0.002979	0.000000
0.036080	0.033892
400.058400	400.000000
11.500000	10.900000
2.400537	
187.227600	
77.994060	

Attachment 5

SWENSON

15700 Lathrop Avenue
Harvey, Illinois 60426-5198
Telephone 708 • 331-5500
Fax 708 • 331-5559

November 25, 1998
S-No: . New Inquiry

Lockheed Martin Idaho Technologies Company
P.O. Box 1625
Idaho Falls, ID 83415-3710

Attention: Jack Prendergast, P.E.

Subject: Budgetary proposal, four (4) spray dryers, Calcine and frit

Gentlemen,.

Thank you for your interest in Swenson Process Equipment. Based on the information provided in your fax dated November 17, 1998, regarding the above referenced project, we are pleased to offer the following budgetary proposal for four (4) small steam heated, spray dryer systems. These systems are provided on and equipment only basis as they are simple to erect and install.

We look forward to assisting LMITCO as this project develops and offering firm pricing for engineering and equipment when the time is appropriate.

Budgetary pricing information on the spray dryer systems are provided below. Budget prices are within approximately +/- 50% for use with your feasibility study.

The design is based upon the following dryer design parameters:

Feed Rate (lbs/hr): 545
Feed Mositure (wt%): 60
Product Rate (lbs/hr): 219
Product Moisture (wt%): 0.5

The base case presented below is for an open system whereby all vapors leave the system following the bag house. An option for a closed loop system has been provided below by addition of a heat exchanger and additional ductwork.

Base System:
For this application, we recommend using a 4'-6" diameter x 30'-0" long on the straight side, parallel flow spray dryer in stainless steel construction. Along with the dryer, the system will contain the following components:

- Steam Coils

SWENSON

- High Pressure Atomization Pump
- Baghouse with rotary air lock (SS)
- Interconnecting Duct-work (SS)
- Exhaust Fan (SS)
- Instrumentation and Control Panel

From the dryer feed tank (supplied by Others), slurry is pumped to the spray dryer. A high pressure nozzle ensures that the brine is atomized as it enters the dryer chamber. Air is heated using steam coils (steam at 150 psig) and is tangentially mixed with the atomized brine near the top of the dryer vessel. The brine dries as the mixture cocurrently decends downward into the vessel passing the "tacky" stage before cotact with the dryer walls occur. This prevents caking on the dryer walls.

The dry solids are then ducted to the baghouse where the solids fall to the bottom and the warm, moist vapor exits upwards - first through the bag filters, up through the exhaust fan and out the exhaust stack. The highly efficient Nomex bag filters prevent salt particles from exiting the exhaust stack. The solids are discharged from the baghouse cone bottom through a rotary air lock and into the Client's solids handling system.

The estimated utility consumption for each dryer is:

Steam Consumption: about 1,100 lbs/hr of steam at 150 PSIG
Electrical Power (Hp): about 24

The budgetary selling price (+/- 50%) for one dryer system as described above is USD $330,000 for each dryer or $1,320,000 for the four dryer systems.

Closed loop system:
As requested, a close loop system has been reviewed. In order to recycle the air in the system and minimize air exhaust, a plate type heat exchanger and additional ductwork would need to be included following the baghouse. The condenser/heat exchanger, constructed of 316 SS, would require about 10 gpm of cooling water. Exit temperature from the condenser/heat exchanger is approximately 115 deg. F. The vapors exiting this unit are saturated in water vapor until reheated by the steam coils.

The budget price addition (+/- 50%) to include an optional plate type heat exchanger is USD $4,000 or $16,000 for the four spray dryer systems.

Again, thank you for the opportunity to provide assistance on this project. If you have any questions, please feel free to contact the undersigned at (425) 313-

3668 or Mr Brian Dempsy, Dryer Department, Assistant Manager, at (708) 331-5500.

Sincerely yours,
SWENSON

David J. Bowlin
Regional Sales Manager

Enclosure

SWENSON

15700 Lathrop Avenue
Harvey, Illinois 60426-5198
Telephone 708 • 331-5500
Fax 708 • 331-5559

November 30, 1998
S-No: New Inquiry

Lockheed Martin Idaho Technologies Company
P.O. Box 1625
Idaho Falls, ID 83415-3710

Attention: Jack Prendergast, P.E.

Subject: Additional Information

Reference: Budget proposal, 11/25/98, Four (4) spray dryers, Calcine and frit

Gentlemen,

Thank you for your phone call this morning. And thank you for your continued interest in Swenson Process Equipment. We will be pleased to work with LMITCO when the time arrives on this project.

As mentioned in the above referenced budgetary letter, the dryer is 4'-6" diameter and 30'-0" on the straight side. With the conical bottom and elbow required for the vapor duct to the dryer, the overall height is approximately 38 feet.

Overall dimensions of the system are approximately 15' x 20' x 38' (L x W x H).

Air flow to the dryer is estimated at 3,500 ACFM.

If you have any questions, please feel free to contact the undersigned at (425) 313-3668 or Mr Brian Dempsy, Dryer Department, Assistant Manager, at (708) 331-5500.

Sincerely yours,
SWENSON

David J. Bowlin
Western Regional Sales Manager

Enclosure

swenson
Swenson Process Equipment, Inc.
15700 Lathrop Avenue, Harvey, IL 60426
PHONE: 708 331-5500 Telex 25-3274
FAX: 708 331-5559

ATTN: MR. DAVID BOWEN SEATTLE, WASH. OFFICE. (FAX NO. 425-313-7349)

DRYER QUESTIONNAIRE

Name W. (JACK) PRENDERGAST, P.E.

Company Name LOCKHEED-MARTIN IDAHO TECHNOLOGIES CO.

Address P.O. BOX 1625
IDAHO FALLS, IDAHO 83415-3710
PHONE #: (208) 526-8221, FAX #: (208) 526-6802

VENDOR TO DETERMINE - MOST ECONOMICAL

Type of equipment desired (please check)

Spray dryer/cooler	✓	Rotary dryer/cooler	✓
Fluid bed dryer/cooler		Flash dryer/cooler	
Steam tube dryer		Water tube cooler	

(OR)

Description of process: IT IS REQUIRED TO DRY A 60 WT% SLURRY TO A 50 WT% DRY SOLID PRIOR TO FEEDING A WASTE VITRIFICATION MELTER @ THE INEEL. PLEASE SIZE & COST BOTH DRYER TYPES CHECKED.

Material to be processed WASTE OF 10 WT% CALCINE, 30 WT% FRIT, AND 60 WT% WATER.

Chemical composition (if known) (SOLIDS CONTENT): 8 WT% Al_2O_3, 8.7% CaF_2, 3% ZrO_2, 14% B_2O_3, 4% LiO_2, 13.6% Na_2O, & 48% SiO_2.

Desired material of construction 304 SS

Solid Feed

Capacity _____
Basis: feed product dry basis (circle)

Initial moisture _____

Specific heat _____

Bulk density _____

Feed temperature _____

Liquid Feed (PER DRYER, 4 REQ'D)

(DESIGN) Capacity 544.5 LBS/HR

Percentage Solids
dissolved _____
suspended 40 WT%

Liquid density 89.5 LBS/FT^3

Viscosity UNKNOWN.

Feed temperature 85°F

Type of atomization (please circle)
wheel (pressure) two fluid

Product

Final moisture .5 WT %

Bulk density 126.8 LBS/FT³

Maximum product temperature 250°F

Melting point ~1562°F

Product screen analysis

U.S. screen	Percent Retained
10 mesh (2.00 mm)	
14 mesh (1.41 mm)	
20 mesh (.841 mm)	
40 mesh (.42 mm)	
50 mesh (.297 mm)	
60 mesh (.250 mm)	
80 mesh (.177 mm)	
100 mesh (.149 mm)	
120 mesh (.125 mm)	
140 mesh (.105 mm)	
170 mesh (.088 mm)	
200 mesh (.074 mm)	
230 mesh (.063 mm)	
270 mesh (.053 mm)	
325 mesh (.044 mm)	

ALL SOLIDS WHICH ARE COMPOSED OF CALCINE & FRIT WILL HAVE A PARTICLE SIZE OF 50 TO 100 MICRONS.

Plant Location IDAHO NAT'L ENG'NG & ENV'MTL LAB. (INEE

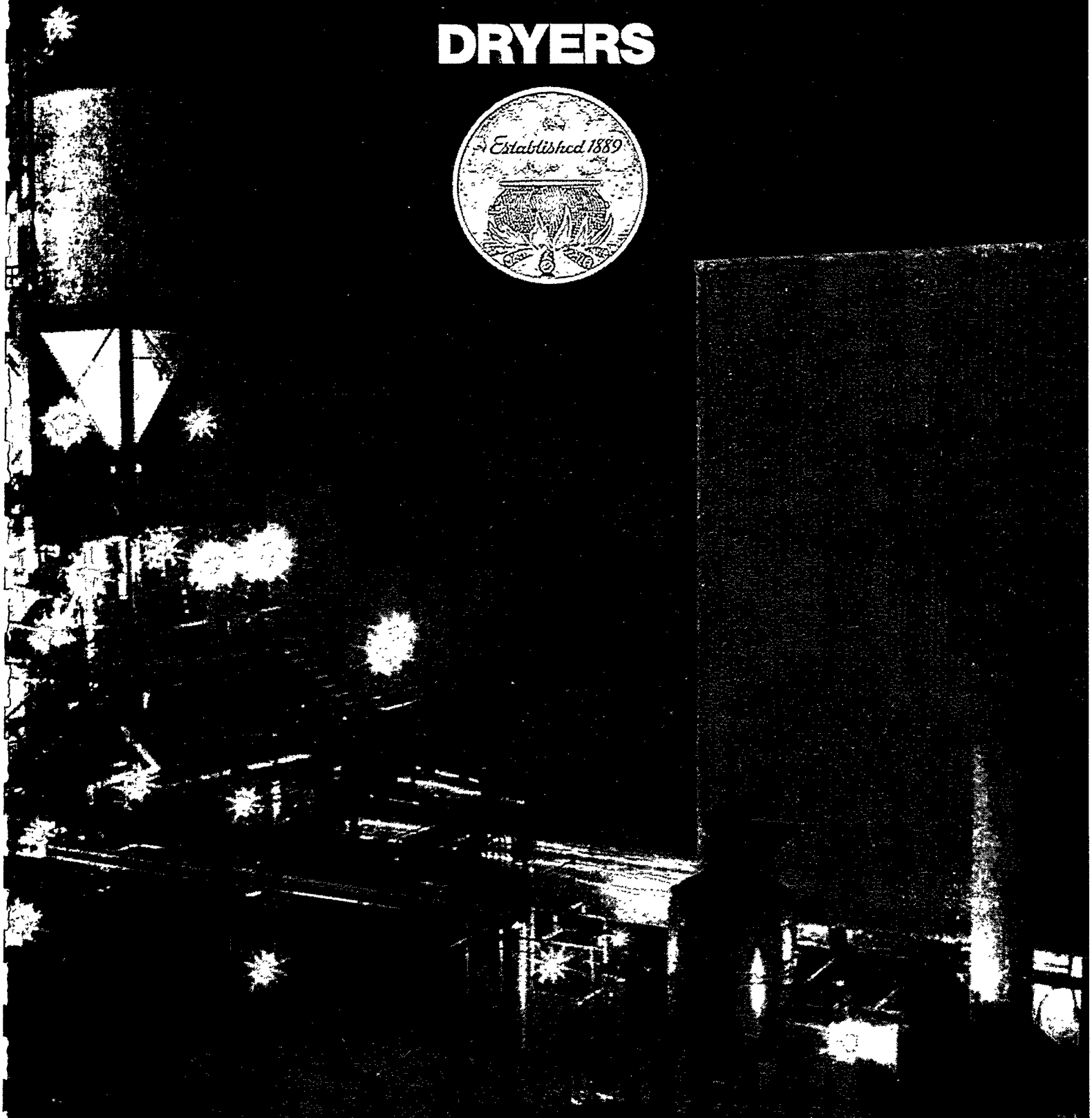
A. Abient temperature winter db. 70°F (INDOORS)
summer db 100°F wb

Elevation 5500 FEET ABOVE MEAN SEA LEVEL
Fuel type N/A.
Cooling water temperature 79°F
Pressure Pressure 50 PSIG
Electricity 220 Volt 3 Phase Hertz 60

COMMENTS: IT IS REQUESTED THAT SWENSON PROVIDE A PACKAGE SYSTEM DESIGN AND COST ESTIMATE FOR A CLOSED LOOP AND OPEN LOOP AIR ADDITION (OR NITROGEN) SYSTEM. THIS IS FURTHER REQUESTED FOR BOTH DRYER TYPES SO THAT (4) COST ESTIMATES BE PROVIDED.

SWENSON®

DRYERS



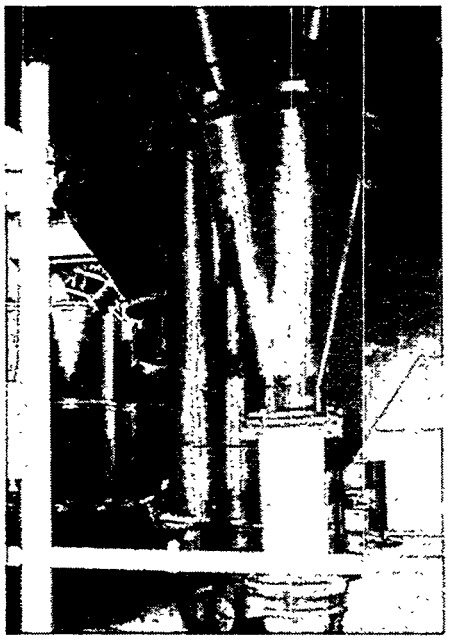
SWENSON® Dryers make the difference . . . the SWENSON difference

SWENSON® DRYING EQUIPMENT

Founded in 1889 by the chemical engineering pioneer Magnus Swenson, (1854-1936), SWENSON has been associated with innovation and quality in process equipment design and manufacturing. SWENSON is conveniently located in Harvey, Illinois.

Around the world, literally thousands of evaporators, crystallizers, dryers and other process equipment bear the SWENSON name. They represent decades of SWENSON engineering experience throughout the chemical processing industry. . . a record of achievement equalled by none.

The SWENSON line of drying equipment is unsurpassed. SWENSON is the only manufacturer which supplies parallel-flow and mixed-flow spray dryers, rotary and fluid bed dryers and coolers and suspension dryers.



Bottom view of 4'6" diameter parallel-flow spray dryer in SWENSON laboratory

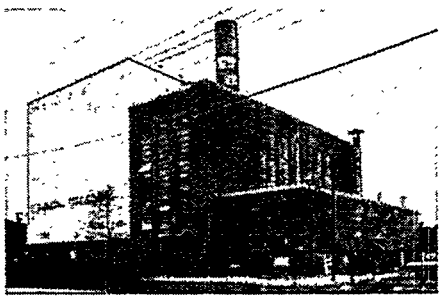
This extensive equipment line has provided SWENSON engineers and technicians with expert solutions for a wide variety of drying problems. The wide variety of drying requirements encountered over the years has allowed SWENSON engineers to make numerous important advances in drying technolgy. It is an enviable track record that can go to work for you now.

SWENSON DRYER TEST CENTER

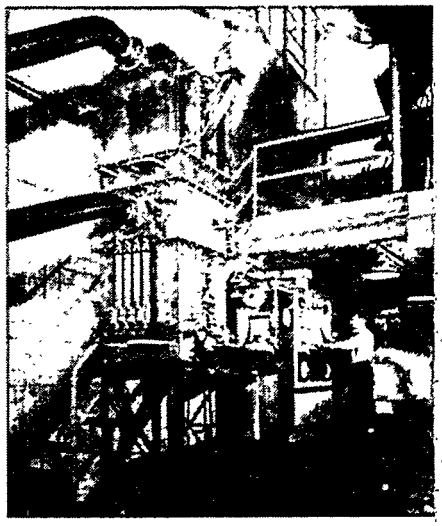
SWENSON has long recognized the customer's need for product testing. The information available through testing is crucial to the success of the ultimate full-scale production application.

Using firsthand dryer test results obtained in the SWENSON Test Center, SWENSON engineers can assist customers in making knowledgeable decisions about drying techniques and recommend the appropriate, full-scale production equipment.

The SWENSON Test Center, located in Harvey, Illinois, is a completely equipped laboratory able to pretest, in either production or pilot operations, virtually any product. SWENSON has tested more



SWENSON Test Center



Laboratory fluid bed dryer

than 700 different products over the past forty years.

In addition to crystallization and evaporation testing equipment, the test center maintains a variety of dryers exclusively for testing purposes. These include a steam tube dryer, a fluid bed dryer, a suspension (flash) dryer, a mixed-flow spray dryer, a parallel-flow spray dryer, and a rotary air swept dryer. All are fabricated from T-304 stainless steel and utilize steam-heated air or combustion products as the drying medium. The rotary dryer is operable in either the parallel current or counter-current mode.

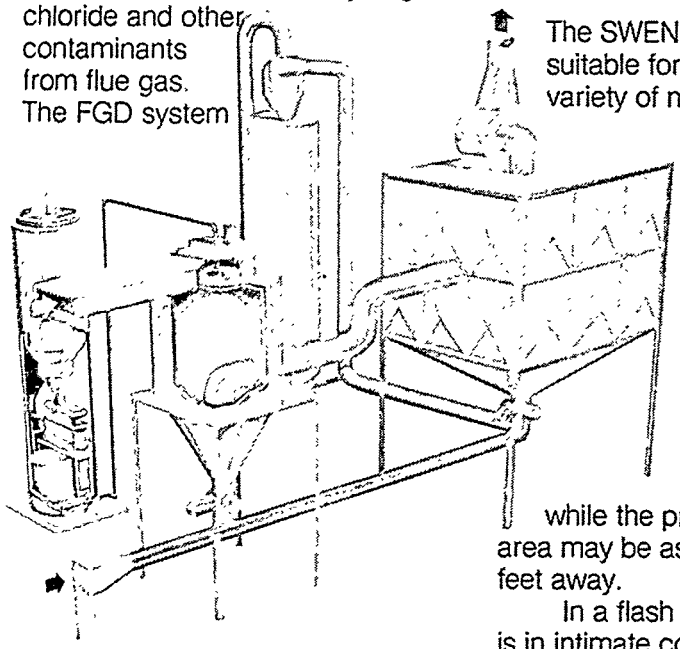
Each test is conducted by highly trained, experienced technicians under the supervision of SWENSON design engineers. Test results reveal important product drying characteristics, summarized in terms of particle size, moisture content, flowability, solubility, color and operating parameters. Tests are conducted so that the laboratory process will duplicate the commercial process as closely as possible for customer evaluation.

Custom drying of material is possible on a limited scale. The facilities of the SWENSON Test Center are available to our customers for this purpose.

TOTAL PROCESS CAPABILITY

Flue Gas Dry Scrubbing

The SWENSON Flue Gas Dry scrubbing system (FGD) is designed to remove sulfur dioxide, hydrogen chloride and other contaminants from flue gas. The FGD system



SWENSON Flue Gas Dry Scrubbing System

consists of an alkali (Na or Ca) feed preparation, spray dryer and dry collector (fabric filter or electrostatic precipitator). Alkali feed is atomized by means of a two-fluid nozzle or centrifugal atomizer. Collection efficiencies of up to 99% on HCl and over 70% on SO_2 can be achieved.

Ammonium Sulfate Processing Plant

Crystals formed by cooling concentrated ammonium sulfate solution in a SWENSON DTB crystallizer are centrifuged and passed through a SWENSON co-current direct heat rotary dryer. Ammonium sulfate containing 2-5% moisture is screw fed into the dryer; anhydrous ammonium sulfate containing 0.1% or less moisture is discharged at 200°F. Hot gases (390 to 700°F) are produced by the air heater. Vent gases enter a fabric filter or wet scrubber where any dust is removed.

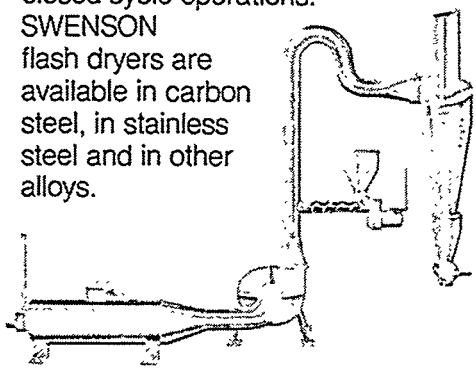
FLASH DRYERS

The SWENSON flash dryer is suitable for drying a wide variety of materials. The product is dried in a hot gas stream which pneumatically conveys the material through the body of the dryer. This unique feature of the flash dryer allows the dryer to be positioned near the process while the product storage area may be as far as 200 feet away.

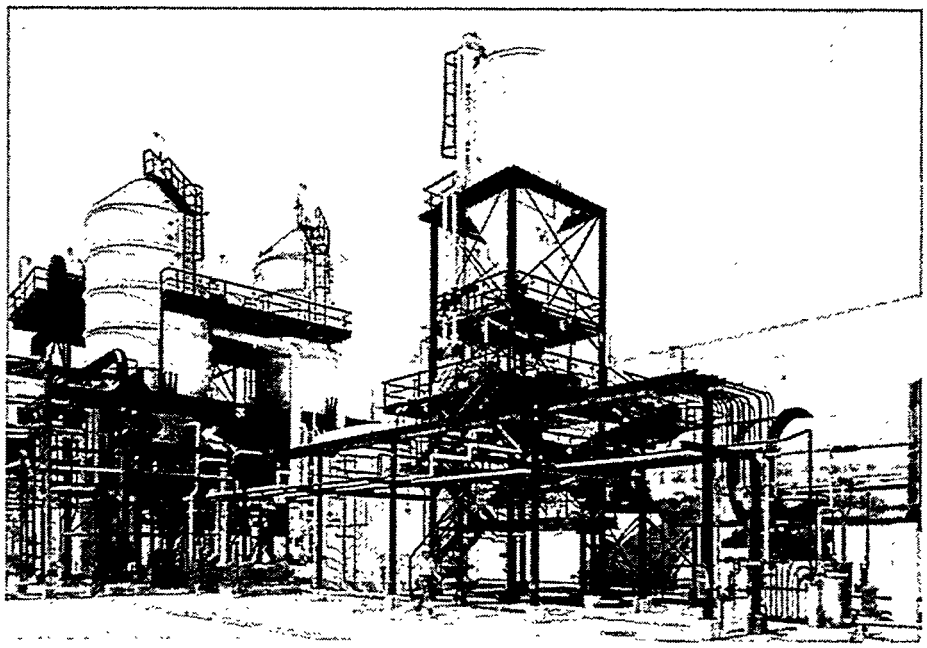
In a flash dryer, the product is in intimate contact with the gas stream for only a very short time. The flash dryer is, therefore, ideally suited for removing free moisture from the surface of the material being dried.

Operation of the flash dryer is straightforward. A single exhaust fan, located on the clean gas side of the dust collector, is used to induce the flow of gas through the heater, uptake pipe, horizontal duct, and dust collector separator. On occasion, a cage mill fan is used as a lump breaker to disintegrate any large agglomerates of material.

Cyclone or fabric filter dust collectors are commonly used for dust collection and separation. Due to the design and operating techniques employed, the flash dryer can be easily adapted for closed-cycle operations. SWENSON flash dryers are available in carbon steel, in stainless steel and in other alloys.



SWENSON Flash Drying System

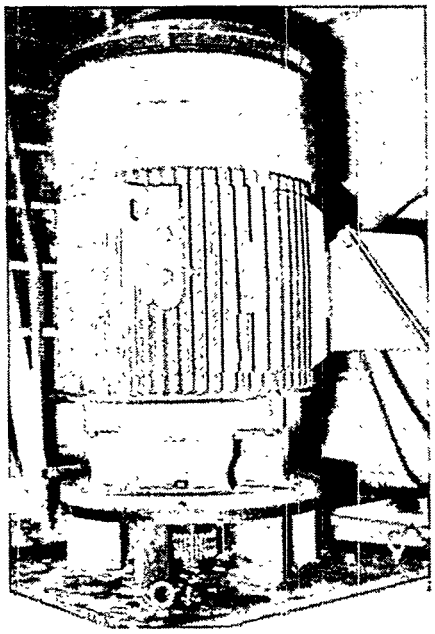


Ammonium sulfate system with 9′ diameter x 40′ rotary dryer

SPRAY DRYERS

SWENSON manufactures spray dryers suitable for either parallel, reverse, or mixed-flow operation.

The operation of the spray dryer is relatively simple. A slurry is atomized into the drying chamber



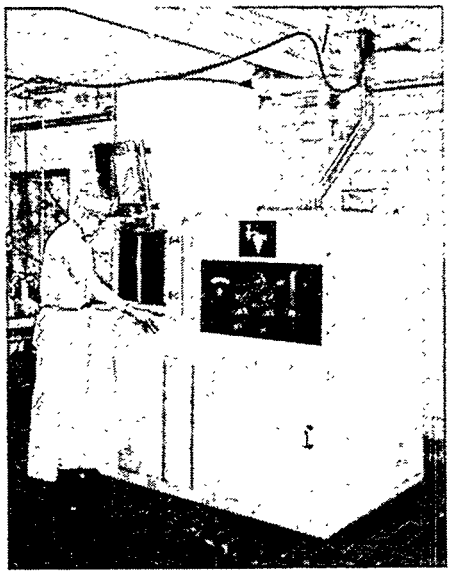
150 HP drive for direct-driven rotary wheel atomizer being tested in laboratory test pit

in the form of droplets. When these droplets contact the warm gases, they dry to a powder.

The hot gases, generated by either steam coils or a combustion furnace, enter the cylindrical drying chamber at various points, depending on the type of dryer. In the parallel-flow configuration, the air enters through the top: in the mixed flow configuration, the air enters tangentially: and, in the reverse flow configuration, the air enters through the bottom.

Atomization may be achieved in one of three ways: (1) high pressure nozzles, (2) two-fluid nozzles, or (3) centrifugal atomizers. The selection of the proper atomizer is governed by the characteristics of the material to be dried.

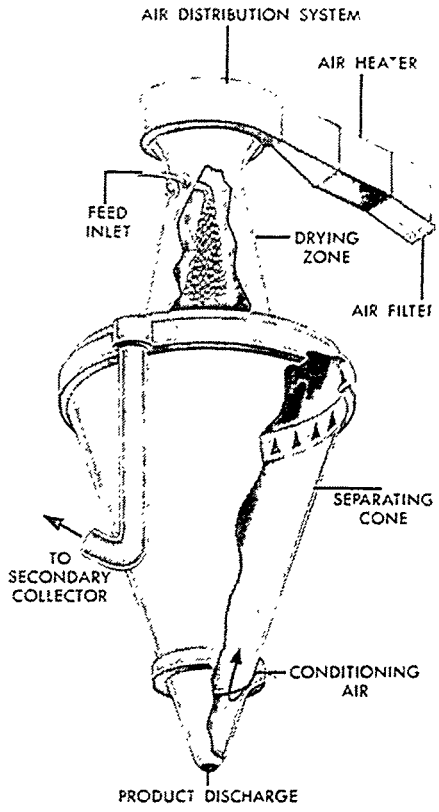
Any product which is removed from the chamber by the spent drying gases is separated



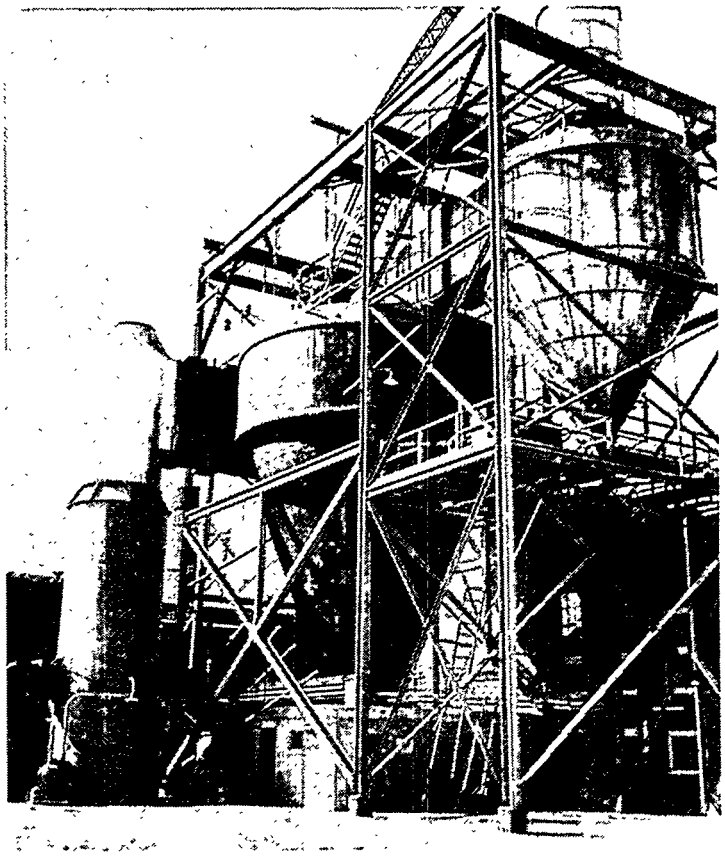
SWENSON Test Center spray dryer designed primarily for use in laboratory and pilot plants

from them by means of a cyclone or a fabric filter dust collector. The exhaust gases can be further cleaned by a wet scrubber if required.

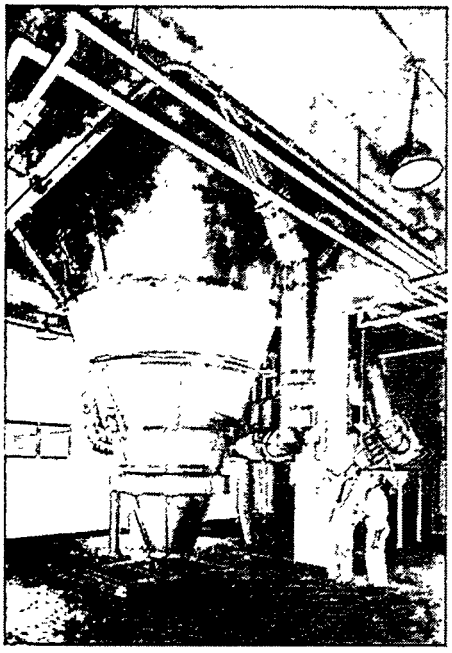
A spray dryer can also be operated in a closed loop using an inert gas, such as nitrogen, as the drying medium.



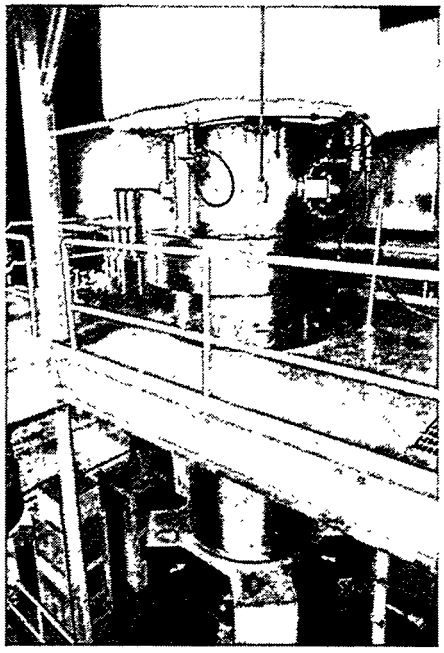
Operating diagram of a parallel-flow SWENSON spray dryer for special products



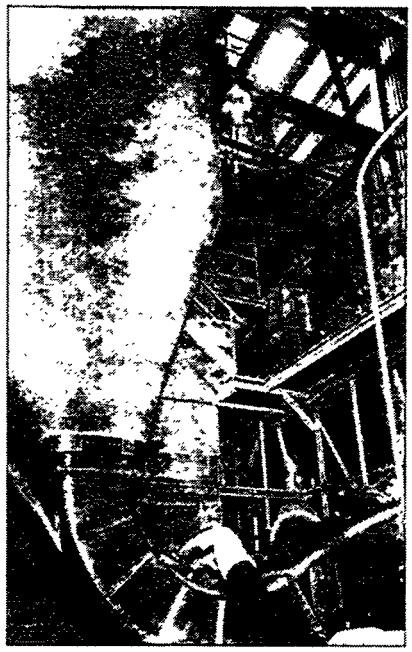
SWENSON 22′ diameter mixed-flow spray dryer used for drying silica gel catalyst



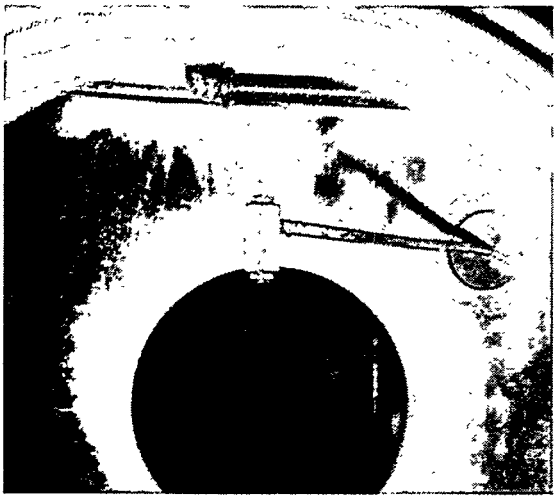
Bottom discharge cone on parallel-flow spray dryer



SWENSON 4′ 6″ diameter parallel-flow spray dryer



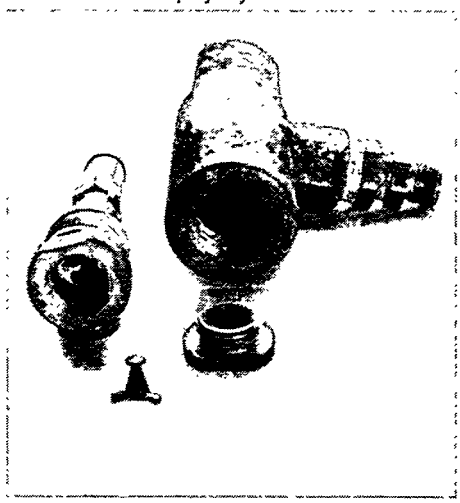
SWENSON spray dryer discharge duct for 10′ diameter PF spray dryer



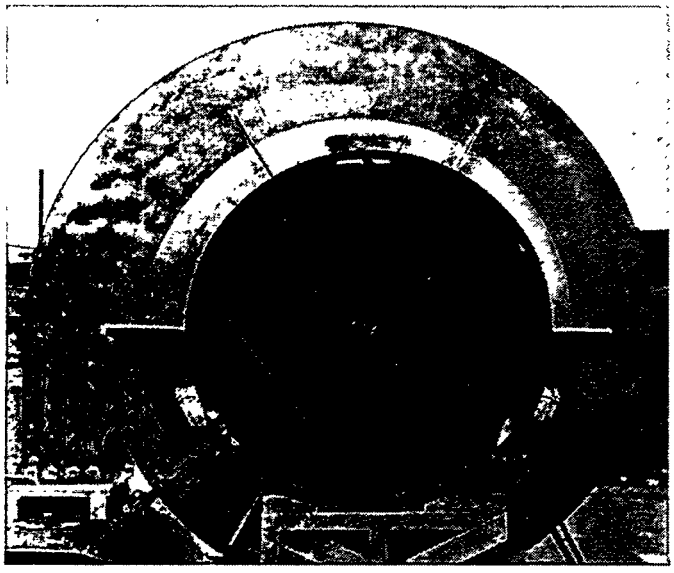
Pressure atomizer



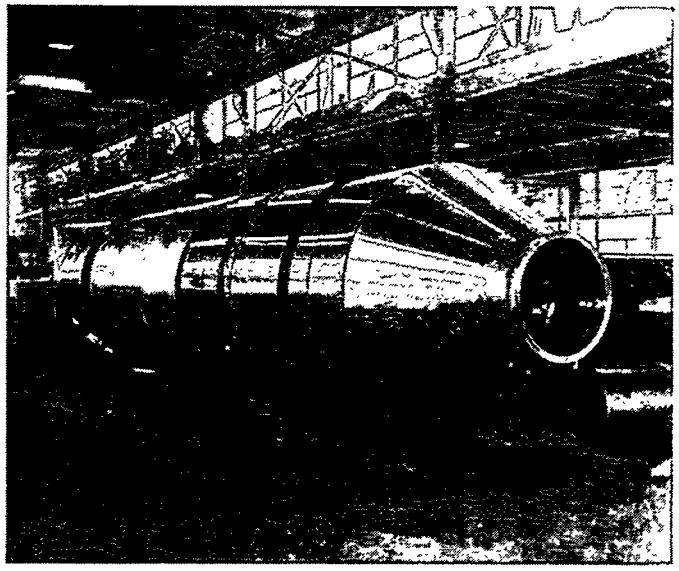
Wheel atomizer



Two-fluid atomizer



WFAP head for 12′ diameter parallel-flow coffee dryer



SWENSON spray dryer drying chamber, partially insulated and sheathed

FLUID BED DRYERS

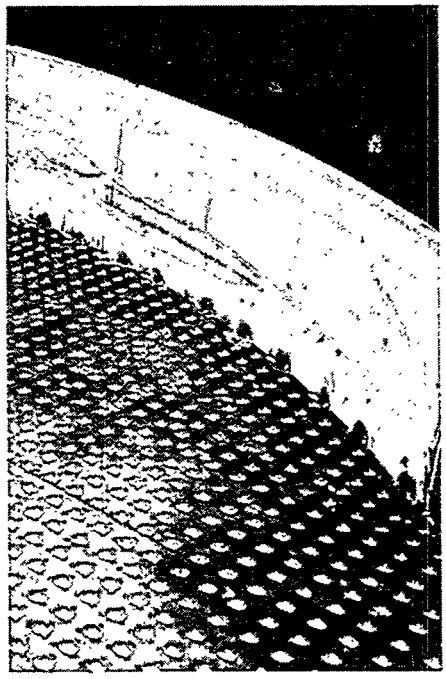
When optimum heat transfer efficiency is required for the drying process, the SWENSON fluid bed dryer is the best choice.

The drying system features a stationary, upright shell, through which heated air is forced and/or induced by a blower arrangement.

Material enters the system through a feed chute or screw feeder, and is fluidized by the heated gas stream. This produces a high degree of intermixing and intimate contact of the material and the drying media, resulting in optimum heat transfer efficiency.

The hot gases used for drying can be generated by either steam coils or a combustion furnace. These gases enter the plenum chamber and are evenly distributed across the body of the dryer by a perforated plate. The holes in this plate are covered with caps which prevent material from entering the plenum when the dryer is not in operation. The vent gases are exhausted through a dust collector for maximum recovery of fines.

The dry product overflows an adjustable weir plate and is discharged continuously through a rotary air lock. The fluid bed dryer can be operated in either open or closed cycles.

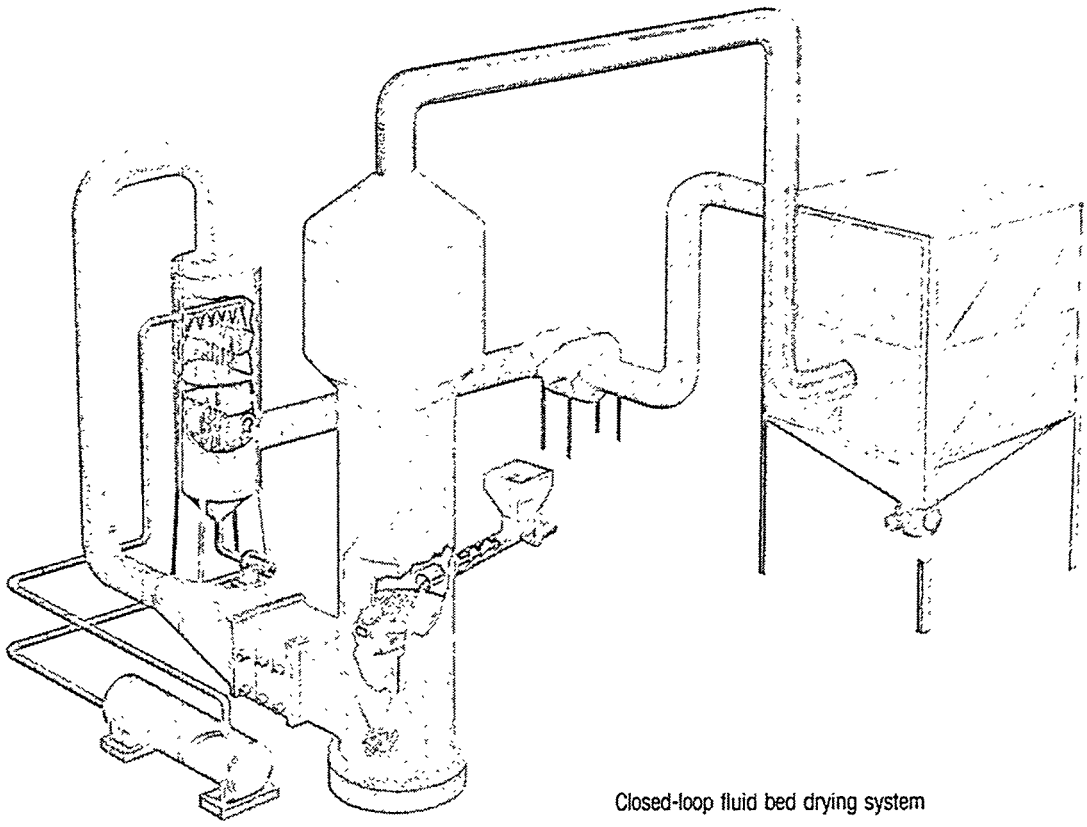


Air distribution plate



SWENSON 12′ diameter fluid bed dryer for plastic

The fluid bed dryer could be operated in a closed cycle with the addition of a solvent recovery system and the use of an inert gas, such as nitrogen, as the drying medium. Vent gases leaving the fluid bed dryer are first cleaned by passing them through a cyclone, or fabric collector, and then cooled in a condenser to remove the solvent. The cooled, saturated gases are reheated in an indirect-fired air heater or steam coils, prior to entering the dryer.



Closed-loop fluid bed drying system

STEAM TUBE DRYERS

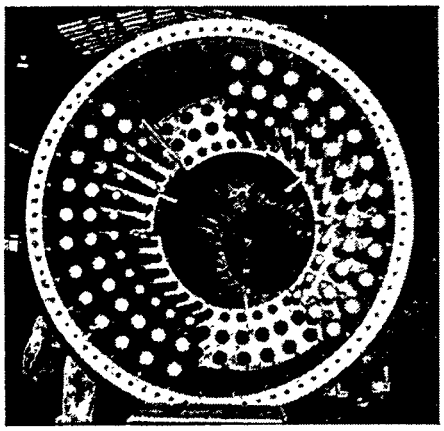
The SWENSON steam tube dryer is a rotating cylinder containing rows of steam tubes, arranged in concentric circles, and extending the full length of the cylinder. The tubes are designed to transfer heat from the steam to the material being dried and may be supplied with or without fins, according to the design specifications.

Together with radial flights, the tubes serve to agitate the material and to provide uniform mixing and drying. The dried product is discharged through discharge chutes.

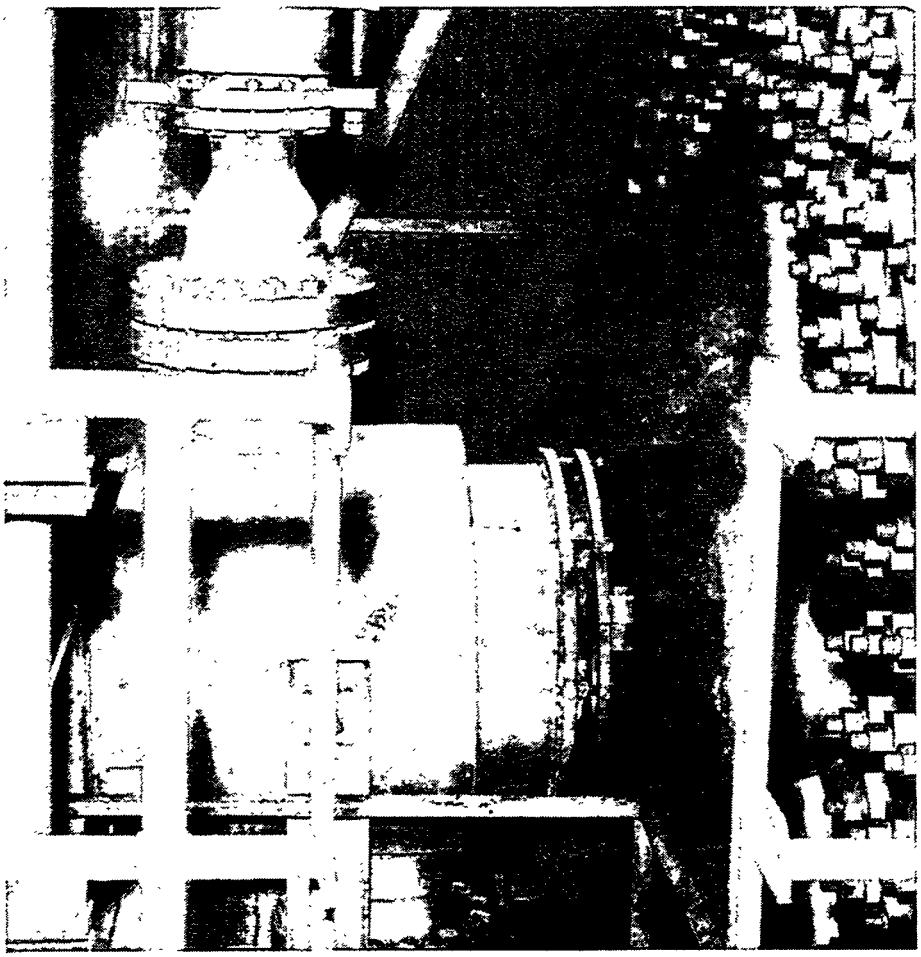
Steam is introduced into the tubes through a manifold located at the discharged end of the cylinder. The manifold is connected to a rotary steam joint which admits the steam and continuously drains the condensate. The thermal efficiency of the dryer is very high and heat loss through the cylinder wall is minimal, because the steam tubes are completely enclosed by the dryer.

SWENSON steam tube dryers are designed and manufactured in accordance with the ASME Code, Section VIII, for Unfired Pressure Vessels. Steam tube dryers may range in size from 12″ to 144″ in diameter and from 8′ to 90′ in length.

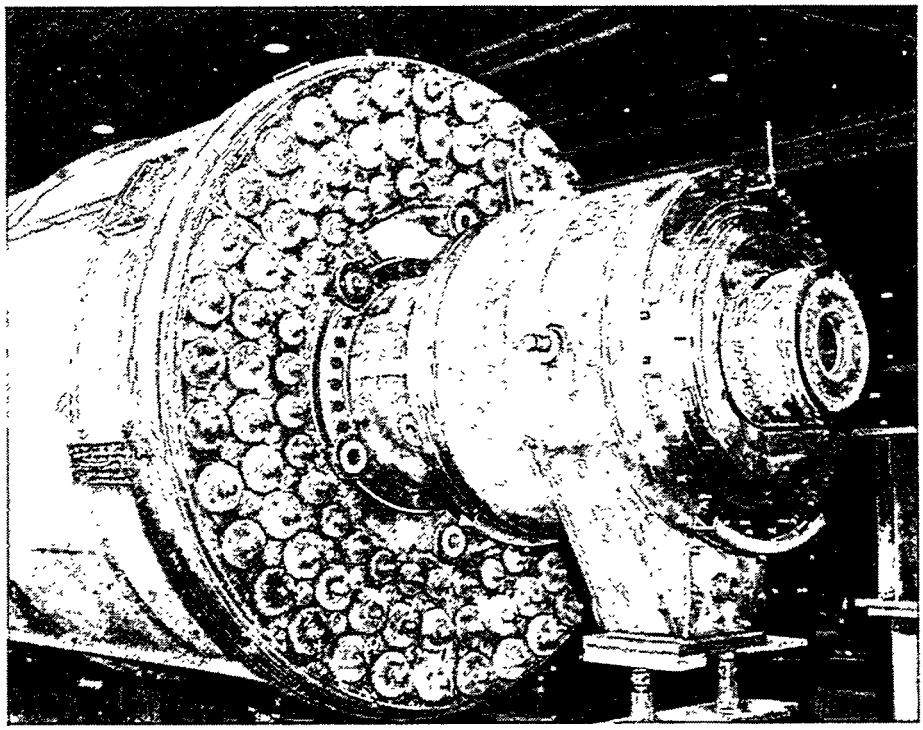
Water tube coolers are similar in appearance to steam tube dryers. The cooling water enters the cooler at the discharge end and leaves at the feed end.



SWENSON 8′ diameter x 75′ steam tube rotary dryer showing capped tube ends and tube supports



SWENSON steam neck for 450 psi steam on 12′ diameter x 90′ rotary steam tube dryer



Central discharge assembly on 8′ diameter x 60′ rotary steam tube dryer

ROTARY DRYERS

Parallel current operation exposes the wettest material to the hottest air, thus enabling heat-sensitive or sticky materials to be dried successfully. The evaporation of water prevents the material from overheating. As the material becomes drier, the air becomes cooler. The hot air at the feed end of the dryer warms the shell and flights, helping to prevent sticking of wet or tacky material to the metal.

Counter-current operation exposes the driest material to the hottest air, thereby producing a product having a very low moisture content, without sacrificing thermal efficiency.

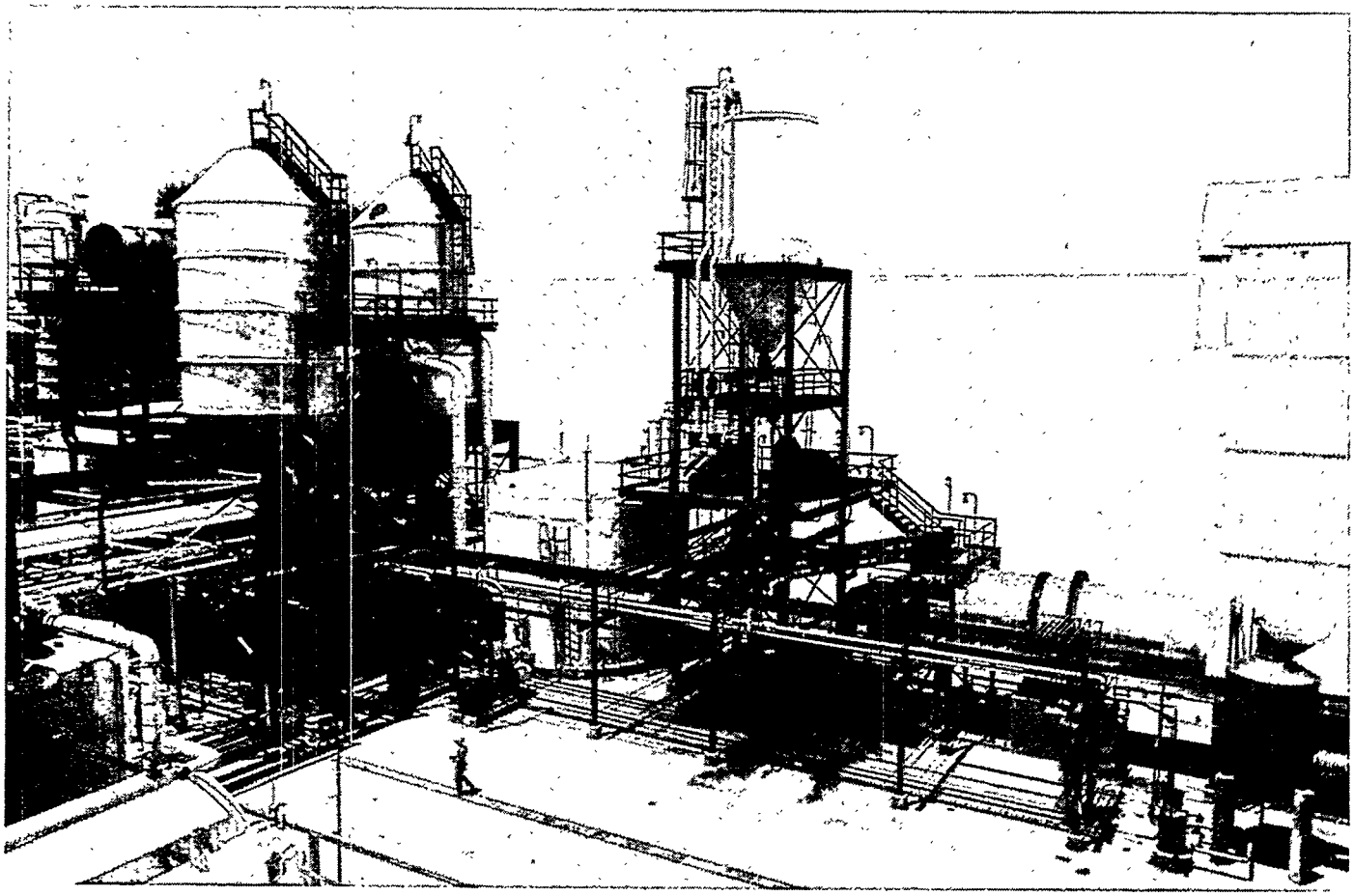
Warm air dryers utilize steam coils to heat ambient air to temperatures as high as 350°F. An exhaust fan, located on either the clean side of a dry dust collector or before a wet scrubber, is used to induce the flow of air through the steam coils, dryer, and pollution control equipment.

Direct heat dryers use an oil, gas or dual-fuel burner housed in a combustion furnace to produce hot air, reaching temperatures of up to 1800°F. The air is drawn through the dryer and pollution control equipment by an exhaust fan.

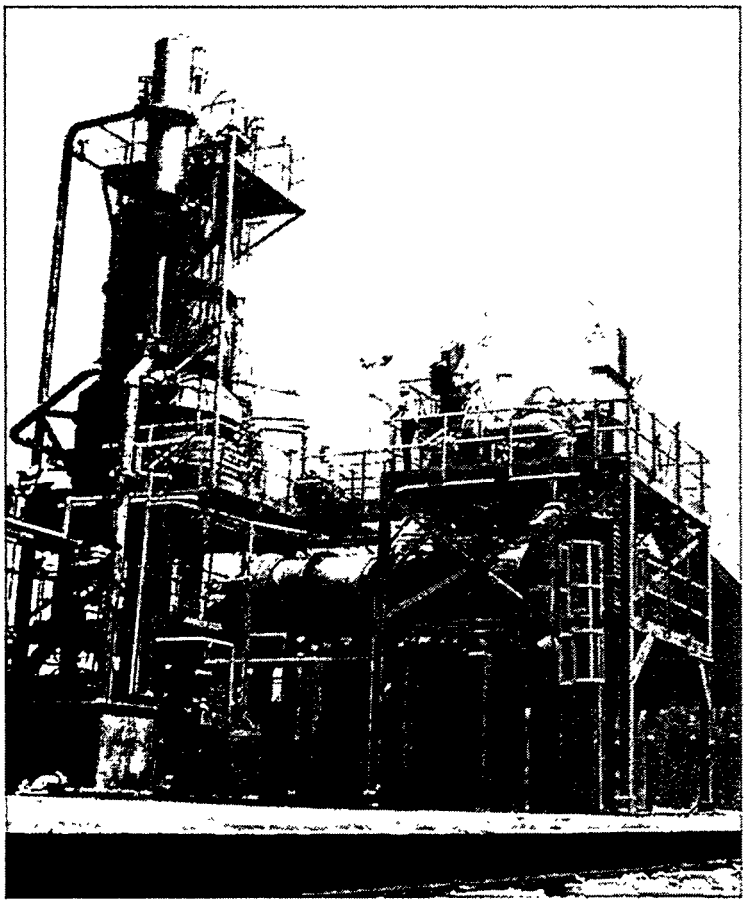
Rotary coolers, using either ambient or refrigerated air as the cooling medium, are designed much like the rotary dryer and operate in the counter-current mode.



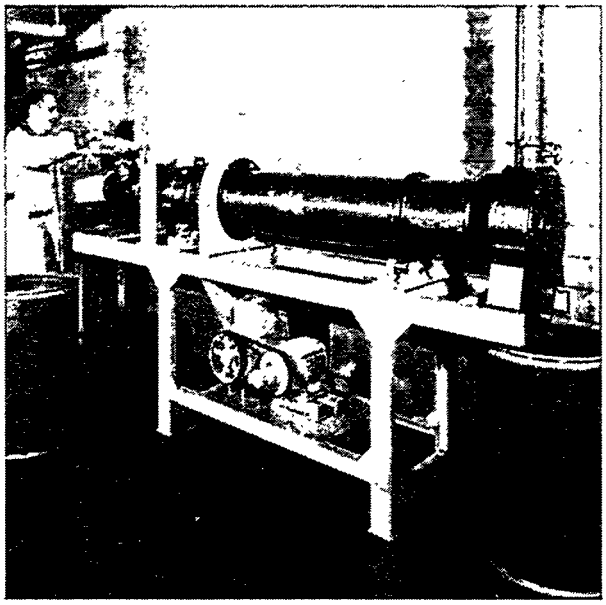
Mounting of girth gear



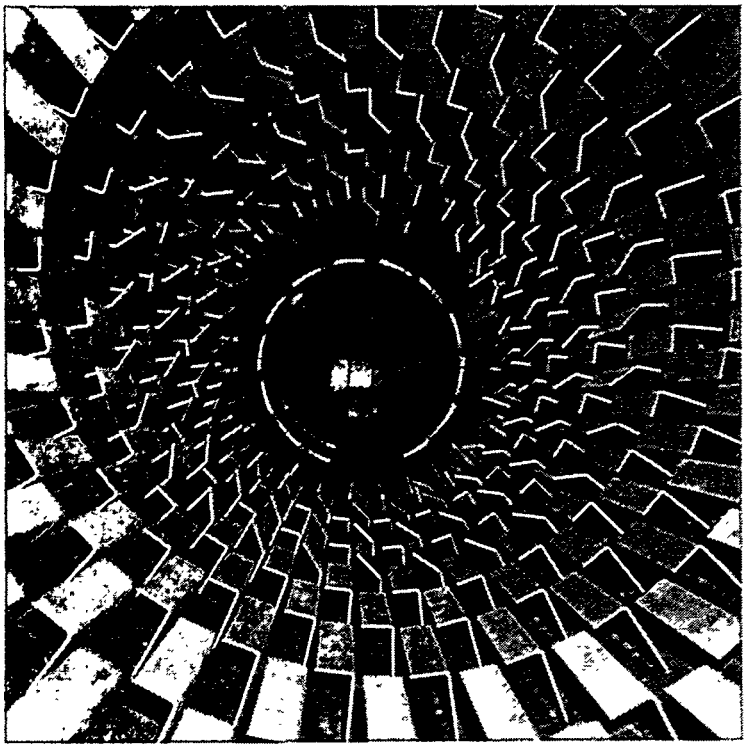
SWENSON DTB crystallizers and 8′ diameter x 40′ parallel-flow dryer for production of ammonium sulfate and drying system for anhydrous sodium sulfate



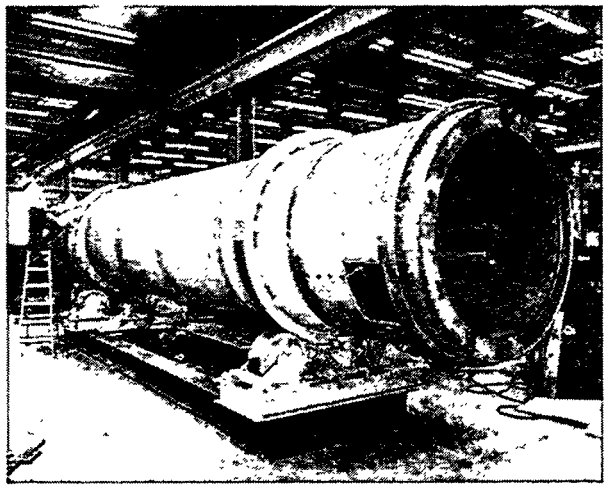
SWENSON DTB crystallizer and 4′ diameter x 25′ parallel-flow rotary dryer and cooler



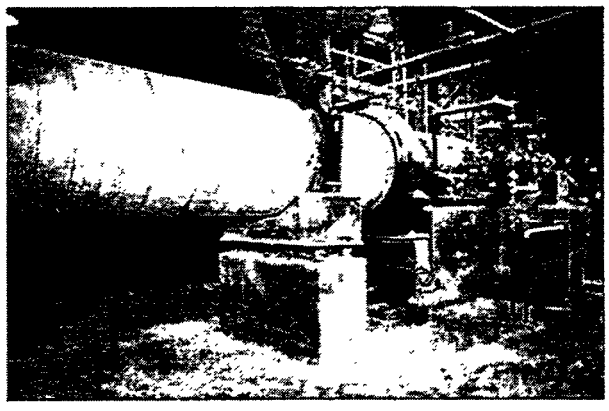
12″ diameter by 8′ long rotary dryer for laboratory use in pilot testing. Convertible to either direct fired or warm air / counter or co-current operation



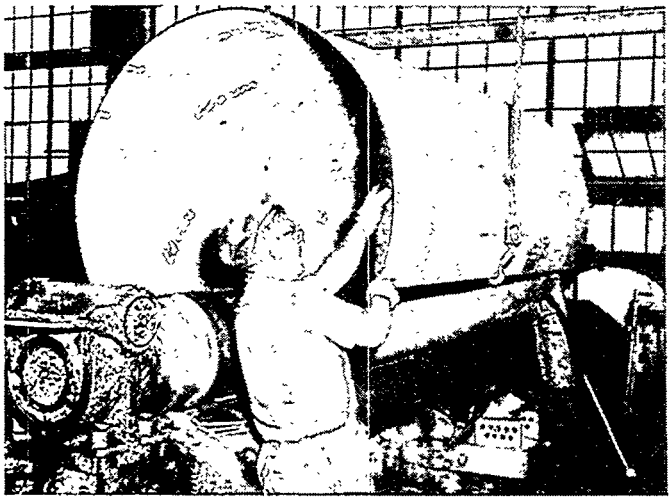
Interior of rotary dryer showing flights



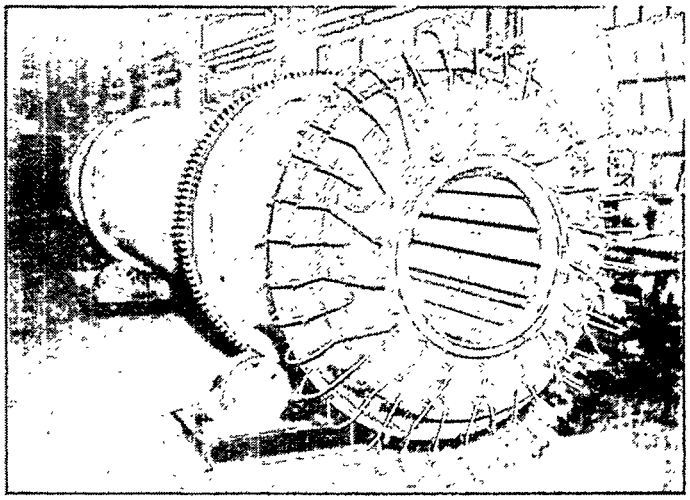
SWENSON 5′ diameter x 25′ CCDH dryer



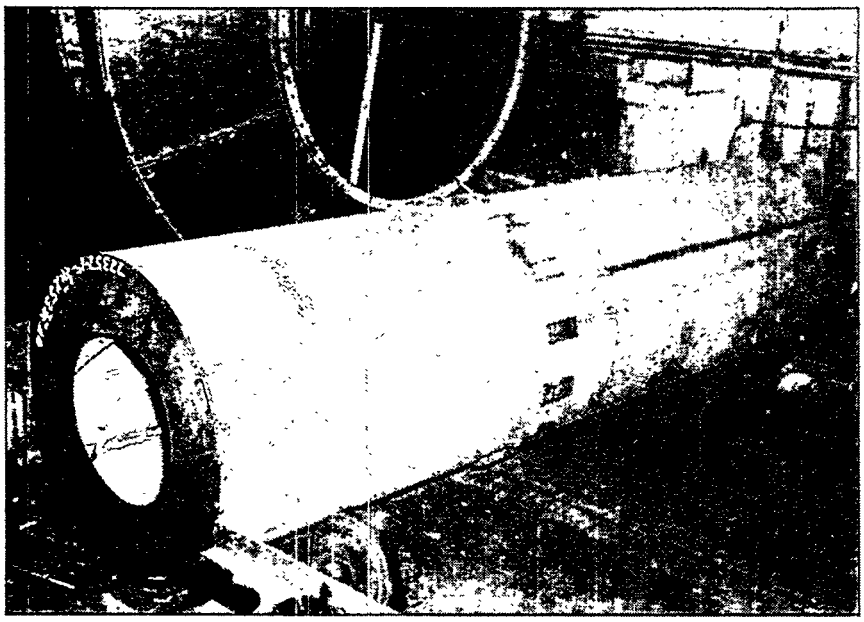
13′6″ diameter x 90′ long PCDH dryer for soda ash



Rolling of dryer shell section



SWENSON 54″ diameter x 25′ rotary steam tube dryer



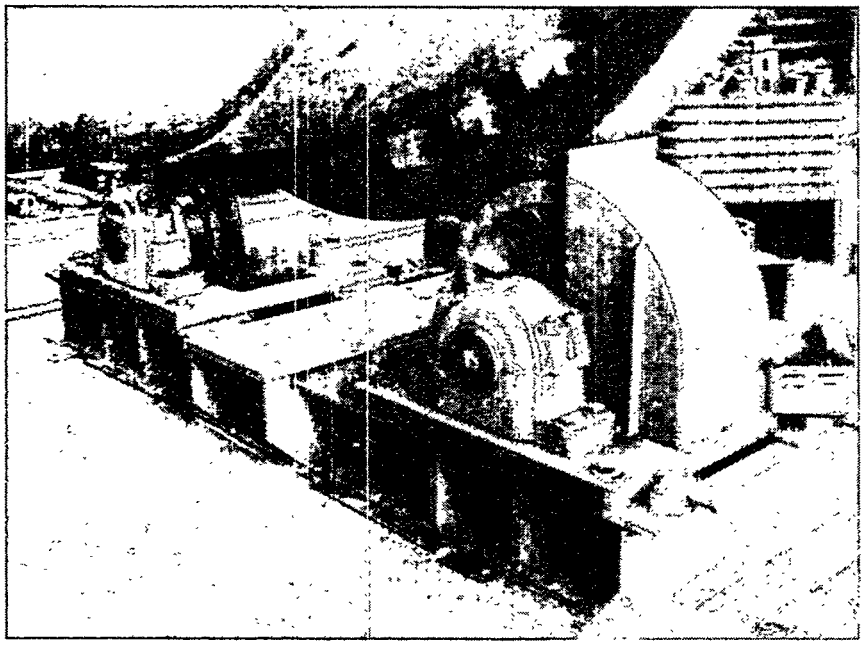
Partially finished dryer cylinder



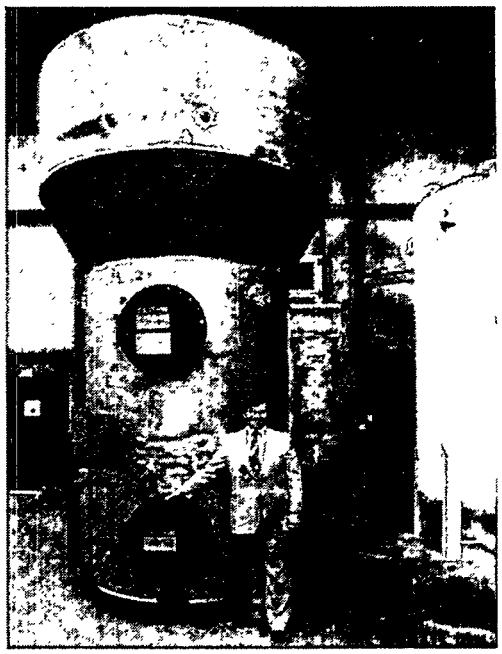
Thrust base showing thrust rolls, trunnion rolls and adjustments



Drive end base showing pinion, trunnion rolls and adjustments

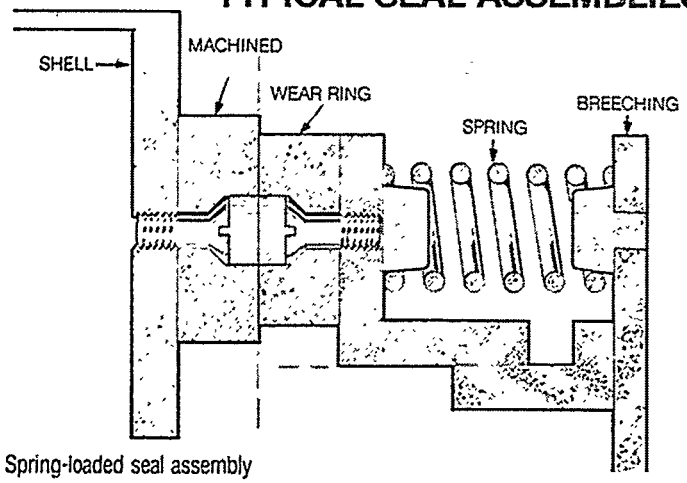


Free-end trunnion base

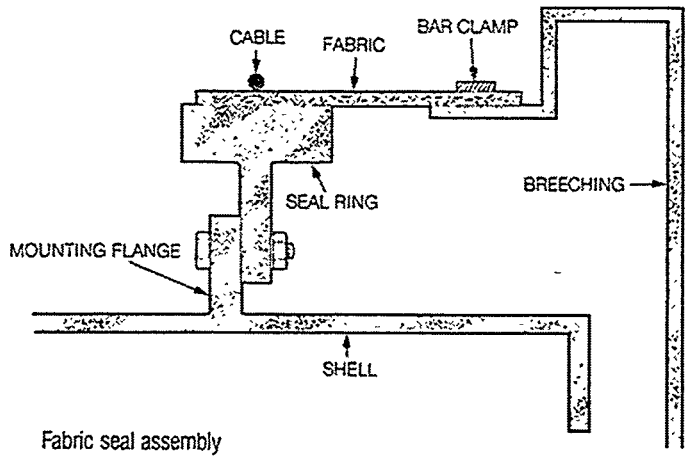


SWENSON 6′ diameter fluid bed dryer for the production of sodium chlorate

TYPICAL SEAL ASSEMBLIES USED ON ROTARY DRYERS



Spring-loaded seal assembly



Fabric seal assembly

THE FOLLOWING IS A PARTIAL LIST OF PRODUCTS WHICH HAVE BEEN DRIED SUCCESSFULLY IN THE SWENSON TEST CENTER:

Acid Filtrate
Alumina Gel
Aluminum Hydroxide Sorbose
Aluminum Salts
Aluminum Sulfate
Amino Acids
Ammonium Nitrate
Ammonium Sulfate
Bentonite Clay
Bleach, Chlorinated
Blood, Soluble and Insoluble
Bone Glue
Brewers Yeast
Calcium Propionate
Calcium Salts
Carbon Activated
Carmel Color
Cascara Extract
Catalyst
Ceramic Mix
Cheese, Soluble
Chloromycetin Liquor
Chocolate Powder
Chrome Yellow Pigment
Chromic Sulfate
Citric Acid
Clay Slip
Coffee
Corn Flour
Corn Starch
Dessert Powders
Detergents
Dextrine
Dextrose
Diammonium Phosphate
Disodium Phosphate, Anhydrous
Distillers Dry Grain
Dyes
Eggs — Whole, Whites, Yolks
Enzymes
Ferrites
Fertilizers
Fluorborate Solutions
Food Flavorings
Gelatin
Glaubers Salt
Gluten, Wheat
Gun Powder
Herbicide
Lactose
Latex
Lignin Slurry
Lime
Lithium Chloride
Lithium Hypochlorite
Magnesium Hydroxide
Magnesium Sulfate
Manganese Sulfate
Milk — Cocoa — Sugar Blend
Milk, Skim and Whole
Monosodium Glutamate
Ore — Mineral
Organic Pigment
Organic Salts
Papain
Pectin
Penicillin Waste Liquor
Pharmaceuticals
Phosphate Compound
Pigments
Plastics
Polysaccarides
Polystyrene Emulsion
Polyvinyl Acetate
Polyvinyl Chloride
Polyvinyl Pyrollidone
Potassium Sorbate
Protein, Soy Bean
Puddings
Sand
Shampoos
Silica Gel
Sludge
Sodium Bicarbonate
Sodium Borate
Sodium Carbonate
Sodium Chlorate
Sodium Chloride
Sodium Nitrate
Sodium Sulfate
Starch
Starch, Hydrolyzed
Steepwater
Stillage, Distillery
Streptomycin Waste Liquor
Sucrose
Sulfite Liquor
Tanning Agent and Extract
Tea, Soluble
Urea Resin
Vitamin Concentrate and Extract
Wax, Spray-cooled
Wetting Agents
Whey Modified, Cheese
Zinc Salts

SWENSON® EQUIPMENT FOR THE PROCESS INDUSTRIES

CONDENSERS
- Direct Contact Type
- Digester Blow
- Surface Type

COOLERS
- Flash
- Fluidized Bed
- Rotary
- Spray

CRYSTALLIZERS
- Batch
- Direct Contact Refrigeration
- Draft Tube
- Draft Tube Baffle
- Forced-Circulation
- Surface Cooled
- Reaction
- Decomposition
- Recompression
- Teflon Tube
- Multi-Stage Horizontal
- Spray Evaporators

DRYERS: FLUIDIZED
- Closed Cycle
- Direct Fired
- Indirect Heated

DRYERS: ROTARY
- Countercurrent
- Direct Fired
- Indirect Heated
- Parallel Flow
- Steam Tube

DRYERS: SPRAY
- Closed Cycle
- Countercurrent
- Mixed Flow
- Parallel Flow
- Research
- Reverse Flow

DRYERS: FLASH
- Direct Fired
- Indirect Heated

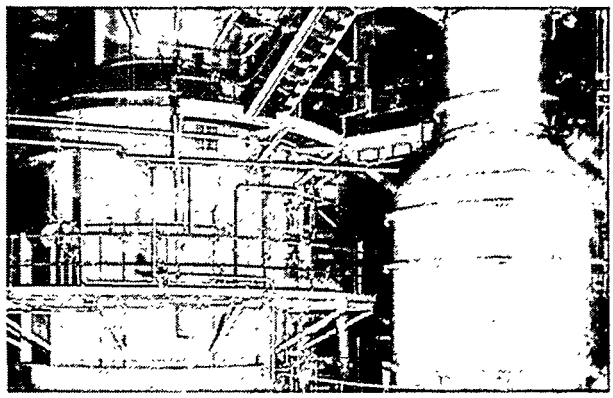
LABORATORY FACILITIES
- Bench Scale Tests
- Crystallization
- Evaporation
- Flash Dryers
- Fluidized Bed Crystallizers
- Fluidized Bed Dryers – Coolers
- Rotary Dryers – Coolers
- Spray Dryers
- Steam Tube Dryers

EVAPORATORS
- Calandria
- Forced-Circulation
- LTV Falling-Film
- LTV Rising-Film
- Natural Circulation
- Recompression

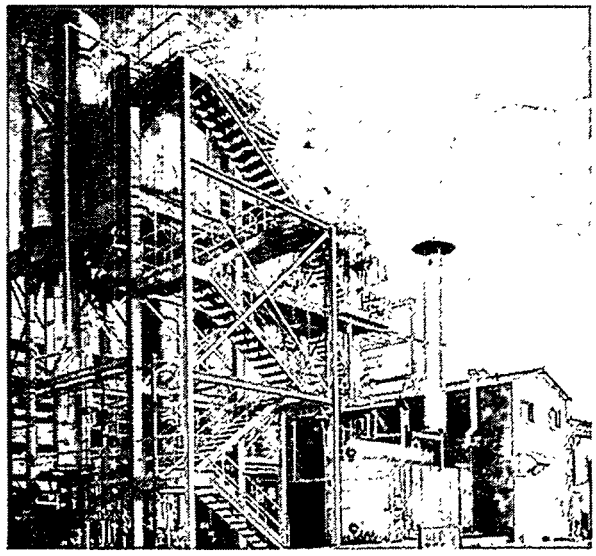
FILTERS
- Top Feed

HEAT EXCHANGERS
- Direct Contact
- Shell and Tube

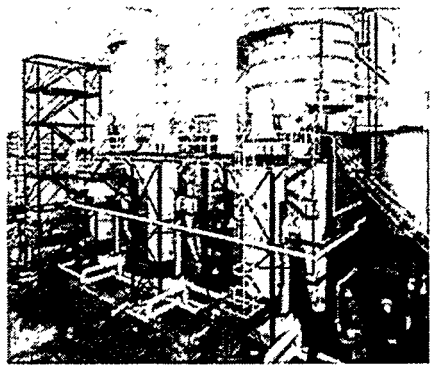
PROCESSING AND PROJECT ENGINEERING
- Ammonium Sulfate Crystallization & Drying
- Caustic Soda Systems
- Citric Acid Systems
- Fluorine Recovery
- Salt Crystallization & Drying
- Sodium Sulfate Recovery & Drying
- Sodium Chlorate System
- Wet Process Phosphoric Acid
- Potash Crystallization & Drying
- Soda Ash Calcining, Crystallization & Drying
- Others



Two DTB Crystallizers used for the production of potash



SWENSON Forced-Circulation Crystallizer used for producing sodium sulfate



Triple Effect Caustic Evaporator

SWENSON LICENSEES & AFFILIATES

Please see insert for list of SWENSON LICENSEES and AFFILIATES or call SWENSON to obtain the latest up-to-date list.

Swenson

Swenson Process Equiptment Inc.

15700 Lathrop Ave., Harvey, IL 60426-5198

Phone: (708) 331-5500

FAX: (708) 331-5559/0639/6713

SWENSON
Swenson Western Regional Office
3020 Issq. Pine Lake Rd., Suite 500
Issaquah, WA 98029 USA

Phone: (425) 313-3668
Fax: (425) 313-7349
E-Mail: DBowlin@Swenson-Equip.com

FAX TRANSMITTAL

July 8, 1999
No. of Pages 1

TO:	Jack Prendergast	**FAX NO:**	(208) 526-6802
COMPANY:	Lockheed Martin, INEL Facility Idaho Falls, Idaho	**PHONE NO:**	(208) 526-8221
FROM:	David Bowlin Sales Manager, Swenson West		

Subject: Permission to publish Swenson Dryer Drawing #SBK 78234-0

Gentlemen,

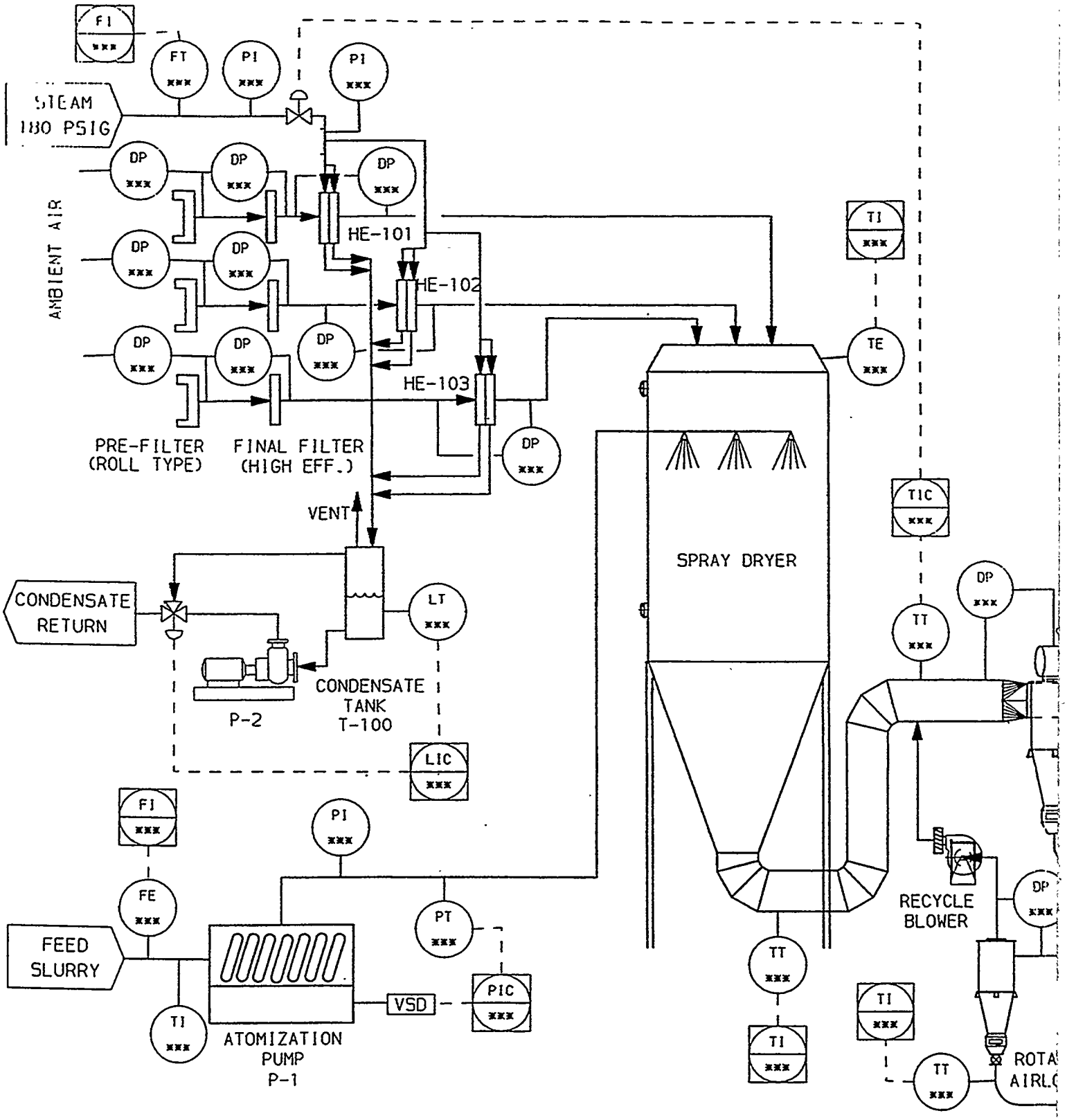
Swenson Process Equipment, Inc., Harvey IL, hereby grants permission to Lockheed Idaho Technologies Company and INEL to publish Swenson drawing No. SBK 78234-0 in the project report "High Level Waste Vitrification Facility Feasibility Study." This permission is limited to the above report.

Again, thank you for your continued interest in Swenson Process Equipment. If your future needs include Evaporation, Crystallization, Drying and/or Wastewater Treatment technologies, we hope that you will continue to contact us. For further assistance, please contact the undersigned or our main offices at (708) 331-5500.

Very truly yours,
SWENSON

David Bowlin
Sales Manager, Swenson West

Attachment 6



1

CONFIDENTIAL per letter dated 7-8-99

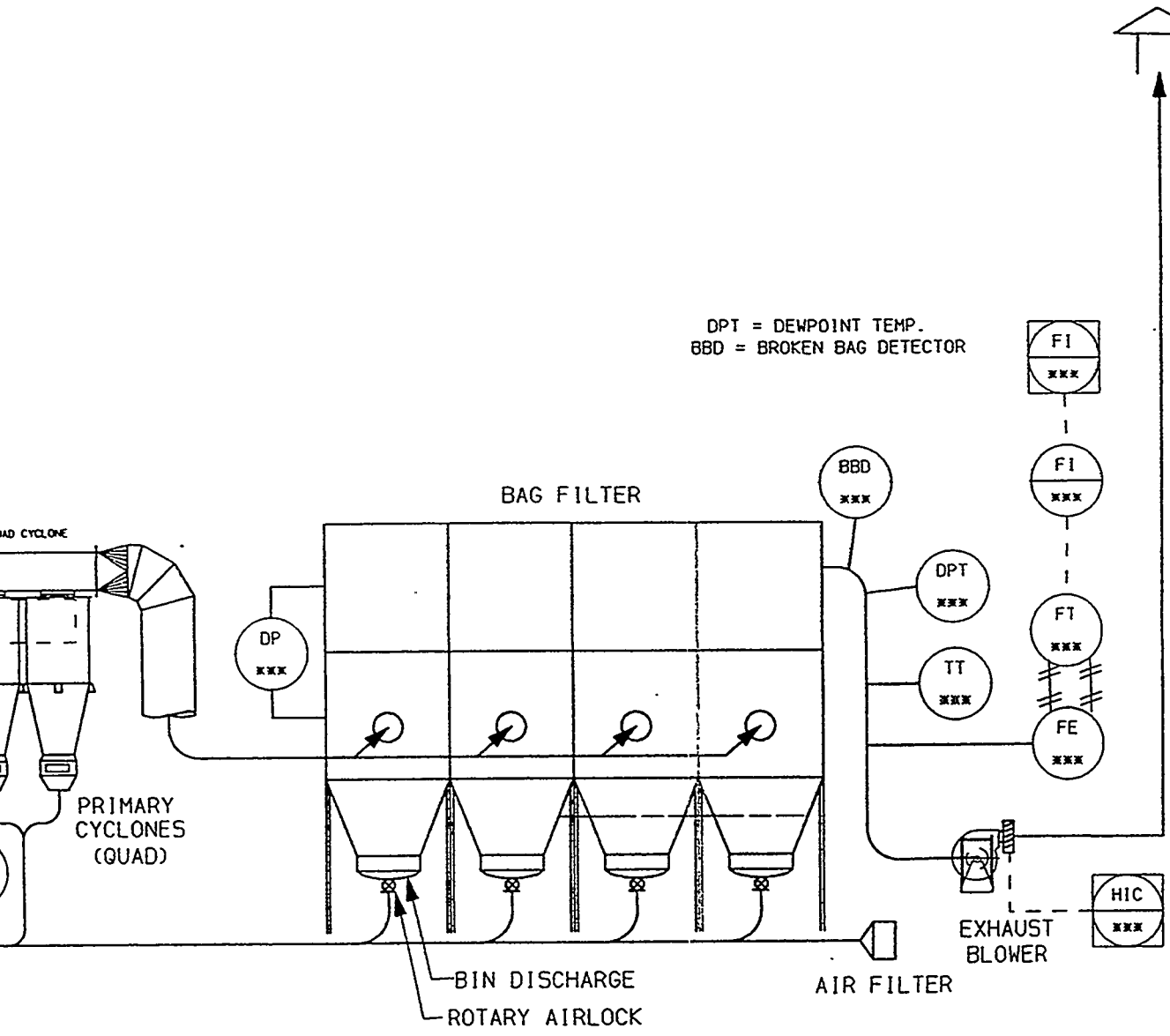
THE INFORMATION TRANSMITTED HEREIN HAS BEEN SPECIALLY DEVELOPED BY SWENSON, AND IS STRICTLY CONFIDENTIAL. TRANSMISSION OR USE OF THIS INFORMATION IS PROHIBITED IN THE ABSENCE OF WRITTEN PERMISSION OF SWENSON, HARVEY, ILLINOIS.

SWENSON

Swenson Process Equipment
15700 Lathrop Avenue, Harvey, I
Phone: 708-331-5500 -- Fax: 7

CAD 22-SEP-98 at 16:05:49

P & ID - "TYPICAL"
(FOR OPEN-LOOP FLOW)



Inc. 60426-5198 8-331-5559	CONTRACT /	TITLE- PIPING AND INSTRUMENTATION PVC SPRAY DRYER SYSTEM /
	DR. FJH DATE 22 SEP 1998	
	CH. / DATE /	FOR-
	APPR.	
	SCALE /	SBK-78234-01

Sept. 29, 1998

MEMO OF TELEPHONE CONVERSATION

Person Calling: Jack Prendergast
Representing Org.: 4170, Chem. Engineering — Time: 2:15 PM
Person Called: Mr Tony Licata — Phone Number: 914-779-3451
Representing Co.: Independent Consultant supporting Dravo Lime Co.
City: New York, N, Y.

Subject: Potential Application of Dravo Lime's "SORBALIT" re faxed Request for HF and Hg Removal Requirements per MACT Implementation

Distribution: a: Rod Kimmitt b: Dean Taylor c: John DelDebbio
d: Gary Leatherman

The highlights of the discussion were focused on the FAX I sent Tony describing our Offgas stream from the HLW-VIT process. (See copy attached.)

1. **We discussed the use of "Sorbalit"—a mixture of dry lime and activated carbon. Tony to send info on Sorbalit concentrations (3% to approx. 65% carbon w/w) with cost and shipping details.**
2. **Offgas pre-treatment with sodium tetrasulfide (Na2S4) by spraying the liquid into the offgas stream as a fog or well dispersed mist.**
3. **Enhanced mercury removal with HF or HCl present since the acid drives the mercury to the ionic species which is much more easily removed by carbon than the elemental species.**
4. **Dravo Lime's capability and willingness to assist the INEEL in Hg-removal process development. This was identified as a very important need once the actual offgas stream is reasonably well identified by pilot plant testing.**
5. **The initial test results of Dravo's use of a combined system for both Hg and acid (HF or HCl) gas constituent removal. This trial by Dravo used Na2S4, HCl, and Sorbalit. The Hg removal measured was greater than 99%.**
6. **My previous discussions with Mr. Heinz Beutner of ITEQ Filtration Group were talked about with Tony Licata and Lewis Benson (Dravo, Pittsburgh). They both have worked with Heinz in the past on similar offgas treatment requirements. Heinz has sent us complete package description and cost data for the Interel Dry Additive Process which uses Sorbalit.**
7. **Tony believes he can supply us with some assurance of which system will work best for the offgas provided. He will discuss this with both Lewis Benson, Technical VP for Dravo and Manny Babu, Research VP for Dravo.**

Attachment 7

AMEREX Amerex Industries, Inc.

Post Office Box 1093
Woodstock, Georgia 30188

(770) 928-0970
Fax (770) 928-2249

November 25, 1998

Idaho National Engineering Laboratory
Lockheed Martin
P.O. Box 1625
Idaho Falls, ID 83415-3710

ATTN: Mr. Jack Prendergast

RE: Fluoride Emission Control
Amerex Proposal No. AP-981129A

Dear Mr. Prendergast,

In response to your request for a budget proposal to control emissions from a vitrification process we have prepared the following estimates for Case 1 of your inquiry:

Conditions:

Altitude	5400 ft. ASL

Off-gas Composition:

H_20	31.2 lbs/hr
N_2	696.1 lbs/hr
O_2	214.4 lbs/hr
HF	0.40 lbs/hr
NO	0.84 lbs/hr
NO_2	0.01 lbs/hr
HG	1.22 lbs/hr
Total Flow	944.17 lbs/hr
Temperature	2167°F
Gas pressure Total	12.9 PSIA
Flowrate at Conditions	1213 ACFM

Proposal:

For the conditions specified we propose to supply an Interel Dry Additive Process (IDAP-III) installation.

The gas exiting the vitrification process is cooled via recirculated 300°F exhaust gas at the outlet of the vitrifier to maintain a temperature below 900°F after mixing. The gas will enter the self cleaning heat exchanger for cooling to 300°F. Hydrated lime is added upstream of the heat exchanger via Interel supplied lime feed and injection system. The gas then enters the reaction tower with dust conditioning drum where recirculated dust and lime is re-entrained into the gas prior to entering the fabric filter. The fabric filter captures and collects the particulate prior to the gas exiting through the ID fan and stack.

The hydrogen fluoride concentration of 0.40 lbs/hr (612 PPM) requires a reagent feed rate of approximately 1.0 lb/hr to achieve a removal efficiency of 99% or better.

- Gas-to-Air heat exchanger including hopper
- Dry reactor with conditioning drum
- Fabric Filter including hopper, screw conveyor and dust discharge valve.
- Additive storage and feed system
- Exhaust fan and discharge stack
- Recirculation fan including recirculation duct and eductor type hot gas mixer

Ancillary equipment such as required electrical control panel, field instrumentation, support structure is included in the price estimate. Drawings for a typical installation are attached for reference.

Process Flow Diagram

The major process parameters are summarized as follows:

Off-gas Conditions	944.17 lbs/hr - 2167°F 210 SCFM (1,213 ACFM)
Recirculated Dilution Gas	444 SCFM - 300°F (742 ACFM)

Heat Exchanger Inlet	654 SCFM - 900°F
Leakage Air (5%)	33 SCFM - 100°F
Reagent Transport Air	100 SCFM - 100°F
Heat Exchanger Outlet/	
Baghouse Inlet	787 SCFM - 300°F (1,314 ACFM)
Recirculation Fan	444 SCFM - 300°F (742 ACFM)
Exhaust Fan	343 SCFM - 300°F (572 ACFM)

It is necessary to add leakage air in the heat exchanger and reagent transport air to the total gas flowrate leaving the baghouse and to the ID fan flowrate for discharge.

Process Equipment Parameters

Gas-to-Air Heat Exchanger:

Heat Exchanger Model	F 1.6/1.0/2.0
Type	Horizontal flat tube, self cleaning
Number of Heat Exchanger Tubes	126
Heat Transfer Area	1076 ft^2
Inlet Temperature	900°F
Outlet Temperature	300°F
Gas Flowrate	654 SCFM (2940.5 lbs/hr)
Cooling Air Fan	1 x 9500 CFM/0.5" SP
Cooling Air Fan Motor	5.0 HP - variable speed
Cleaning Mechanism Drive	1/4 HP
Pressure Differential	1.5 in w.g.

Dry Reactor:

Dry Reactor Model	KUV 12
Conditioning Drum Motor	1/4 HP
Pressure Differential	1.5 in. W.G. (max)

Fabric Filter:

Fabric Filter Model	DF 1.6/1.0/2.0
Type of Bag Cleaning	On-Line, Pulse Jet
Nominal Fabric Area	797 sq. ft.
Flue Gas Flowrate	1,314 ACFM at 300°F

Air-To-Cloth Ratio	1.65:1
Fabric Material	Nomex
Temperature	300°F
Number of Bags	108
Dust Load (Design)	1.0 lbs/hr
Dust Concentration	0.06 gr/ACF @ 3 x recirc.
Cleaning Cycle	10 minutes (typical)
Pressure Differential	5 inches WG @ 3 x recirc.
Compressed Air Requirements	20 SCFM/90 psig (min.) -40°F dewpoint
Recirculation Screw Conveyor	
-Diameter	6 inches
-Motor	1-1/2 HP
Dust Discharge Screw Conveyor	
-Diameter	9 inches
-Motor	1 HP
Dust Discharge Valve	
-Type	Rotary Air Lock
-Motor	1/4 HP

Reagent Storage and Feed System

Type of Reagent	Bagged hydrated lime
Type of Storage	Hopper, 20 cubic ft capacity
Metering Screw	
-Diameter	4 inches
-Motor	½ HP DC Drive
-Capacity	0-100 lbs/hr
Dust Discharge Valve	
-Type	Rotary Airlock
-Motor	1/4 HP
Reagent Transport Blower	
-Blower Capacity	100 CFM/80" w.g.
-Motor	3.0 HP

Induced Draft Fan

Type	Radial blade centrifugal
Flow	572 ACFM at 5,400 ft. ASL
Static Pressure	12 in. w.g.
Motor	5.0 HP @ 1800 RPM

Recirculation Fan

Type	Radial blade centrifugal
Flowrate	742 ACFM at 5.400 ft. ASL
Static Pressure	6 in. w.g.
Motor	3.0 HP @ 1800 RPM

Electrical Panel

Type Enclosure	NEMA 4
Disconnect	Door operated
Microprocessor	Allen Bradley SLC 5/04
Illuminated HOA Switches	10
Motor Starters	10
VFD Controllers	Cooling Air Fan ID Fan Recirculation Fan

Price

For the installation as described, FOB jobsite: $250,000.00

Price excludes any and all applicable federal, state or local sales, use, excise or property taxes.

All prices are firm for acceptance within 60 days from date of this proposal.

Approval Drawings

Approval drawings in three (3) sets, including foundation loads and electrical information, could be furnished no later than two weeks after receipt of an order or a formal Notice to Proceed.

Equipment Delivery

Equipment delivery could be completed within sixteen (16) weeks after receipt of approved drawings.

Manuals and Certified Drawings

Three (3) complete manuals shall be provided upon final delivery including operational procedures, vendors' certified data sheets, design data sheets, and spare parts lists. Also provided are three (3) certified sets of all mechanical and electrical assembly and installation drawings.

Items Not Quoted

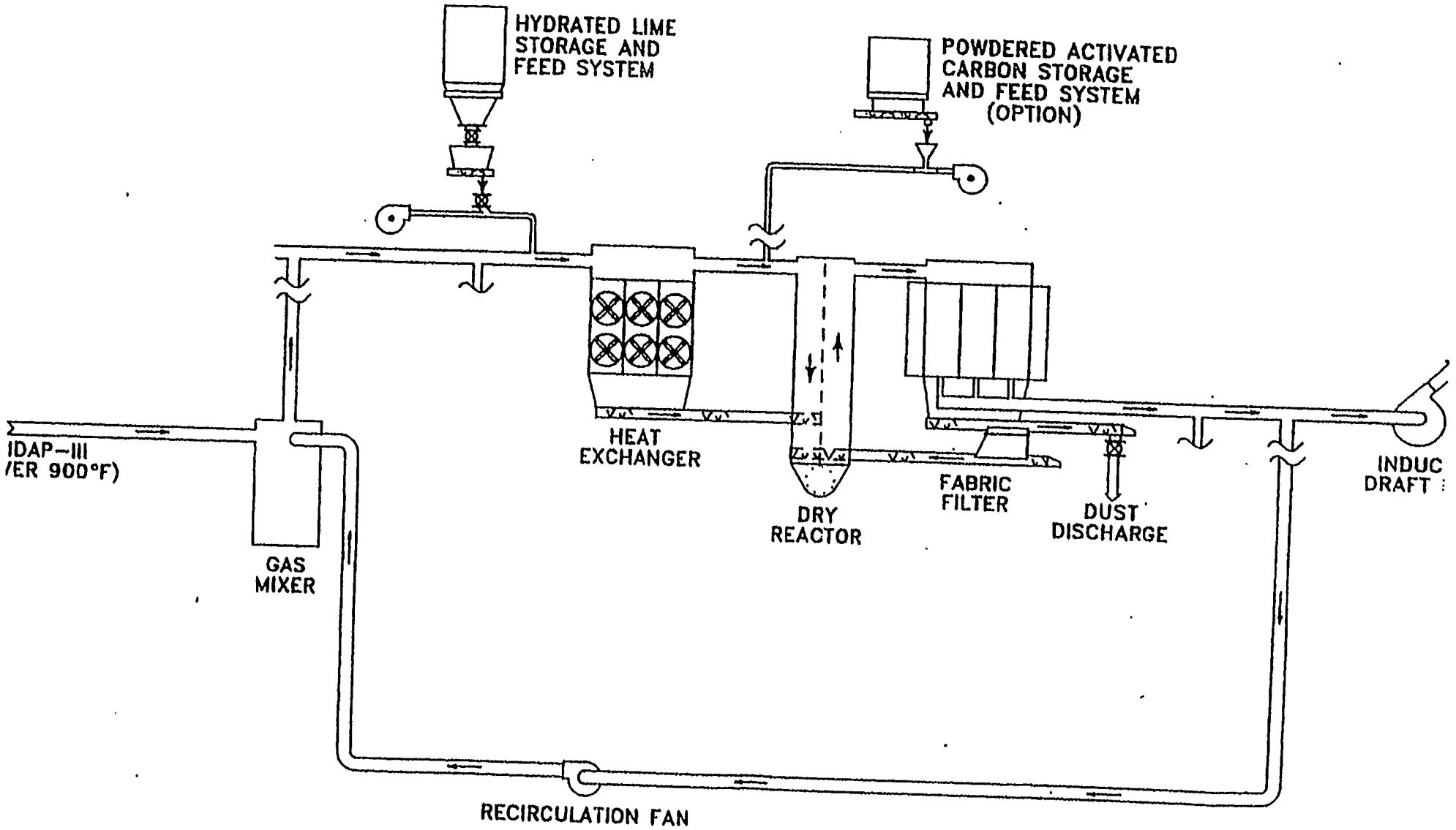
- Mechanical and Electrical erection
- Foundations and site preparation
- Interconnecting electrical and thermocouple wiring
- Compressed air system and piping
- Incoming power supply with circuit breakers
- Permits and documents necessary for installation and erection
- Any and all items not specifically quoted

We trust this proposal meets your requirements.

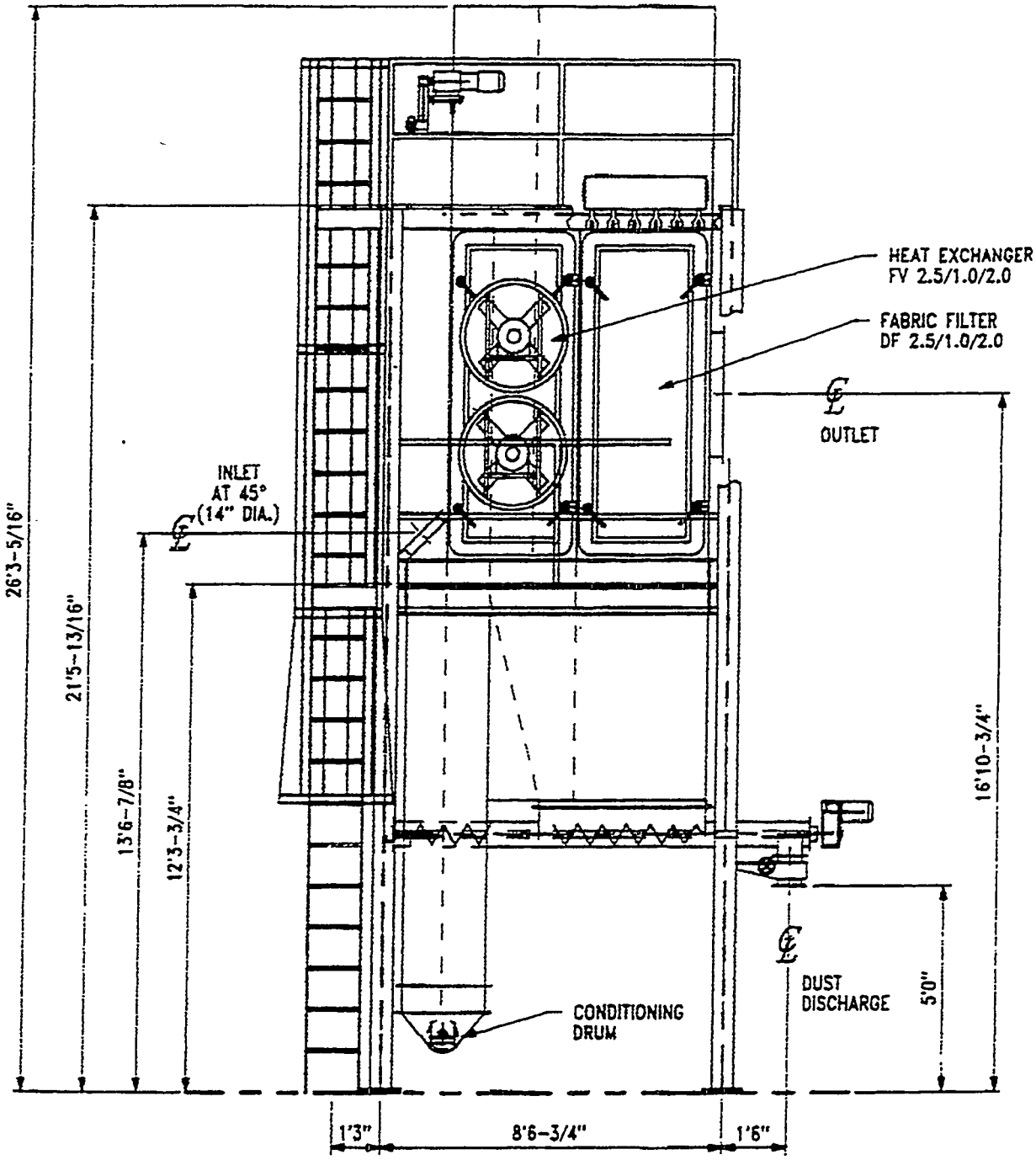
Sincerely,

Heinz P. Beutner

Heinz P. Beutner



Interel Dry Additive Process (IDAP-III)



For Illustration Only

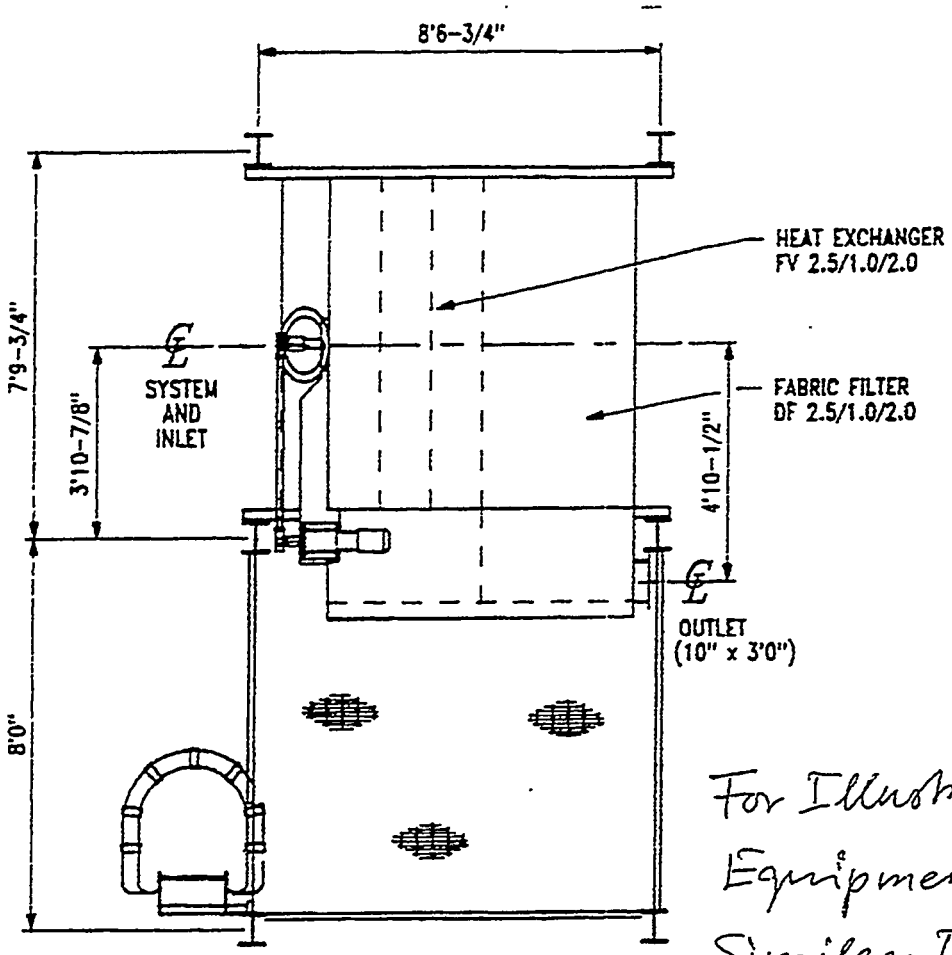
Equipment Package Similar To Proposed System Case 1

FRONT ELEVATION

This Document contains information proprietary to Interel Environmental Tech. Inc. and is furnished upon the express condition that the information contained herein will not be used for second source procurement or directly or indirectly in any way detrimental to the interests of Interel Environmental Tech. Inc.

REV.	DESCRIP

NOTE: THIS DRAWING IS FOR PROPOSAL PURPOSES ONLY.
DO NOT USE FOR CONSTRUCTION UNLESS DIMENSIONS ARE CERTIFIED.



PLAN VIEW

For Illustration Only
Equipment Package
Similar To Proposed
System Case 1

BY	DATE

DRAWN BY: Collin	DATE: 7/6/93
CHECKED BY:	DATE:
CONTRACT NUMBER: # 934-080	
TOLERANCES: GENERAL DIMENSIONS: ±1/16" HOLES: ± 1/32" ANGLES: ± 0°-30'	

INTEREL Environmental Technologies, Inc.

HOSPITAL / INFECTIOUS WASTE INCINERATOR AIR QUALITY CONTROL SYSTEM

SCALE:	DRAWING NUMBER:	SHEET	REV.
1/4"=1'0"	PB-1237	1 OF 1	

Amerex Industries, Inc.

Post Office Box 1093
Woodstock, Georgia 30188

(770) 928-0970
Fax (770) 928-2249

November 25, 1998

Idaho National Engineering Laboratory
Lockheed Martin
P.O. Box 1625
Idaho Falls, ID 83415-3710

ATTN: Mr. Jack Prendergast

RE: Fluoride Emission Control
Amerex Proposal No. AP-981129B

Dear Mr. Prendergast,

In response to your request for a budget proposal to control emissions from a vitrification process we have prepared the following estimates for Case 2 of your inquiry:

Conditions:

Altitude	5400 ft. ASL

Off-gas Composition:

H_2O	143.5 lbs/hr
N_2	14,201.8 lbs/hr
O_2	4,315.3 lbs/hr
HF	0.40 lbs/hr
NO	0.84 lbs/hr
NO_2	0.01 lbs/hr
HG	1.22 lbs/hr
Total Flow	18,663.07 lbs/hr
Temperature	355°F
Gas pressure Total	11.9 PSIA
Flowrate at Conditions	7958 ACFM

The Interel Dry Additive Process (IDAP-I) is based on the addition of hydrated lime to the gas and dust collection in a fabric filter. The added dust is recirculated with a portion continuously discharged.

The hydrogen fluoride concentration of 0.40 lbs/hr (35 PPM) requires a reagent feed rate of approximately 1.0 lb/hr to achieve a removal efficiency of 95% or better.

Proposal:

For the conditions specified we propose an IDAP-I installation as described in the equipment specifications. Major process equipment furnished are:

- Dry reactor with conditioning drum
- Fabric Filter including hopper, screw conveyor and dust discharge valve.
- Additive storage and feed system
- Exhaust fan and discharge stack

Ancillary equipment such as required electrical control panel, field instrumentation, support structure is included in the price estimate. Drawings for a typical installation are attached for reference.

Process Equipment Parameters

Dry Reactor:

Dry Reactor Model	KUV 18
Conditioning Drum Motor	1/4 HP
Pressure Differential	2.5 in. W.G. (max)

Fabric Filter:

Fabric Filter Model	DF 2.5/2.0/2.0
Type of Bag Cleaning	On-Line, Pulse Jet
Isolation Dampers	None
Nominal Fabric Area	2583 sq. ft.
Flue Gas Flowrate	7,958 ACFM at 355°F
Air-To-Cloth Ratio	3.1:1

Fabric Material	Nomex
Temperature	355°F
Number of Bags	308
Dust Load (Design)	1.0 lbs/hr
Dust Concentration	0.06 gr/ACF @ 3 x recirc.
Cleaning Cycle	10 minutes (typical)
Pressure Differential	5 inches WG @ 3 x recirc.
Compressed Air Requirements	20 SCFM/90 psig (min.) -40°F dewpoint
Recirculation Screw Conveyor	
-Diameter	6 inches
-Motor	1-1/2 HP
Dust Discharge Screw Conveyor	
-Diameter	9 inches
-Motor	1 HP
Dust Discharge Valve	
-Type	Rotary Air Lock
-Motor	3/4 HP

<u>Reagent Storage and Feed System</u>

Type of Reagent	Bagged hydrated lime
Type of Storage	Hopper, 20 cubic ft capacity
Metering Screw	
-Diameter	4 inches
-Motor	½ HP DC Drive
-Capacity	0-100 lbs/hr
Dust Discharge Valve	
-Type	Rotary Airlock
-Motor	3/4 HP
Reagent Transport Blower	
-Blower Capacity	250 CFM/80" w.g.
-Motor	5.0 HP

Induced Draft Fan

Type	Radial blade centrifugal
Flow	8,000 ACFM at 5,400 ft. ASL
Static Pressure	12 in. w.g.
Motor	50 HP @ 1800 RPM

Electrical Panel

Type Enclosure	NEMA 4
Disconnect	Door operated
No. of Motor Starters	7
Microprocessor	Allen Bradley SLC 5/04
Illuminated HOA Switches	7

Price

For the installation as described, FOB jobsite: $215,000.00

Price excludes any and all applicable federal, state or local sales, use, excise or property taxes.

All prices are firm for acceptance within 60 days from date of this proposal.

Approval Drawings

Approval drawings in three (3) sets, including foundation loads and electrical information, could be furnished no later than two weeks after receipt of an order or a formal Notice to Proceed.

Equipment Delivery

Equipment delivery could be completed within sixteen (16) weeks after receipt of approved drawings.

Manuals and Certified Drawings

Three (3) complete manuals shall be provided upon final delivery including operational procedures, vendors' certified data sheets, design data sheets, and spare parts lists. Also provided are three (3) certified sets of all mechanical and electrical assembly and installation drawings.

Items Not Quoted

- Mechanical and Electrical erection
- Foundations and site preparation
- Interconnecting electrical and thermocouple wiring
- Compressed air system and piping
- Incoming power supply with circuit breakers
- Permits and documents necessary for installation and erection
- Any and all items not specifically quoted

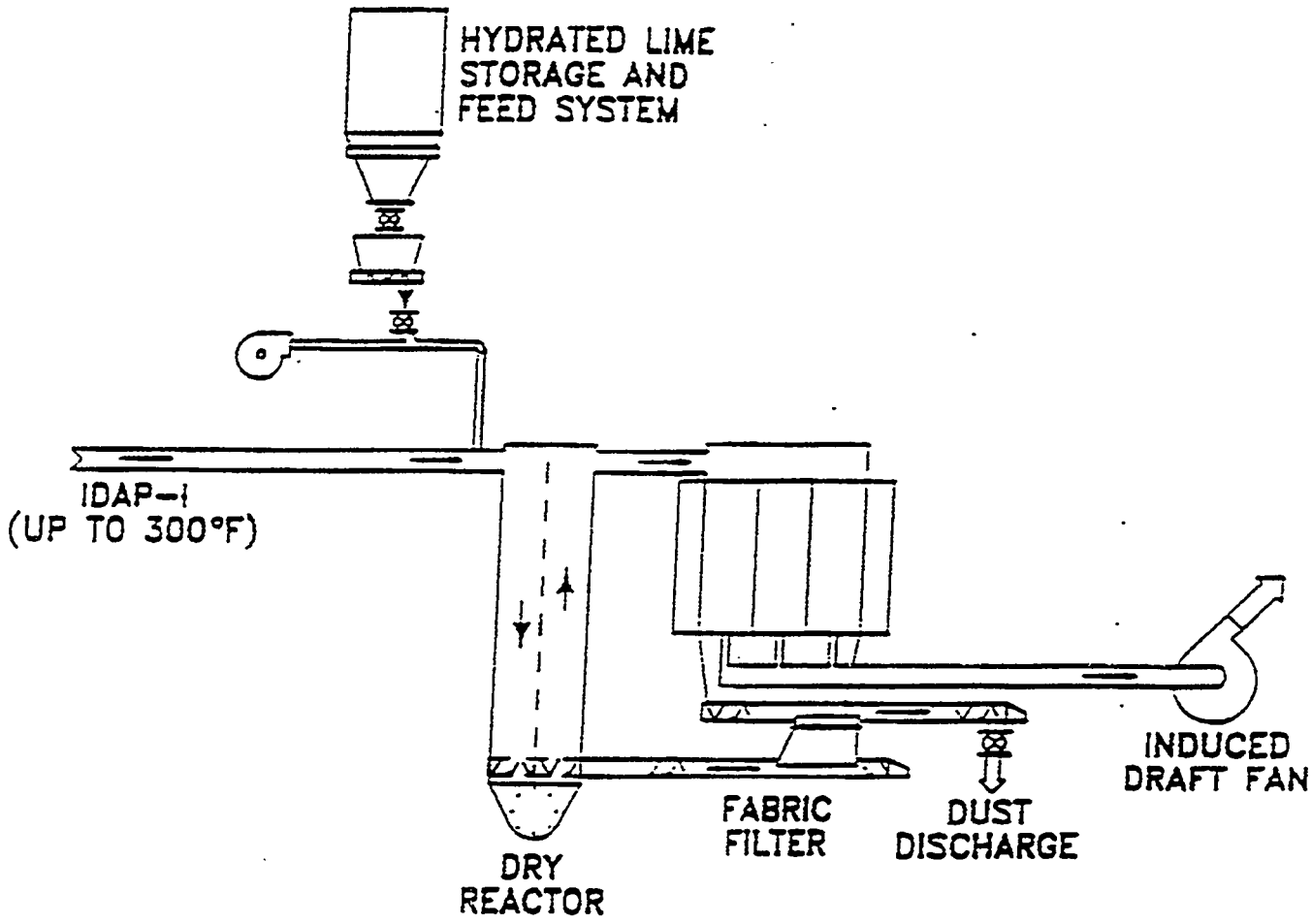
We trust this proposal meets your requirements.

Sincerely,

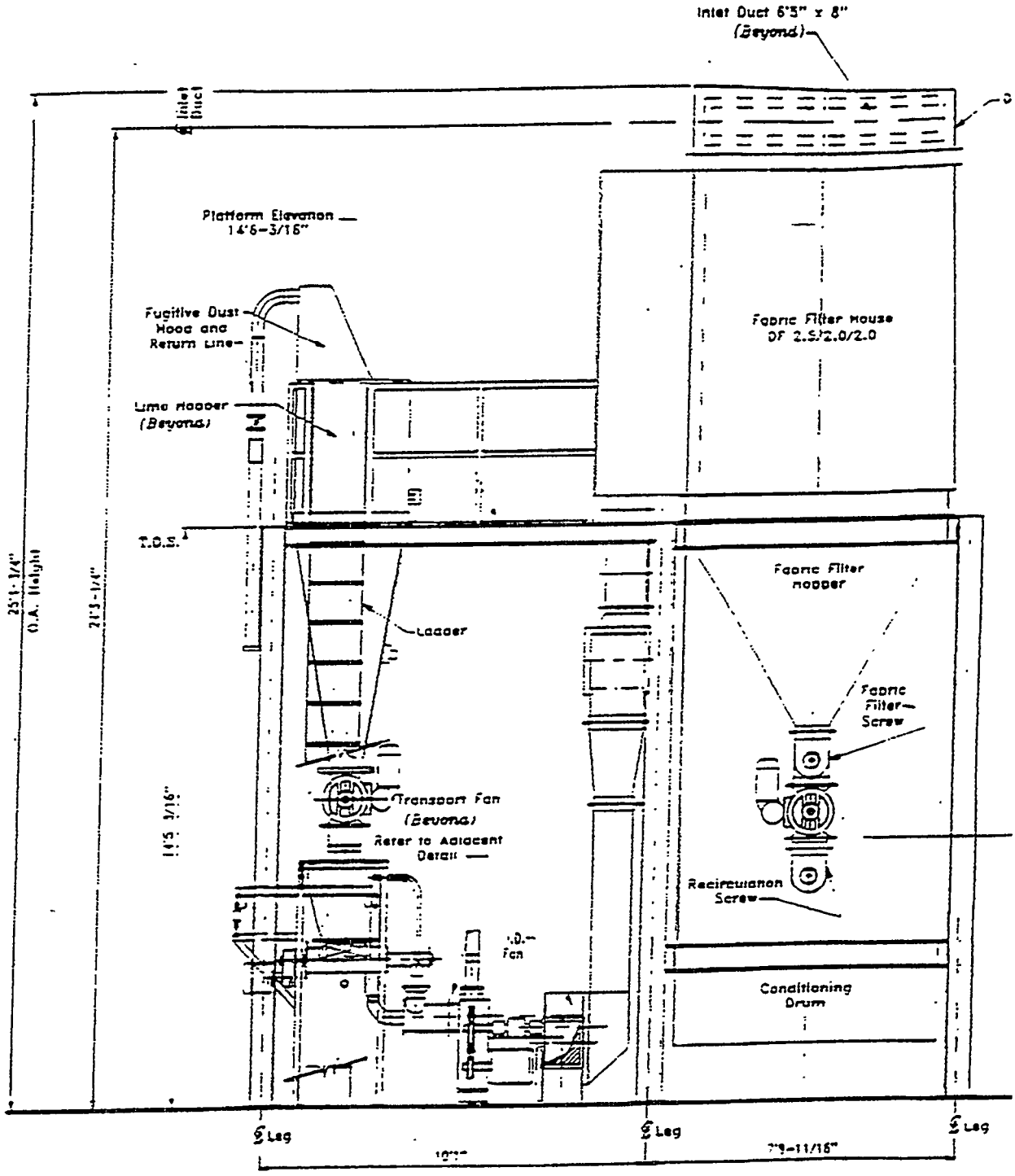
Heinz P. Beutner

Heinz P. Beutner

INTEREL Environmental Technologies, Inc.



Interel Dry Additive Process (IDAP-I)

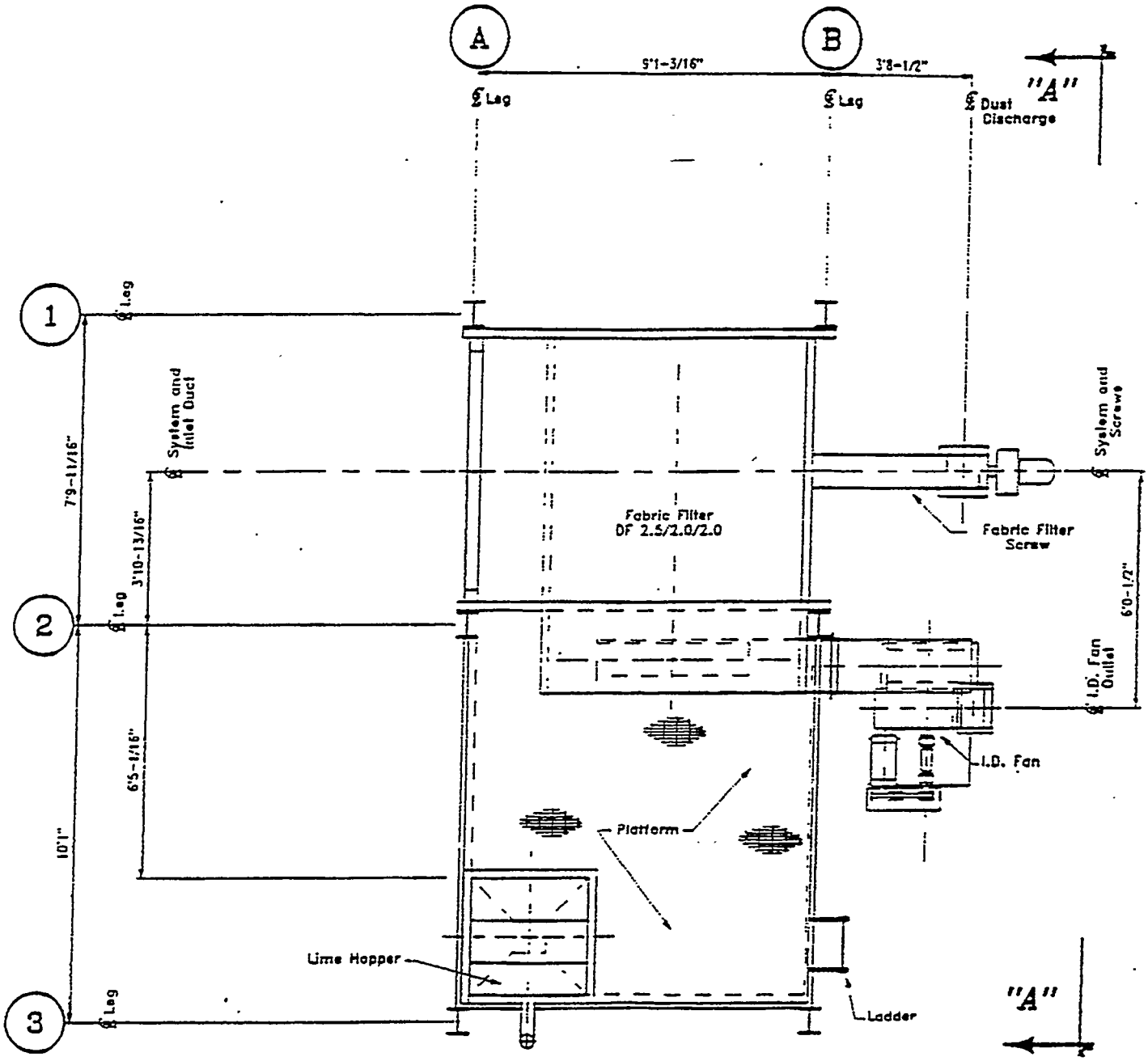


ELEVATION "A-A"

THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO INTEREL CORPORATION AND IS FURNISHED UPON THE EXPRESS CONDITION THAT THE INFORMATION CONTAINED HEREIN WILL NOT BE USED FOR SECOND SOURCE PROCUREMENT OR DIRECTLY OR INDIRECTLY IN ANY WAY DETRIMENTAL TO THE INTERESTS OF INTEREL CORPORATION.

NEXT ASS'Y:

REV.



PLAN VIEW of AIR QUALITY CONTROL SYSTEM

THIS DOCUMENT CONTAINS INFORMATION PROPRIETARY TO INTEREL CORPORATION AND IS FURNISHED UPON THE EXPRESS CONDITION THAT THE INFORMATION CONTAINED HEREIN WILL NOT BE USED FOR SECOND SOURCE PROCUREMENT OR DIRECTLY OR INDIRECTLY IN ANY WAY DETRIMENTAL TO THE INTERESTS OF INTEREL CORPORATION.

NEXT ASS'Y:

REV.	DESCRIPTION	BY	DATE

DRAWN BY: Heritage	DATE: 9/23/91
CHECKED BY:	DATE:
CONTRACT NUMBER: # 901-149	
TOLERANCES: [illegible]	1/4"

Attachment 8

INEEL

William J Prendergast 12/01/98 02:42:33 PM

To: JoeENNEKING@nucon-int.COM
cc:
Subject: Sizing Validation for Hg Removal

Joe, I have tried to contact you several times over last few weeks regarding a mercury removal requirement I am looking at for MACT compliance with a specific offgas. Below is the offgas stream size and Hg content that I am using as design basis for sizing the Nucon MERSORB adsorbent bed. I have rough sized the adsorbent bed for a one-time/year bed removal requirement. The offgas has a relatively high mercury concentration in a relatively small gas stream such that a large bed is required for the adsorption capacity at estimated 70% breakthrough. This first-cut design yields a small face velocity (superficial) of 4.2 ft/minute while providing for the one year turnaround changeout of the bed contents. Please look over my requirements and let me know if this design will work while meeting our specified criteria.

- Offgas Flow Rate: 1,268 acfm at 250 deg F and 11.5 PSIA
- Hg Content: 1.22 lbs/hr
- On-Stream time: 200 days/yr @ 24 hrs/day
- Approx. Hg Absorption Capacity of MERSORB: 0.14 lbs Hg per lb of MERSORB (assuming 70% BT at 0.20 lbs/lb)
- Use 2 beds in series arrangement with breakthrough monitoring between beds

Rough sizing determined: 10' dia. bed by 30' long by 4-foot bed thickness, two beds in series, delta P for 1.5 mm. MERSORB is approx. 0.5 inches w.g./ft bed depth or 2 inches per bed plus inlet and outlet effects (assumed 4" H2O/bed delta P) per page 11 of MERSORB Bulletin 11B28 R1. Please give me your assessment as soon as practicable, Thanks Joe for your assistance and consideration. Please call me for any question you may have on this requirement @ 208-526-8221.

NUCON International Inc.

TO: William Prendergast

FROM: Joe Enneking

CC: W.P. Freeman

DATE: 2 Dec 98

SUBJECT: Evaluation of mercury removal beds design

The E-mail message of 1 December outlining the design of the mercury removal beds was evaluated . Listed below are our comments and recommendations.

1. Removing the mercury from the subject air stream requires large amounts of MERSORB® adsorbent because of the very high concentration. We did make a calculation to determine how much mercury should be removed from the air stream if it were cooled to 30 °C. Approximately 90% of the mercury would be condensed. You would still be considerably above the water dew point which is about 15 °C. The MERSORB® bed size would then be reduced by 90% for a 1 year life. However, as you indicated by phone, this results in a complication of the system and there would be a waste mercury stream to dispose of.

2. We checked the sizing calculations you made for the amount of carbon required for the 1.22 lbs/hr inlet level. Your sizing is correct. The flow velocity is still higher than that used in our laboratory tests (see page 5 of our bulletin). The empty bed contact time is very long at about 1 minute. You might get an even greater dynamic adsorption efficiency than 70%.

3. You may want to consider a vertical bed because you have a relatively low flow rate. The 1200 ft^3 of carbon will fit into a 10 ft diameter by 15 ft high bed. The vessel itself would be about 20 ft tall but this is still less than the size of the horizontal bed. The pressure drop for each bed would be about 20 inches water plus inlet and outlet effects. If that is too high, then the horizontal bed is more appropriate.

4. The concept of using two beds in series is a good one.

5. You have used the lab test data to design your system. Your operating temperature of 250 °F will improve the dynamic adsorption characteristics so you

have in a sense used a conservative method.

I believe you have developed a good design for this, the preliminary design stage. We will be glad to work with you to refine it when appropriate.

Attachment 9

SepraDyne Corporation

December 10, 1998

Mr. Jack Prendergast
Lockheed Martin Idaho Technologies
P.O. Box 1625
Idaho Falls, ID 83415-3710

Subject: Raduce Cost Estimate for Contaminated Carbon (Mersorb) Cleanup Services.

Dear Mr. Prendergast

I appreciate the opportunity to provide the following cost estimate for mercury desorption services at the DOE LMITCO site. These services will be performed using one of our state of the art vacuum desorption systems. Compared to other mercury removal systems, the Raduce process (SepraDyne subsidiary) can provide complete material recovery while producing the smallest volume of waste. Raduce can provide this feature because only those materials volatilized within the retort are exhausted as a gas and collected through our impinger and condensate system. Due to our vacuum capabilities, purge gases are not required to transport vapors from the retort.

Our patented systems have been designed to meet the intent of applicable regulatory guidelines commonly recognized within the DOE/nuclear industry. The operating controls have been designed to create a fail-safe condition if an operational upset were to occur. These systems are extremely safe and are designed to eliminate the release of any contaminants. The processing equipment is designed to cease operating should system control setpoints be exceeded. For instance, any breach of the retort will result in a vacuum decrease (inflow) and, if program setpoints are reached, cause automatic shutdown and complete system isolation.

The specific waste matrix provided to Raduce has been cost estimated using the following assumptions:

- 42,000 pounds (annual capacity) of waste sulfur-impregnated carbon.
- Waste carbon contains 10% sulfur
- Waste carbon contains 0.14 lbs. Hg / lb. C (5,880 lbs. Hg)
- All sulfur is volatilized (worse case) from the carbon during processing
- Residual carbon will contain less than 10 mg/kg Hg
- Waste product has a 1% moisture content

Raduce has attempted to optimize a system per your requirements. Based on the above data, it is suggested that LMITCO employ a unit designed for a batch capacity of 200 pounds (CMM-200). The CMM-200 is a skid mounted unit and will have the capability to treat a typical month's waste inventory (4000 lbs.) in a 5-day time frame. This design will allow flexibility in operation and might enable LMITCO to treat other waste streams.

7201 I-35 North Denton, Texas 76207 940-243-8203 fax 940-243-9089 1-800-688-0484

Raduce proposes to install its equipment at the LMITCO site and process the wastes at a cost of $4/lb. This cost is based on a minimum annual guaranteed volume of 42,000 lbs. and Raduce will supply one fully trained operator for a one-week per month basis. Additional waste inventory will be prorated on a mutually agreed upon rate base.

This equipment will require a 6' x 20' floor plan with a clearance of at least 10 feet. We suggest that an operator control station be remotely located in an environmentally controlled room (6' x 6') suitable for computer operation. Services and utilities to be provided by LMITCO include:

- Auxiliary services such as instrument air, electricity (480v 3 pH source) and service water
- pH adjustment chemicals (caustic) depending on sulfur loading
- Pre and post process material storage containers
- Analytical services
- Health Physics and security services
- Protective clothing

Raduce has also evaluated the operation of its unit with respect to mercury loaded Mersorb. Based on the assumptions provided above, the following summary is the worse case estimate for the quantity and type of wastes or byproducts produced.

- 37,800 pounds of activated carbon. The mercury and some percentage of sulfur will be removed. Further evaluation and testing will be required to determine the efficiency of this carbon for original reuse. It is expected that a majority of the carbon can be reused as originally intended. If this is not the case, the carbon should be acceptable for other water treatment services. In either case, this product will now be only a low-level radioactive waste and not require mixed waste disposal.
- 4,200 pounds (maximum) of low level rad contaminated sulfur. This is a worse case, very unrealistic estimate and is attributable only if the entire sulfur concentration (10%) was removed via operations. Raduce plans to control operation times and temperature in an attempt to minimize sulfur removal rates.
- 5,880 pounds of potentially low level rad contaminated mercury. This waste will require amalgamation. This service has not been provided in our process rate however, can be addressed if requested.
- 420 pounds of low level rad contaminated water. This water can be efficiently processed through a typical ion exchange column.

The CMM-200 can be mobilized 3 months after contract award. The term of the contract can be mutually agreed. I hope that this work scope and the information provided earlier clarifies the Raduce proposal and helps LMITCO's planning requirements. Please do not hesitate to call me if LMITCO has any further questions regarding the Raduce estimate.

Sincerely,

D B. Malkmus

David B. Malkmus
Technology Development
SepraDyne Corporation

SepraDyne Corporation

December 3, 1998

Jack Prendergast
LMITCO
P.O. Box 1625
Idaho Falls, ID 83415-3710

RE: SepraDyne Corporation – Vacuum Desorption Technology

Jack:

It has been a pleasure talking to you recently. I thank you for allowing me the opportunity to provide input regarding your mercury remediation feasibility studies. As follow-up to conversations, I have enclosed select background information regarding our corporation and technological advances.

The SepraDyne Corporation is a privately held company with patented (U.S. and abroad) state of the art high vacuum - high temperature desorption technology. Vacuum desorption has been selected as a Best Demonstrated Available Technology (BDAT) by the U.S. DOE for the removal and recovery of hazardous waste constituents (i.e. mercury) from solid, sludge and slurry inventories. We have developed our units for the government and commercial sector in order to fulfill process needs for materials contaminated with heavy metals and other hazardous compounds..

The process is extremely effective at removing and recovering volatile organic compounds, semi-volatile organic compounds, organic contaminants such as polychlorinated biphenyl's (PCBs), polyaromatic hydrocarbons (PAH), herbicides, pesticides and other hard to treat constituents such as mercury, arsenic, sulfur and heavy tars. In addition to its material recycling capabilities, the technology is also regarded as a very efficient and economical means in volume reducing radioactive, mixed and/or hazardous waste stream sources.

Our systems uniquely combine the use of an indirectly heated (up to 1,600°F) rotary kiln operated under high (~28" Hg) vacuum. This combination of operating parameters within a rotating kiln affords SepraDyne advantages over all other available technologies. Under varied parameters and controlled modes of operation, our technology offers recycling capabilities by being able to selectively volatilize, remove and reclaim a wide range of constituents. We can provide products available for recycle/free release and a minimized final waste form easily suitable for final stabilization processes such as amalgamation or vitrification (if required). Any kiln off-gases are contained and condensed to liquid via our state-of-the-art chiller/impinger system. This equipment virtually eliminates any particulate, toxin and/or radionuclide discharge to the environment.

7201 I-35 North Denton, Texas 76207 940-243-8203 fax 940-243-9089 1-800-688-0484

As described in earlier faxed information, we are currently engaged in full-scale commercial operation at a large U.S. copper smelter. Here we are removing mercury from a waste sludge. Our contract stipulates that the mercury concentration be reduced to levels below 10 ppm. To date, we have treated over 560 tons of this sludge having a "pre-process" mercury concentration as high as 2,800 ppm and are consistently providing a reusable product with readings less than 3 ppm.

We will soon (January) be at a DOE National Laboratory under charter to demonstrate our removal capabilities for mercury in soils as well as our minimization efficiencies on a wide range of wastes similar to what is commonly generated in the commercial, nuclear and DOE sector. Due to our wide-scale capabilities, the DOE, Mixed Waste Focus Area has chosen our system(s) as the benchmark standard for comparison to other treatment alternatives.

Our advances have valuable applicability in the field of hazardous waste remediation as well as the in the low level and mixed waste environment. With our operating parameters described above, not only can we volume reduce a waste source to nothing more than a fine "carbon black" but, we can (and have demonstrated) that we can transform a mixed inventory into a radioactive waste. This capability has aroused substantial interest from radioactive waste generators as well as those that offer final stabilization and disposal alternatives. Our technology could be a vital asset with regard to centralized site waste processing and is a perfect candidate for you in developing strategies to treat your mercury contaminated waste materials in a cost effective and environmentally save manner.

Our units are of the modular skid-mounted design, fabricated to meet or exceed applicable regulatory guidelines and geared to operate commercially in the nuclear/DOE environment. We have built treatability prototype units with holding capacities as low as 200 grams up to commercial scale units having process capacities of 2 tons per batch. This flexibility enables us to perform feasibility testing using any variation of equipment to satisfy a client's process needs.

As mentioned, we will be at East Helena MT (early 99) demonstrating our technology. We are willing to visit your site and exhibit our capabilities using actual or surrogate wastestream sources. Included is information that highlights our recent activities and system attributes. I hope that you find this information helpful and look forward to talking to you in the future. If you require additional information, please do not hesitate to contact me.

Sincerely,

Dave Malkmus .

David B. Malkmus

DBM/Enclosures

Sulfur -Impregnated Activated Carbon

Processing Conditions:

Material - Calgon HGR 4X10 sulfur-impregnated activated carbon contaminated with elemental mercury

Processing Temperature - 350° C

Processing Time - One hour at 350° C

Processing Pressure - 40 mm or 28" of Mercury Vacuum

Processing Rotational Speed - 4 RPM

Results:

Before Processing - 1400 mg/kg Total Mercury

After Processing - 0.51 mg/kg Total Mercury

% Removal > 99.96 %

TREATABILITY STUDY

Activated Carbon

Processing Conditions:

Material - 20-40 mesh activated carbon contaminated with elemental mercury

Processing Temperature - 350° C

Processing Time - One hour at 350° C

Processing Pressure - 40 mm or 28" of Mercury Vacuum

Processing Rotational Speed - 4 RPM

Results:

Before Processing - 580 mg/kg Total Mercury

After Processing - 2.7 mg/kg Total Mercury

% Removal > 99.5 %

ACTIVATED CARBON

Processing Conditions:

Material - 30 - 60 mesh activated carbon
saturated with BTEX compounds

Processing Temperature - 350° C

Processing Time - one hour at 350° C

Processing Pressure - 40 mm or 28" of Mercury Vacuum

Processing Rotational Speed - 4 RPM

Results:

Compound	Before Processing	After Processing	%Removal
Benzene	**71,500 mg/kg**	**1.1 mg/kg**	**> 99.99 %**
Ethyl benzene	**21,500 mg/kg**	**0.8 mg/kg**	**> 99.99 %**
Toluene	**143,000 mg/kg**	**0.6 mg/kg**	**> 99.99 %**
Xylenes	**264,000 mg/kg**	**19 mg/kg**	**>99.99 %**

COMMERCIAL OPERATION TO REMOVE AND RECOVER MERCURY FROM CHLOR-ALKALI PLANT WASTEWATER TREATMENT PLANT SLUDGE

1. **Sludge Characteristics**

   Up to 40 % Water

   Up to 5000 mg/kg Total Mercury

   Up to 30 % Sulfur

2. **Treatment Criteria Met**

   Less than 260mg/kg Total Mercury

   Less than 0.2 mg/l TCLP Mercury

3. **Air Pollution Criteria**

   Less than 417 mg of Mercury Emitted per Hour

4. **Process Parameters**

   Vacuum Level-Greater than 25 inches of Mercury

   Temperature - 650° C

   Time at Temperature - 15 Minutes

Attachment 10

SM

MERCURY RECOVERY SERVICES, INC.

700 Fifth Ave., New Brighton, PA 15066 Phone: 724-843-5000 Fax: 724-843-5353

MRS

December 3, 1998

Mr. Jack Prendergast, P.E.
Lockheed Martin Idaho Technology Co.
PO Box 1625
Idaho Falls, ID 83415-3710

Dear Mr. Prendergast:

With reference to our recent telephone conversation, enclosed is information regarding Mercury Recovery Services' (MRS) process for the removal and recovery of mercury from soils, solid wastes, and industrial process streams. The following is a summary of this technology and the status of MRS' operations.

The MRS Mercury Removal/Recovery Process, described in the enclosed brochure, video, and Remediation magazine article is a mobile or fixed-site medium-temperature thermal desorption method for removing mercury from a wide variety of solid materials that has been proven to:

- consistently reduce the mercury content of the treated material to less than one part per million (< 1 ppm) regardless of the level and form of mercury originally contained,
- produce a 99% pure metallic mercury suitable for direct refining to high purity metal,
- recover mercury from compounds such as mercury oxide, mercury chloride, and mercury sulfide,
- prevent the released sulfur and/or chlorine from entering the process exhaust,
- operate without generating any secondary liquid, solid, or gaseous secondary waste,
- produce a gaseous effluent that meets all clean air standards,
- efficiently treat materials having high moisture contents, and
- effectively utilize "double containment" for added worker and environmental safety.

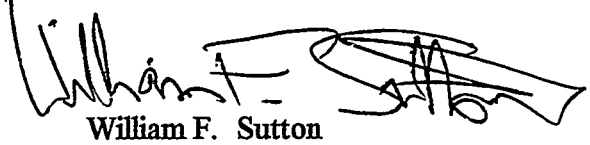
The MRS Mercury Removal/Recovery Process (i) has been designated as Best Demonstrated Available Technology (BDAT) for treatment of mercury-contaminated materials by the U.S. Environmental Protection Agency (EPA); (ii) has been classified as "Recycling" by the EPA and regulatory agencies in several states, thereby greatly simplifying permitting; and (iii) based upon its low emission rate and the absence of secondary solid waste, MRS' commercial mobile units have been exempt from air and solid waste permitting requirements by the States of New Mexico and Arizona and easily met all air standards in the United Kingdom. Because of its modular nature, the MRS equipment can be configured for mobile operations at capacities ranging from 4-to-12 tons/day or for "fixed-site" operation at capacities in the range of 4-64 tons/day.

Introduced commercially in 1994, the MRS Process has been successful in removing and recovering mercury from a wide variety of materials, including soils, chlor-alkali wastes, copper and precious metals smelting and refining by-products, waste water treatment sludges, catalysts, carbon products, batteries, fluorescent bulbs, and low-level radioactive wastes. MRS' 12 tons/day mobile unit has been used to treat over 6,000 tons of natural gas pipeline metering site soils, consistently reducing the total mercury content to <1 ppm, as shown in the attached table. This unit also operated 24 hours per day seven days per week, removing mercury from waste streams at a major copper smelter. Over 3,000 tons of smelter "waste" has been converted to "product" for which full metal value was recovered. In addition, MRS' 4 tons/day mobile unit has demonstrated equivalent success treating chlor-alkali wastes at a major chemical facility in the United Kingdom.

The MRS Mercury Removal/Recovery Process was accorded and R&D 100 Award and named by R&D Magazine as one of the most technologically significant new products in 1994, and the company and its technology were featured in a special supplement in Forbes Magazine listing the 25 top new environmental technology companies to watch. The process is the subject of US Patent 5,300,137 and patent applications pending in twelve countries.

If you require further details, please call, fax or e-mail me at *mercury@ccia.com*. I also invite you to visit our web site at *http//www.mrs-inc.com.*

Sincerely,



William F. Sutton
President

WFS/bjd
Enclosures

MERCURY RECOVERY SERVICES, INC.

MRS Process Resolves Mercury Issues in the Metals Industry

Mercury contamination is a worldwide problem that greatly affects the metal mining, smelting and refining industries.

The U.S. Environmental Protection Agency has designated mercury the most harmful heavy metal contaminant in the environment and regulations prohibit land disposal of most wastes containing total mercury in amounts greater than 260 ppm without prior treatment. Safe, efficient and economical removal of mercury from gold, silver and copper mining, smelting and refining by-products requires a treatment process that reduces mercury content to desired levels and recovers the mercury in pure, saleable form without producing any solid, liquid or gaseous wastes.

Mercury Recovery Services, Inc., (MRS) an environmental technology company headquartered in New Brighton, Pa., has developed and successfully commercialized a patented medium-temperature thermal process that removes and recovers mercury from soils and industrial wastes safely and cost-effectively. The MRS system is capable of reducing residual total mercury to insignificant amounts (less than 1 part per million) so treated materials can be returned or reused and the recovered mercury can be recycled for refining and reuse.

TURNING EXPENSES INTO EARNINGS

In metals mining, smelting and refining, mercury is found as a naturally-occurring material in ores; in concentrates; in leach residues; in pyro-metallurgical treatment residues; in refinery materials and residues in electrowinning electrodes; in autoclave discharge solids; and in waste water treatment and acid sludges.

The presence of mercury in these materials can severely decrease, or completely eliminate, the ability to recover residual metal values from the contaminated material. Because of the need to treat and/or dispose of the material, it can also increase production costs. By removing and recovering the mercury in resaleable form, the MRS Process converts expenses into earnings by:

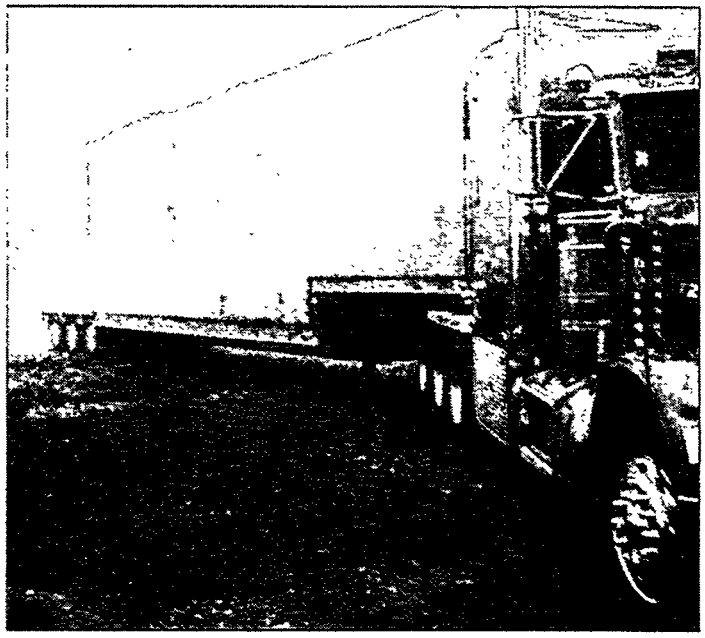
- Eliminating the penalties charged by custom smelters to process mercury-contaminated materials for the recovery of other metal values
- Recovering full metal value from the by-product or waste by the generator, if treated internally
- Re-using or receiving payment for the recovered mercury

COMMERCIAL SUCCESSES OF THE MRS PROCESS

The MRS Process is currently being used on a commercial scale to remove and recover mercury from copper acid plant blow-down sludge at a major copper smelter in the United States. To date, more than 2,500 tons of sludge have been processed, the mercury content has been reduced from between 1,000 to 2,500 ppm to less than 10 ppm, and the treated material is being reprocessed to yield the full metal value.

MRS recently completed a commercial operation involving the successful treatment of more than 6,000 tons of soil from metering sites along the natural gas pipeline system in New Mexico. Taking less than two years, the project was completed ahead of schedule and under budget.

The MRS Process is also currently in commercial use treating chlor-alkali waste at a chemical plant in the United Kingdom, and has been demonstrated to reduce the mercury content in Merrill-Crowe precipitate from 20 percent by weight (dry basis) to less than 10 ppm, and in precious metals refining materials to less than 10 ppm in pilot-scale studies.



One of MRS' mobile mercury removal/recovery units.

MRS PROCESS

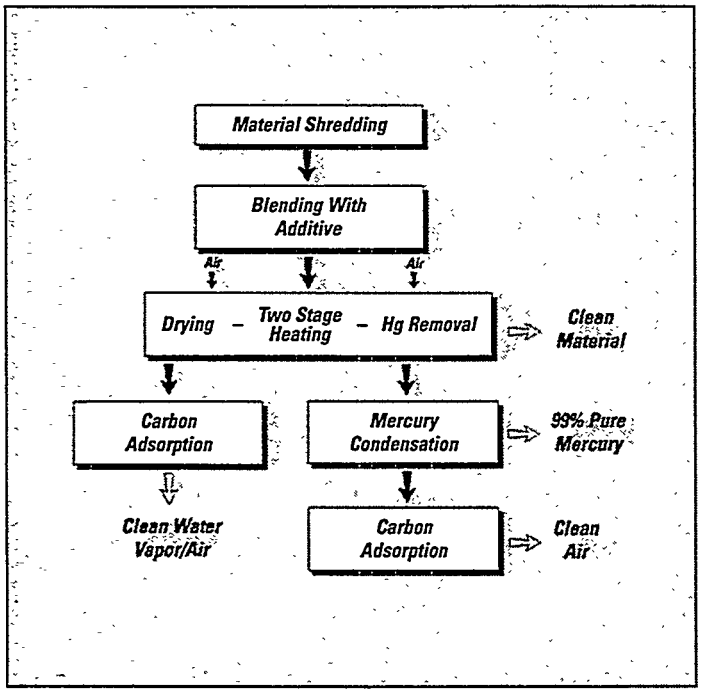
The MRS thermal process is capable of consistently reducing the total mercury content of treated material to less than 1 part per million, regardless of the form and the amount of the mercury contamination present.

The process meets or exceeds all federal, state and OSHA air standards and produces only clean treated solids, metallic mercury and clean air, thereby eliminating the liability inherent in hazardous waste disposal.

In addition to removing metallic mercury, the process recovers mercury from such compounds as sulfides, chlorides, oxides, and amalgams while eliminating gaseous sulfur and chlorine compounds from the process off-gas. The removed mercury is captured in 99 percent pure metallic form suitable for directly refining and recycling. No liquid effluent or secondary solid waste is produced. The process can be designed for batch or semi-continuous operation and can be configured for either "fixed site" or "mobile" operation.

The MRS Process, which is the subject of U.S. patent 5,300,137, and pending patents in 12 other countries, has been designated by the EPA as Best Demonstrated Available Technology (BDAT) for the treatment of mercury-contaminated materials. Both state and federal (EPA) departments have classified the MRS process as "recycling" rather than "waste treatment" and the process has been exempt from air and solid waste permitting requirements.

Process Flow Diagram



Process Description

1. The mercury-containing material is crushed and shredded to attain consistent particle size and surface area.
2. The sized material is then blended with an environmentally-safe additive that breaks down oxides, sulfides and chlorides and prevents gaseous sulfur and chlorine compounds from mixing with the exhaust gas.
3. The blended material is heated in a furnace in two stages. All moisture is removed during the first low-temperature stage and the resulting water vapor in the exhaust is carried through carbon columns to trap mercury. Once moisture-free, the temperature is raised and mercury is vaporized.
4. The vaporized mercury is carried by a dry air stream through a condenser where it is cooled, returned to its liquid metallic state and collected.
5. Finally, the carrier air is sent through a series of carbon columns for cleaning before it is released into the atmosphere.

A sophisticated computerized control and recording system monitors performance of the process.

TEST FACILITY/PILOT PLANT

MRS maintains a test facility/pilot plant in New Brighton, Pa. and is continually testing mercury removal from soils, chlor-alkali wastes, petroleum sludge, and a variety of other industrial wastes. MRS has performed demonstration projects and treatability studies on a wide variety of contaminated materials, including soils, fluorescent bulb wastes, mercury vapor lamps, electric switches and low-level radioactive mixed waste.

For more information, please contact:

Mercury Recovery Services, Inc.
700 Fifth Avenue
New Brighton, PA 15066
Tel: (724) 843-5000
Fax: (724) 843-5353
email: mercury@ccia.com

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Calcine Grinding

5. Summary: The following discussion summarizes the INEEL study suggesting the selection of a calcine pulverizer.

In the process for producing vitrified high level waste (HLW) in the HLW Vitrification Facility, radioactive calcine is mixed with glass "frit" and water, which produces a slurry. This slurry is then agitated, which keeps it uniformly mixed, then it is fed into a dryer and finally into a melter where the mixture is melted, forming a molten borated silicon glass. This mixture is then poured into a stainless steel canister where it cools and the molten material solidifies. This glass filled canister then becomes the final form of vitrified HLW that is ready for transport to a HLW repository.

Because the calcine and glass frit are of different specific gravities and the calcine particles are large, compared to the frit, then the calcine and frit particles will exhibit different settling velocities, within the slurry mixture. Thus, it is anticipated that it will be difficult to keep the slurry well mixed so that the different particles are uniformly dispersed. One of the means of mitigating a tendency to separate is by reducing the size of the calcine particles so that both the calcine and frit have approximately the same settling properties. Hence, the two components will tend to stay mixed as the slurry is agitated. The means of reducing the size of the calcine particles is to subject them to a process in which the larger particles are fractured into smaller particles, such as in a grinding or pulverizing process. At the same time, the action of pulverizing the calcine must not cause particles to adhere to the pulverizing mechanisms and the mechanism itself must be as simple as possible with a minimum of moving or active parts. This, in turn, will minimize the amount of maintenance and radioactive decontamination required during the calcine processing.

The type of pulverizer that best fits these requirements is a jet mill (i.e. jet pulverizer, fluid energy mill, or air impact pulverizer) in which the pulverizing force is provided by two opposing energetic air streams rather than by mechanical means, such as in a ball, hammer or impact mill. The action of the two opposing air streams is to cause particles to collide with each other, which causes some of them to fracture into smaller particles. Two such types of mill are available, which are: The Fluid Energy Aljet fluidized-bed "Jet-O-Mizer", and the Garlock-Trost "Air Impact Pulverizer". Three such mills are required and the estimated cost of each is $25,000.00 or $30,000.00, respectively.

A more detailed discussion of "Calcine Grinding", including an INTEC test report, pertinent calculations and references is attached.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	D. M. Kiser	Dennis M. Kiser	3/4/1999
Independent Verification	R	R. Rodney Kimmitt	R. R. Kimmitt	3/10/99
Requestor	A	D. A. Lopez	D A Lopez	3/20/99

CALCINE GRINDING

Introduction

The purpose of this engineering design file (EDF) study is to suggest one or more pulverizers that can reduce the mean size of the calcine particles to the desired size and at the same time minimize decontamination and maintenance of pulverizer parts.

If the calcine is pulverized in a mechanical mill, experience at the INTEC with mechanical calcine screw conveyors indicates that the calcine will stick to the mechanical mill surfaces and foul the pulverizing action. This will require periodic removal of the calcine build-up by washing the parts in a solution of nitric acid. Hence, a significant maintenance and decontamination problem results when using this type of equipment. Conversely, however, experience at the INTEC with air transport of calcine and cyclone particle separators indicates that the calcine will not stick to mill surfaces in which the calcine interacts in an air stream. Thus, air stream jet mills will have the fewest maintenance and decontamination problems. As a result of this conclusion, INTEC has tested the performance of several types of air powered jet mills, including a spinning torus[1], a fluidized-bed jet mill with a centrifugal particle classifier[2,3,4], and a simple fluidized-bed jet mill[5].

Of the three types of jet mills that were tested, the simple fluidized-bed jet mill was the best performer because the system has a high throughput with virtually no moving parts. Both the pulverizing action and the transport of calcine particles through the mill are achieved by utilizing two opposing high-pressure jets of air. By utilizing two opposing air-streams from jets imbedded within a bed of particles, particles are slightly lifted and agitated by the airflow. The agitated particles near the air-streams then collide with each other and some of them fracture into smaller sizes. Separation of larger particles from the smaller particles is achieved by the airflow up through the bed of particles, which lifts the smaller particles above the freeboard height and through the outlet of the pulverizer. The larger particles then fall back into the fluidized bed where they recycle through the process. For the jet mill tested at INTEC, the mean calcine particle size fed into the test pulverizer ranged from 0.2 to 0.6 mm in diameter (i.e. 200 to 600 microns), with a small percentage ranging from 10 to 200 microns in diameter. The mean particle size produced by the test pulverizer was about 128 microns in diameter, with a standard deviation of about 15 microns. Accurate control of the resulting particle sizes is achieved by varying the air jet sizes and distance of separation. Performance of the unit tested is summarized in the first table of Attachment 1, which is a spreadsheet, entitled "Calcine Grinder", and is denoted as the INTEC type of pulverizer. Detailed test results and test apparatus configurations can be obtained from the test report[5], which is included as Attachment 2, herein. Attachment 2 is a letter report from Laura J. Young to D. V. Croson, entitled "Two-Dimensional Fluidized-Bed Jet Mill Run Report - LJY-03-95".

Because the unit tested was only a small laboratory prototype with a throughput of only 34 grams/min of pulverized calcine, then a scaled version of the INTEC pulverizer is shown as the second item, denoted as the INTEC (Scaled) type. Three commercially available units, similar in performance to the INTEC (scaled) type, are also shown, which are the:

1. CCE Technologies[6] unit, which is a fluidized bed pulverizer with a centrifugal classifier,
2. Jet-O-Mizer[7] unit, which is a fluidized bed pulverizer with a cyclone type of air flow classifier that is adjustable for control of particle size distribution,
3. Trost Air Impact Pulverizer[8] unit, which is a fluidized-bed pulverizer with a cyclone type of airflow classifier that is adjustable for control of particle size distribution.

The production rates established by the process design engineer for the HLW Vitrification Facility Feasibility Study[9,10,11] are shown in the second table of Attachment 1, where the:

1. First row gives the production rate for the facility, based on 24 hr operation
2. Second row gives the production rate required for each glass melter, in order to achieve the facility production rate, and

3. Third row gives the production rate required for each calcine pulverizer (grinder), in order to achieve half the facility production rate.

The design of the process specifies that three pulverizers will be required that will feed three melter feed tanks, that, in turn, will feed four glass melters. The third grinder/feed tank system is required to eliminate process interference caused by awaiting sample analysis or feed tank maintenance. Thus, any pair of grinder/feed tank systems must provide the facility production rate. The production capacity of each calcine pulverizer is given by rows three and four which give the normal and peak calcine pulverizer production rates that will be required.

In performing the literature search in order to find the commercial availability of such a mill, the World Wide Web computer network (Internet) was searched via the Thomas Register of American Manufacturers. For completeness, Attachments 3, 4, and 5 are the documents retrieved during the Internet search of the Thomas-Register database. These documents give information for the commercially available jet mills denoted in Attachment 1 as the: CCE Technologies[6], Inc. fluidized-bed jet mill with a centrifugal particle classifier, the Fluid Energy Aljet[7] fluidized-bed "Jet-O-Mizer", and the Garlock-Trost Air Impact Pulverizer[8], respectively. Each of the manufacturers was contacted by telephone and an approximate cost was estimated for each of three jet mills, constructed of stainless steel, that would each normally pulverize about 1726 lbm/hr of calcine (2158 lbm/hr peak).

Approximate cost per unit:

1. **INTEC unit: ..... unknown**
2. **INTEC (Scaled) unit: ..... unknown**
3. **CCE Technologies unit: .... $159,000.00 each (complete system)**
4. **Jet-O-Mizer unit: ..... $25,000.00 each (mill only)**
5. **Garlock/Trost unit: ..... $30,000.00 each (mill only)**

In order to determine the calcine and frit particle sizes required to achieve equal settling velocities a spreadsheet was developed for tabulating and calculating the terminal velocities of various sized spheres of both calcine and frit that are settling or falling through a water field. This spreadsheet is shown in Attachment 6, in which two sets of results are tabulated. The first set of results are tabulated for a sphere falling at terminal velocity through a field of water assuming Newton's Law of Viscosity, and computed using a typical drag coefficient formula. The coefficient of drag is calculated using a straight-line approximation for the transition regime for Reynold's Number between 0.8 and 100. The second set of results are tabulated for a sphere falling at terminal velocity through a field of water assuming Stoke's Law of Viscosity, and computed using a typical drag coefficient formula. The coefficient of drag is calculated using a straight-line approximation for the creep flow regime for Reynold's Number less than 0.8. A plot of drag coefficient versus Reynold's Number from which these results are computed, is shown in Attachment 7 entitled, "Figure 10.10 Drag coefficient for bodies of revolution". This figure is taken from Reference 12. The valid results are shown as numbers in a white background. Invalid results are shown as numbers in a gray background. Invalid results are those results for which the Reynold's Number lies outside the range of formulation. As seen in the table, for calcine pulverized to a mean size of 128 microns, as produced by the INTEC test pulverizer, the settling velocity is in the range of 0.617 to 0.725 ft/min. The size of frit required in order to approximately match the settling velocity of the calcine is therefore about 60 to 70 microns, which results in a settling velocity between 0.579 and 0.788 ft/min. It must be pointed out, however, that a commercial unit manufacturer will most likely desire to determine an optimum pulverizer configuration and calcine particle size that will be produced. Based on these results the table of Attachment 6 can then be utilized to select the proper frit particle size that will match the calcine particle settling velocity. Then the proper size frit can be purchased.

Based on the information contained herein, either of two commercially available units can be suggested, which are: the Fluid Energy Aljet "Jet-O-Mizer" unit, or the Garlock-Trost "Air Impact Pulverizer" unit.

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2. W. D. Bolon, letter WDB-07-92 to L. J. McQuinn, "Summary of Work Completed on the Fluidized Bed Jet Mill", dated December 14, 1992.
3. L. J. McQuinn, letter LJM-06-92 to J. D. Herzog, "Run Plan for CGS Fluidized Bed Jet Mill - Five Sets of Calcium Carbonate Runs", dated November 16, 1992.
4. L. J. McQuinn, Lab Notebook LN-463, "General Laboratory Experiments", dated March 1992 to April 1993.
5. Laura J. Young, letter LJY-03-95 to D. V. Croson, "Two-Dimensional Fluidized Bed Jet Mill Run Report", dated September 25, 1995. Attached as Attachment 2.
6. Search http://www.thomasregister.com, Criteria: "pulverizers: jet", CCE Technologies, Inc.
7. Search http://www.thomasregister.com, Criteria: "pulverizers: jet", Fluid Energy Aljet.
8. Search http://www.thomasregister.com, Criteria: "pulverizers: jet", Garlock Plastomer Products-Trost Air Impact Pulverizers.
9. Personal Communication with R. R. Kimmitt, 2/8/99 and R. R. Kimmitt spreadsheet "FS-Bill of Materials-Rev. 1.xls".
10. Personal Communication with R. R. Kimmitt, 2/8/99, "Normal production rate is approximately 80% of peak rate ".
11. Personal Communication with R. R. Kimmitt, 2/8/99, "3 mix-tanks feed 2 melter feed-tanks so that 1 grinder/mix-tank can be down or awaiting sample analysis".
12. Robert L. Daugherty, et al, "Fluid Mechanics with Engineering Applications", Eighth Edition, McGraw-Hill, Inc., 1985.

Attachment 1
Two-Dimensional Fluidized Bed Jet Mill Run Report-LJY-03-95

LOCKHEED MARTIN

Lockheed Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date: September 25, 1995

To: D. V. Croson MS 5218 6-3402

From: Laura J. Young LJ Young MS 5213 6-3132

Subject: Two-Dimensional Fluidized Bed Jet Mill Run Report -LJY-03-95

Attached is the comprehensive run report for tests conducted in the two-dimensional fluidized bed jet mill. A two-dimensional fluidized bed jet mill was constructed and tested to determine the optimum grinding jet configuration that maximizes the transformation of kinetic energy into fracture energy. The configuration variables tested include: jet separation, jet depth below the surface of the bed, jet off-sets, and jet angles.

The optimum configuration tested in the 2-dimensional fluidized bed jet mill using calcium carbonate resulted in a grinding rate of 34.3 grams/minute. The jets were located 5 inches below the surface of the bed, directly opposed, with a 6-inch jet separation, and a jet angle of 0° from the horizontal. This configuration is thought to have maximized the force of impact by encouraging head-on particle-particle collisions. Increasing the separation distance, offsetting or angling the jets sharply decreased the grinding rate. The optimum jet configuration will vary with the physical properties of the material to be ground.

This report completes PTS Milestone 8.03.37 which requests that a report be issued on calcine grinding tests by September 30, 1995. Please contact me at (208) 526-3132, if you have any questions or comments concerning this work.

enclosures

cc: T. A. Batcheller, MS 5218
R. D. Boardman, MS 5218
J. H. Valentine, MS 5220
L. J. Young - 2

M. J. Steinkamp, w/o enclosure, MS 5217

Two-Dimensional Fluidized Bed Jet Mill Run Report

L. J. Young

September 1995

ABSTRACT

Since 1963, the highly radioactive liquid wastes generated from reprocessing nuclear fuels at the Idaho Chemical Processing Plant (ICPP) have been calcined to form a solid granular waste. Over 3800 cubic meters of calcined high-level waste (HLW) are currently stored at the ICPP. Prior to permanent disposal, the calcine must be processed to immobilize the radioactive and hazardous components. A suitable waste form and the process technologies required to produce the waste form are currently being developed by the HLW Immobilization Section. A fluidized bed jet mill was investigated as a means of meeting the particle size control requirements for several of the proposed process technologies.

In a fluidized bed jet mill granular particles are fluidized with air. Additional air for grinding is introduced into the mill through square-edge orifice jets. This air entrains some of the particles thus increasing their kinetic energy. The kinetic energy is transformed into fracture energy as the particles undergo particle-particle and particle-wall collisions if the collisions occur with a sufficient force. The force exerted on the particles during a collision depends on the velocity of the objects involved and the angle of impact. The physical structure of the particle also affects the force required for breakage.

A two-dimensional fluidized bed jet mill was constructed and tested to determine the optimum grinding jet configuration that maximizes the transformation of kinetic energy into fracture energy. The configuration variables tested include; jet separation, jet depth below the surface of the bed, jet off-sets, and jet angles.

The optimum configuration tested in the 2-dimensional fluidized bed jet mill using calcium carbonate resulted in a grinding rate of 34.3 grams/minute. The jets were located 5 inches below the surface of the bed, directly opposed, with a 6-inch jet separation, and a jet angle of 0° from the horizontal. This configuration maximized the force of impact by encouraging head-on particle-particle collisions. Increasing the separation distance, offsetting or angling the jets sharply decreased the grinding rate by reducing the interaction between entrained particles. Locating the jets at a 5-inch depth below the surface optimized the particle concentration around the jets. The optimum jet configuration will vary with the physical properties of material to be ground.

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Two-Dimensional Fluidized Bed Jet Mill Run Report

I. INTRODUCTION

Since 1963, the highly radioactive liquid wastes generated from reprocessing nuclear fuels at the Idaho Chemical Processing Plant (ICPP) have been calcined to form a solid granular waste. Over 3800 cubic meters of calcined high-level waste (HLW) are currently stored at the ICPP. Although the calcined waste form eliminates the problems of storing liquid wastes on a long term basis, it is not considered suitable for permanent storage in a repository. Prior to permanent storage, the calcine must be processed to immobilize the radioactive and hazardous components. A suitable waste form and the process technologies required to produce the waste form are currently being developed by the HLW Immobilization Section. A fluidized bed jet mill was investigated as a means of meeting the particle size control requirements for several of the proposed process technologies.

Several of the proposed technologies require a smaller and more uniform particle size distribution than the as-formed calcined waste. The as-formed calcine consists of two parts; bed particles ranging from 0.2 to 0.6 mm in diameter and fines ranging from 10 to 200 microns in diameter. Larger agglomerates may also have formed during storage. The advantages of controlling particle size distribution include minimizing segregation and improving reaction rates in downstream unit operations. Segregation affects both transport properties and blending characteristics. The dissolution rate and the stabilization (off-gassing) rate are both expected to increase with a decrease in particle size.

A principle design criterion for the proposed immobilization technologies is to minimize the maintenance and replacement requirements for systems that will be used in radioactive areas. Typically, minimizing the number of moving parts satisfies this criterion best. A jet mill was chosen over standard mechanical mills such as ball, hammer, or impact mills since the breakage force is supplied by air rather than mechanical moving parts. In jet mills, air is used to cause particle-particle and particle-wall collisions that result in fragmentation and abrasion of the particles.

The final particle size distribution is also a key criterion for selecting and developing a particle size reduction system. The desired average particle size is approximately 180 microns, which corresponds to a Geldart Type B powder.[1] Other jet mills were investigated and a torus jet mill was tested in a previous study.[2] The earlier study showed that the torus jet mill reduced the solids to below the desired size distribution and could not be modified to create a larger size

distribution. Commercially available fluidized bed jet mills were also rejected because they are designed to produce only an extremely fine particle size distribution (<20 microns). The commercially available fluidized bed jet mills also rely on mechanical turbine classifiers as an integral part of their design. Preliminary testing of a cylindrical fluidized bed jet mill constructed in-house indicates, that the desired size distribution can be obtained in a fluidized bed jet mill without the use of a mechanical classifier.[3,4,5]

A two-dimensional fluidized bed jet mill was constructed and tested, to determine the optimum grinding jet configuration for verification testing in an intermediate-scale fluidized bed jet mill.[6,7] The configuration variables tested include jet separation, jet depth in the bed, jet offsets, and jet angles. The 2-dimensional design was chosen for its jet configuration flexibility and ability to isolate jet interactions. The results of the tests conducted using the 2-dimensional fluidized bed jet mill are discussed in the following sections.

II. EXPERIMENTAL EQUIPMENT

The two-dimensional fluidized bed jet mill was installed in the Calcine Grinding Setup (CGS) enclosure located in the Low Bay of CPP-637. The experimental equipment included a 2-dimensional fluidized bed jet mill, air supply system, product-collection/filter vessel, a process controller and instrumentation. In a fluidized bed jet mill, air is used to cause particle-particle and particle-wall collisions. The particles abrade and fracture due to the collisions. The resulting smaller particles are elutriated from the mill into the product-collection/filter vessel. The particles disengage from the air and settle into the collection vessel due to the reduction in air velocity. Sintered metal filters are located at the outlet of the product collection vessel to trap particles larger than 2.9 microns that are still entrained in the air. The air then passes through a HEPA filter to remove any remaining particles. A simplified process and instrument diagram is shown in Figure 1 and the major components are described below.

A. Calcine Grinding Setup Enclosure

The CGS enclosure serves as a Type II walk-in hood to prevent the spread of dust. Ventilation for the enclosure is provided by the module ventilation blower and HEPA filter on the 10-cm Calciner Pilot Plant.

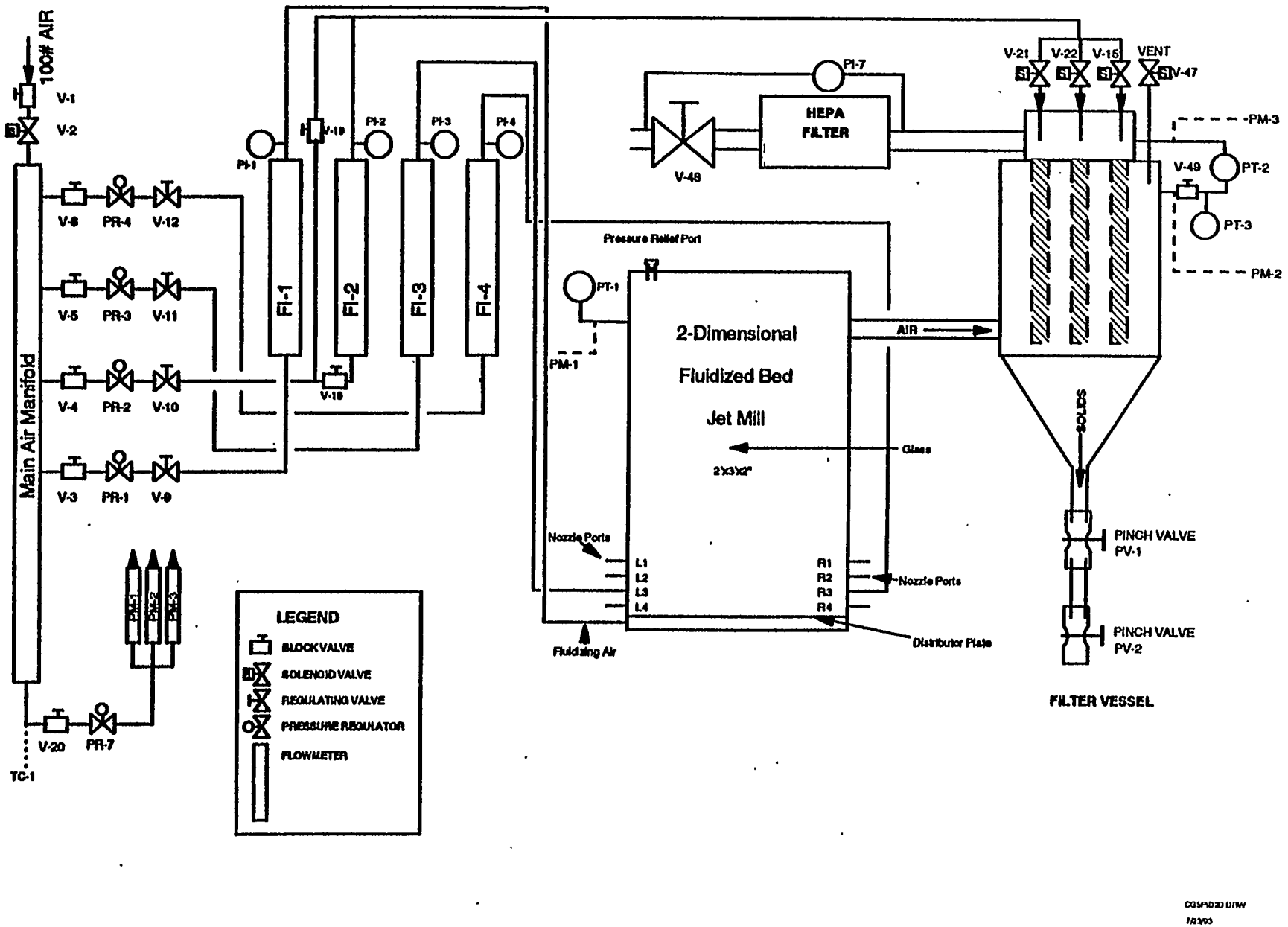


Figure 1. Simplified Process and Instrument Diagram of the CGS

B. Two-Dimensional Fluidized Bed Jet Mill

The 2-dimensional fluidized bed jet mill was constructed from two sections of ¼-inch plate glass (2 feet by 3 feet) and 1⅝-inch stainless steel channel as shown in Figure 2. The channel was welded together to form the frame of the mill. The glass was attached to the front and back sides of the frame using aluminum retaining bars as detailed in Figure 2A. The plenum was constructed by removing the turned-in portions of the channel sides and closing off the ends of a 2 foot section of channel. Three-layer Dynapore mesh (No. 407520) was welded to the open side of the plenum to serve as the distributor plate (see Figure 2B). Fluidizing air was supplied to the plenum through a ½-inch port on the left side of the mill.

The mill was equipped with eight jet ports located at three-inch intervals along each side of the bed, starting two inches above the distributor plate. For the jet ports, ¼-inch Swaglock unions were drilled out to allow the grinding jets to be slid varying distances into the bed. The grinding jets were constructed from ¼-inch stainless steel tubing. A stainless steel plug with a 0.062-inch square-edge orifice was press fit into the end of each tube. Angled grinding jets were made by using 30° and 45° tubing bends.

The mill was equipped with a ½-inch solids removal port above the distributor plate, a ¼-inch pressure gauge connection, and a 1-inch off-gas line. Due to the size limitations of the channel, the off-gas line had an elliptical cross section at the connection to the vessel. The off-gas line gradually tapered into a circular cross section to match the inlet to the product-collection/ filter vessel. Solids were added to the mill through the pressure relief/solids addition port on top of the vessel. The plug for the pressure relief port was designed to vent the vessel if the pressure exceeded 3 psi.

C. Air Supply System

The system was supplied with high pressure (100 psi) plant air. The air was split at the main air manifold into five lines which supplied; fluidization air, jet air (2), filter blowback system air, and purge air to the differential pressure cells. Each line was equipped with a pressure regulator, pressure indicator, and rotameter. Flexible plastic tubing was used for the jet air lines to ensure that they could be routed to any of the eight jet ports.

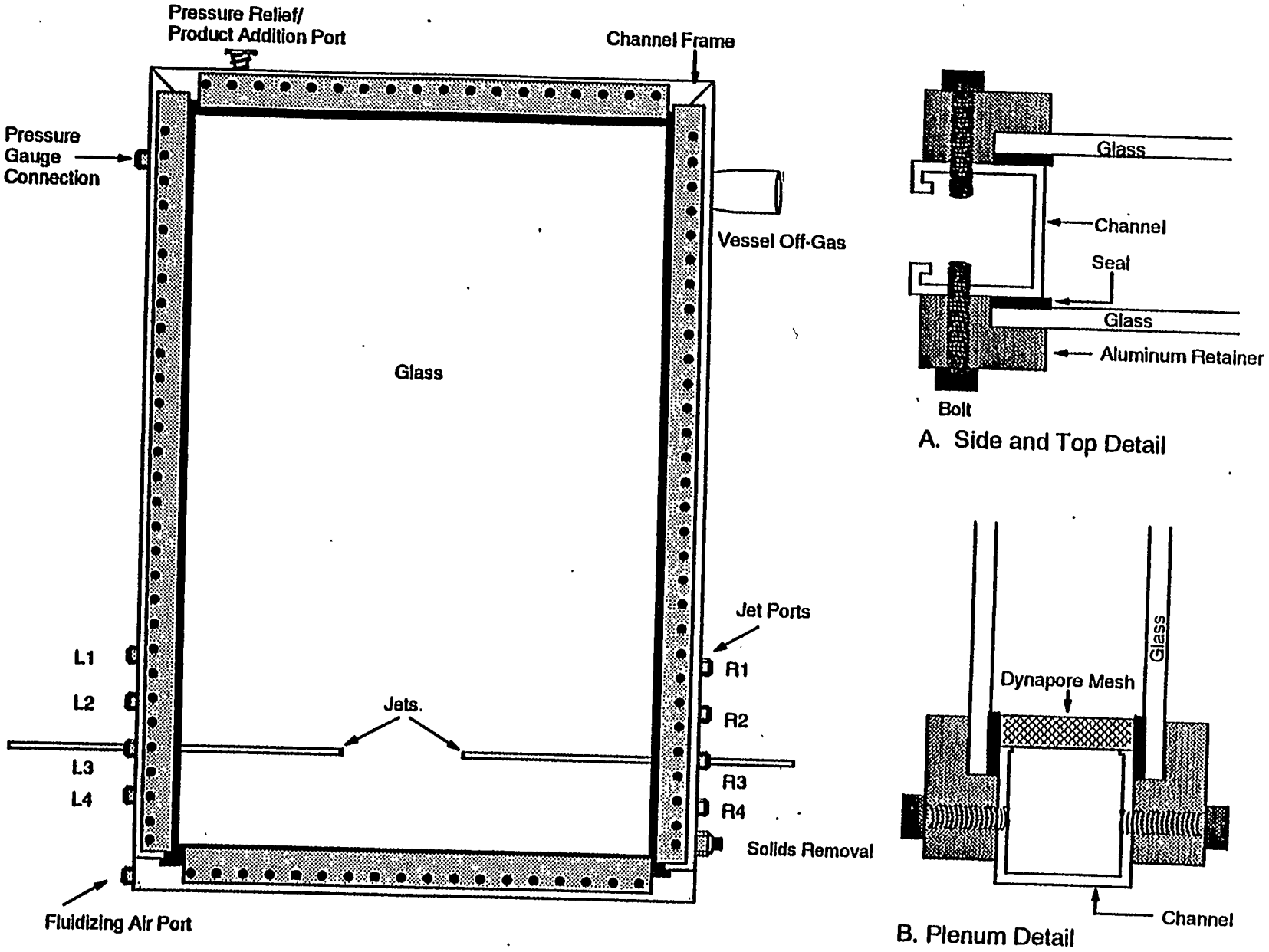


Figure 2. Two-Dimensional Fluidized Bed Jet Mill

D. Product-Collection/Filter Vessel

A four sided stainless steel hopper with a rectangular upper section was used as the product collection/filter vessel. The hopper sides were angled greater than 60° from horizontal to aid solids flow from the vessel . A 2-inch flexible plastic line equipped with two pinch valves was used as the hopper discharge line. Three sintered metal filters were located in the rectangular upper section at the vessel off-gas outlet. The filters were rated at 2.9 microns absolute.

The sintered metal filters were connected to a blowback system to clear them. The blowback system forced air through the filters opposite the normal direction of flow. The filters were blown back individually in sequence to minimize the change in the air flow in the mill. The filter blowback system could be started either manually or automatically by the process control system.

E. Process Controller and Instrumentation

An Allen-Bradley PS 2/15 process controller was used to control the blowback system and monitor the pressure within the system. As a safety precaution, the controller was programmed to close the solenoid valve (V-2) on the main air line if the pressure in the bed exceeded 65 inches of water or to open the vent on the filter vessel (V-47) if the pressure in that vessel exceeded 14 psi. The controller was also programmed to start the blowback sequence if the pressure drop across the sintered metal filters exceeded 13 psi. Independent of the process controller, four thermocouples were used to monitor the air temperature in the main air manifold, each jet manifold and the jet mill.

F. Test Materials

High-calcium limestone (calcium carbonate) was used to simulate the calcined high-level waste for these tests. Calcium carbonate was chosen since it is nonhazardous and has a similar density and particle size distribution to actual calcine. The calcium carbonate was screened prior to use and only the fractions greater than 210 microns in size were used in the jet mill.

III. EXPERIMENTAL PROCEDURE

A. General Procedure

The operating instructions and parameters for the 2-dimensional fluidized bed jet mill are specified in the run plans for these tests and in the Calcine Grinding Setup Operating Instructions.[6,7,8] The data collected was recorded in the Lab Notebooks LN-521, LN-572, and LN-577.[9,10,11] The general experimental procedure was as follows. The jet configurations and airflow rates were adjusted to the values listed in Table 1 at the start of each run. The total air flowrate was maintained at 13 scfm for each run to ensure a consistent particle size carryover between tests. Approximately 14 kilograms of limestone were charged to the mill prior to the first run. Additional limestone was added to maintain the bed height at approximately 13 inches prior to subsequent runs. The fluidizing air was started after the calcium carbonate was added. Next, the jet air and timer were started. The jet and fluidizing air were stopped at five minute intervals and the ground solids were removed from the product collection vessel. Each run consisted of six grinding intervals. The grinding rate and particle size distribution (PSD) were determined for each grinding interval.

B. Test Variations

Fifteen nozzle configurations were tested in the 2-dimensional fluidized bed jet mill. Duplicate or triplicate runs were completed for each configuration test. The jet configurations for each test are given in Table 1. The background elutriation rate of solids from the mill was established in Test 1. A fluidizing air flowrate of 13 scfm with no grinding air was used in Test 1. The jet separation, depth below the surface of the bed, offset distance on opposite sides of the bed, offset distance on same side of the bed, and jet angle were individually varied for the following runs. The tests are grouped in Table 2 according to parameter varied. Test 3 is used as a reference in each group for comparison.

Jet separations distances of 4, 6, 8, and 10 inches were tested to determine the maximum jet separation in the Group I tests. The gap between the jets was centered in the vessel. A jet separation of six inches was maintained at approximately 2, 5, and 11 inches below the surface of the bed for the Group II tests. The depth below the surface changed slightly during the runs as solids were elutriated. The grinding jets were placed 3 inches from the vessel centerline for the Group III and IV tests. The jets were offset on opposite sides of the bed at vertical distances of 0, 3, 6, and 9 inches for the Group III tests. The jets were offset on the same side of the vessel at

Table 1. Operating Parameters

Test Number [a,b]	Run Numbers	Jet Separation Distance (inches)	Jet Ports[c]	Jet Angle	Fluidizing Air Flowrate (scfm)	Jet Air Flowrate (scfm, each)
1	1A,1B,1C	4	L1/R1	0°	13	0
2	2A,2B,2C	4	L1/R1	0°	5	4
3	3A,3B	6	L1/R1	0°	5	4
4	4A,4B	8	L1/R1	0°	5	4
5	5A,5B	10	L1/R1	0°	5	4
7	7A,7B	6	L4/R4	0°	5	4
8	8A,8B	6	L1/R4	0°	5	4
9	9A,9B	6	L1/R3	0°	5	4
10	10A,10B	6	L1/R2	0°	5	4
11	11A,11B	NA	L1/L2	0°	5	4
12	12A,12B	NA	L1/L3	0°	5	4
13	13A,13B	NA	L1/L4	0°	5	4
14	14A,14B	6	L2/R2	0°	5	4
16	16A,16B	6	L1/R1	30°	5	4
17	17A,17B	6	L1/R1	45°	5	4

General: The test number refers to the configuration used and the run number refers to the replicates completed using those conditions.

a. Test 6 (12-inch jet separation) was optional according to the run plan and was not conducted since there was no significant change between Tests 4 and 5

b. The Test 15 designation was inadvertently skipped while conducting and numbering the runs.

c. The jet ports are labeled 1 to 4 from the top to bottom on both sides of the bed. L1 is the top port on the left side.

Table 2. Comparison Groupings

Group Number	Test Number	Parameter Varied
I	2, 3, 4, 5	Jet separation
II	3, 7, 14	Depth below bed surface
III	3, 8, 9, 10	Offset-opposite sides of bed
IV	3, 11, 12, 13	Offset-same side of bed
V	3, 16, 17	Jet angle
-	1	Baseline elutriation rate

vertical distances of 3, 6, and 9 inches for the Group IV tests. The grinding jets were angled 0°, 30°, and 45° below the horizontal for the Group V tests. A jet separation distance of 6 inches and depth of 2 inches were used in the Group V tests.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Particle size distributions and grinding rates were determined for each grinding interval during a run. Averages for each run were then determined to allow comparisons to be made between the individual runs, tests, and groups. The particle size distribution calculations and results will be discussed first, followed by the grinding rate results.

A. Particle Size Distribution

The particle size distributions of the starting bed material and the product collected for each grinding interval were determined by sieve analysis. The particle size distributions were determined using the US Standard Mesh Sieve series. Multiple representative samples of the starting bed material and a single representative sample for each grinding interval were analyzed. The average weight percentages for each sieve size were determined from the sieve analysis data using Equation 1. The individual grinding interval particle size distributions for Run 3B are shown in Figure 3. The frequency distribution or weight percent versus mesh size is shown in Figure 3a and the cumulative size distribution is shown in Figure 3b. The solid lines in Figures 3a and 3b represent the average for the run calculated using Equation 1. The variations between the average and individual grinding interval distributions for this run are representative of the runs overall. The sieve analysis data,

average distributions and standard deviations for each mesh size are given in Appendix I for all of the runs.

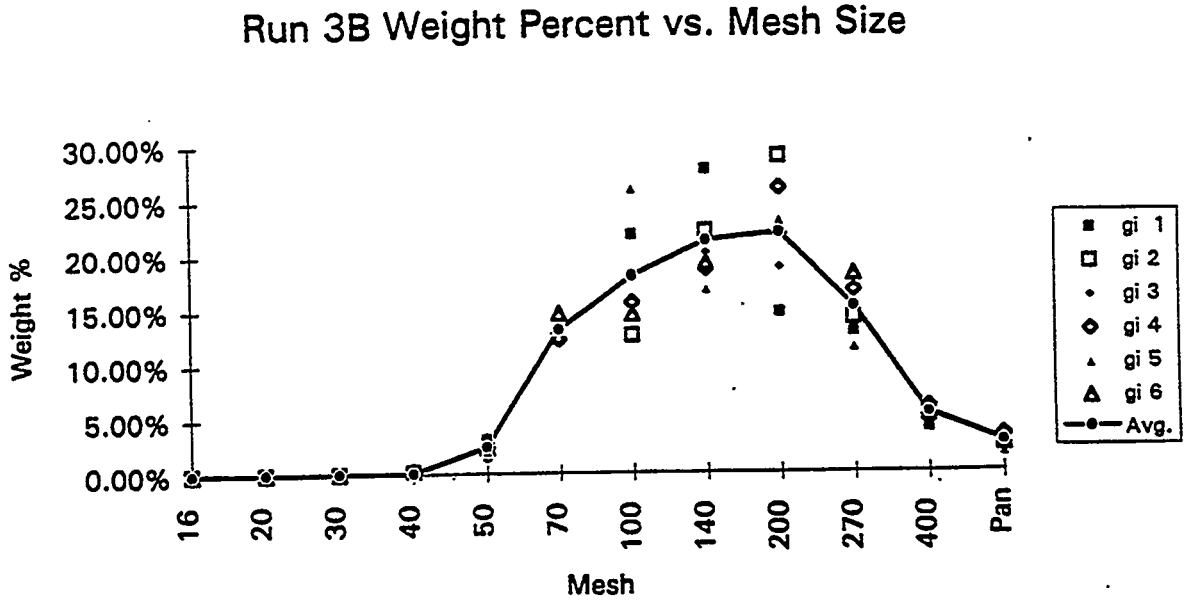
$$\overline{x_i} = \frac{\sum_{gi=1}^{6} (x_{i,gi} * W_{Tot,gi})}{\sum_{gi=1}^{6} W_{Tot,gi}} = \frac{\sum_{gi=1}^{6} W_{i,gi}}{\sum_{gi=1}^{6} W_{Tot,gi}} \qquad (1)$$

x_i = Weight percent collected on each sieve tray
$W_{Tot,gi}$ = Total weight of solids collected during grinding interval (gi)
I = US Standard Mesh Sieve (16, 20, 30, 40, 50, 70, 100, 140, 200, 270, 400, Pan)
gi = grinding interval

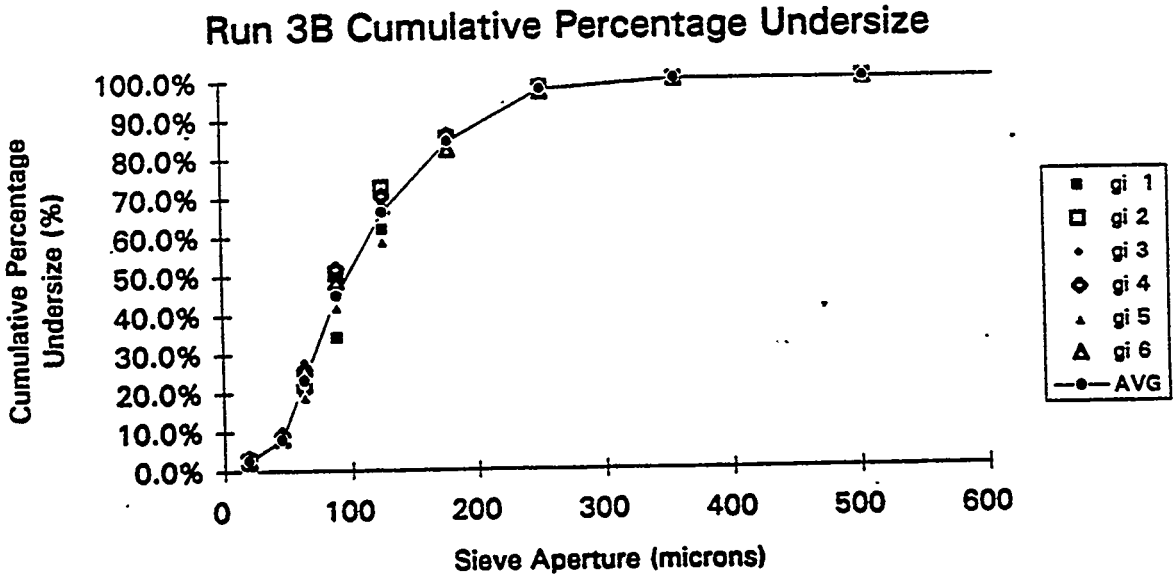
The average standard deviations per screen were less than 6%. The 70, 140 and 200 mesh screens had the highest deviations. These higher deviations can be attributed to cohesion and the freeboard height in the mill. The standard deviations for the 140 and 200 mesh screens (105 and 74 microns respectively) averaged approximately 6% due to cohesion. At approximately 100 microns, calcium carbonate changes from a Geldart Type B powder to a more cohesive Type A powder. The increased cohesiveness of this size of powder caused the sieve trays to intermittently plug and small agglomerates to form. The arbitrary retention of material on these screens caused the larger deviations.

The average standard deviation for the 70 mesh screen (210 microns) was 4%, yet it had the highest maximum deviation at 13%. The freeboard height in the mill contributed to this wide range. Due to space limitations, the 2-dimensional jet mill was constructed with a freeboard height of approximately 20 inches which is lower than the transport disengagement height required for some of the jet configurations. Certain configurations caused large particles to be ejected into the top of the freeboard region and increased their carry-over rate. The number of particles ejected varied during the grinding intervals and with the jet configurations.

The deviations caused by cohesion and the freeboard height were noticeable but were within an acceptable range. The average distributions are therefore representative of each run and can be used in place of the individual grinding interval distributions. The average particle size distributions for each run are also shown in Appendix I. A representative change in particle size



(a)



(b)

Figure 3. Particle Size Distribution for Run 3B: (a) Weight Percent versus Mesh Size; (b) Cumulative Percentage Undersize

distribution due to grinding is shown in Figure 4 using the average particle size distributions calculated for the starting bed material and Test 4.

To further simplify the particle size comparisons between runs, the harmonic mean particle diameter (HMPD) and the mass mean particle diameter (MMPD) were calculated for each run using Equations 2 and 3. The harmonic mean particle diameter, or Sauer particle diameter, is the surface-volume particle diameter. The HMPD characterizes the powder behavior as a whole and emphasizes the important influence of fines on powder behavior. The mass mean particle diameter is simply the median size of the particles.

$$HMPD = \frac{1}{\Sigma\, x_i/d_{pi}} \tag{2}$$

$$MMPD = \Sigma\, x_i d_{pi} \tag{3}$$

The MMPD and HMPD for starting bed and each grinding interval are listed in Appendix I. The average MMPD and HMPD are given in Table 3. As the mean particle diameters show, the deviations in particle sizes between runs were minor. This consistency indicates that the jet configuration variations had no significant impact on the particle size distribution of material elutriated from the system. The changes in elutriation rate can therefore be credited to the changes in jet configuration.

B. Grinding Rates

The total elutriation rate, the elutriation rate of particles greater than 210 microns (+70 mesh), and the elutriation rate of particles less than 210 microns (-70 Mesh) were calculated for each grinding interval. First the total weights of the +70 and -70 mesh fractions were determined from the particle size analysis data. The elutriation rates were calculated using Equation 4. The three rates for each run are given in Appendix II. The +70 mesh elutriation rate represents the amount of unground material transported out of the mill since a +70 mesh starting bed was used in these tests. The -70 mesh elutriation rate therefore represents the actual grinding rate for the mill.

$$r_{gr_{gi}} = \frac{W_{gi}}{\Delta t_{gi}} \tag{4}$$

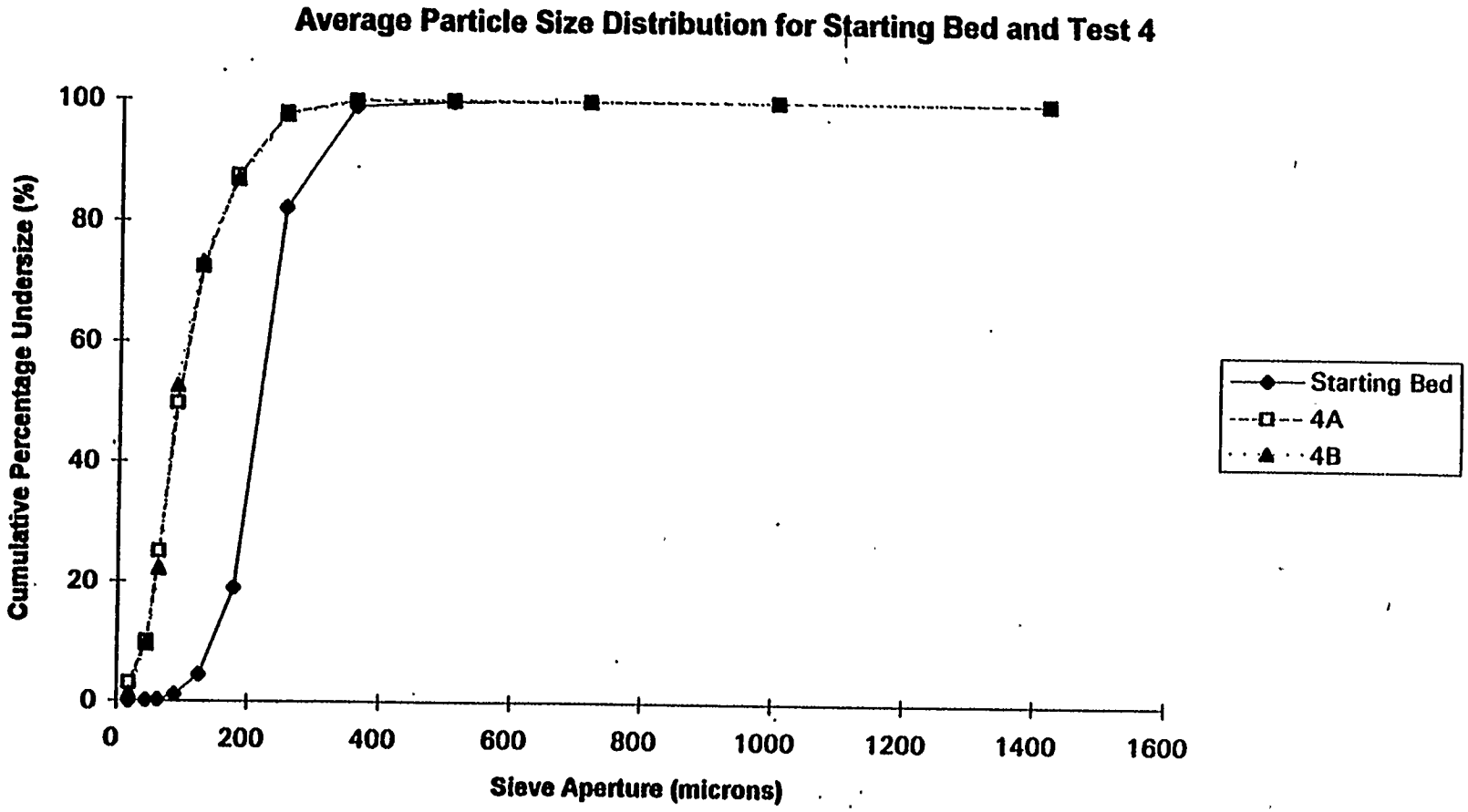


Figure 4. Average Particle Size Distributions for Starting Bed Material and Test 4.

Table 3. Average Mass Mean and Harmonic Mean Particle Diameters

Group #	Run #	Average MMPD (microns)	Standard Deviation (microns)	Average HMPD (microns)	Standard Deviation (microns)
	Starting Bed	255.7		236.7	
-	1B	133.2	23.4	88.0	12.6
-	1C	164.9	18.6	118.2	18.9
I	2A	156.6	26.1	103.4	20.7
I	2B	134.8	35.3	93.1	19.5
I	2C	132.4	12.1	96.7	6.6
I	3A	136.9	9.9	98.2	8.6
I	3B	133.8	5.7	93.5	5.0
I	4A	122.6	6.9	87.5	4.7
I	4B	123.2	6.5	92.0	4.6
I	5A	103.5	1.7	80.8	3.6
I	5B	115.6	12.4	86.6	7.2
II	7A	135.4	5.9	93.1	4.3
II	7B	134.2	6.9	92.5	6.3
III	8A	125.0	11.7	90.1	8.6
III	8B	130.1	16.2	95.7	10.9
III	9A	117.8	9.5	88.5	6.5
III	9B	115.8	5.3	90.7	4.3
III	10B	122.1	10.1	88.2	7.3
III	10C	123.5	14.6	86.0	11.4
IV	11A	136.1	8.5	98.0	4.7
IV	11B	131.8	5.0	93.6	5.3
IV	12A	121.7	8.5	90.1	4.9
IV	12B	115.2	9.9	85.7	7.8
IV	13A	114.2	9.5	85.2	5.9
IV	13B	110.1	4.6	83.9	4.7
II	14A	151.2	6.6	97.5	6.5
II	14B	156.8	7.7	101.8	12.3
V	16A	103.6	8.9	73.4	8.6
V	16B	116.1	10.0	75.5	7.1
V	17A	121.6	6.3	81.5	10.6
V	17B	131.0	5.3	94.5	7.4
Average		128.3		91.7	
Standard Deviation		14.6		9.0	

An average grinding rate for each run was determined from the total amount of -70 mesh material elutriated from the mill during the run divided by the total time span of the run. This average was in most cases equivalent to averaging the individual grinding interval rates. A test average was determined by averaging the rates for the individual runs. An example of the individual run and test averages is shown in Figure 5 for Tests 7 and 14. The average run and test grinding rates are given in Appendix II. The average grinding rate for a test was used to compared the effects of jet configuration variations.

In a fluidized bed jet mill, the energy required for grinding is supplied to the system by the jet air. Air entrains the particles and increases their kinetic energy. This kinetic energy is transformed into fracture energy when the particle collides with another object with sufficient force to cause breakage or fracturing of the particles. The force required to fracture a particle depends on the structure and physical properties of the particle. The force exerted on the particle during a collision depends on the velocity of the objects involved and the angle of impact. Particles in a jet mill collide with either other entrained particles (jet particles), fluidized bed particles, or stationary objects such as the vessel walls. The jet configuration parameters were varied to determine the optimum conditions for energy transfer during collisions. The changes in grinding rates correlate directly to the changes in energy transfer.

Jet Separation The effect of jet separation on the grinding rate is shown in Table 4. The grinding rate for a separation distance of 6 inches was the highest obtained in Group I. The grinding rate decreases rapidly for separation distances larger than 6 inches. The drop in grinding rates for distances greater than 6 inches indicates that the energy transfer decreases as the jets are separated. As the jets are separated the frequency of collisions between jet particles and bed particles is expected to increase and the frequency of collisions between jet particles entrained by opposite jets is expected to decrease. The decrease in grinding rate suggests that more energy is converted into fracture energy during the collisions of jet-to-jet particles, than jet-to-bed particles.

The grinding rate for a separation distance of 4 inches is slightly lower than that at 6 inches when only Runs 2B and 2C are considered. It is unclear from the data what the affect is on the grinding rate when the separation distance is less than 6 inches. A separation distance of 6 inches was used in Groups II, III and IV since it was the maximum grinding rate obtained.

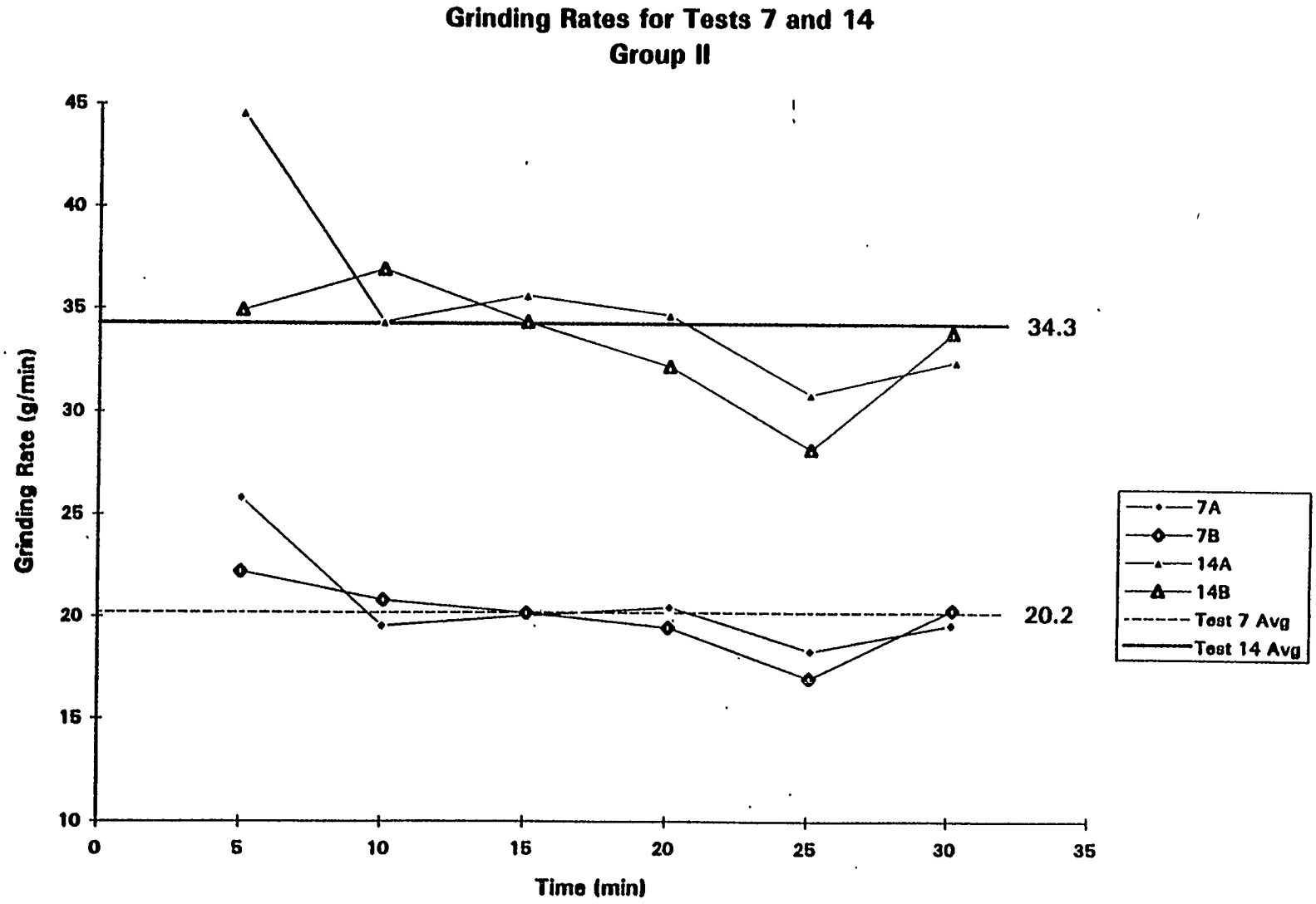


Figure 5. Grinding Rates For Tests 7 and 14

Table 4. Group I - Jet Separation Distance

Test Number	Separation Distance (inches)	Grinding Rate (g/min)
2	4	(27.5)[1] 24.1
3	6	27.7
4	8	20.9
5	10	14.5

1. Average for runs 2B and 2C. A t-Test indicated that the data from Run 2A was not statistically in the same group of data as the Runs 2B and 2C.

Jet Depth Below Bed Surface The effect of jet depth below the surface on the grinding rate is shown in Table 5. A depth of 5 inches gave the best grinding rate for Group II and for all the tests combined. The grinding rate deceased at a rate of approximately 7 g/min with every 3-inch change in depth both above and below the five-inch depth. This consistent change in grinding rate suggests that 5 inches is the optimum depth at the air flowrate used in these tests. The decline in grinding rates for depths greater than 5 inches is most likely caused by the increased particle concentration lower in the bed. At the lower depths, more jet-to-bed particles collisions are expected to occur and the velocity of the jet particles may be reduced slightly. The lower particle velocity reduces the kinetic energy of the particle and therefore reduces the energy available for fracturing. The decline in grinding rates for depths less than 5 inches may also be attributed to particle concentration. Near the surface of the bed the particle concentration decreases as the bubble sizes increase. This decrease in concentration reduces the probability that a particle will collide with another particle, even though it may reach its maximum velocity.

Table 5. Group II - Depth Below Bed Surface

Test Number	Depth (inches)	Grinding Rate (g/min)
3	2	27.7
7	11	20.2
14	5	34.3

Jet Offsets The effects of offsetting the jets on opposite sides and the same side of the jet mill are shown in Tables 6 and 7. Any offset in the jets was shown to significantly decrease the grinding rate. Theoretically the maximum force of impact, thereby the highest grinding rate, is obtained when both particles are moving in opposite directions and collide head-on. Offsetting the jets changed the angle of impact and reduced the interaction between particles entrained by different jets. The probability of an entrained particles colliding with a bed particle rather than jet particle are increased for both types of offset conditions. The force of impact and therefore the grinding rate were reduced by these factors. The grinding rates were slightly higher when the jets were located on opposite sides rather than the same side of the mill. This higher rate indicates that there is a limited amount of interaction between the entrained jet particles.

Table 6. Group III - Offset: On Opposite Sides

Test Number	Offset On Opposite Sides (inches)	Grinding Rate (g/min)
3	0	27.7
8	9	17.3
9	6	19.3
10	3	16.6

Table 7. Group IV - Offset: On Same Side

Test Number	Offset Same Side of the Bed (inches)	Grinding Rate (g/min)
3	Opposite	27.7
11	3	13.2
12	6	11.6
13	9	12.0

Jet Angle The effects of changing the jet angle are shown in Table 8. Not angling the jets resulted in the best grinding rate for Group V tests. The grinding rates for angled jets were similar to those for jets offset on the same side of the mill. The interaction between entrained particles was reduced by angling the jets. As explained previously, the reduction in interactions reduced the grinding rate.

Table 8. Group V - Jet Angle

Test Number	Jet Angle	Grinding Rate (g/min)
3	0°	27.7
16	30°	11.9
17	45°	14.0

V. CONCLUSIONS

The maximum grinding rate of 34.3 g/min was achieved with the jets located 5 inches below the surface of the bed, directly opposed, with a 6-inch jet separation, and a jet angle of 0° from the horizontal. The jet separation distance, offset and angle of this configuration maximized the interaction between particles entrained by different jets. This configuration encouraged head-on particle-particle collisions so that the force of impact was at a maximum value. Increasing the separation distance, offsetting or angling the jets sharply decreased the grinding rate by reducing the interaction between entrained particles. It is unclear from the data what effect reducing the jet separation has on the grinding rate. Locating the jets at a 5-inch depth below the surface optimized the particle concentration around the jets.

VI. RECOMMENDATIONS

The 2-dimensional fluidized bed jet mill was constructed to determine the optimum jet configuration for use in an intermediate scale fluidized bed jet mill. The jet configuration used for Test 14 was the optimum configuration tested. The following design criteria are recommended for the intermediate-scale fluidized bed jet mill:

- Directly opposed jets
- Horizontal jet angle (0°)
- 8-Inch bed diameter
- Variable jet separation distances between 2 and 8 inches
- Variable bed depth above jets between 2 and 8 inches.
- Sufficient freeboard height
- Multiple pairs of jets.

Directly opposed, horizontal jets are recommended to maximize the interaction between entrained jet particles. An eight-inch vessel diameter is recommended to allow sufficient supply of material for entrainment into the jets. Variable bed depths and jet separations are recommended since only one type of material was tested in the 2-dimensional fluidized bed jet mill. The optimum bed depths and jet separation distance may vary with the density, hardness, and structure of the material to be ground. A freeboard height sufficient to minimize the direct carryover of unground solids is also recommended. Multiple jet pairs are recommended to increase the grinding rate in the mill. Increasing the number of jets may affect the optimum separation distance and bed depth.

VII. REFERENCES

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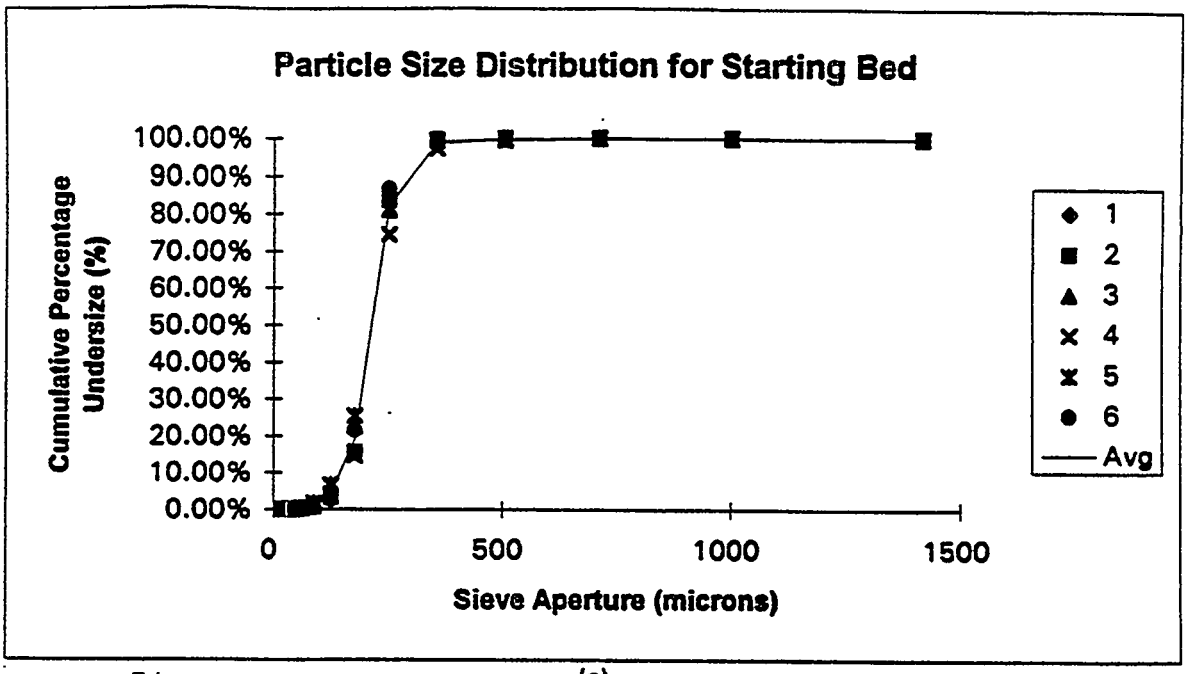
11. L. J. McQuinn, Lab Notebook LN-577, "Particle Size Reduction Experiments", dated November 1993 to April 1994.

APPENDIX I

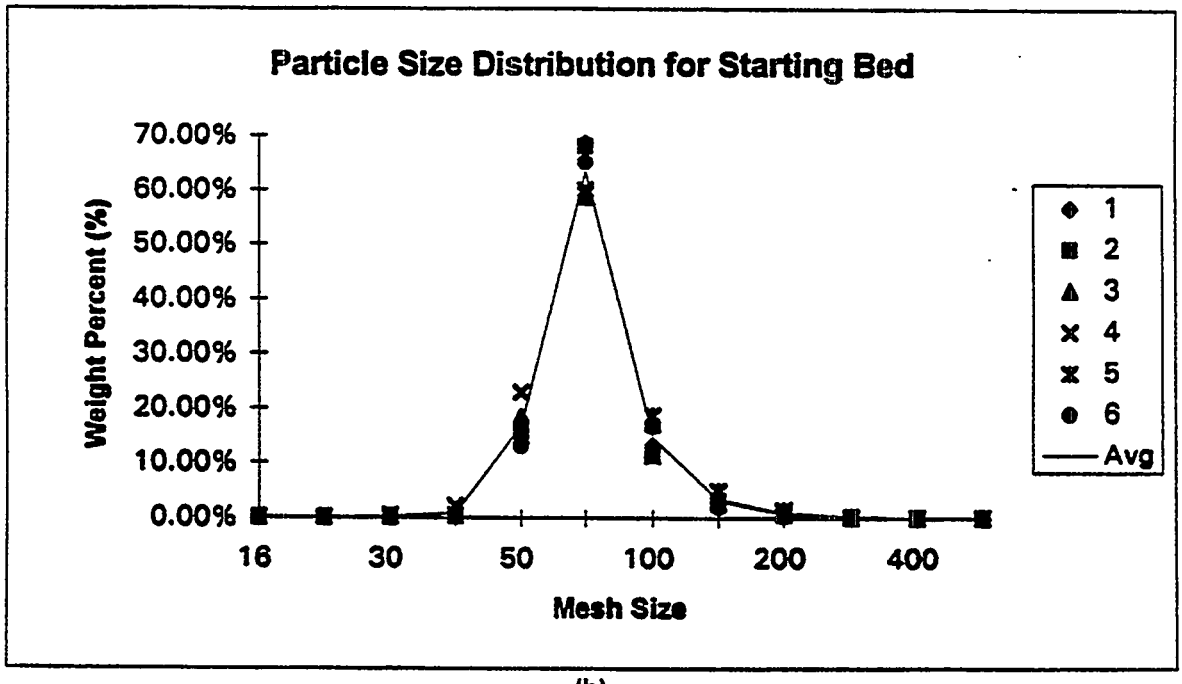
PARTICLE SIZE DISTRIBUTIONS AND CALCULATIONS

Starting Bed

Sample # (g)		1		2		3		4		5		6		Average		
W_{Total}		323.9		321.1		310.7		329.6		309.9		299.5		$\Sigma W_{i,p}$ = 1899.7		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Avg $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.03%	0.1	0.03%	0.1	0.03%	0.1	0.03%	0.1	0.03%	0.1	0.00%	0.0	0.5	0.03%	0.01%
714	30	0.22%	0.7	0.09%	0.3	0.10%	0.3	0.42%	1.4	0.13%	0.4	0.07%	0.2	3.3	0.17%	0.13%
505	40	0.99%	3.2	0.37%	1.2	0.42%	1.3	2.15%	7.1	0.48%	1.5	0.23%	0.7	15.0	0.79%	0.72%
357	50	14.73%	47.7	16.07%	51.6	18.38%	57.1	22.88%	75.4	14.81%	45.9	13.08%	39.1	317.7	16.72%	3.62%
252	70	68.51%	221.9	67.99%	218.3	58.58%	182.0	59.98%	197.7	59.24%	183.6	65.04%	194.8	1201.4	63.24%	4.61%
178	100	13.15%	42.6	11.49%	36.9	17.09%	53.1	11.29%	37.2	18.62%	57.7	16.73%	50.1	278.4	14.65%	3.15%
126	140	1.91%	6.2	3.11%	10.0	4.02%	12.5	2.61%	8.6	4.87%	15.1	3.54%	10.6	63.2	3.33%	1.05%
89	200	0.37%	1.2	0.72%	2.3	1.16%	3.6	0.55%	1.8	1.42%	4.4	1.00%	3.0	16.3	0.86%	0.40%
63	270	0.06%	0.2	0.09%	0.3	0.16%	0.5	0.06%	0.2	0.23%	0.7	0.17%	0.5	2.4	0.13%	0.07%
45	400	0.03%	0.1	0.03%	0.1	0.06%	0.2	0.03%	0.1	0.10%	0.3	0.10%	0.3	1.1	0.06%	0.03%
19	Pan	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.06%	0.2	0.07%	0.2	0.4	0.02%	0.03%
+70 mesh (g)		273.6		271.5		240.8		281.7		231.5		234.8		1537.9	80.96%	
-70 mesh (g)		50.3		49.6		69.9		47.9		78.4		64.7		361.8	19.04%	
MMPD (mm)		0.2593		0.2566		0.2530		0.2710		0.2466		0.2475		0.2557		
HMPD (mm)		0.2437		0.2408		0.2326		0.2607		0.2242		0.2289		0.2307		



(a)



(b)

Figure AI-1. Particle Size Distribution for Starting Bed Material, (a) Cumulative Weight Percent vs Sieve Aperture, (b) Frequency Distribution

Run 2D.1B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{int,g}$		353.6		75		40.6		86.6		21.6		109.6		$\Sigma W_{int.} = 686.0$		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Avg $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.00%	0.0	0.41%	0.31	0.00%	0.0	0.35%	0.3	0.46%	0.1	0.24%	0.3	0.97	0.14%	0.18%
357	50	0.75%	2.6	2.86%	2.1	2.44%	1.0	2.13%	1.8	7.17%	1.5	3.21%	3.6	12.7	1.85%	1.98%
252	70	5.79%	20.5	15.40%	11.5	14.39%	5.8	12.04%	10.3	36.77%	7.9	16.61%	18.1	74.2	10.82%	9.58%
178	100	6.07%	21.5	9.72%	6.5	13.17%	5.3	10.39%	8.9	15.70%	3.4	15.91%	17.4	63.1	9.20%	3.61%
126	140	38.68%	137.5	10.49%	7.9	29.51%	12.0	10.51%	9.0	8.52%	1.8	12.59%	13.8	182.0	26.52%	11.64%
89	200	13.63%	48.9	26.84%	20.1	5.61%	2.3	21.25%	18.2	11.66%	2.5	29.93%	32.8	124.8	18.20%	8.68%
63	270	14.58%	51.6	23.98%	18.0	8.78%	3.6	36.48%	31.2	8.97%	1.9	16.03%	17.6	123.8	18.05%	9.66%
45	400	18.22%	64.4	5.72%	4.3	21.22%	8.6	3.42%	2.9	8.52%	1.8	2.97%	3.3	85.4	12.45%	7.16%
19	Pan	1.87%	6.6	5.59%	4.2	4.88%	2.0	3.42%	2.9	2.24%	0.5	2.61%	2.9	19.1	2.78%	1.37%
+70 mesh (g)		23.1		14.0		6.8		12.4		9.8		21.9		87.9	12.8%	
-70 mesh (g)		330.5		61.0		33.8		73.2		12.0		87.7		598.1	87.2%	
MMPD (mm)		0.1071		0.1224		0.1266		0.1155		0.1795		0.1370		0.1181		
HMPD (mm)		0.0785		0.0766		0.0769		0.0787		0.1107		0.0944		0.0817		

Run 2D.1C

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{in,g}$		23		36		106		108		72		84.0		$\Sigma W_{in,g}$ = 429		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Avg $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.21%	0.2	0.2	0.04%	0.08%
505	40	0.87%	0.2	0.28%	0.1	0.22%	0.2	0.27%	0.3	0.23%	0.2	0.42%	0.4	1.3	0.31%	0.23%
357	50	6.99%	1.6	8.10%	2.9	4.53%	4.8	3.30%	3.6	3.23%	2.3	7.40%	6.2	21.4	4.99%	1.98%
252	70	37.12%	8.5	37.43%	13.5	25.22%	26.7	15.38%	16.6	15.01%	10.8	21.56%	18.1	94.3	21.98%	9.17%
178	100	16.59%	3.8	16.76%	6.0	14.44%	15.3	21.70%	23.4	22.88%	16.5	44.40%	37.3	102.4	23.86%	10.10%
126	140	8.73%	2.0	18.44%	6.6	16.16%	17.1	22.53%	24.3	37.68%	27.3	9.94%	8.3	85.7	19.98%	9.70%
89	200	12.23%	2.8	10.06%	3.6	13.59%	14.4	19.23%	20.8	11.32%	8.1	9.73%	8.2	57.9	13.50%	3.20%
63	270	9.61%	2.2	6.42%	2.3	17.24%	18.3	11.54%	12.5	6.47%	4.7	4.65%	3.9	43.8	10.22%	4.20%
45	400	3.93%	0.9	1.96%	0.7	6.25%	6.6	5.49%	5.9	2.64%	1.9	1.48%	1.2	17.2	4.02%	1.78%
19	Pan	3.93%	0.9	0.56%	0.2	2.37%	2.5	0.55%	0.6	0.46%	0.3	0.21%	0.2	4.7	1.10%	1.36%
+70 mesh (g)		10.3		16.5		31.8		20.5		13.3		24.9		117.2	0.3	
-70 mesh (g)		12.7		19.5		74.2		87.5		59.7		59.1		311.8	0.7	
MMPD (mm)		0.183		0.192		0.153		0.146		0.154		0.188		0.1632		
HMPD (mm)		0.109		0.143		0.099		0.108		0.124		0.151		0.1169		

Run 2D.2A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{in}		138		102		108		149		120		163.0		$\Sigma Wt_{in.} = 770$		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	W_{mesh}	$Wt\%_{mesh}$	W_{mesh}	$Wt\%_{mesh}$	W_{mesh}	$Wt\%_{mesh}$	W_{mesh}	$Wt\%_{mesh}$	W_{mesh}	$Wt\%_{mesh}$	W_{mesh}	ΣW_{mesh}	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.42%	0.6	0.20%	0.2	0.00%	0.0	0.12%	0.2	0.00%	0.0	0.00%	0.0	1.0	0.12%	0.16%
357	50	8.42%	11.6	6.15%	6.3	4.94%	5.3	4.39%	6.5	2.97%	3.6	1.98%	3.0	36.4	4.72%	2.10%
252	70	44.84%	61.9	30.95%	31.6	27.26%	29.4	21.23%	31.6	16.35%	19.6	12.10%	18.5	192.7	25.02%	10.71%
178	100	20.42%	28.2	18.25%	18.6	17.04%	18.4	16.01%	23.9	21.22%	25.5	18.02%	27.6	142.1	18.45%	1.81%
126	140	10.53%	14.5	15.67%	16.0	21.12%	22.8	16.73%	24.9	33.78%	40.5	16.56%	23.8	142.6	18.52%	7.34%
89	200	6.65%	9.6	13.89%	14.2	11.07%	12.0	11.86%	17.7	10.14%	12.2	16.56%	23.8	89.4	11.60%	2.74%
63	270	3.58%	4.9	8.93%	9.1	9.71%	10.5	24.91%	37.1	5.68%	6.8	14.81%	22.7	91.1	11.83%	7.04%
45	400	2.32%	3.2	3.17%	3.2	6.88%	7.5	2.85%	4.2	6.36%	7.6	13.09%	20.0	45.9	5.96%	3.71%
19	Pan	2.53%	3.5	2.78%	2.8	1.87%	2.0	1.90%	2.8	3.51%	4.2	8.89%	13.6	29.0	3.76%	2.44%
+70 mesh		74.1		38.0		34.8		38.4		23.2		21.5		230.0	0.3	
-70 mesh		63.9		64.0		73.2		110.6		96.8		131.5		540.0	0.7	
MMPD (mm)		0.20476		0.1731		0.1627		0.1473		0.1483		0.1200		0.1679		
HMPD (mm)		0.1369		0.1134		0.1090		0.0989		0.1010		0.0891		0.0988		

Run 2D.2B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{tot}		388		123		125		125		218		167.0		ΣW_{int}		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	ΣW_{int}	Avg $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.23%	0.3	0.13%	0.3	0.00%	0.0	0.6	0.05%	0.09%
505	40	0.78%	3.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.13%	0.3	0.15%	0.2	3.5	0.31%	0.28%
357	50	10.89%	42.3	2.58%	3.2	0.62%	0.8	0.92%	1.1	0.64%	1.4	3.23%	5.4	54.2	4.73%	3.61%
252	70	43.32%	168.1	11.40%	14.0	6.20%	7.7	9.63%	12.0	3.85%	8.4	9.53%	15.9	226.2	19.74%	13.35%
178	100	16.73%	64.9	24.62%	30.2	14.26%	17.8	15.37%	19.2	9.87%	21.5	35.92%	60.0	213.6	18.64%	8.56%
126	140	7.26%	28.2	24.73%	30.4	15.70%	19.6	26.38%	33.0	18.97%	41.4	17.74%	29.6	182.2	15.90%	6.27%
89	200	7.65%	29.7	18.08%	22.2	19.42%	24.3	14.22%	17.8	24.74%	53.9	14.37%	24.0	171.9	15.00%	5.27%
63	270	4.41%	17.1	8.92%	10.8	17.36%	21.7	15.60%	19.5	21.28%	46.4	13.49%	22.5	138.1	12.05%	6.54%
45	400	4.80%	18.6	9.25%	11.4	20.45%	25.6	16.28%	20.4	17.82%	38.9	5.13%	8.6	123.3	10.76%	6.19%
19	Pan	4.15%	16.1	0.65%	0.8	5.99%	7.5	1.39%	1.7	2.56%	5.6	0.44%	0.7	32.4	2.83%	1.99%
+70 mesh		213.4		17.2		9.6		13.5		10.3		21.5		284.5	0.2	
-70 mesh		174.6		105.8		116.5		111.5		207.7		145.5		861.5	0.8	
MMPD (mm)		0.2035		0.1387		0.1016		0.1188		0.0890		0.1463		0.1481		
HMPD (mm)		0.1185		0.1032		0.0869		0.0849		0.0730		0.1108		0.0934		

Run 2D. 2C

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{tot}		220		160		146		136		135.5		126.0		$\Sigma Wt_{tot.}$ = 923.5		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.11%	0.2	0.12%	0.2	0.12%	0.2	0.13%	0.2	0.00%	0.0	0.00%	0.0	0.8	0.09%	0.06%
357	50	4.44%	9.8	2.24%	3.6	3.86%	5.6	2.32%	3.2	1.29%	1.8	1.50%	1.9	25.8	2.79%	1.16%
252	70	15.32%	33.7	13.82%	22.1	13.06%	19.1	11.08%	15.1	7.76%	10.5	6.76%	8.5	109.0	11.80%	3.13%
178	100	26.64%	58.6	15.07%	24.1	20.65%	30.1	15.34%	20.9	13.40%	18.2	9.39%	11.8	163.7	17.72%	6.53%
126	140	19.20%	42.2	23.41%	37.5	30.97%	45.2	25.13%	34.2	27.03%	36.6	34.04%	42.9	238.6	25.84%	4.86%
89	200	13.65%	30.0	23.66%	37.9	13.18%	19.2	30.67%	41.7	23.74%	32.2	30.79%	38.8	199.8	21.64%	7.11%
63	270	15.09%	33.2	12.95%	20.7	12.19%	17.8	8.25%	11.2	17.16%	23.2	7.88%	9.9	116.1	12.57%	3.36%
45	400	3.44%	7.6	5.98%	9.6	4.60%	6.7	4.90%	6.7	8.23%	11.1	7.63%	9.6	51.3	5.55%	1.69%
19	Pan	2.11%	4.6	2.74%	4.4	1.37%	2.0	2.19%	3.0	1.41%	1.9	2.00%	2.5	18.4	2.00%	0.47%
+70 mesh		43.7		25.9		24.9		18.4		12.3		10.4		135.6	14.68%	
-70 mesh		176.3		134.1		121.1		117.6		123.2		115.6		787.9	85.32%	
MMPD		0.1502		0.1322		0.1448		0.1309		0.1180		0.1182		0.1343		
HMPD		0.1046		0.0926		0.1063		0.0985		0.0893		0.0909		0.0970		

Run 2D.3A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{init}		251		161		162		144		176.5		160		$\Sigma W_{i,s}$ = 1044.5		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.11%	0.3	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.3	0.03%	0.04%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.22%	0.6	0.24%	0.4	0.00%	0.0	0.12%	0.2	0.24%	0.4	0.14%	0.2	1.7	0.17%	0.09%
357	60	3.26%	8.2	3.77%	5.7	1.63%	2.6	2.17%	3.1	2.74%	4.8	2.86%	4.6	29.0	2.78%	0.68%
252	70	19.44%	48.8	19.32%	29.2	10.75%	17.4	12.69%	18.6	12.02%	21.2	14.97%	23.9	169.1	16.23%	3.41%
178	100	14.83%	37.2	17.50%	26.4	15.65%	25.3	25.30%	36.4	14.64%	25.8	20.14%	32.2	183.5	17.57%	3.76%
126	140	18.88%	47.4	26.85%	40.6	22.04%	35.7	17.35%	25.0	16.90%	29.8	39.05%	62.5	240.9	23.07%	7.72%
89	200	19.44%	48.8	15.07%	22.8	27.89%	45.2	20.36%	29.3	31.07%	54.8	10.61%	17.0	217.9	20.86%	7.01%
63	270	13.71%	34.4	12.52%	18.9	12.93%	20.9	16.02%	23.1	14.88%	26.3	6.26%	10.0	133.6	12.79%	3.12%
45	400	7.87%	19.7	3.69%	5.9	6.39%	10.4	4.68%	6.6	5.71%	10.1	4.22%	6.7	59.4	5.69%	1.39%
19	Pan	2.25%	5.6	0.85%	1.3	2.72%	4.4	1.20%	1.7	1.79%	3.2	1.77%	2.8	19.0	1.82%	0.62%
+70 mesh		57.8		35.2		20.1		21.9		26.5		28.7		190.2	0.2	
-70 mesh		193.2		115.8		141.9		122.1		150.0		131.3		854.3	0.8	
MMPD	(mm)	0.1434		0.1515		0.1249		0.1382		0.1288		0.1493		0.1394		
HMPD (mm)		0.0953		0.1113		0.0888		0.1015		0.0927		0.1116		0.0990		

Run 2D.3B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
W_{feed}		203		180		165		142		131		137		$\Sigma Wt_{i,gi}$ = 958		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.00%	0.0	0.12%	0.2	0.00%	0.0	0.12%	0.2	0.00%	0.0	0.23%	0.3	0.7	0.07%	0.09%
357	60	3.10%	6.3	2.09%	3.8	2.39%	3.9	1.73%	2.5	2.04%	2.7	2.90%	4.0	23.1	2.41%	0.48%
252	70	13.27%	26.9	12.66%	22.8	13.07%	21.6	12.24%	17.4	13.16%	17.2	14.63%	20.0	126.0	13.16%	0.74%
178	100	21.79%	44.2	12.54%	22.6	17.95%	29.6	15.59%	22.1	25.98%	34.0	14.62%	19.9	172.5	18.00%	4.67%
126	140	27.65%	56.1	22.07%	39.7	20.11%	33.2	18.69%	26.4	16.78%	22.0	19.16%	26.3	203.7	21.26%	3.46%
89	200	14.60%	29.6	28.80%	51.8	18.75%	30.9	26.98%	38.9	23.13%	30.3	22.30%	30.6	210.2	21.94%	4.63%
63	270	12.83%	26.0	14.05%	25.3	18.30%	30.2	16.63%	23.6	11.45%	15.0	18.12%	24.8	146.0	15.13%	2.62%
45	400	3.98%	8.1	5.11%	9.2	6.25%	10.3	5.89%	8.4	5.78%	7.6	5.69%	7.8	61.3	5.36%	0.74%
19	Pan	2.77%	5.6	2.56%	4.6	3.19%	5.3	3.23%	4.6	1.70%	2.2	2.44%	3.3	26.6	2.67%	0.51%
+70 mesh		33.2		26.8		25.5		20.0		19.9		24.3		149.7	0.2	
-70 mesh		169.8		153.2		139.5		122.0		111.1		112.7		808.3	0.8	
MMPD (mm)		0.1415		0.1274		0.1304		0.1258		0.1385		0.1327		0.1329		
HMPD (mm)		0.0985		0.0912		0.0888		0.0873		0.1003		0.0916		0.0930		

Run 2D.4A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{feed}		134		123		119		109		119		130.0		$\Sigma W_{i,p}$ = 734		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00%	0.00%
1002	20	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00%	0.00%
714	30	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.0	0.00%	0.00%
505	40	0.00	0.2	0.00	0.0	0.00	0.3	0.00	0.0	0.00	0.3	0.00	0.0	0.7	0.09%	0.10%
357	50	0.01	1.7	0.02	2.7	0.02	2.1	0.03	2.8	0.02	2.1	0.02	3.2	14.6	1.99%	0.46%
252	70	0.08	11.4	0.12	14.4	0.11	12.8	0.11	12.0	0.10	11.5	0.11	14.7	76.7	10.46%	1.11%
178	100	0.12	16.6	0.26	31.8	0.12	14.0	0.16	17.0	0.11	13.0	0.14	18.2	110.6	15.07%	6.08%
126	140	0.18	24.2	0.18	21.6	0.21	24.6	0.27	29.7	0.20	24.1	0.32	41.9	166.0	22.62%	5.31%
89	200	0.33	44.6	0.20	25.0	0.30	35.6	0.16	17.1	0.32	38.1	0.16	20.9	181.4	24.72%	7.43%
63	270	0.19	24.2	0.11	13.9	0.11	12.5	0.21	23.4	0.17	20.1	0.13	16.6	110.7	15.08%	3.94%
45	400	0.06	7.6	0.07	9.0	0.09	11.0	0.05	4.9	0.06	7.0	0.09	11.7	51.4	7.00%	1.76%
19	Pan	0.03	3.6	0.04	4.6	0.05	6.0	0.02	2.1	0.02	2.9	0.02	2.7	21.8	2.97%	1.09%
+70 mesh (g)		13.2		17.1		15.2		14.8		13.8		17.9		92.1	0.1	
-70 mesh (g)		120.8		105.9		103.8		94.2		105.2		112.1		641.9	0.9	
MMPD (mm)		0.1154		0.1347		0.12		0.1289		0.1189		0.1297		0.1245		
HMPD (mm)		0.0849		0.0806		0.0798		0.0931		0.0869		0.0926		0.0877		

Run 2D.4B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{feed}		139		108		129		121		105		104.0		$\Sigma W_{i,p}$ = 703		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.11%	0.2	0.00%	0.0	0.13%	0.2	0.00%	0.0	0.13%	0.1	0.11%	0.1	0.6	0.08%	0.06%
357	50	2.95%	4.1	3.25%	3.4	1.67%	2.2	1.72%	2.1	1.53%	1.6	2.40%	2.5	15.9	2.25%	0.66%
252	70	13.33%	18.4	11.91%	12.6	9.62%	12.4	10.32%	12.5	9.08%	9.5	9.83%	10.2	75.6	10.76%	1.48%
178	100	16.50%	22.9	17.09%	18.1	13.65%	17.9	9.92%	12.0	11.35%	11.9	12.91%	13.4	96.1	13.67%	2.67%
126	140	18.47%	25.5	20.46%	21.7	17.56%	22.7	28.70%	34.7	12.50%	13.1	25.94%	27.0	144.7	20.68%	6.38%
89	200	24.81%	34.2	25.99%	27.6	33.97%	43.8	32.01%	38.7	39.80%	41.8	27.31%	28.4	214.5	30.52%	6.22%
63	270	14.21%	19.6	13.60%	14.4	10.51%	13.6	9.92%	12.0	15.56%	16.3	12.91%	13.4	89.4	12.71%	1.99%
45	400	7.97%	10.9	6.66%	7.3	11.03%	14.2	6.88%	8.3	8.80%	9.2	7.69%	8.2	68.1	8.27%	1.42%
19	Pan	1.75%	2.4	0.84%	0.9	1.67%	2.2	0.53%	0.6	1.28%	1.3	0.69%	0.7	8.1	1.16%	0.47%
+70 mesh (g)		22.6		16.1		14.7		14.6		11.3		12.8		92.1	0.1	
-70 mesh (g)		116.4		89.9		114.3		106.4		93.8		91.2		610.9	0.9	
MMPD (mm)		0.1322		0.1328		0.1197		0.1239		0.1143		0.1257		0.1249		
HMPD (mm)		0.0933		0.0881		0.0876		0.0974		0.0862		0.0955		0.0927		

Run 2D.5A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{total}		76		89		76		80		73		87		$\Sigma W_{i,n}$ = 481		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
605	40	0.13%	0.1	0.11%	0.1	0.00%	0.0	0.13%	0.1	0.00%	0.0	0.12%	0.1	0.4	0.08%	0.06%
357	60	2.39%	1.8	0.90%	0.8	1.83%	1.4	0.76%	0.6	1.10%	0.8	1.15%	1.0	6.4	1.33%	0.57%
252	70	9.56%	7.3	4.39%	3.9	7.72%	5.9	2.90%	2.3	6.31%	4.6	5.29%	4.6	28.6	5.94%	2.18%
178	100	13.68%	10.4	6.75%	6.0	31.81%	24.2	9.97%	8.0	5.21%	3.8	8.17%	7.1	59.5	12.36%	8.99%
126	140	25.37%	19.3	16.99%	15.1	20.68%	15.7	30.81%	24.6	28.94%	21.1	12.08%	10.5	106.4	22.12%	6.60%
89	200	22.97%	17.5	42.93%	37.9	19.50%	14.9	29.29%	23.4	29.22%	21.3	48.79%	42.4	157.4	32.73%	10.39%
63	270	16.97%	12.9	18.45%	16.4	10.34%	7.9	14.52%	11.6	18.38%	13.4	14.04%	12.2	74.3	15.46%	2.84%
45	400	7.84%	6.0	8.32%	7.4	6.89%	4.5	8.71%	7.0	7.13%	5.2	8.06%	7.0	37.0	7.70%	0.93%
19	Pan	1.20%	0.9	1.46%	1.3	2.23%	1.7	2.90%	2.3	3.70%	2.7	2.30%	2.0	10.9	2.27%	0.64%
+70 mesh (g)		9.2		4.8		7.3		3.0		5.4		5.7		35.4	0.1	
-70 mesh (g)		66.8		84.2		68.7		77.0		67.6		81.3		445.6	0.9	
MMPD (mm)		0.1244		0.1018		0.1358		0.1069		0.1071		0.1041		0.1128		
HMPD(mm)		0.0921		0.0815		0.099		0.0819		0.0793		0.0808		0.0850		

Run 2D.5B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{in,p}$		83		79		78		72		74		72.0		$\Sigma W_{in,} = 458$		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.12%	0.1	0.00%	0.0	0.12%	0.1	0.00%	0.0	0.13%	0.1	0.14%	0.1	0.4	0.09%	0.06%
357	50	1.10%	0.9	1.02%	0.8	1.00%	0.8	0.42%	0.3	0.81%	0.6	0.55%	0.4	3.8	0.83%	0.25%
252	70	6.82%	5.7	8.04%	6.3	5.99%	4.7	4.87%	3.5	4.45%	3.3	4.16%	3.0	26.5	5.78%	1.38%
178	100	6.46%	5.4	6.25%	4.9	7.98%	6.2	5.70%	4.1	7.95%	5.9	4.16%	3.0	29.5	6.44%	1.32%
126	140	10.84%	9.0	18.49%	14.6	14.46%	11.3	29.90%	21.5	10.65%	7.9	33.93%	24.4	88.7	19.37%	9.09%
89	200	52.74%	43.8	36.99%	29.2	36.16%	28.2	29.21%	21.0	52.29%	38.7	30.75%	22.1	183.1	39.97%	9.48%
63	270	13.03%	10.8	12.76%	10.1	19.08%	14.9	17.60%	12.8	11.99%	8.9	15.37%	11.1	68.5	14.96%	2.66%
45	400	7.19%	6.0	12.12%	9.6	11.85%	9.2	10.29%	7.4	10.11%	7.5	9.14%	6.6	46.2	10.10%	1.66%
19	Pan	1.71%	1.4	4.34%	3.4	3.37%	2.6	1.81%	1.3	1.62%	1.2	1.80%	1.3	11.3	2.46%	1.04%
+70 mesh (g)		6.7		7.2		5.5		3.8		4.0		3.5		30.7	0.1	
-70 mesh		76.3		71.8		72.5		68.2		70.0		68.5		427.3	0.9	
MMPD (mm)		0.1056		0.1056		0.1019		0.1038		0.1013		0.1048		0.1038		
HMPD (mm)		0.0932		0.0751		0.0749		0.0817		0.0808		0.0834		0.0798		

Run 2D.7A

Grinding Interval (g)		1		2		3		4		5		6		Average		
W_{feed}		164		116		121		122		114		117		$\Sigma W_{i,n}$ = 764		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.12%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.21%	0.2	0.4	0.05%	0.08%
505	40	0.30%	0.5	0.24%	0.3	0.11%	0.1	0.20%	0.2	0.33%	0.4	0.21%	0.2	1.8	0.23%	0.07%
357	50	3.38%	5.6	2.06%	2.4	2.23%	2.7	2.40%	2.9	2.99%	3.4	2.18%	2.6	19.5	2.59%	0.48%
252	70	17.66%	28.9	13.35%	15.5	14.89%	18.0	13.63%	16.5	16.39%	18.7	13.71%	16.0	113.7	15.08%	1.61%
178	100	16.55%	27.1	14.20%	16.5	13.61%	16.3	10.92%	13.3	21.37%	24.4	16.72%	19.6	117.2	15.55%	3.26%
126	140	20.54%	33.7	15.05%	17.5	32.23%	39.0	18.24%	22.2	13.18%	15.0	20.87%	24.4	161.8	20.14%	6.12%
89	200	16.85%	26.0	25.36%	29.4	15.00%	18.2	30.86%	37.7	19.71%	22.5	28.48%	31.0	164.7	21.84%	6.80%
63	270	17.25%	28.3	21.48%	24.9	9.36%	11.3	13.53%	16.5	13.84%	15.8	12.88%	15.1	111.9	14.84%	3.79%
45	400	5.38%	8.8	5.22%	6.1	8.09%	9.8	8.42%	10.3	10.74%	12.2	5.61%	6.6	53.7	7.13%	2.02%
19	Pan	3.09%	5.1	2.91%	3.4	4.57%	5.5	1.90%	2.3	1.44%	1.6	1.14%	1.3	19.3	2.56%	1.17%
+70 mesh (g)		35.0		19.3		20.9		19.7		22.6		19.1		136.4	0.2	
-70 mesh (g)		129.0		97.7		100.1		102.3		91.5		97.9		618.6	0.8	
MMPD (mm)		0.1414		0.1263		0.1345		0.1262		0.1397		0.1353		0.1343		
HMPD (mm)		0.0934		0.0867		0.0881		0.0898		0.0948		0.0993		0.0919		

Run 2D.7B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{in,g}$		130		119		121		120		100		120		$\Sigma W_{in,g}$ = 710		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.11%	0.1	0.00%	0.0	0.11%	0.1	0.00%	0.0	0.00%	0.0	0.12%	0.1	0.4	0.06%	0.06%
505	40	0.22%	0.3	0.22%	0.3	0.22%	0.3	0.32%	0.4	0.21%	0.2	0.24%	0.3	1.7	0.24%	0.04%
357	60	2.20%	2.9	1.78%	2.1	2.88%	3.5	3.49%	4.2	2.24%	2.2	2.42%	2.9	17.8	2.50%	0.55%
252	70	12.09%	15.7	10.56%	12.6	13.44%	16.3	15.13%	18.2	12.71%	12.7	12.44%	14.9	90.3	12.72%	1.38%
178	100	19.46%	24.0	20.67%	24.6	14.21%	17.2	26.67%	32.0	14.85%	14.9	28.50%	34.2	146.8	20.68%	5.44%
126	140	25.16%	32.7	25.78%	30.7	16.08%	19.5	15.24%	18.3	14.32%	14.3	13.65%	16.4	131.8	18.57%	5.08%
89	200	16.81%	21.9	13.11%	15.6	24.78%	30.0	15.56%	18.7	27.78%	27.8	16.79%	20.1	134.0	18.88%	6.27%
63	270	13.30%	17.3	15.56%	18.5	17.07%	20.7	11.11%	13.3	16.24%	16.2	19.20%	23.0	109.1	15.36%	2.61%
45	400	8.35%	10.9	8.78%	10.4	9.03%	10.9	11.43%	13.7	8.33%	8.3	5.80%	7.0	61.2	8.62%	1.64%
19	Pan	3.30%	4.3	3.56%	4.2	2.20%	2.7	1.06%	1.3	3.31%	3.3	0.85%	1.0	16.8	2.36%	1.10%
+70 mesh		19.0		14.9		20.1		22.7		15.2		18.3		110.2	0.2	
-70 mesh		111.0		104.1		100.9		97.3		84.8		101.7		599.8	0.8	
MMPD (mm)		0.1325		0.1294		0.1288		0.1451		0.1249		0.1398		0.1338		
HMPD (mm)		0.0895		0.0874		0.0881		0.0998		0.0845		0.1008		0.0914		

Run 2D.8A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{init}		137		101		103		101		104		89.0		$\Sigma W_{i,n}$ = 635		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1003	[illegible]	0.00%	0.0	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.02%	0.05%
714	30	0.13%	0.2	0.13%	0.1	0.13%	0.1	0.00%	0.0	0.30%	0.3	0.14%	0.1	0.8	0.14%	0.09%
505	40	0.13%	0.2	0.26%	0.3	0.00%	0.0	0.14%	0.1	0.15%	0.2	0.14%	0.1	0.9	0.14%	0.08%
357	50	3.71%	5.1	2.08%	2.1	2.19%	2.3	1.83%	1.8	1.94%	2.0	1.44%	1.3	14.6	2.30%	0.72%
252	70	19.31%	26.5	12.21%	12.3	11.46%	11.8	10.28%	10.4	9.42%	9.8	7.93%	7.1	77.8	12.25%	3.64%
178	100	17.01%	23.3	15.45%	15.6	10.66%	10.9	8.59%	8.7	15.25%	15.9	10.23%	9.1	83.4	13.14%	3.16%
126	140	21.89%	30.1	12.88%	13.0	22.66%	23.3	13.24%	13.4	25.71%	26.7	24.21%	21.6	128.1	20.18%	5.13%
89	200	17.77%	24.4	33.51%	33.8	23.62%	24.5	34.51%	34.9	25.41%	26.4	29.25%	26.0	170.0	26.78%	5.78%
63	270	12.28%	16.8	14.16%	14.3	14.93%	15.4	16.48%	16.6	12.56%	13.1	13.83%	12.3	88.5	13.94%	1.42%
45	400	7.03%	9.6	7.27%	7.3	11.81%	12.2	12.64%	12.7	8.22%	8.6	11.10%	9.9	60.2	9.48%	2.22%
19	Pan	0.64%	0.9	1.95%	2.0	2.45%	2.5	2.39%	2.4	1.05%	1.1	1.73%	1.5	10.4	1.64%	0.67%
+70 mesh		31.9		15.0		14.2		12.4		12.3		8.6		94.3	0.1	
-70 mesh		105.1		86.0		88.8		89.6		91.7		80.4		540.7	0.9	
MMPD (mm)		0.1483		0.1278		0.1213		0.1123		0.1275		0.1157		0.1270		
HMPD (mm)		0.1081		0.0901		0.0843		0.0788		0.0947		0.0854		0.0902		

Run 2D.8B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{feed}		117		104		95		92		107		98		$\Sigma W_{i,p}$ = 613		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.14%	0.1	0.00%	0.0	0.14%	0.1	0.00%	0.0	0.15%	0.1	0.4	0.07%	0.07%
505	40	0.26%	0.3	0.27%	0.3	0.25%	0.2	0.14%	0.1	0.15%	0.2	0.30%	0.3	1.4	0.23%	0.08%
357	50	3.31%	3.9	3.42%	3.6	4.18%	4.0	1.78%	1.6	1.18%	1.3	1.78%	1.7	16.0	2.62%	1.08%
252	70	12.17%	14.2	15.48%	16.1	20.76%	19.7	8.78%	8.1	9.32%	10.0	7.25%	7.1	75.2	12.27%	4.63%
178	100	23.41%	27.4	13.97%	14.5	26.84%	25.5	13.99%	12.9	6.51%	7.0	9.47%	9.3	96.6	15.75%	7.22%
126	140	23.84%	28.0	15.07%	15.7	12.03%	11.4	24.97%	23.0	21.60%	23.1	19.53%	19.1	120.3	19.63%	4.65%
89	200	20.90%	24.5	27.07%	28.0	21.52%	20.4	26.47%	24.4	37.87%	40.5	36.69%	36.0	174.5	28.47%	6.66%
63	270	7.01%	8.2	12.05%	12.5	8.35%	7.9	13.58%	12.5	10.80%	11.6	11.98%	11.7	64.5	10.52%	2.27%
45	400	8.07%	9.4	10.27%	10.7	5.19%	4.9	8.92%	8.2	10.36%	11.1	11.09%	10.9	55.2	9.01%	1.97%
19	Pan	0.93%	1.1	1.64%	1.7	0.69%	0.6	1.23%	1.1	2.22%	2.4	1.78%	1.7	8.9	1.45%	0.48%
+70 mesh (g)		19.4		20.1		23.9		10.0		11.4		9.3		93.1	0.2	
-70 mesh (g)		99.6		83.9		71.1		82.0		95.6		88.7		519.9	0.8	
MMPD (mm)		0.1425		0.1346		0.1583		0.1229		0.1128		0.1141		0.1310		
HMPD (mm)		0.1049		0.092		0.114		0.0915		0.0839		0.0844		0.0940		

Run 2D.9A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
W_{feed}		94		110		84		98		96		113		$\Sigma W_{i,g}$ = 595		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.02%	0.05%
505	40	0.25%	0.2	0.14%	0.2	0.12%	0.1	0.00%	0.0	0.13%	0.1	0.13%	0.2	0.8	0.13%	0.07%
357	50	2.28%	2.2	3.16%	3.5	1.54%	1.3	2.09%	2.0	1.39%	1.3	2.43%	2.7	13.1	2.19%	0.59%
252	70	9.03%	8.5	14.42%	15.9	9.89%	7.5	9.41%	9.2	6.59%	6.3	6.34%	7.2	54.6	9.17%	2.66%
178	100	11.70%	11.0	13.60%	15.0	8.18%	6.	8.69%	8.7	6.21%	6.0	6.34%	7.2	54.7	9.19%	2.70%
126	140	32.32%	30.4	32.01%	35.2	17.89%	15.0	30.65%	30.2	30.54%	29.3	28.61%	32.3	172.5	28.99%	4.98%
89	200	21.37%	20.1	20.60%	22.7	38.66%	32.6	31.11%	30.5	31.94%	30.7	34.56%	39.0	175.6	29.51%	6.66%
63	270	11.86%	11.2	9.34%	10.3	14.57%	12.2	7.84%	7.7	14.70%	14.1	10.53%	11.9	67.5	11.34%	2.66%
45	400	9.41%	8.8	5.63%	6.2	7.82%	6.6	7.45%	7.3	7.73%	7.4	8.50%	9.6	45.9	7.72%	1.16%
19	Pan	1.53%	1.4	1.10%	1.2	2.13%	1.9	2.35%	2.3	0.76%	0.7	2.56%	2.9	10.4	1.74%	0.66%
+70 mesh (g)		11.0		19.5		8.9		11.3		7.8		10.1		68.6	0.1	
-70 mesh (g)		83.0		90.5		75.1		86.7		88.2		102.9		526.5	0.9	
MMPD (mm)		0.1258		0.1389		0.1133		0.1223		0.1131		0.1144		0.1218		
HMPD (mm)		0.0922		0.1042		0.0846		0.0908		0.09		0.0852		0.0910		

Run 2D.9B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{i,m}$		102		98		129		109		122		124		$\Sigma W_{i,m}$ = 682		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.14%	0.1	0.16%	0.1	0.14%	0.2	0.26%	0.3	0.00%	0.0	0.13%	0.2	0.9	0.13%	0.07%
357	50	2.11%	2.1	1.08%	1.0	1.40%	1.8	1.02%	1.1	0.80%	1.0	1.28%	1.6	8.6	1.27%	0.42%
252	70	7.58%	7.7	6.33%	6.1	5.73%	7.4	5.61%	6.1	4.26%	5.2	5.00%	6.2	38.7	5.68%	1.04%
178	100	11.80%	12.0	8.14%	7.8	12.87%	16.6	15.82%	17.2	8.39%	10.2	9.23%	11.4	75.4	11.05%	2.75%
126	140	32.44%	33.1	15.08%	14.5	28.25%	36.4	22.32%	24.3	35.42%	43.2	23.72%	29.4	181.0	26.54%	6.75%
89	200	26.97%	27.5	43.89%	42.1	29.37%	37.9	30.23%	33.0	34.89%	42.6	38.59%	47.9	230.9	33.86%	5.84%
63	270	11.52%	11.7	14.63%	14.0	11.19%	14.4	15.43%	16.8	9.05%	11.0	13.21%	16.4	84.5	12.39%	2.17%
45	400	6.46%	6.6	8.90%	8.5	9.23%	11.9	7.91%	8.6	6.13%	7.5	7.56%	9.4	52.5	7.70%	1.14%
19	Pan	0.99%	1.0	1.81%	1.7	1.82%	2.3	1.40%	1.5	1.07%	1.3	1.28%	1.6	9.5	1.39%	0.33%
+70 mesh (g)		10.0		7.2		9.4		7.5		6.2		7.9		48.3	0.1	
-70 mesh (g)		92.0		88.8		119.6		101.5		115.8		116.1		633.7	0.9	
MMPD (mm)		0.1236		0.1066		0.1163		0.1159		0.1129		0.1105		0.1143		
HMPD (mm)		0.096		0.0825		0.0883		0.0888		0.093		0.0875		0.0892		

Run 2D.10B

Grinding Interval (gi)		1		2		3		4		6		8		Average		
W_{in-a}		104		102		92		94		100		93		ΣW_{in} = 685		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.14%	0.1	0.14%	0.1	0.13%	0.1	0.12%	0.1	0.5	0.09%	0.08%
505	40	0.25%	0.3	0.25%	0.3	0.14%	0.1	0.28%	0.3	0.13%	0.1	0.12%	0.1	1.2	0.20%	0.07%
357	50	2.16%	2.2	2.42%	2.6	1.42%	1.3	1.99%	1.9	1.44%	1.4	1.49%	1.4	10.7	1.83%	0.39%
252	70	14.74%	15.3	12.08%	12.3	7.67%	7.1	17.81%	16.7	8.24%	8.2	9.08%	8.4	68.1	11.65%	3.69%
178	100	11.05%	11.5	14.25%	14.5	14.49%	13.3	15.67%	14.7	10.20%	10.2	11.44%	10.6	74.9	12.81%	2.03%
126	140	29.73%	30.9	22.90%	23.4	18.32%	16.9	16.67%	15.7	13.20%	13.2	13.08%	12.1	112.2	19.17%	6.85%
89	200	16.90%	17.6	20.99%	21.4	36.08%	33.2	23.08%	21.7	36.34%	36.3	28.11%	26.1	156.4	26.73%	7.35%
63	270	13.09%	13.6	13.99%	14.3	12.93%	11.9	17.66%	16.6	16.08%	16.1	24.26%	22.6	95.0	16.24%	3.92%
45	400	10.29%	10.7	11.45%	11.7	7.67%	7.1	6.13%	5.8	11.63%	11.6	9.58%	8.9	65.7	9.53%	1.99%
19	Pan	1.78%	1.9	1.65%	1.7	1.14%	1.0	0.57%	0.5	2.61%	2.6	2.74%	2.6	10.3	1.76%	0.76%
+70 mesh (g)		17.8		16.1		8.6		19.0		9.9		10.1		80.5	0.1	
-70 mesh (g)		86.2		86.9		83.4		75.0		90.1		82.9		504.5	0.9	
MMPD (mm)		0.1315		0.1276		0.1189		0.1379		0.1105		0.1117		0.1231		
HMPD (mm)		0.0923		0.0896		0.0907		0.0997		0.0794		0.079		0.0879		

Run 2D.10C

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{in,n}$		115		100		91		100		91		80		ΣW_{in} = 577		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.14%	0.1	0.17%	0.1	0.3	0.05%	0.07%
505	40	0.26%	0.3	0.14%	0.1	0.00%	0.0	0.27%	0.3	0.14%	0.1	0.17%	0.1	1.0	0.17%	0.09%
357	50	3.44%	4.0	2.16%	2.2	2.30%	2.1	2.13%	2.1	1.16%	1.0	1.46%	1.2	12.6	2.18%	0.72%
252	70	17.33%	19.9	12.09%	12.1	11.52%	10.5	14.76%	14.8	6.92%	6.3	8.26%	6.6	70.2	12.16%	3.56%
178	100	16.80%	19.3	16.12%	16.1	7.63%	7.1	28.06%	28.1	5.91%	5.4	6.29%	5.0	81.0	14.04%	7.87%
126	140	19.25%	21.0	10.65%	10.6	10.60%	9.6	20.21%	20.2	22.62%	20.6	26.00%	20.8	102.9	17.83%	5.76%
89	200	22.09%	25.4	28.06%	28.1	28.67%	26.0	12.90%	12.9	38.04%	34.6	33.29%	26.6	153.6	26.62%	8.04%
63	270	14.55%	16.7	19.08%	19.0	15.07%	14.3	10.24%	10.2	14.41%	13.1	9.94%	7.9	81.3	14.09%	3.13%
45	400	6.35%	7.3	7.77%	7.8	15.21%	13.8	8.11%	8.1	7.78%	7.1	13.25%	10.6	64.7	9.48%	3.27%
19	Pan	0.93%	1.1	4.03%	4.0	8.28%	7.5	3.32%	3.3	2.88%	2.6	1.16%	0.9	19.5	3.38%	2.44%
+70 mesh (g)		24.2		14.4		12.6		17.2		7.6		8.1		84.0	0.1	
-70 mesh (g)		90.8		85.6		78.4		82.8		83.4		71.9		493.0	0.9	
MMPD (mm)		0.142		0.1222		0.1083		0.1438		0.1093		0.1141		0.1245		
HMPD (mm)		0.1013		0.0813		0.0858		0.0956		0.0817		0.0857		0.0843		

Run 2D.11A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{i,s,a}$		78		80		94		88		80		71		$\Sigma W_{i,s} = 491$		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.11%	0.1	0.11%	0.1	0.00%	0.0	0.14%	0.1	0.3	0.06%	0.06%
505	40	0.13%	0.1	0.13%	0.1	0.21%	0.2	0.23%	0.2	0.13%	0.1	0.28%	0.2	0.9	0.19%	0.06%
357	50	2.21%	1.7	4.22%	3.4	1.39%	1.3	3.08%	2.7	2.02%	1.6	2.46%	1.7	12.5	2.64%	0.90%
252	70	9.62%	7.5	19.57%	15.7	9.65%	9.1	22.72%	20.0	9.60%	7.7	22.98%	16.3	76.2	16.52%	6.16%
178	100	19.64%	15.3	14.07%	11.3	26.90%	25.3	12.33%	10.8	18.58%	14.8	16.04%	11.4	88.9	18.11%	4.72%
126	140	26.27%	20.5	16.75%	13.4	7.61%	7.2	13.68%	12.0	27.40%	21.9	16.33%	11.6	86.5	17.62%	6.93%
89	200	20.16%	15.7	20.72%	16.6	32.26%	30.3	25.23%	22.2	14.39%	11.5	23.55%	16.7	113.1	23.03%	5.45%
63	270	12.48%	9.7	17.14%	13.7	12.97%	12.2	11.42%	10.0	16.66%	12.5	11.13%	7.9	66.1	13.46%	2.20%
45	400	8.84%	6.9	6.39%	5.1	8.25%	7.8	10.27%	9.0	10.61%	8.5	6.50%	4.6	41.9	8.54%	1.64%
19	Pan	0.65%	0.5	1.02%	0.8	0.64%	0.6	1.03%	0.9	1.64%	1.3	0.68%	0.4	4.6	0.93%	0.37%
+70 mesh (g)		9.3		19.1		10.7		23.0		9.4		18.4		89.9	0.2	
-70 mesh (g)		68.7		60.9		83.3		65.0		70.6		52.6		401.1	0.8	
MMPD (mm)		0.1308		0.1435		0.1293		0.1437		0.1274		0.1493		0.1370		
HMPD (mm)		0.0982		0.0998		0.0982		0.0977		0.0911		0.107		0.0979		

Run 2D.11B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{i,n}$		79		77		78		74		81		80		$\Sigma W_{i,n}$ = 469		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1418	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.02%	0.05%
505	40	0.25%	0.2	0.26%	0.2	0.23%	0.2	0.14%	0.1	0.25%	0.2	0.13%	0.1	1.0	0.21%	0.08%
357	50	2.28%	1.8	1.57%	1.2	1.61%	1.3	2.47%	1.8	2.23%	1.8	3.25%	2.6	10.5	2.24%	0.57%
252	70	13.94%	11.0	11.68%	9.0	8.97%	7.0	11.25%	8.3	13.15%	10.7	16.65%	13.3	59.3	12.64%	2.39%
178	100	15.08%	11.9	14.17%	10.9	30.34%	23.7	12.62%	9.3	17.99%	14.6	16.27%	13.0	83.4	17.79%	6.88%
126	140	10.90%	8.6	20.21%	15.6	7.01%	5.5	28.12%	20.8	31.51%	25.5	17.77%	14.2	90.2	19.23%	8.68%
89	200	26.11%	20.6	34.78%	26.8	24.71%	19.3	23.05%	17.1	11.54%	9.3	23.78%	19.0	112.1	23.90%	6.80%
63	270	16.22%	12.8	8.53%	6.6	16.21%	12.6	13.72%	10.2	12.28%	9.9	14.02%	11.2	63.3	13.51%	2.62%
45	400	12.42%	9.8	8.01%	6.2	9.43%	7.4	7.82%	5.8	9.68%	7.8	7.01%	5.6	42.6	9.07%	1.76%
19	Pan	2.66%	2.1	0.79%	0.6	1.49%	1.2	0.82%	0.6	1.36%	1.1	1.13%	0.9	6.5	1.39%	0.63%
+70 mesh (g)		13.1		10.4		9.4		10.3		12.7		16.0		70.9	0.2	
-70 mesh (g)		65.9		66.6		69.6		63.7		68.3		64.0		398.1	0.8	
MMPD (mm)		0.1256		0.1272		0.1291		0.1286		0.1367		0.1389		0.1311		
HMPD (mm)		0.0933		0.0965		0.0919		0.0962		0.0979		0.0988		0.0937		

Run 2D.12A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
W_{init}		63		61		61		60		61		67		$\Sigma W_{i,n}$ = 393		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.16%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.03%	0.08%
505	40	0.00%	0.0	0.13%	0.1	0.16%	0.1	0.17%	0.1	0.16%	0.1	0.00%	0.0	0.4	0.10%	0.07%
357	50	2.56%	1.6	2.88%	2.3	2.93%	1.8	2.18%	1.3	1.31%	0.8	0.90%	0.6	8.4	2.16%	0.77%
252	70	11.20%	7.1	21.90%	17.7	9.79%	6.4	12.75%	7.7	8.05%	4.9	8.97%	6.0	48.7	12.40%	4.73%
178	100	8.98%	5.6	12.14%	9.8	16.60%	9.6	14.93%	9.0	10.34%	6.3	8.07%	5.4	45.8	11.65%	2.89%
126	140	21.60%	13.6	11.69%	9.6	38.27%	23.3	14.77%	8.9	26.27%	16.0	28.10%	18.8	90.3	22.98%	8.77%
89	200	25.92%	16.3	26.16%	21.2	9.47%	5.2	22.32%	13.4	31.03%	18.9	27.35%	18.3	93.3	23.76%	7.21%
63	270	18.40%	11.6	13.27%	10.7	17.10%	10.4	19.63%	11.8	15.44%	9.4	15.99%	10.7	64.7	16.46%	2.06%
45	400	9.76%	6.1	10.39%	8.4	7.82%	4.8	11.24%	6.7	6.73%	4.1	9.12%	6.1	36.3	9.23%	1.62%
19	Pan	1.44%	0.9	1.25%	1.0	0.65%	0.4	2.01%	1.2	0.66%	0.4	1.49%	1.0	4.9	1.25%	0.48%
+70 mesh		9.8		20.2		7.3		9.1		5.8		6.6		57.7	0.1	
-70 mesh		54.2		40.8		53.7		50.9		55.2		60.4		335.3	0.9	
MMPD (mm)		0.1210		0.1392		0.1317		0.1236		0.1178		0.1144		0.1252		
HMPD (mm)		0.0870		0.0944		0.0990		0.0850		0.0926		0.0870		0.0907		

Run 2D.12B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
W_{in}		70		77		65		64		68		70		ΣW_{in} = 394		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.17%	0.1	0.14%	0.1	0.2	0.05%	0.07%
505	40	0.15%	0.1	0.13%	0.1	0.00%	0.0	0.19%	0.1	0.00%	0.0	0.14%	0.1	0.4	0.10%	0.07%
357	50	1.60%	1.1	0.52%	0.4	0.77%	0.5	1.11%	0.6	1.37%	0.8	1.58%	1.1	4.5	1.14%	0.40%
252	70	7.40%	5.2	4.55%	3.5	4.17%	2.7	8.70%	4.7	5.13%	3.0	10.80%	7.6	26.8	6.76%	2.41%
178	100	11.47%	8.0	4.03%	3.1	6.17%	4.0	8.33%	4.5	8.21%	4.8	19.74%	13.8	38.2	9.70%	5.04%
126	140	36.67%	25.6	26.66%	20.5	30.86%	20.1	23.33%	12.6	27.86%	16.2	18.47%	12.9	107.9	27.38%	5.67%
89	200	17.71%	12.4	34.20%	26.3	28.86%	18.8	31.85%	17.2	27.18%	15.8	26.56%	18.6	109.0	27.68%	5.20%
63	270	12.77%	8.9	14.30%	11.0	18.21%	11.8	11.48%	6.2	17.61%	10.2	15.91%	11.1	69.3	16.06%	2.44%
45	400	10.01%	7.0	9.62%	7.4	8.02%	5.2	13.16%	7.1	9.23%	5.4	5.82%	4.1	36.2	9.18%	2.20%
19	Pan	2.32%	1.6	5.98%	4.6	2.93%	1.9	1.65%	1.0	3.25%	1.9	0.85%	0.6	11.6	2.95%	1.58%
+70 mesh		6.4		4.0		3.2		5.4		3.9		9.8		31.7	0.1	
-70 mesh		93.6		73.0		61.8		48.6		64.1		61.2		362.3	0.9	
MMPD (mm)		0.1203		0.0997		0.1045		0.1129		0.1088		0.1294		0.1126		
HMPD (mm)		0.0881		0.0717		0.0804		0.0833		0.0798		0.097		0.0826		

Run 2D.13A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{fm,n}$		78		76		66		76		34		68		$\Sigma W_{fm,n}$ = 398		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$\Sigma W_{mesh,gi}$	Average $Wt\%_{mesh}$	Standard Deviation
1410	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.13%	0.1	0.15%	0.1	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.3	0.08%	0.07%
505	40	0.26%	0.2	0.26%	0.2	0.15%	0.1	0.13%	0.1	0.29%	0.1	0.15%	0.1	0.8	0.20%	0.07%
357	50	2.06%	1.6	1.45%	1.1	1.53%	1.0	1.31%	1.0	0.59%	0.2	1.75%	1.2	6.1	1.53%	0.45%
252	70	9.12%	9.3	7.63%	5.8	5.82%	3.8	5.40%	0.4	2.35%	0.8	9.94%	6.8	29.9	7.52%	2.43%
178	100	9.66%	7.5	5.92%	4.5	5.67%	3.7	9.01%	6.1	4.40%	1.5	9.50%	6.5	29.8	7.49%	1.99%
126	140	27.19%	21.2	31.58%	24.0	23.28%	15.4	46.19%	35.1	20.23%	6.9	28.80%	19.6	122.1	30.69%	8.30%
89	200	32.73%	25.5	24.87%	18.9	41.65%	27.5	19.55%	14.9	39.30%	13.4	27.34%	18.6	118.7	29.83%	7.82%
63	270	7.35%	5.7	13.55%	10.3	12.58%	8.3	8.92%	6.8	22.29%	7.6	9.50%	6.5	45.1	11.34%	4.92%
45	400	10.18%	7.9	10.13%	7.7	6.43%	4.2	4.86%	3.7	8.80%	3.0	8.19%	5.6	32.1	8.07%	1.93%
19	Pan	2.46%	1.9	4.47%	3.4	2.76%	1.8	2.49%	1.9	1.76%	0.6	4.82%	3.3	12.9	3.24%	1.12%
+70 mesh		9.1		7.2		5.1		7.6		1.1		8.1		37.1	9.33%	
-70 mesh		69.9		68.8		60.9		68.4		32.9		59.9		360.9	90.67%	
MMPD (mm)		0.1184		0.1131		0.1098		0.1256		0.0961		0.1202		0.1159		
HMPD (mm)		0.0971		0.0785		0.0833		0.0953		0.0781		0.0919		0.0843		

Run 2D.13B

Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{i,n}$		57		68		67		75		72		66		$\Sigma W_{i,n}$ = 395		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.18%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.03%	0.07%
505	40	0.00%	0.0	0.17%	0.1	0.15%	0.1	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.3	0.08%	0.08%
357	50	1.05%	0.6	1.05%	0.6	1.21%	0.8	0.80%	0.6	1.26%	0.9	1.26%	0.8	4.4	1.11%	0.16%
252	70	8.87%	5.1	4.37%	2.5	7.89%	5.3	1.74%	1.3	7.72%	5.6	6.53%	4.3	24.1	6.09%	2.44%
178	100	6.21%	3.5	11.36%	6.6	8.04%	5.4	9.25%	6.9	13.62%	9.8	6.99%	4.6	36.9	9.34%	2.56%
126	140	9.22%	5.3	16.88%	11.0	28.38%	19.0	26.81%	20.1	20.65%	14.9	29.77%	19.7	89.8	22.74%	7.05%
89	200	47.70%	27.2	35.84%	20.8	35.66%	23.9	37.27%	27.9	27.81%	20.0	24.76%	16.3	136.2	34.48%	7.35%
63	270	12.06%	6.9	17.13%	9.9	9.56%	6.4	12.87%	9.7	16.29%	11.7	19.14%	12.6	57.2	14.49%	3.28%
45	400	10.92%	6.2	8.92%	5.2	8.19%	5.5	9.52%	7.1	10.67%	7.7	9.97%	6.5	38.2	9.66%	0.92%
19	Pan	3.90%	2.2	2.27%	1.3	0.91%	0.6	1.61%	1.2	1.97%	1.4	1.67%	1.1	7.9	1.99%	0.92%
+70 mesh (g)		5.8		3.2		6.2		2.0		6.6		5.1		28.8	0.1	
-70 mesh (g)		51.2		64.8		60.8		73.0		65.5		60.9		366.2	0.9	
MMPD (mm)		0.1057		0.1088		0.1167		0.104		0.1144		0.1098		0.1097		
HMPD (mm)		0.0758		0.0816		0.0919		0.0838		0.0843		0.0837		0.0835		

Run 2D.14A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{i,gi}$		315		240		246		223		218		213		$\Sigma W_{i,M}$ = 1466		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.31%	1.0	0.10%	0.2	0.00%	0.0	0.13%	0.3	0.12%	0.3	0.00%	0.0	1.8	0.12%	0.10%
505	40	0.41%	1.3	0.30%	0.7	0.35%	0.9	0.25%	0.6	0.25%	0.5	0.38%	0.8	4.8	0.33%	0.06%
357	50	3.42%	10.8	3.94%	9.5	2.89%	7.1	2.68%	6.4	3.99%	8.7	3.26%	6.9	49.4	3.40%	0.44%
252	70	25.08%	79.0	24.04%	57.7	24.22%	59.6	18.90%	42.1	24.78%	54.0	20.08%	42.8	335.2	23.04%	2.43%
178	100	19.90%	62.7	19.90%	47.8	19.88%	48.9	17.15%	38.2	22.17%	48.3	19.07%	40.6	286.5	19.69%	1.48%
126	140	14.61%	46.0	14.09%	33.8	13.86%	34.1	15.39%	34.3	15.07%	32.8	14.81%	31.6	212.6	14.61%	0.53%
89	200	15.34%	48.3	16.35%	39.3	17.71%	43.6	21.65%	48.3	14.32%	31.2	17.94%	38.2	248.9	17.10%	2.35%
63	270	9.50%	29.9	10.94%	26.2	12.89%	31.7	14.77%	32.9	7.85%	17.1	11.54%	24.6	159.4	10.95%	2.39%
45	400	9.74%	30.7	7.88%	18.9	7.35%	18.1	6.01%	13.4	8.34%	18.2	7.15%	15.2	114.5	7.87%	1.15%
19	Pan	2.69%	8.5	2.46%	5.9	0.84%	2.1	2.88%	6.4	3.11%	6.8	5.77%	12.3	42.0	2.88%	1.46%
+70 mesh (g)		92.1		68.1		67.6		49.4		63.5		60.5		391.2	0.3	
-70 mesh (g)		222.9		171.9		178.4		173.6		154.5		152.5		1063.8	0.7	
MMPD (mm)		0.1574		0.1555		0.1534		0.1418		0.1593		0.1443		0.1524		
HMPD (mm)		0.0998		0.1007		0.1066		0.0939		0.1011		0.0861		0.0979		

Run 2D.14B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{int,gi}$		281		252		233		214		198		223		$\Sigma W_{int,gi}$ = 1379		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$Wt\%_{mesh}$	$W_{mesh,gi}$	$\Sigma W_{mesh,gi}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.14%	0.4	0.13%	0.3	0.14%	0.3	0.13%	0.2	0.12%	0.3	1.5	0.11%	0.05%
505	40	0.43%	1.1	0.43%	1.1	0.26%	0.6	0.27%	0.6	0.25%	0.5	0.24%	0.5	4.4	0.32%	0.08%
357	60	4.28%	11.2	3.71%	9.4	3.84%	8.9	3.27%	7.0	3.90%	7.7	4.35%	9.7	53.8	3.90%	0.36%
252	70	28.39%	74.1	22.43%	56.5	21.99%	51.2	21.01%	45.0	23.80%	46.7	19.32%	43.1	316.6	22.96%	2.84%
178	100	22.40%	58.5	19.71%	49.7	21.23%	49.5	18.83%	40.3	24.31%	47.6	20.17%	45.0	290.5	21.07%	1.82%
126	140	17.93%	46.6	16.14%	40.7	16.50%	38.4	16.37%	35.0	16.62%	32.6	19.08%	42.6	235.8	17.10%	1.04%
89	200	15.69%	41.0	16.43%	41.4	14.71%	34.3	19.51%	41.7	16.37%	30.1	16.43%	36.6	225.1	16.32%	1.63%
63	270	4.28%	11.2	9.14%	23.0	7.93%	18.5	11.46%	24.5	6.30%	12.3	9.42%	21.0	110.6	8.02%	2.31%
45	400	6.13%	16.0	6.43%	16.2	6.78%	15.8	5.32%	11.4	6.42%	12.6	7.00%	15.6	87.6	6.35%	0.64%
19	Pan	0.57%	1.5	5.43%	13.7	6.65%	15.5	3.82%	8.2	2.90%	5.7	3.86%	8.6	53.1	3.85%	1.91%
+70 mesh (g)		86.4		67.3		61.1		52.8		55.0		53.6		376.3	0.3	
-70 mesh (g)		174.6		184.7		171.9		161.2		141.0		169.4		1002.7	0.7	
MMPD (mm)		0.1708		0.1527		0.1523		0.1488		0.1614		0.1507		0.1564		
HMPD (mm)		0.1245		0.0911		0.0877		0.0953		0.1061		0.0955		0.0989		

Run 2D.16A

Grinding Interval (gl)		1		2		3		4		5		6		Average		
W_{feed}		91		70		76		61		53		59		$\Sigma W_{i,n}$ = 409		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
505	40	0.00%	0.0	0.14%	0.1	0.13%	0.1	0.16%	0.1	0.00%	0.0	0.00%	0.0	0.3	0.07%	0.07%
357	50	1.10%	1.0	1.72%	1.2	1.85%	1.4	1.15%	0.7	0.57%	0.3	0.52%	0.3	4.9	1.20%	0.51%
252	70	6.41%	5.8	9.05%	6.3	7.61%	5.8	7.86%	4.8	3.03%	1.6	5.84%	3.4	27.9	6.82%	1.93%
178	100	9.28%	8.4	6.90%	4.8	11.92%	9.1	6.22%	3.8	5.49%	2.9	6.19%	3.6	32.6	7.98%	2.25%
126	140	38.01%	34.6	17.82%	12.5	12.58%	9.6	18.82%	11.5	11.55%	6.1	17.01%	9.9	84.1	20.56%	8.78%
89	200	21.33%	19.4	30.75%	21.5	41.19%	31.3	26.88%	16.3	41.88%	22.2	34.71%	20.1	130.8	31.99%	7.41%
63	270	11.05%	10.1	14.22%	10.0	15.76%	12.0	14.73%	9.0	22.92%	12.1	16.16%	9.4	62.5	15.28%	3.58%
45	400	9.50%	8.6	12.64%	8.9	6.49%	4.9	14.73%	9.0	9.09%	4.8	12.03%	7.0	43.2	10.56%	2.69%
19	Pan	3.31%	3.0	6.75%	4.7	2.25%	1.7	9.66%	5.9	5.49%	2.9	7.56%	4.4	22.6	5.54%	2.61%
+70 mesh (g)		6.9		7.6		7.4		5.6		1.9		3.7		33.1	0.1	
-70 mesh (g)		84.2		62.4		68.6		55.4		51.1		54.3		375.9	0.9	
MMPD (mm)		0.1164		0.1077		0.114		0.101		0.0908		0.0989		0.1059		
HMPD (mm)		0.0845		0.07		0.0848		0.083		0.0884		0.0884		0.0732		

Run 2D.16B

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{tot,g}$		72		65		63		67		68		70		$\Sigma W_{tot,p}$ = 385		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1418	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.14%	0.1	0.16%	0.1	0.00%	0.0	0.16%	0.1	0.00%	0.0	0.00%	0.0	0.3	0.08%	0.08%
505	40	0.14%	0.1	0.00%	0.0	0.16%	0.1	0.16%	0.1	0.00%	0.0	0.14%	0.1	0.4	0.10%	0.07%
357	50	1.84%	1.4	1.71%	1.1	2.86%	1.8	1.24%	0.7	1.04%	0.6	1.99%	1.4	7.0	1.82%	0.59%
252	70	9.56%	6.9	7.32%	4.8	12.38%	7.8	13.81%	7.9	5.19%	3.0	12.22%	8.6	38.9	10.10%	3.04%
178	100	11.50%	8.3	9.10%	5.3	12.86%	8.1	7.26%	4.1	5.54%	3.2	10.37%	7.3	36.2	9.41%	2.53%
126	140	31.86%	22.9	13.08%	8.5	18.10%	11.4	27.98%	15.9	16.44%	9.5	19.89%	13.9	82.2	21.36%	6.57%
89	200	21.75%	15.7	35.67%	23.2	19.84%	12.5	17.70%	10.1	34.26%	19.9	22.44%	15.7	97.0	25.20%	7.03%
63	270	13.99%	10.1	20.56%	13.4	14.60%	9.2	10.62%	6.1	19.20%	11.1	15.63%	10.9	60.8	15.78%	3.31%
45	400	6.65%	4.8	8.57%	5.6	12.06%	7.6	14.34%	8.2	11.59%	6.7	10.65%	7.5	40.3	10.47%	2.48%
19	Pan	2.49%	1.8	4.83%	3.1	7.14%	4.5	6.73%	3.8	6.75%	3.9	6.68%	4.7	21.9	5.68%	1.64%
+70 mesh		9.5		6.0		9.7		6.8		3.6		10.0		46.6	0.1	
-70 mesh		63.5		59.0		53.3		48.2		64.4		60.0		338.4	0.9	
MMPD (mm)		0.1249		0.1061		0.1215		0.1197		0.0984		0.118		0.1149		
HMPD (mm)		0.0904		0.0738		0.0729		0.0734		0.0672		0.0736		0.0760		

Run 2D.17A

Grinding Interval (gi)		1		2		3		4		5		6		Average		
$W_{in,p}$		87		95		84		78		73		64		$\Sigma W_{in,p}$ = 481		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$Wt\%_{mesh}$	$W_{mesh,p}$	$\Sigma W_{mesh,p}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.02%	0.05%
505	40	0.13%	0.1	0.00%	0.0	0.26%	0.2	0.00%	0.0	0.00%	0.0	0.16%	0.1	0.4	0.09%	0.10%
357	50	2.02%	1.8	2.22%	2.1	1.46%	1.2	1.26%	1.0	2.28%	1.7	1.26%	0.8	8.6	1.77%	0.44%
252	70	12.10%	10.5	9.85%	9.4	10.33%	8.7	8.96%	7.0	12.18%	8.9	7.33%	4.7	49.1	10.21%	1.70%
178	100	17.61%	15.3	15.63%	14.8	12.45%	10.5	12.42%	9.7	15.98%	11.7	17.47%	11.2	73.1	15.19%	2.12%
126	140	20.43%	17.8	35.37%	33.6	25.96%	21.8	16.98%	13.2	21.00%	15.3	31.83%	20.4	122.1	25.39%	6.53%
89	200	18.95%	16.5	20.67%	19.6	20.53%	17.2	27.83%	21.7	21.00%	15.3	19.97%	12.8	103.2	21.45%	2.91%
63	270	11.28%	9.8	7.35%	7.0	14.17%	11.9	14.62%	11.4	12.02%	8.8	14.98%	9.6	58.5	12.16%	2.63%
45	400	10.89%	9.5	7.91%	7.5	9.40%	7.9	11.79%	9.2	10.20%	7.4	6.40%	4.1	45.6	9.48%	1.82%
18	Pan	6.59%	5.7	1.11%	1.1	5.30%	4.5	6.13%	4.8	5.33%	3.9	0.62%	0.4	20.3	4.22%	2.39%
+70 mesh (g)		12.4		11.5		10.2		8.0		10.6		5.6		58.2	0.1	
-70 mesh (g)		74.6		83.5		73.8		70.0		62.4		58.4		422.8	0.9	
MMPD (mm)		0.1256		0.1317		0.1209		0.111		0.1256		0.1251		0.1236		
HMPD (mm)		0.0772		0.1004		0.079		0.0728		0.0803		0.098		0.0834		

Run 2D.17B

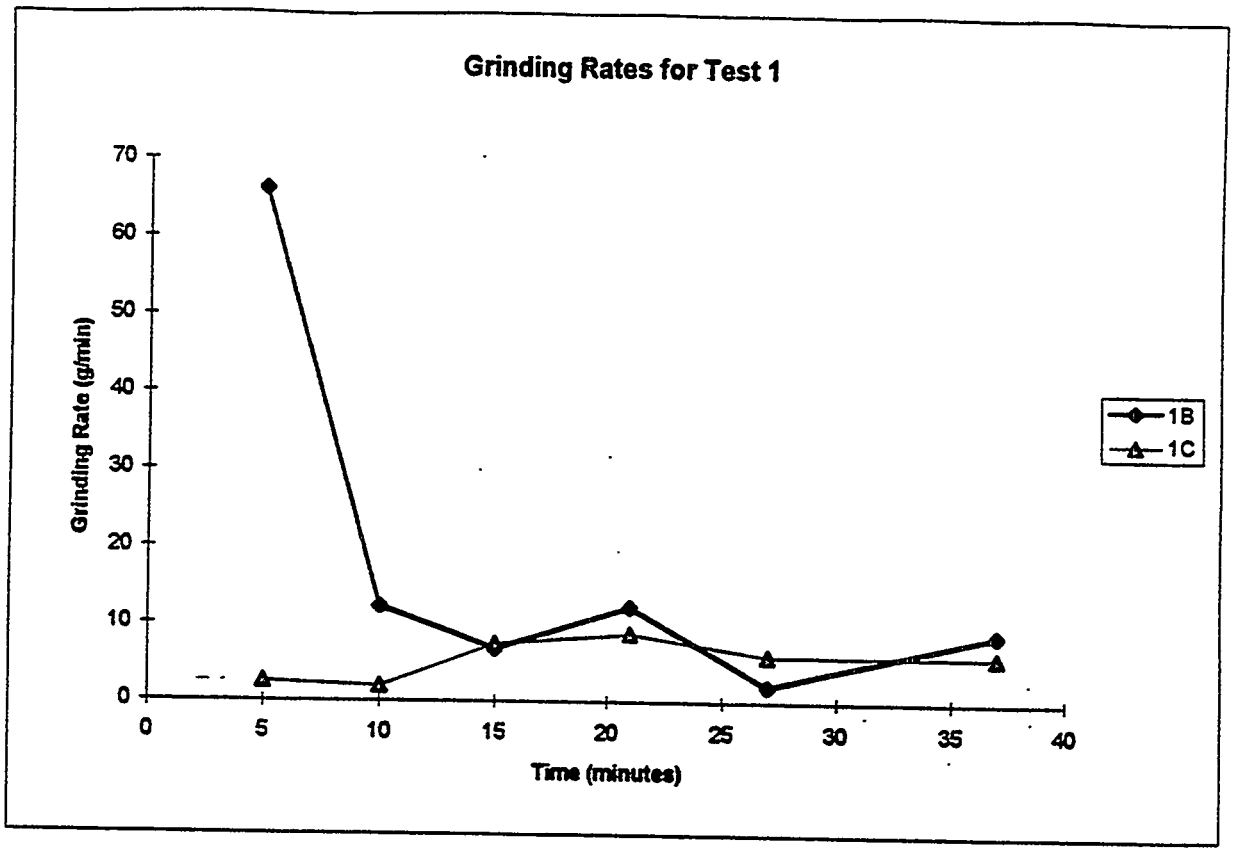
Grinding Interval (gl)		1		2		3		4		5		6		Average		
$W_{in,g}$		105		83		85		81		70		67		ΣW_{in} = 491		
Sieve Aperture	Mesh #	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$Wt\%_{mesh}$	$W_{mesh,g}$	$\Sigma W_{mesh,g}$	Average $Wt\%_{mesh}$	Standard Deviation
1416	16	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
1002	20	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.0	0.00%	0.00%
714	30	0.00%	0.0	0.00%	0.0	0.13%	0.1	0.00%	0.0	0.00%	0.0	0.00%	0.0	0.1	0.02%	0.05%
505	40	0.14%	0.1	0.15%	0.1	0.26%	0.2	0.12%	0.1	0.14%	0.1	0.15%	0.1	0.8	0.16%	0.05%
357	50	2.52%	2.6	2.04%	1.7	2.24%	1.9	1.75%	1.4	2.00%	1.4	1.95%	1.3	10.4	2.11%	0.24%
252	70	15.80%	16.6	8.88%	7.4	12.12%	10.3	8.25%	6.7	10.86%	7.6	10.18%	6.8	55.4	11.28%	2.49%
178	100	15.38%	16.2	12.81%	10.6	12.52%	10.6	18.00%	14.6	12.86%	9.0	16.77%	11.2	72.2	14.71%	2.14%
126	140	25.17%	26.4	25.47%	21.1	20.16%	17.1	37.50%	30.4	38.00%	26.6	28.74%	19.3	140.9	28.71%	6.66%
89	200	22.24%	23.3	25.47%	21.1	25.43%	21.6	17.50%	14.2	16.71%	11.7	22.75%	15.2	107.2	21.84%	3.46%
63	270	9.23%	9.7	16.01%	13.3	11.59%	9.9	8.63%	7.0	11.29%	7.9	12.72%	8.5	56.2	11.46%	2.43%
45	400	7.65%	7.9	9.01%	6.6	9.88%	8.4	6.88%	5.6	6.29%	4.4	5.39%	3.6	36.6	7.44%	1.42%
19	Pan	1.98%	2.1	1.16%	1.0	5.67%	4.8	1.37%	1.1	1.86%	1.3	1.35%	0.9	11.2	2.27%	1.66%
+70 mesh (g)		19.4		9.2		12.5		8.2		9.1		8.2		66.6	0.1	
-70 mesh (g)		85.6		73.8		72.5		72.8		60.9		58.8		424.4	0.9	
MMPD (mm)		0.138		0.1219		0.1239		0.1313		0.1312		0.1304		0.1297		
HMPD (mm)		0.0977		0.0913		0.0786		0.1005		0.0974		0.0984		0.0931		

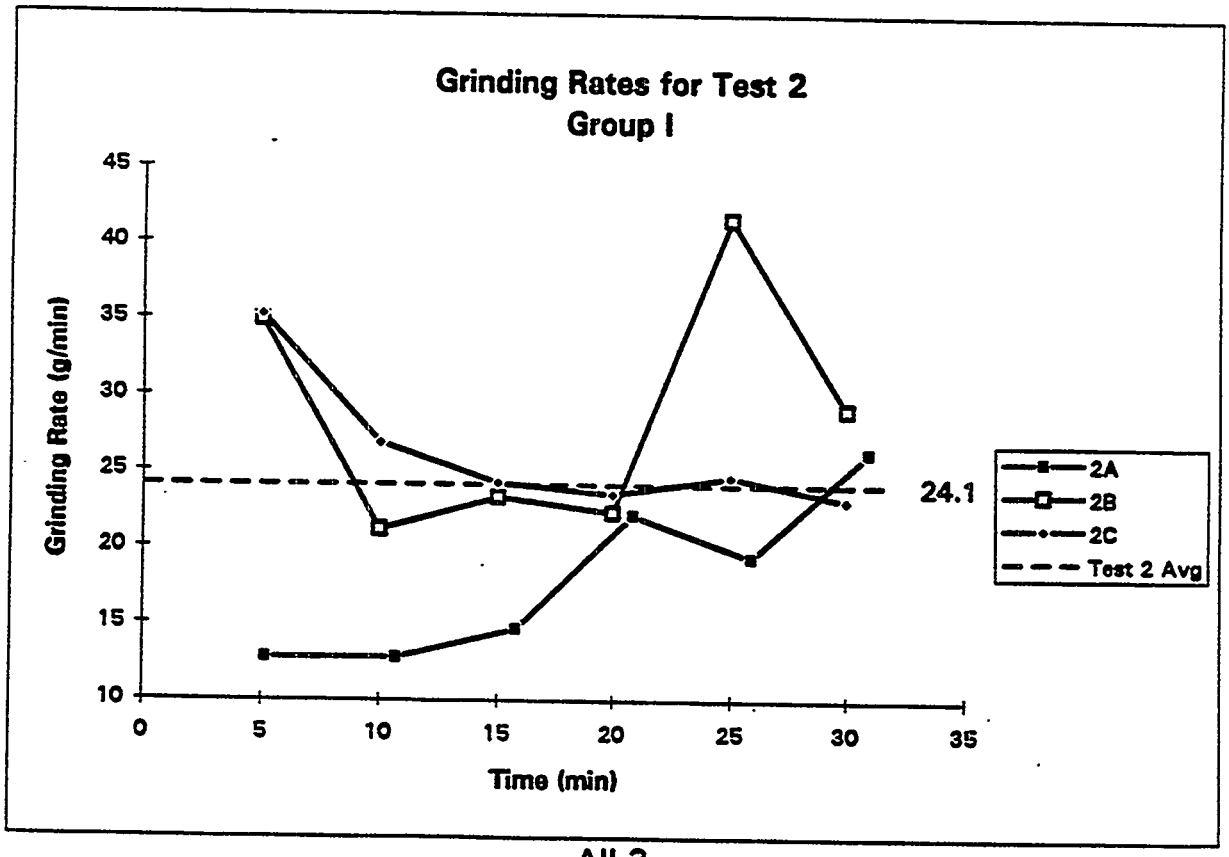
APPENDIX II

GRINDING AND ELUTRIATION RATES

GRINDING AND ELUTRIATION RATES

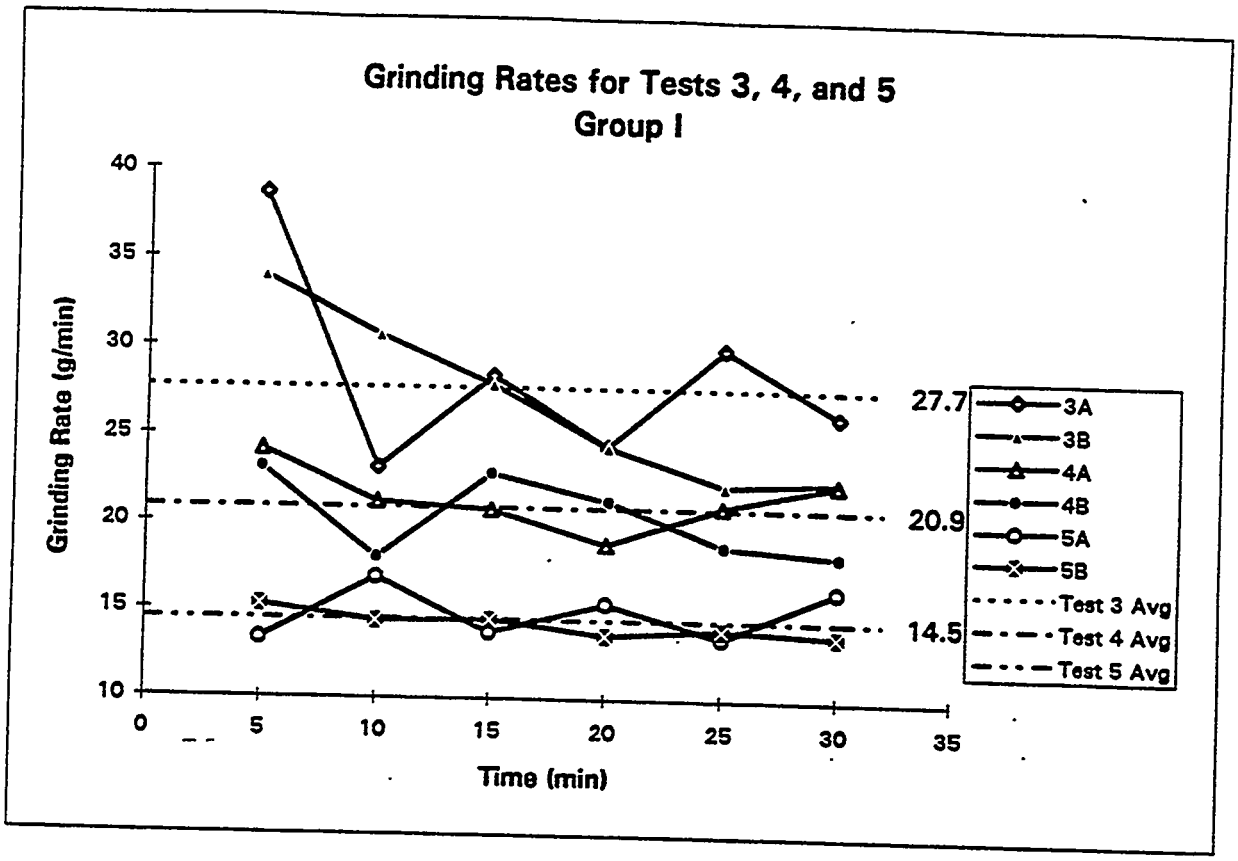
Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.1B	1	5.0	70.8	4.6	66.1
	2	10.0	15.0	2.8	12.2
	3	15.0	8.1	1.4	6.8
	4	21.0	14.3	2.1	12.2
	5	27.0	3.6	1.6	2.0
	6	37.0	11.0	2.2	8.8
	Ave		18.5	2.4	16.2
2D.1C	1	5.0	4.6	2.1	2.5
	2	10.0	3.6	1.6	2.0
	3	15.0	10.6	3.2	7.4
	4	21.0	10.8	2.0	8.8
	5	27.0	7.2	1.3	5.9
	6	37.0	8.4	2.5	5.9
	Avg.		7.7	2.1	5.6
2D.2A	1	5.2	27.6	14.8	12.8
	2	10.7	20.4	7.6	12.8
	3	15.8	21.6	7.0	14.6
	4	20.9	29.8	7.7	22.1
	5	25.9	24.0	4.6	19.4
	6	30.9	30.6	4.3	26.3
	Avg.		24.9	7.4	17.5
2D.2B	1	5.0	77.6	42.7	34.9
	2	10.0	24.6	3.4	21.2
	3	15.0	25.0	1.7	23.3
	4	20.0	25.0	2.7	22.3
	5	25.0	43.6	2.1	41.5
	6	30.0	33.4	4.3	29.1
	Avg.		38.2	9.5	28.7
2D.2C	1	5.0	44.0	8.7	35.3
	2	10.0	32.0	5.2	26.8
	3	15.0	29.2	5.0	24.2
	4	20.0	27.2	3.7	23.5
	5	25.0	27.1	2.5	24.6
	6	30.0	25.2	2.1	23.1
	Avg.		30.8	4.5	26.3

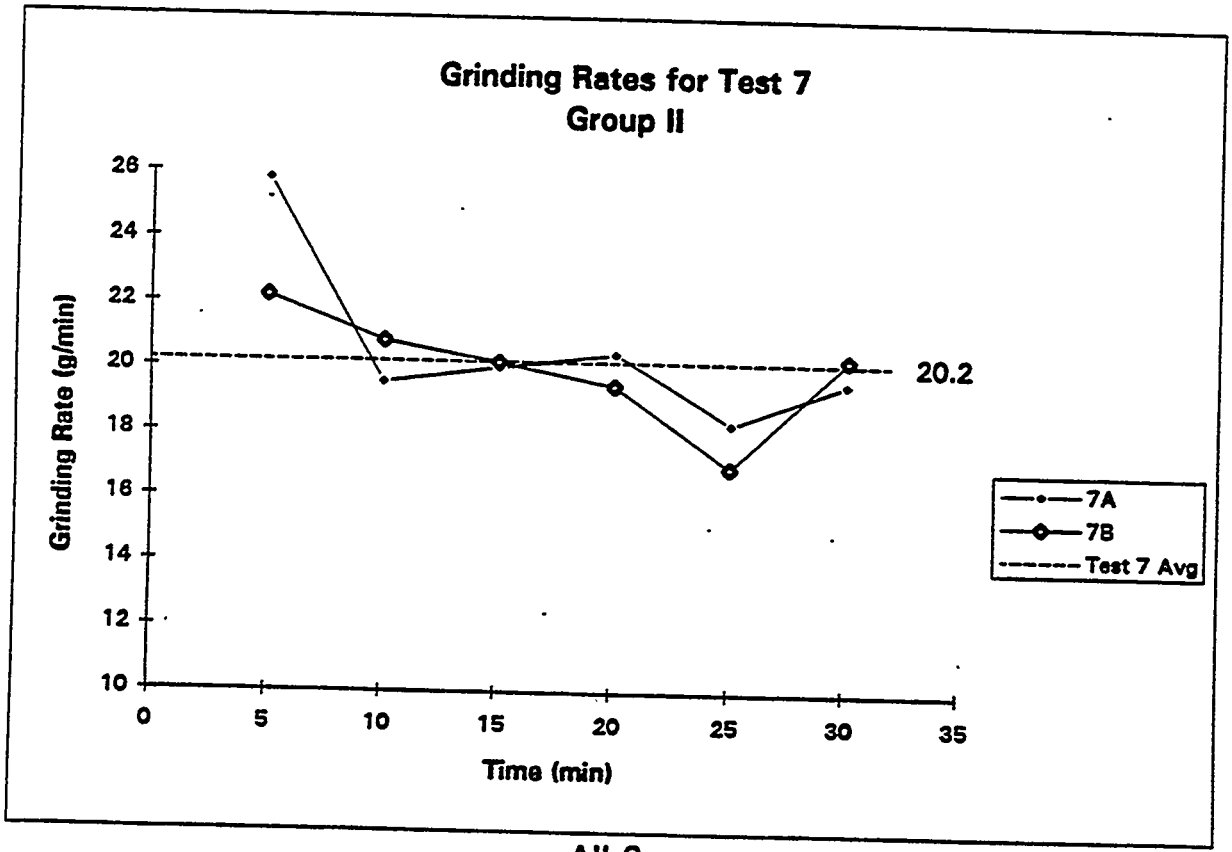

Grinding Rates for Test 1
Grinding Rate (g/min)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
Time (minutes)
1B
1C


Grinding Rates for Test 2
Group I
Grinding Rate (g/min)
45
40
35
30
25
20
15
10
0
5
10
15
20
25
30
35
Time (min)
24.1
2A
2B
2C
Test 2 Avg

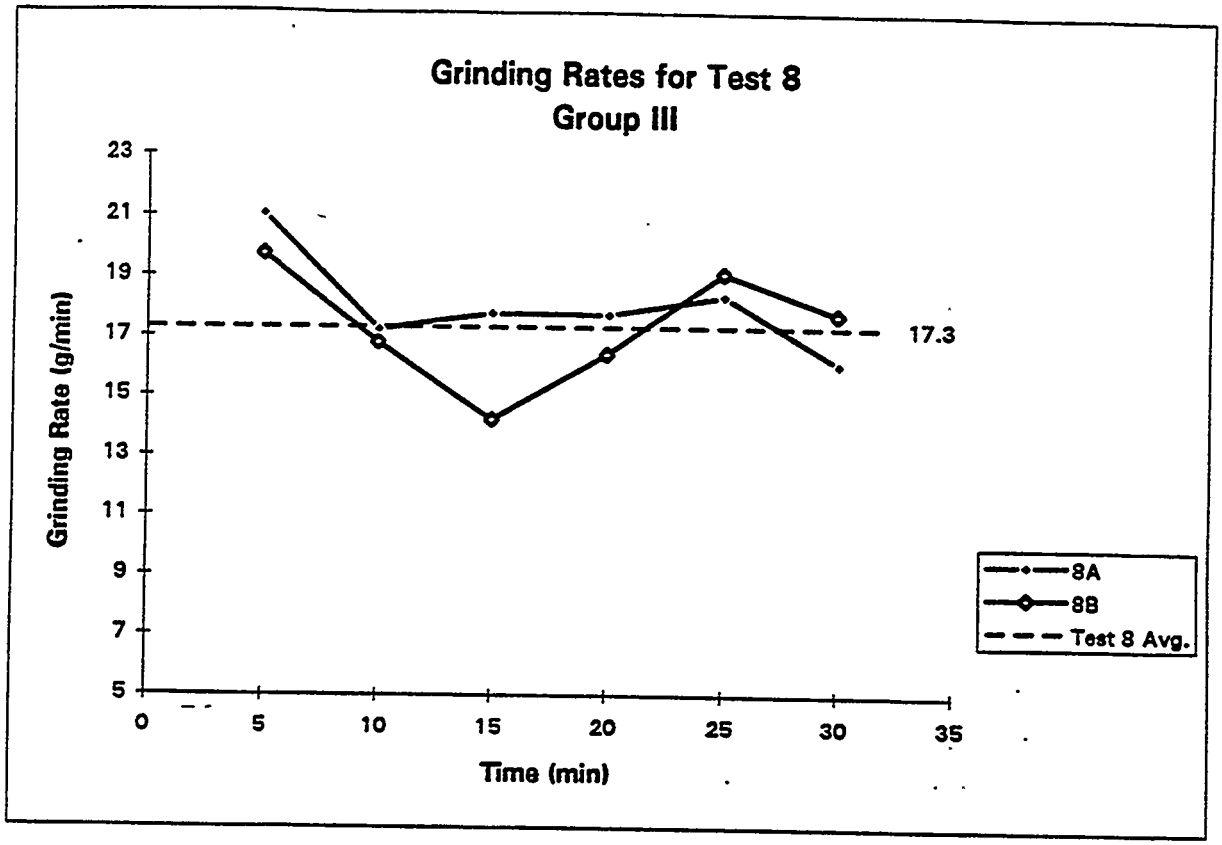
Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.3A	1	5.0	50.2	11.6	38.6
	2	10.0	30.2	7.0	23.2
	3	15.0	32.4	4.0	28.4
	4	20.0	28.8	4.4	24.4
	5	25.0	35.3	5.3	30.0
	6	30.0	32.0	5.7	26.3
	Avg.				
2D.3B	1	5.0	40.6	6.6	34.0
	2	10.0	36.0	5.4	30.6
	3	15.0	33.0	5.1	27.9
	4	20.0	28.4	4.0	24.4
	5	25.1	26.2	4.0	22.2
	6	30.1	27.4	4.9	22.5
	Avg.		31.8	5.0	26.9
2D.4A	1	5.0	26.8	2.6	24.2
	2	10.0	24.6	3.4	21.2
	3	15.0	23.8	3.0	20.8
	4	20.0	21.8	3.0	18.8
	5	25.0	23.8	2.8	21.0
	6	30.0	26.0	3.6	22.4
	Avg.		24.5	3.1	21.4
2D.4B	1	5.0	27.6	4.4	23.2
	2	10.0	21.2	3.2	18.0
	3	15.0	25.8	2.9	22.9
	4	20.1	24.2	2.9	21.3
	5	25.1	21.0	2.2	18.8
	6	30.1	20.8	2.6	18.2
	Avg.		23.4	3.1	20.3
2D.5A	1.0	5.0	15.2	1.8	13.4
	2	10.0	17.8	1.0	16.8
	3	15.0	15.2	1.5	13.7
	4	20.0	16.0	0.6	15.4
	5	25.1	14.6	1.1	13.5
	6	30.1	17.4	1.1	16.3
	Avg.		16.0	1.2	14.8

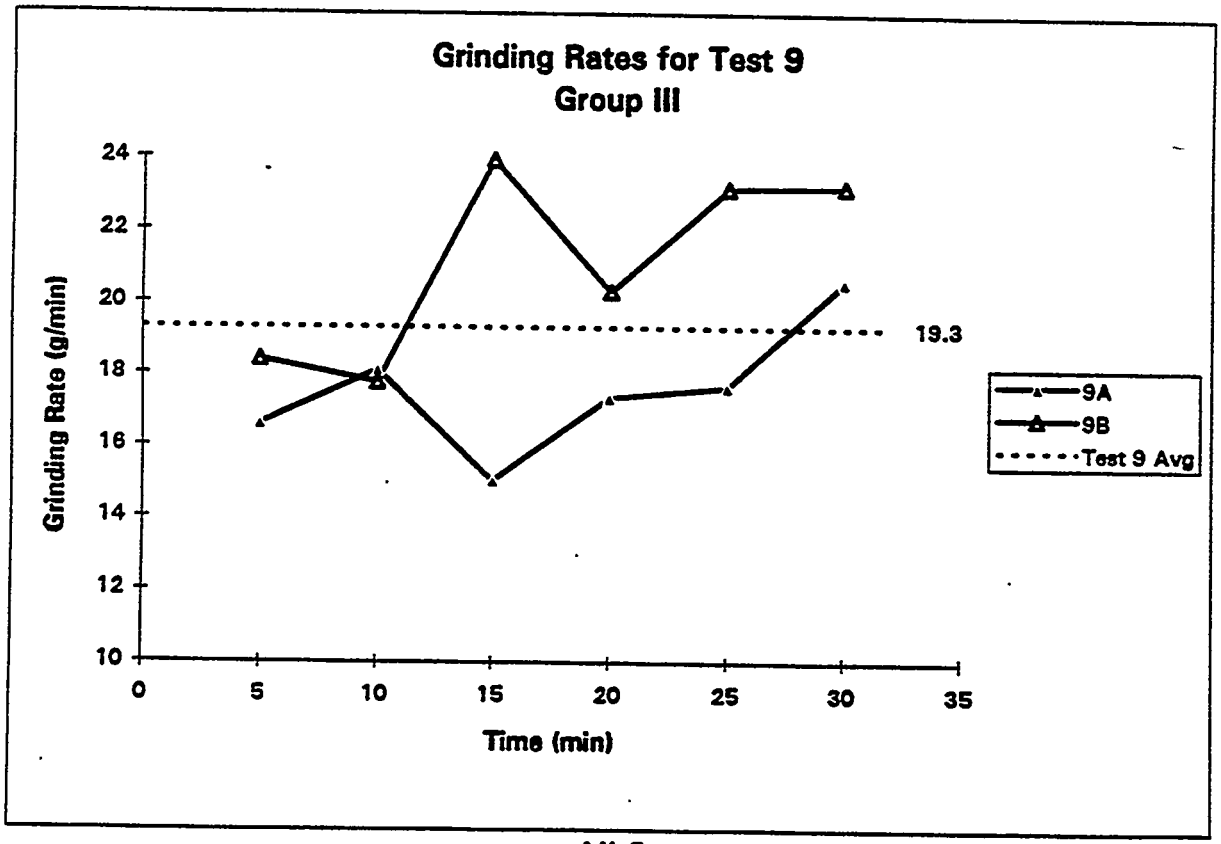
Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.5B	1.0	5.0	16.6	1.3	15.3
	2	10.0	15.8	1.4	14.4
	3	15.0	15.6	1.1	14.5
	4	20.0	14.4	0.8	13.6
	5	25.1	14.8	0.8	14.0
	6	30.1	14.4	0.7	13.7
	Avg.		15.2	1.0	14.2
2D.7A	1.0	5.0	32.8	7.0	25.8
	2	10.0	23.2	3.7	19.5
	3	15.1	24.2	4.2	20.0
	4	20.1	24.4	3.9	20.5
	5	25.1	22.8	4.5	18.3
	6	30.1	23.4	3.8	19.6
	Avg.		25.0	4.5	20.6
2D.7B	1.0	5.0	26.0	3.8	22.2
	2	10.1	23.8	3.0	20.8
	3	15.1	24.2	4.0	20.2
	4	20.1	24.0	4.5	19.5
	5	25.1	20.0	3.0	17.0
	6	30.2	24.0	3.7	20.3
	Avg.		23.5	3.7	19.9
2D.8A	1.0	5.0	27.4	6.4	21.0
	2	10.0	20.2	3.0	17.2
	3	15.0	20.6	2.8	17.8
	4	20.1	20.2	2.5	17.7
	5	25.1	20.8	2.5	18.3
	6	30.1	17.8	1.7	16.1
	Avg.		21.1	3.1	18.0
2D.8B	1.0	5.0	23.4	3.7	19.7
	2	10.0	20.8	4.0	16.8
	3	15.0	19.0	4.8	14.2
	4	20.0	18.4	2.0	16.4
	5	25.0	21.4	2.3	19.1
	6	30.0	19.6	1.9	17.7
	Avg.		16.5	2.5	14

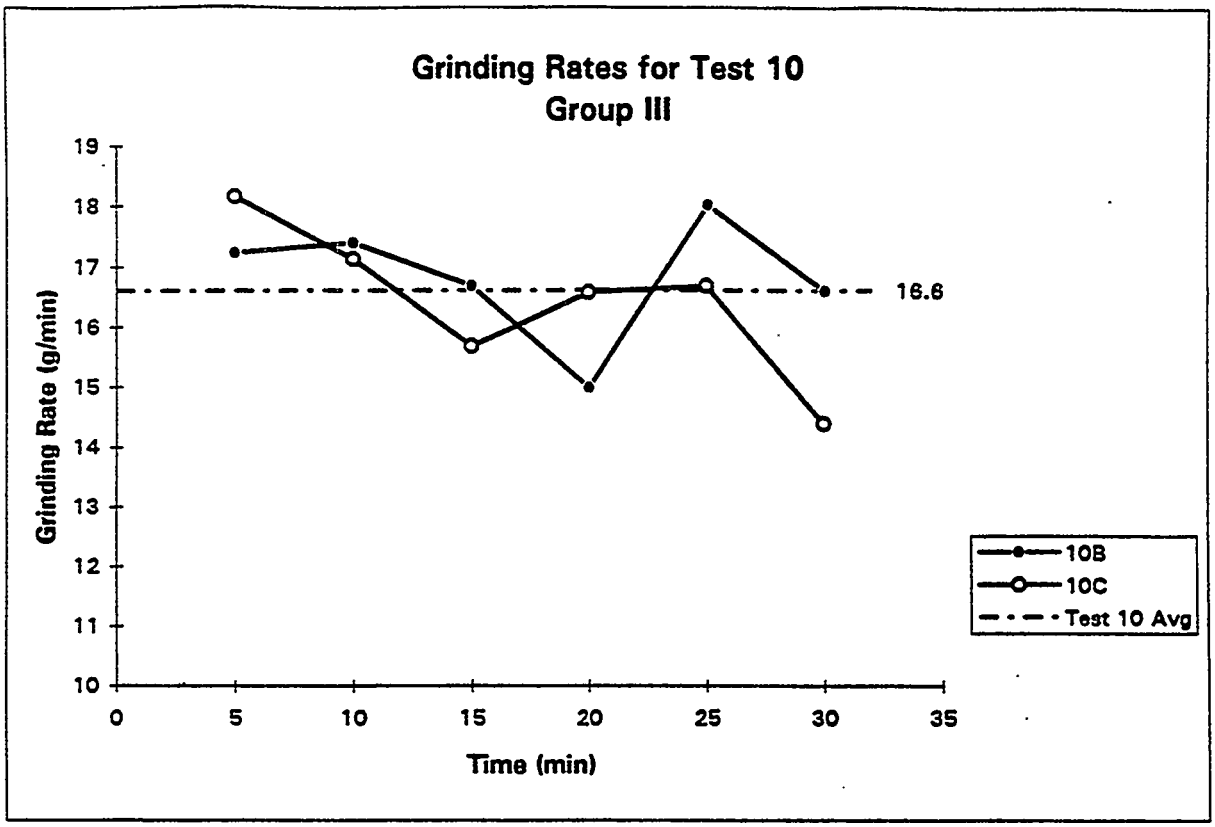

Grinding Rates for Tests 3, 4, and 5
Group I
Grinding Rate (g/min)
40
35
30
25
20
15
10
0
5
10
15
20
25
30
35
Time (min)
27.7
20.9
14.5
3A
3B
4A
4B
5A
5B
Test 3 Avg
Test 4 Avg
Test 5 Avg

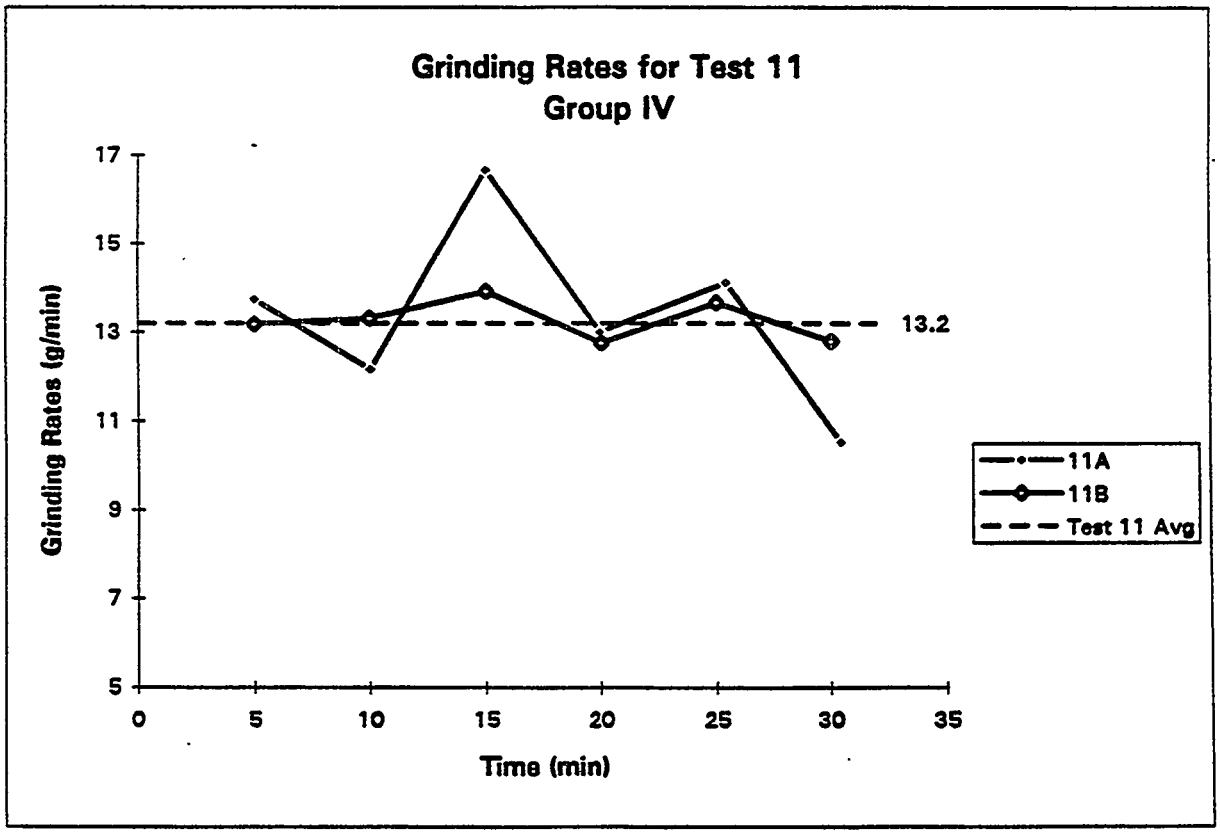

Grinding Rates for Test 7
Group II
Grinding Rate (g/min)
26
24
22
20
18
16
14
12
10
0
5
10
15
20
25
30
35
Time (min)
20.2
7A
7B
Test 7 Avg

Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.9A	1.0	5.0	18.8	2.2	16.6
	2	10.0	22.0	3.9	18.1
	3	15.0	16.8	1.8	15.0
	4	20.0	19.6	2.3	17.3
	5	25.0	19.2	1.6	17.6
	6	30.0	22.6	2.0	20.6
	Avg.		19.8	2.3	17.5
2D.9B	1.0	5.0	20.4	2.0	18.4
	2	10.0	19.2	1.4	17.8
	3	15.0	25.8	1.9	23.9
	4	20.1	21.8	1.5	20.3
	5	25.1	24.4	1.2	23.2
	6	30.1	24.8	1.6	23.2
	Avg.		22.7	1.6	21.1
2D.10B	1.0	5.0	20.8	3.6	17.2
	2	10.0	20.4	3.0	17.4
	3	15.0	18.4	1.7	16.7
	4	20.0	18.8	3.8	15.0
	5	25.0	20.0	2.0	18.0
	6	30.1	18.6	2.0	16.6
	Avg.		19.5	2.7	16.8
2D.10C	1.0	5.0	23.0	4.8	18.2
	2	10.0	20.0	2.9	17.1
	3	15.0	18.2	2.5	15.7
	4	20.0	20.0	3.4	16.6
	5	25.0	18.2	1.5	16.7
	6	30.0	16.0	1.6	14.4
	Avg.		19.2	2.8	16.4
2D.11A	1.0	5.0	15.6	1.9	13.7
	2	10.0	16.0	3.8	12.2
	3	15.0	18.8	2.1	16.7
	4	20.0	17.6	4.6	13.0
	5	25.5	16.0	1.9	14.1
	6	30.5	14.2	3.7	10.5
	Avg.		16.1	2.9	13.2

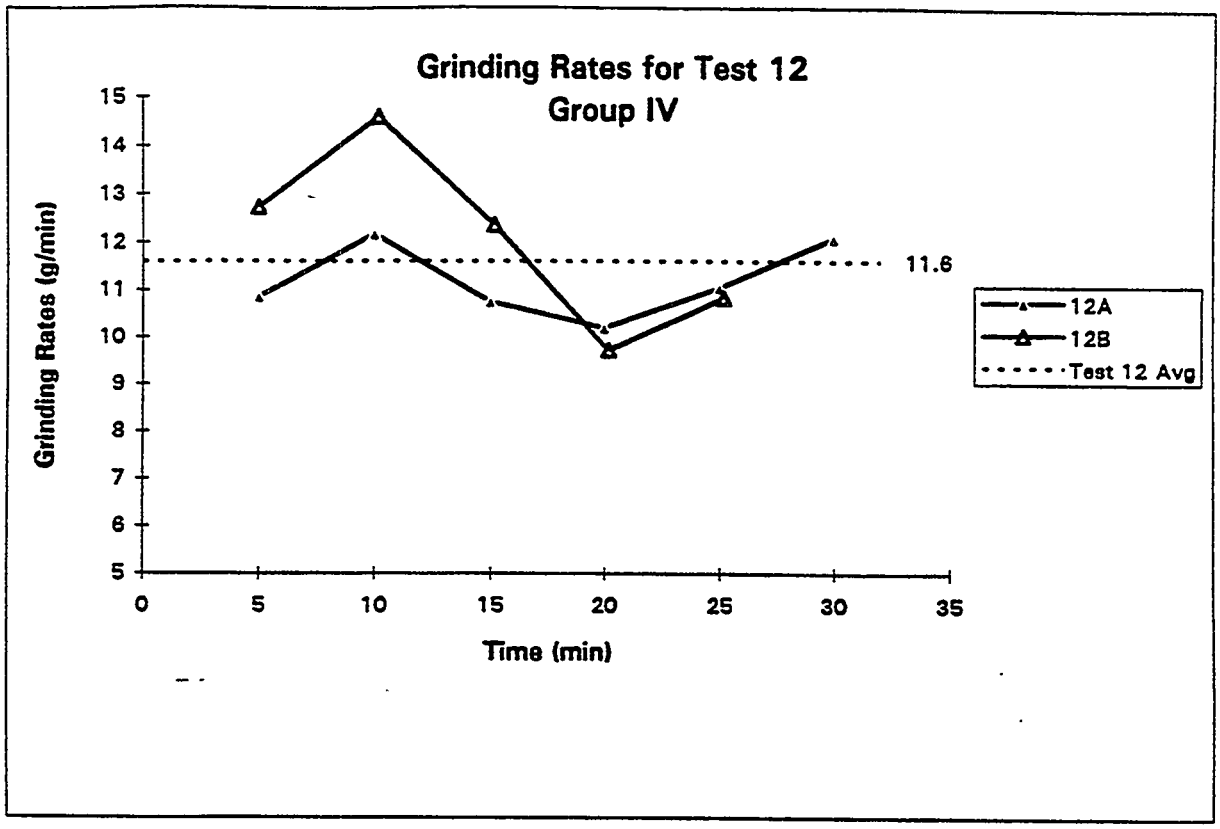

Grinding Rates for Test 8
Group III
Grinding Rate (g/min)
23
21
19
17
15
13
11
9
7
5
0
5
10
15
20
25
30
35
Time (min)
17.3
8A
8B
Test 8 Avg.

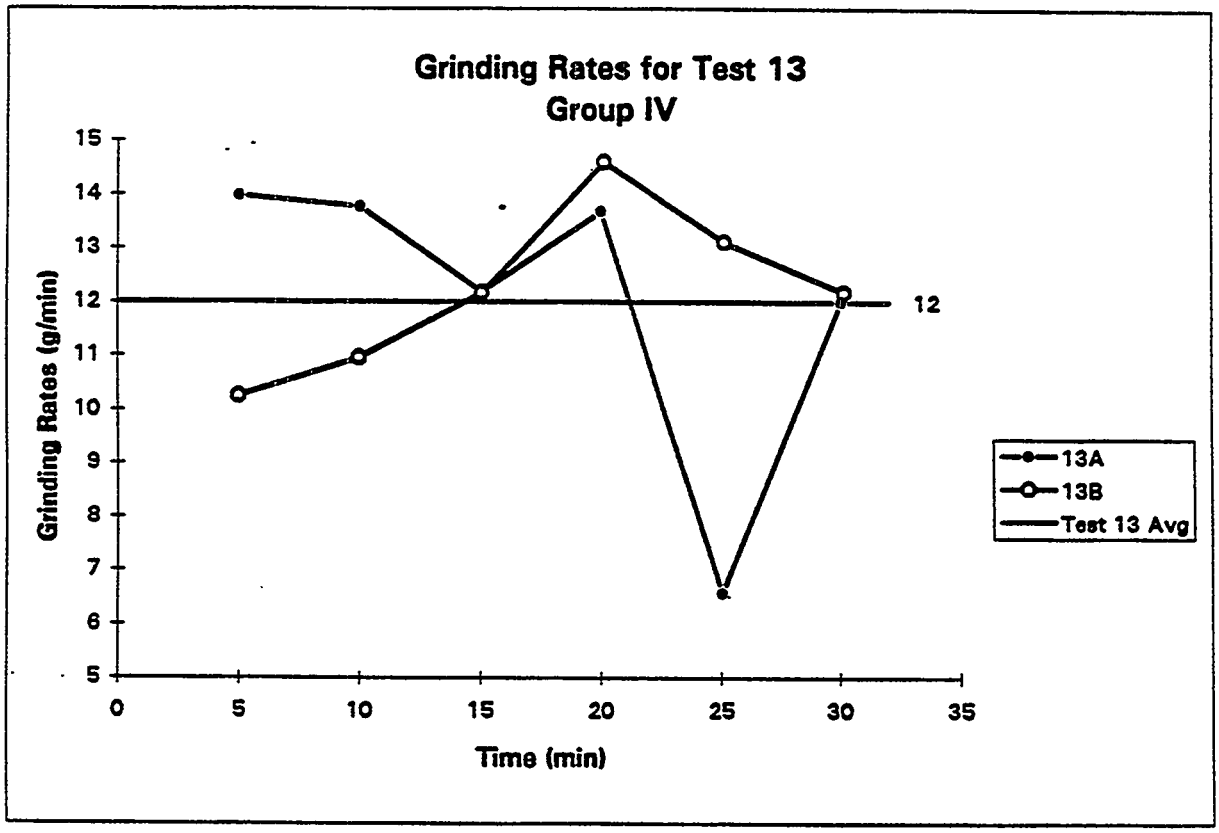

Grinding Rates for Test 9
Group III
Grinding Rate (g/min)
24
22
20
18
16
14
12
10
0
5
10
15
20
25
30
35
Time (min)
19.3
9A
9B
Test 9 Avg


Grinding Rates for Test 10
Group III
Grinding Rate (g/min)
19
18
17
16
15
14
13
12
11
10
16.6
0
5
10
15
20
25
30
35
Time (min)
10B
10C
Test 10 Avg

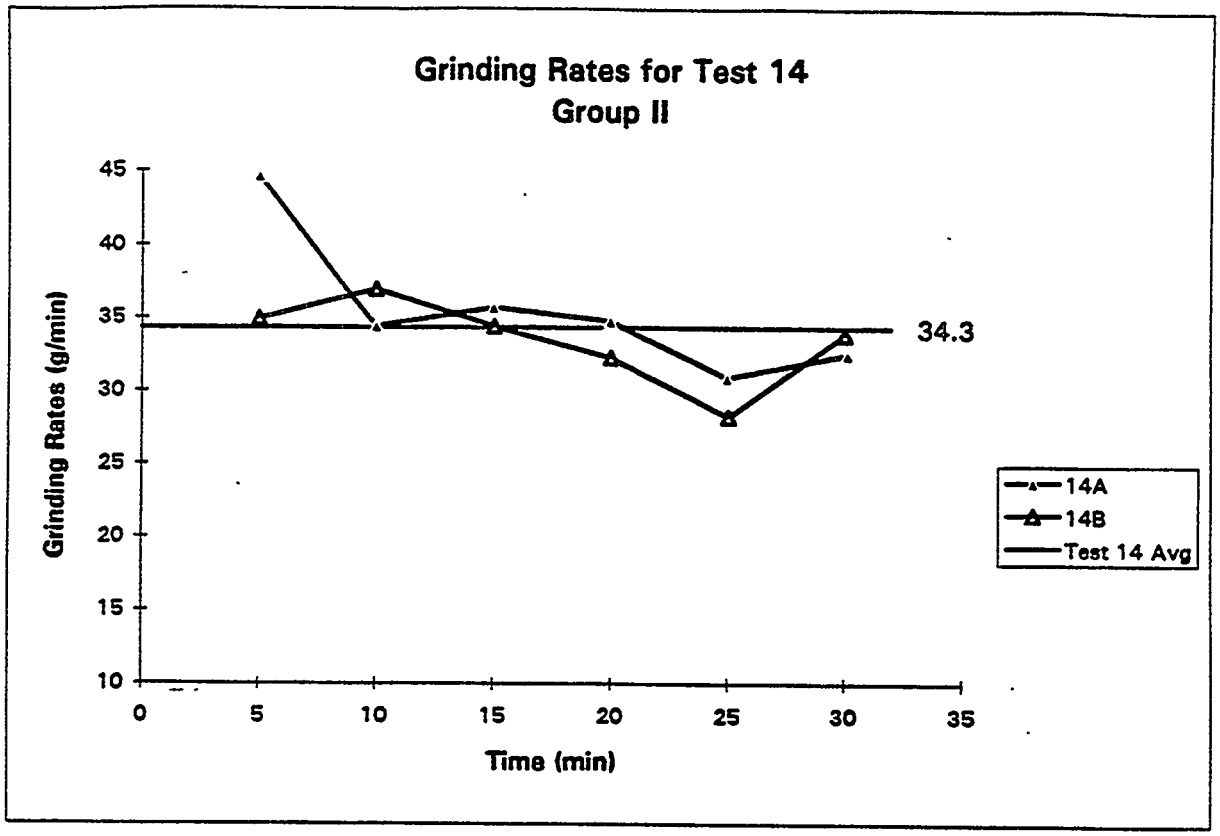

Grinding Rates for Test 11
Group IV
Grinding Rates (g/min)
17
15
13
11
9
7
5
13.2
0
5
10
15
20
25
30
35
Time (min)
11A
11B
Test 11 Avg

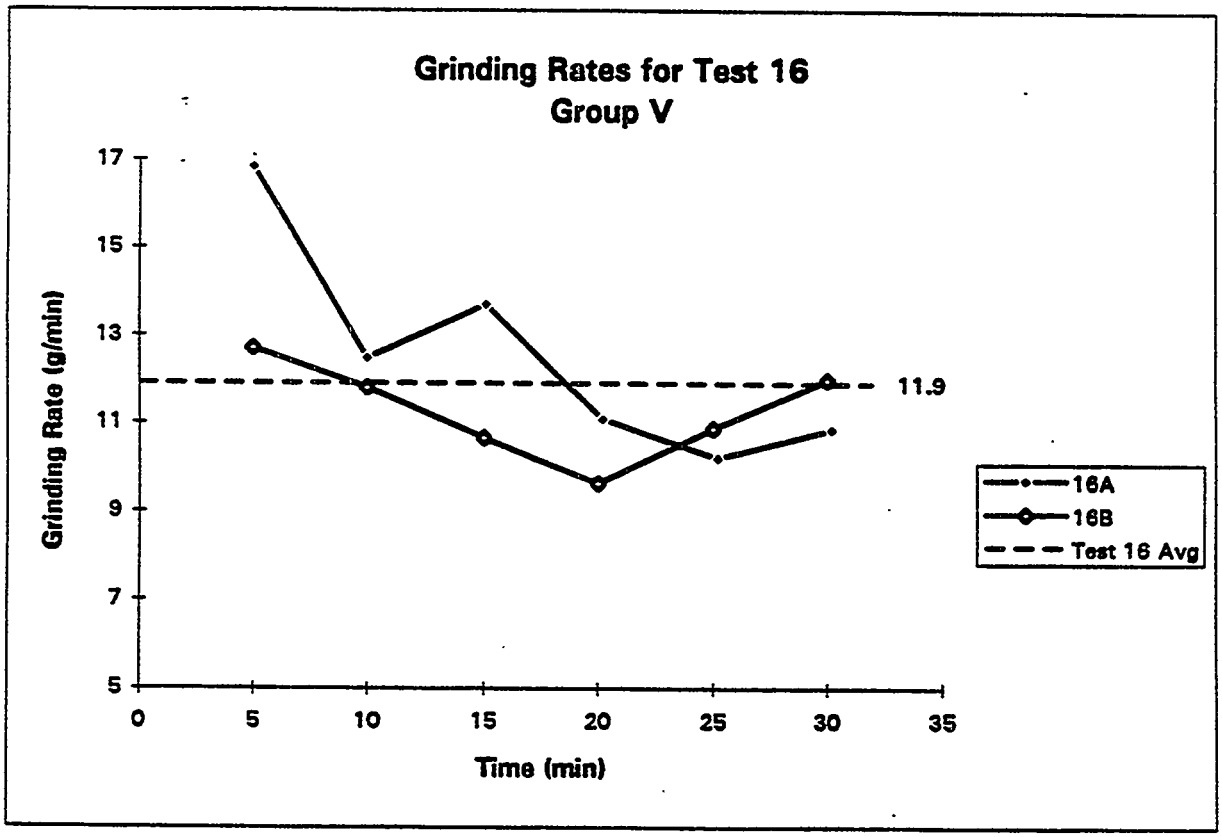
Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.11B	1.0	5.0	15.8	2.6	13.2
	2	10.0	15.4	2.1	13.3
	3	15.0	15.6	1.7	13.9
	4	20.1	14.8	2.1	12.7
	5	25.1	16.2	2.5	13.7
	6	30.1	16.0	3.2	12.8
	Avg.		15.6	2.4	13.2
2D.12A	1.0	5.0	12.6	1.8	10.8
	2	10.0	16.2	4.0	12.2
	3	15.0	12.2	1.5	10.7
	4	20.0	12.0	1.8	10.2
	5	25.0	12.2	1.2	11.0
	6	30.0	13.4	1.3	12.1
	Avg.		13.1	1.9	11.2
2D.12B	1.0	5.0	14.0	1.3	12.7
	2	10.2	15.4	0.8	14.6
	3	15.2	13.0	0.6	12.4
	4	20.2	10.8	1.1	9.7
	5	25.2	11.6	0.8	10.8
	6	30.2	14.0	1.8	12.2
	Avg.		13.0	1.1	12.0
2D.13A	1	5.0	15.6	1.6	14.0
	2	10.0	15.2	1.4	13.8
	3	15.1	13.2	1.0	12.2
	4	20.1	15.2	1.5	13.7
	5	25.1	6.8	0.2	6.6
	6	30.1	13.6	1.6	12.0
	Avg.		13.2	1.2	12.0
2D.13B	1	5.0	11.4	1.2	10.2
	2	10.0	11.6	0.6	11.0
	3	15.1	13.4	1.2	12.2
	4	20.2	15.0	0.4	14.6
	5	25.2	14.4	1.3	13.1
	6	30.2	13.2	1.0	12.2
	Avg.		13.1	1.0	12.1


Grinding Rates for Test 12
Group IV
Grinding Rates (g/min)
15
14
13
12
11
10
9
8
7
6
5
0
5
10
15
20
25
30
35
Time (min)
11.6
12A
12B
Test 12 Avg

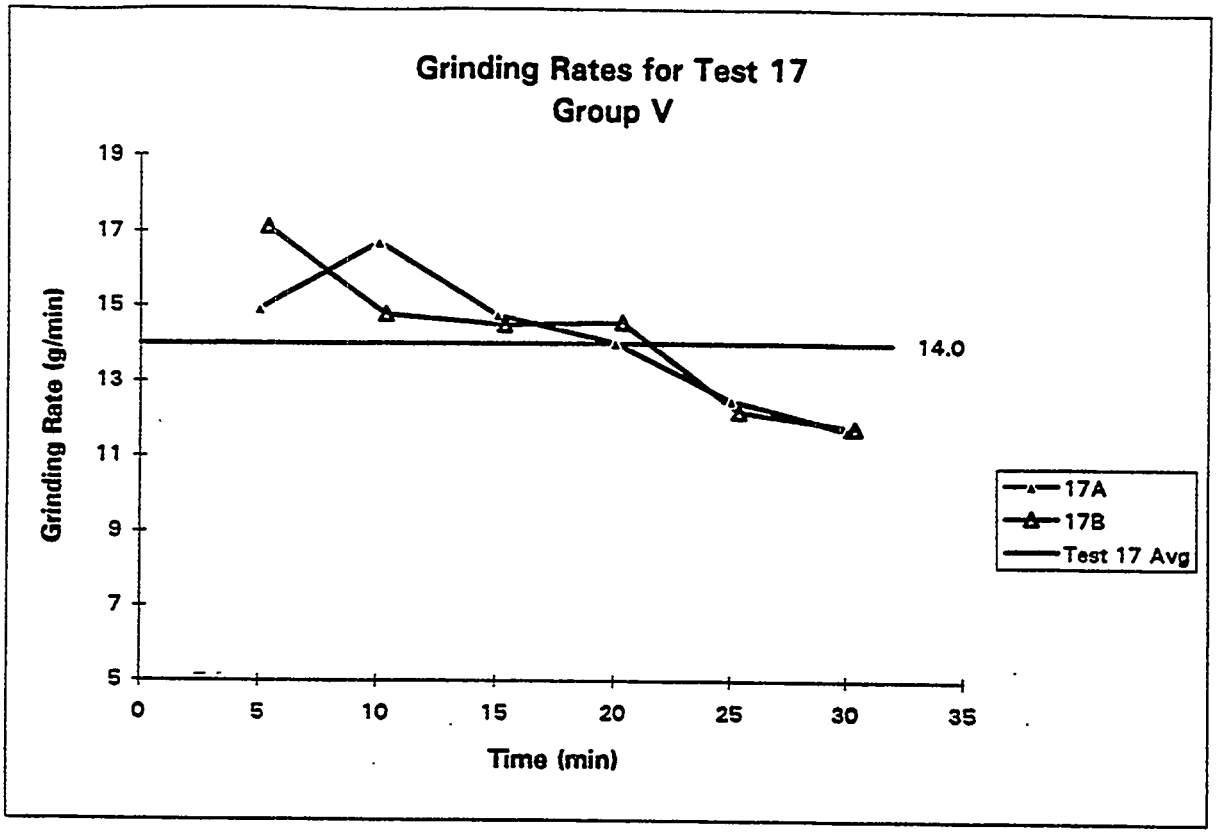

Grinding Rates for Test 13
Group IV
Grinding Rates (g/min)
15
14
13
12
11
10
9
8
7
6
5
0
5
10
15
20
25
30
35
Time (min)
12
13A
13B
Test 13 Avg

Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.14A	1	5.0	63.0	18.4	44.6
	2	10.0	48.0	13.6	34.4
	3	15.0	49.2	13.5	35.7
	4	20.0	44.6	9.9	34.7
	5	25.0	43.6	12.7	30.9
	6	30.2	42.6	10.1	32.5
	Avg.		48.2	13.0	35.2
2D.14B	1	5.0	52.2	17.3	34.9
	2	10.0	50.4	13.5	36.9
	3	15.0	46.6	12.2	34.4
	4	20.0	42.8	10.6	32.2
	5	25.1	39.2	11.0	28.2
	6	30.1	44.6	10.7	33.9
	Avg.		45.9	12.5	33.4
2D.16A	1	5.0	18.2	1.4	16.8
	2	10.0	14.0	1.5	12.5
	3	15.1	15.2	1.5	13.7
	4	20.2	12.2	1.1	11.1
	5	25.2	10.6	0.4	10.2
	6	30.2	11.6	0.7	10.9
	Avg.		13.5	1.1	12.4
2D.16B	1	5.0	14.4	1.7	12.7
	2	10.0	13.0	1.2	11.8
	3	15.0	12.6	1.9	10.7
	4	20.0	11.4	1.8	9.6
	5	25.0	11.6	0.7	10.9
	6	30.0	14.0	2.0	12.0
	Avg.		12.8	1.6	11.3
2D.17A	1	5.0	17.4	2.5	14.9
	2	10.1	19.0	2.3	16.7
	3	15.1	16.8	2.0	14.8
	4	20.1	15.6	1.6	14.0
	5	25.1	14.6	2.1	12.5
	6	30.1	12.8	1.1	11.7
	Avg.		16.0	1.9	14.1


Grinding Rates for Test 14
Group II
Grinding Rates (g/min)
45
40
35
30
25
20
15
10
0
5
10
15
20
25
30
35
Time (min)
34.3
14A
14B
Test 14 Avg


Grinding Rates for Test 16
Group V
Grinding Rate (g/min)
17
15
13
11
9
7
5
0
5
10
15
20
25
30
35
Time (min)
11.9
16A
16B
Test 16 Avg

Run #	Grinding Interval	Time (minutes)	Total Elutriation Rate (g/min)	+70 Mesh Elutriation Rate (g/min)	Grinding Rate (g/min)
2D.17B	1	5.4	21.0	3.9	17.1
	2	10.4	16.6	1.8	14.8
	3	15.4	17.0	2.5	14.5
	4	20.4	16.2	1.6	14.6
	5	25.4	14.0	1.8	12.2
	6	30.4	13.4	1.6	11.8
	Avg.		16.2	2.2	14.0


Grinding Rates for Test 17
Group V
Grinding Rate (g/min)
19
17
15
13
11
9
7
5
0
5
10
15
20
25
30
35
Time (min)
14.0
17A
17B
Test 17 Avg

Attachment 2
Calcine Grinder

Calcine Grinder

Type	Quoted Rate (See Notes)	Production Rate (lbm/hr)	Production Rate (kg/h)	Size (microns)	Air-Flow (scfm)	Air-Pressure (psia)	Air-Pressure (kPa)	Notes
INTEC	34.3	4.5	2.1	170-180	5	100	689.5	Quoted rate = 34.3 g/m, simple fluidized-bed. (Reference 5)
INTEC (Scaled)	11,340.1	1,500.0	680.4	170-180	1,653	100	689.5	Scale factor = 330.6, scaled from item 1
CCE Technologies	2,000.0	2,000.0	907.2	0.5-45	1,500	100	689.5	Quoted rate = 2000 lbm/h, turbine separator, fluidized-bed. (Reference 7, Attachment 3)
Jet-O-Mizer	1,500.0	1,500.0	680.4	0.5-45	800	100	689.5	Quoted rate = 100-1500 lbm/h, simple fluidized-bed, cyclone classifier. (Ref. 8, Attachment 4)
Garlock/Trost	5,000.0	5,000.0	2,268.0	0.5-45	1,000	100	689.5	Quoted rate = 100-5000 lbm/h, simple fluidized-bed, cyclone classifier. (Ref. 9, Attachment 5)

one day 24 hours
Calcine/Mix (wt.) 0.2

Material	Calcine (lbm/day)	Calcine (lbm/h)	Frit (lbm/day)	Frit (lbm/h)	Mix (lbm/day)	Glass (lbm/day)	Off-Gas (lbm/day)	Notes
Calcine/Frit/Glass	3,452.0	143.8	10,700.0	445.8	14,152.0	13,800.0	352.0	Mean total production rate. Off-gas does not including water. (Ref. 10)
	4,315.0	179.8	13,375.0	557.3	17,690.0	17,250.0	440.0	Peak total production rate. Off-gas does not including water. (Ref. 11)
Each melter	863.0	36.0	2,675.0	111.5	3,538.0	3,450.0	88.0	Mean production rate. Off-gas does not including water. (Ref. 10)
	1,078.8	44.9	3,343.8	139.3	4,422.5	4,312.5	110.0	Peak production rate. Off-gas does not including water. (Ref. 11)
Each Grinder	1,726.0	71.9						3 grinders, feed 3 mix-tanks, feed 2 melter feed-tanks. A melter feed-tank serves 2 melters
	2,157.5	89.9						Above assumes that one grinder/mix-tank can be unavailable. (Ref. 12)

Attachment 3
Search Results: CCE Technologies, Inc.

Pulverization - Classification - Custom Processing - Particle Size Analysis
Complete Systems Engineering - Consulting - Field Service

CCE Technologies, Inc.

Specializing in your fine particle needs

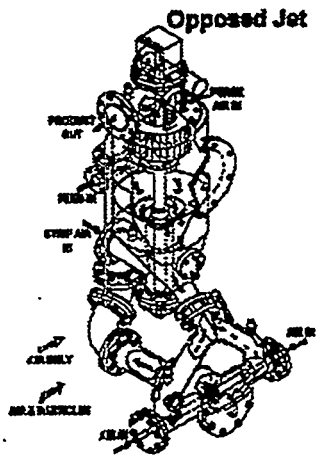
Pulverizing and Classification Equipment for the Powder Processing Industry.

Specializing in the 200 mesh and finer particle size range.

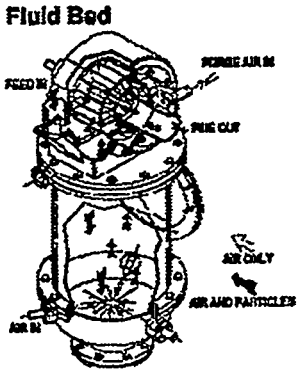
We offer:

- Custom Processing to Your Specifications
- High Efficiency Centrifical Air Classifiers
- Fluid Energy Mills
- Custom Designed Systems
- Particle Size Analysis

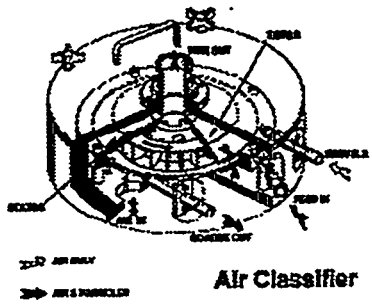
Fine Grinding & Sizing Solutions



Size Range: 95% < 5µm to 95% < 70 µm
Narrow Particle Size Distributions
Precise Top Size Control
Low Maintenance, Easy to Clean
Toners, Abrasives, Powder Coatings
Cost Effective System Design
Low Wear



- Cut Sizes up to 50 µm
- Discrete Particle Size Control
- Rates up to 2000 lb/hr
- Ultra Narrow Size Distributions
- Abrasives, Toners, Chromatography



CCE Technologies, Inc.

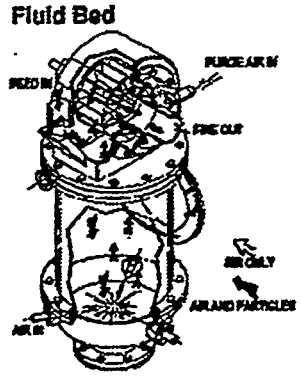
2401 Pilot Knob Road, #126
St. Paul, MN 55120
Phone: 651-688-2656 | Fax: 651-688-8989
Toll Free: 1-800-707-7719
E-mail To Company

Pulverization - Classification - Custom Processing - Particle Size Analysis
Complete Systems Engineering - Consulting - Field Service

CCE Technologies, Inc.

Dense Phase Fluid Energy Mill

The CCE Fluid Bed Jet Mill incorporates dense phase micronization using turbulent free jets in combination with high efficiency centrifugal air classification. This combination allows for enhanced comminution by high probability particle on particle impact for breakage in close proximity with high efficiency at minimum specific energy levels. Abrasive and temperature sensitive products can be finely ground with minimum contamination. The simple, easy to clean, cost effective design offers precise top size control with narrow size distributions in the 95% < 5 µm to 95% < 70 µm size range. Load cells are used to precisely control mill load for optimum grinding efficiency and/or product size distribution control.



Flow description:

Feed is introduced into the common housing through either a double flapper valve or injector. Mill load is formed by flooding the pulverizing zone to a level above the grinding nozzles. Turbulent free jets are used to accelerate the particles for impact and breakage. After impact the fluid and size reduced particles leave the bed and travel upwards to the centrifugal classifier where rotor speed will define what size will continue with the fluid

through the rotor and which will be rejected back to the particle bed for further size reduction. The high degree of particle dispersion leaving the pulverizing zone aids in the efficient removal of fine particles by the classifier. Operating parameters of rotor speed, nozzle pressure, and bed level allows for optimizing productivity, product size, and distribution shape.

The CCE Fluid Bed Mill System comes complete with Mill, Flow Source, Product Cyclone and/or Collector, Feed System, and Control Package.

- Narrow Product Size Distributions
- Load Cell Control
- Precise Top Size Control
- Temperature Sensitive Materials
- Simple Cost Effective Design
- Abrasive Resistant Linings
- Low Maintenance/Easy to Clean
- Four Sizes Ranging from 200 to 1500 scfm
- Ideal for Toners, Abrasives, Powder Coatings and other fine powder applications

CCE Technologies maintains lab facilities for customer testing, equipment evaluation, and custom processing.

CCE Technologies, Inc.

Home

2401 Pilot Knob Road, #126
St. Paul, MN 55120
Phone: 651-688-2656 | Fax: 651-688-8989
Toll Free: 1-800-707-7719

Attachment 4
Search Results: Fluid Energy Aljet

FLUID ENERGY ALJET

Jet Milling, Flash Drying & Calcining Systems

Jet-O-Mizer *Size Reduction System*



High-Efficiency Chamber Design: The Jet-O-Mizer grinding chamber features an inverted trapezoidal design, which forces the circulating particles to concentrate at the nozzles. This unique design improves grinding efficiency and reduces wear on chamber walls.

Adjustable Classification Zone: The Jet-O-Mizer employs an externally adjustable configuration. This feature controls the velocity gradient to isolate the classification process from the grinding chamber. This patented feature allows efficient control of particle size distribution for multiple products or specifications.

No Attritional Heat: The cooling effect of the grinding fluid completely offsets the slight heat generated during grinding. The Jet-O-Mizer system is routinely used to grind products with critical heat limitations.

Combined Operations: In the Jet-O-Mizer system, grinding may be combined with other physical and chemical operations. This saves time, reduces energy and minimizes product handling. While grinding, the Jet-O-Mizer can:

- dry wet-feed
- blend and mix ingredients
- coat product with waxes, oils and dyes
- promote chemical reactions

APPLICATIONS

Hard, Abrasive Materials:
abrasives
minerals
ores

Heat Sensitive Materials:
pigments
waxes
resins

Sanitary, Sterile Applications:
pharmaceuticals
foods
cosmetics

Agricultural Materials:
fungicides
herbicides
pesticides

Volatile Materials:
propellants
explosives
oxidizers

Synthetic Materials:
polymers
plastics
precipitates



promote chemical reactions
(such as oxidization, calcination and sublimation)
- inhibit chemical reactions
- free entrapped solvents

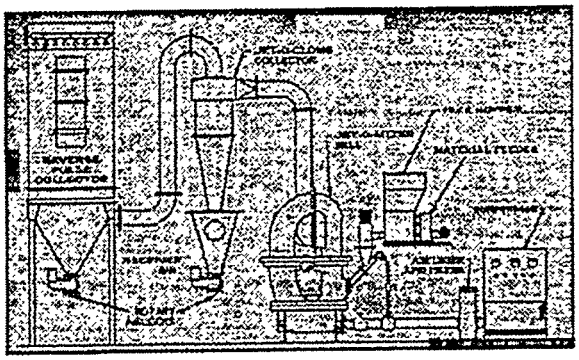
Replaceable Protective Liners: Special alloy, polymer or ceramic liners minimize wear or build-up in strategic areas of the mill. This simplifies operation, extends the life of many components and prevents downtime.

Durable Construction: The low-maintenance design has no moving parts and can be opened quickly and easily for inspection or cleaning. The Jet-O-Mizer system is designed for continuous operation 24 hours a day, 365 days a year.

Typical Operating Parameters

Mill Series #	Production Capacity, lb/hr.	SCFM Air @70 F & 100 psig.	Steam, lb/hr @700 F & 200 psig.
000	0.02-0.25	1.0	N/A
00	0.1-2	4.0	N/A
0101	0.5-20	10-30	60-120
0202	1-100	50-120	200-500
0304	50-750	100-500	400-1000
0405	100-1500	400-800	1000-2000
0506	200-2500	450-1200	1500-2500
0608	300-3500	750-1500	3000-5000
0808	400-6000	1000-2000	4000-6500
1112	500-10,000	2000-4000	6000-9000
1314	800-12,000	3000-6000	8000-15,000

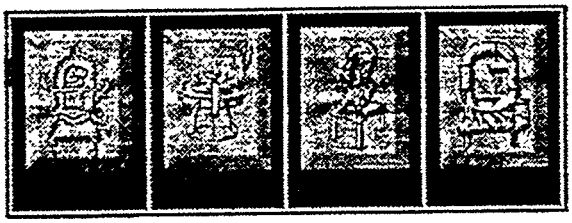
Typical Jet-O-Mizer System



SPECIAL SERVICES

Rental Systems: Most of Fluid Energy Aljet's advanced systems are available on a rental basis to fulfill your immediate processing requirements.

Custom Processing: Fluid Energy Aljet maintains two facilities for coarse and fine grinding of your material on a contractual basis. Other services include blending, drying and packaging. The fully equipped QA laboratory in each facility is available for moisture, particle size and custom analyses of your products.



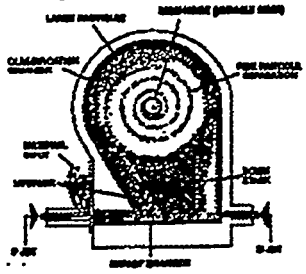
FLUID ENERGY ALJET
PO Box 428, 3136 Applecutter Rd
Plumsteadville, PA 18949
Phone: 215-766-0300 Fax: 215-766-0555

Attachment 5
Search Results: Garlock-Trost Air Impact Pulverizers

GARLOCK
Plastomer Products

Trost Air Impact Pulverizers

TROST
Air Impact Pulverizers



For 0.1 to 45 Micron Powders No One Measures Up to Trost

5 Models Provide Precise Control of Particle Size With Throughput Rates of 1/2 to 5,000 lbs./hr.

Click on the text below to view each model:

- Gem T Research Model
- TX Laboratory Model
- T-15 Pilot Plant
- T-30
- T-60 Production Model

There's a Trost Pulverizer For Every Grinding Operation

HOME

800-618-4670

Garlock Plastomer Products
23 Friends Lane
Newton, PA 18940
Phone: 215-968-5011
Fax: 215-968-7640

GARLOCK Plastomer Products

There's a TROST Pulverizer for every grinding operation

TROST Air Impact Pulverizers are exceptionally easy to adjust for the particle size and output you want.

These advanced-design air mills are easy-to-use, fast and economical, They can handle difficult and abrasive materials without contamination, and with no heat generation.

TROST...the Air Impact Pulverizer that:

- Uses directly opposing jet streams to cause particle-to-particle, head-on impact - four times the impact power of a single force against a stationary object.
- Utilizes fluid energy - compressed air, steam or other gases to produce impact.
- Generates no heat and can be used for low melting point substances.
- Can take almost any material - in fact, every kind of plastic powder, pharmaceutical, chemical or natural material and pulverize it.
- Can pulverize hard, brittle, abrasive, soft or agglomerate material to low micron fineness.
- Has interchangeable parts for controlling jet stream volume and velocity - to produce the optimum particle size and output.
- Has removable liners and parts to match the material being pulverized - effectively eliminating liner damage by abrasive materials with virtually no down time for clean up.
- Is available in various models that can produce from a few grams to 5,000 pounds per hour.

Click on the text below to view information about each topic:

- How It Works (View Diagram) / Variations
- Coating and Compounds / Test Grinds

[Return to Trost Pulverizers Directory]

HOME

GARLOCK

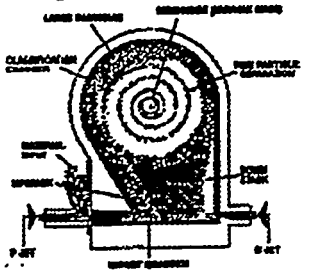
800-618-4670

Garlock Plastomer Products
23 Friends Lane
Newton, PA 18940
Phone: 215-968-5011

GARLOCK

Trost Pulverizers

TROST
Air Impact Pulverizers



How It Works

The TROST Pulverizer (pictured), gets its impact power from opposing jet streams of fluid energy. As material is fed into the hopper, it is fired through the P-tube. After impacting head on with material moving in the opposite direction through the O-tube, both are swept into the classification chamber.

Here larger particles move to the outer perimeter of the chamber through centfifical force, and travel down the downstack and through the O-tube for further impact and fracture. Fine particles, however, move toward the center of the classification chamber and are discharged into bags, cyclones, drums or collectors.

Variations

Liners are available in urethane, stainless, nylon, PTFE and tungsten carbide. The liners are removable and interchangeable depending on the material being ground. The P and O jets can be easily positioned to increase or decrease impact. The ID of the P and O tubes can likewise be varied to control the impact and hence particle size.

[Return to Trost Pulverizers] [Go to Physical Data Chart] [Go to Coating Compounds/Test Grinds]

GARLOCK

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Newton, PA 18940
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Fax: 215-968-7640



Trost Pulverizers (Cont'd)

Coating And Compounds

Encapsulating of particles is possible by injection of coating material into the feed. All particles are coated while reduced. Because of the unique flow pattern by the TROST design, an intimate mix is attained.

Plastic and other powders can be compounded with the TROST Pulverizer. Materials can be preblended or fed simultaneously for continuous compounding.

Test Grinds

We will test brind your material for a nominal fee which is fully applicable to the purchase price of a mill. Tests provide data on feed rates, SCFM, equipment design modifications and product evaluation. Preliminary testing is recommended, for it insures the purchase of requipment which will do the job.

[Return to Trost Pulverizers] [Go to How It Works/Variations] [Go to Physical Data Chart]





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Newton, PA 18940
Phone: 215-968-5011
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[redacted]

Physical Data Chart

MODEL	DIMENSIONS	FEED	CAPACITY	POWER
GEM T	4 3/4" high x 3 1/2" wide x 20 Packaged unit 15" x 12" x 15	mesh or finer	Up to 1,000 grams per hr.	Approx. 6.5 SCFM compressed to 100 PSIG
TX	12 1/2" x high x 9" x 2" Sta10 20" x 28" x 34" high Packaged unit 20" x 28" x 46"	mesh or finer	1/2 lb. to 50 lb. per hour 1 to 10 lbs. average	20 SCFM compressed to 100 PSIG
T-15	34" high x 19" x 3" Packaged unit 69" x 24" x 36	1/8" or finer	1 to 250 lbs. per hour 10 to 50 lbs. average	60, 80 and 100 SCFM compressed to 100 PSIG
T-30	40" high x 31" wide, 10 base	5/16" or finer	50 to 600 lbs. per hour	400 SCFM compressed to 100 PSIG
T-60	72" high, 48" wide, 12" base	5/8" or finer	100 to 5,000 lbs. per hour	600 to 1,000 SCFM compressed to 100 PSIG

WARNING: Installations/applications shown throughout this brochure are typical. Your specific installation/application should not be undertaken without independent study and evaluation for suitability. Failure to select the proper system or to ignore warnings on the MSDS (material safety data sheet) for the product being milled, could result in property damage and or serious injury.

Performance data published in this brochure has been developed from "in-house" testing.

[Return to Trost Pulverizers] [Go to How It Works/Variations] [Go to Coating Compounds/Test Grinds]

[redacted]

[redacted]

800-618-4670

Attachment 6
Calcine & Frit Settling Velocities

Calcine & Frit Settling Velocities
Revised To Use Fitted Cd Formula.
Newtonian results give precise velocities.

		Newtonian Terminal Velocity (homogeneous limit, v < 10 ft/min)								Stoke's Law Terminal Velocity (R < 15)							
Particle Diameter		Calcine				Frit				Calcine				Frit			
(microns)	(feet)	(ft/sec)	R	Cd	(ft/min)	(ft/sec)	R	Cd	(ft/min)	(ft/sec)	R	Cd	(ft/min)	(ft/sec)	R	Cd	(ft/min)
1	3.28E-06	2.03E-05	6.19E-06	1.36E+05	1.22E-03	5.69E-05	1.73E-05	6.53E+04	3.41E-03	7.15E-07	2.18E-07	1.50E+06	4.29E-05	2.68E-06	8.16E-07	5.81E+05	1.61E-04
5	1.64E-05	1.74E-04	2.66E-04	9.25E+03	1.05E-02	4.89E-04	7.44E-04	4.43E+03	2.93E-02	1.79E-05	2.72E-05	4.73E+04	1.07E-03	6.70E-05	1.02E-04	1.84E+04	4.02E-03
10	3.28E-05	4.40E-04	1.34E-03	2.90E+03	2.64E-02	1.23E-03	3.75E-03	1.39E+03	7.39E-02	7.15E-05	2.18E-04	1.07E+04	4.29E-03	2.68E-04	8.16E-04	4.14E+03	1.61E-02
20	6.56E-05	1.11E-03	3.77E-03	9.12E+02	8.87E-02	3.11E-03	1.90E-02	4.38E+02	2.48E-01	2.86E-04	1.74E-03	2.41E+03	1.72E-02	1.07E-03	6.53E-03	9.35E+02	6.43E-02
30	9.84E-05	1.91E-03	5.75E-03	4.83E+02	1.16E-01	5.36E-03	4.09E-02	2.22E+02	3.21E-01	6.43E-04	5.88E-03	1.01E+03	3.86E-02	2.41E-03	2.20E-02	3.92E+02	1.45E-01
40	1.31E-04	2.71E-03	7.92E-03	2.66E+02	1.68E-01	7.65E-03	9.57E-02	1.37E+02	4.71E-01	1.14E-03	1.39E-02	5.44E+02	6.86E-02	4.29E-03	5.23E-02	2.11E+02	2.57E-01
50	1.64E-04	3.78E-03	9.76E-03	1.87E+02	2.27E-01	1.06E-02	1.81E-01	9.43E+01	6.35E-01	1.79E-03	2.72E-02	3.37E+02	1.07E-01	6.70E-03	1.02E-01	1.31E+02	4.02E-01
60	1.97E-04	4.82E-03	1.19E-02	1.44E+02	2.89E-01	1.35E-02	2.47E-01	6.90E+01	8.10E-01	2.57E-03	4.70E-02	2.28E+02	1.54E-01	9.65E-03	1.76E-01	8.84E+01	5.79E-01
70	2.30E-04	5.92E-03	1.46E-02	1.12E+02	3.55E-01	1.66E-02	3.54E-01	5.39E+01	9.95E-01	3.50E-03	7.47E-02	1.64E+02	2.10E-01	1.31E-02	2.80E-01	6.35E+01	7.88E-01
80	2.62E-04	7.08E-03	1.73E-02	8.99E+01	4.25E-01	1.98E-02	4.69E-01	4.30E+01	1.19E+00	4.57E-03	1.11E-01	1.23E+02	2.74E-01	1.72E-02	4.18E-01	4.77E+01	1.03E+00
90	2.95E-04	8.29E-03	2.27E-02	7.33E+01	4.97E-01	2.32E-02	5.96E-01	3.53E+01	1.39E+00	5.79E-03	1.59E-01	9.54E+01	3.47E-01	2.17E-02	5.95E-01	3.70E+01	1.30E+00
100	3.28E-04	9.54E-03	2.81E-02	6.16E+01	5.72E-01	2.67E-02	8.14E-01	2.96E+01	1.60E+00	7.15E-03	2.18E-01	7.61E+01	4.29E-01	2.68E-02	8.16E-01	2.95E+01	1.61E+00
110	3.61E-04	1.08E-02	3.83E-02	5.27E+01	6.50E-01	3.03E-02	1.02E+00	2.52E+01	1.82E+00	8.65E-03	2.90E-01	6.20E+01	5.19E-01	3.24E-02	1.00E+00	2.41E+01	1.95E+00
120	3.94E-04	1.22E-02	4.48E-01	4.56E+01	7.30E-01	3.41E-02	1.25E+00	2.18E+01	2.04E+00	1.03E-02	3.76E-01	5.14E+01	6.17E-01	3.84E-02	1.41E+00	2.00E+01	2.32E+00
130	4.27E-04	1.36E-02	5.36E-01	3.99E+01	8.13E-01	3.79E-02	1.50E+00	1.91E+01	2.27E+00	1.21E-02	4.78E-01	4.33E+01	7.25E-01	4.53E-02	1.78E+00	1.68E+01	2.72E+00
140	4.59E-04	1.50E-02	6.38E-01	3.52E+01	8.97E-01	4.19E-02	1.79E+00	1.69E+01	2.51E+00	1.40E-02	5.97E-01	3.69E+01	8.40E-01	5.28E-02	2.24E+00	1.43E+01	3.16E+00
150	4.92E-04	1.64E-02	7.49E-01	3.14E+01	9.84E-01	4.59E-02	2.10E+00	1.50E+01	2.75E+00	1.61E-02	7.35E-01	3.18E+01	9.65E-01	6.03E-02	2.76E+00	1.24E+01	3.62E+00
160	5.25E-04	1.79E-02	8.71E-01	2.82E+01	1.07E+00	5.00E-02	2.44E+00	1.35E+01	3.00E+00	1.86E-02	8.92E-01	2.77E+01	1.10E+00	6.80E-02	3.34E+00	1.09E+01	4.12E+00
170	5.58E-04	1.94E-02	1.00E+00	2.55E+01	1.16E+00	5.42E-02	2.81E+00	1.22E+01	3.25E+00	2.07E-02	1.07E+00	2.43E+01	1.24E+00	7.75E-02	4.01E+00	9.45E+00	4.68E+00
180	5.91E-04	2.09E-02	1.15E+00	2.32E+01	1.26E+00	5.86E-02	3.21E+00	1.11E+01	3.51E+00	2.32E-02	1.27E+00	2.15E+01	1.39E+00	8.68E-02	4.76E+00	8.36E+00	5.31E+00
190	6.23E-04	2.25E-02	1.30E+00	2.12E+01	1.35E+00	6.29E-02	3.64E+00	1.01E+01	3.78E+00	2.58E-02	1.49E+00	1.92E+01	1.55E+00	9.67E-02	5.60E+00	7.44E+00	5.86E+00
200	6.56E-04	2.41E-02	1.47E+00	1.94E+01	1.45E+00	6.74E-02	4.11E+00	9.29E+00	4.04E+00	2.86E-02	1.74E+00	1.72E+01	1.72E+00	1.07E-01	6.53E+00	6.67E+00	6.43E+00
210	6.89E-04	2.57E-02	1.64E+00	1.79E+01	1.54E+00	7.19E-02	4.60E+00	8.57E+00	4.32E+00	3.16E-02	2.02E+00	1.56E+01	1.89E+00	1.18E-01	7.56E+00	6.00E+00	7.09E+00
220	7.22E-04	2.74E-02	1.83E+00	1.66E+01	1.64E+00	7.66E-02	5.13E+00	7.92E+00	4.59E+00	3.46E-02	2.32E+00	1.40E+01	2.08E+00	1.30E-01	8.69E+00	5.42E+00	7.76E+00
230	7.55E-04	2.90E-02	2.03E+00	1.54E+01	1.74E+00	8.12E-02	5.69E+00	7.36E+00	4.87E+00	3.78E-02	2.65E+00	1.27E+01	2.27E+00	1.42E-01	9.93E+00	4.94E+00	8.51E+00
240	7.87E-04	3.07E-02	2.25E+00	1.43E+01	1.84E+00	8.60E-02	6.29E+00	6.85E+00	5.16E+00	4.12E-02	3.01E+00	1.16E+01	2.47E+00	1.54E-01	1.13E+01	4.51E+00	9.26E+00
250	8.20E-04	3.24E-02	2.47E+00	1.34E+01	1.95E+00	9.08E-02	6.92E+00	6.40E+00	5.45E+00	4.47E-02	3.40E+00	1.06E+01	2.68E+00	1.67E-01	1.26E+01	4.13E+00	1.00E+01
260	8.53E-04	3.42E-02	2.71E+00	1.25E+01	2.05E+00	9.57E-02	7.58E+00	5.99E+00	5.74E+00	4.83E-02	3.83E+00	9.78E+00	2.90E+00	1.81E-01	1.44E+01	3.80E+00	1.09E+01
270	8.86E-04	3.60E-02	2.96E+00	1.18E+01	2.16E+00	1.01E-01	8.28E+00	5.63E+00	6.04E+00	5.21E-02	4.29E+00	9.02E+00	3.13E+00	1.95E-01	1.61E+01	3.50E+00	1.17E+01
280	9.19E-04	3.78E-02	3.22E+00	1.11E+01	2.27E+00	1.06E-01	9.01E+00	5.30E+00	6.34E+00	5.60E-02	4.73E+00	8.34E+00	3.36E+00	2.10E-01	1.79E+01	3.24E+00	1.26E+01
290	9.51E-04	3.96E-02	3.50E+00	1.04E+01	2.37E+00	1.11E-01	9.78E+00	4.99E+00	6.64E+00	6.01E-02	5.21E+00	7.73E+00	3.61E+00	2.25E-01	1.98E+01	3.00E+00	1.36E+01
300	9.84E-04	4.14E-02	3.78E+00	9.86E+00	2.48E+00	1.16E-01	1.06E+01	4.72E+00	6.95E+00	6.43E-02	5.68E+00	7.19E+00	3.86E+00	2.41E-01	2.20E+01	2.79E+00	1.45E+01
310	1.02E-03	4.32E-02	4.08E+00	9.33E+00	2.59E+00	1.21E-01	1.14E+01	4.47E+00	7.26E+00	6.87E-02	6.49E+00	6.70E+00	4.12E+00	2.58E-01	2.43E+01	2.60E+00	1.55E+01
320	1.05E-03	4.51E-02	4.40E+00	8.85E+00	2.71E+00	1.26E-01	1.23E+01	4.24E+00	7.58E+00	7.32E-02	7.13E+00	6.26E+00	4.39E+00	2.74E-01	2.68E+01	2.43E+00	1.65E+01
330	1.08E-03	4.70E-02	4.73E+00	8.40E+00	2.82E+00	1.32E-01	1.32E+01	4.02E+00	7.90E+00	7.78E-02	7.82E+00	5.86E+00	4.67E+00	2.92E-01	2.93E+01	2.28E+00	1.76E+01
340	1.12E-03	4.89E-02	5.07E+00	8.00E+00	2.94E+00	1.37E-01	1.42E+01	3.83E+00	8.22E+00	8.26E-02	8.58E+00	5.50E+00	4.96E+00	3.10E-01	3.21E+01	2.12E+00	1.86E+01
350	1.15E-03	5.09E-02	5.42E+00	7.62E+00	3.05E+00	1.42E-01	1.52E+01	3.65E+00	8.54E+00	8.76E-02	9.34E+00	5.16E+00	5.26E+00	3.28E-01	3.50E+01	2.01E+00	1.97E+01
360	1.18E-03	5.28E-02	5.79E+00	7.27E+00	3.17E+00	1.48E-01	1.62E+01	3.48E+00	8.87E+00	9.26E-02	1.02E+01	4.86E+00	5.56E+00	3.47E-01	3.81E+01	1.89E+00	2.08E+01
370	1.21E-03	5.48E-02	6.18E+00	6.94E+00	3.29E+00	1.53E-01	1.73E+01	3.32E+00	9.20E+00	9.78E-02	1.10E+01	4.58E+00	5.87E+00	3.67E-01	4.14E+01	1.78E+00	2.20E+01
380	1.25E-03	5.68E-02	6.57E+00	6.64E+00	3.41E+00	1.59E-01	1.84E+01	3.18E+00	9.53E+00	1.03E-01	1.16E+01	4.33E+00	6.19E+00	3.87E-01	4.48E+01	1.68E+00	2.32E+01
390	1.28E-03	5.88E-02	6.98E+00	6.36E+00	3.53E+00	1.64E-01	1.95E+01	3.04E+00	9.87E+00	1.09E-01	1.29E+01	4.09E+00	6.52E+00	4.08E-01	4.84E+01	1.59E+00	2.45E+01
400	1.31E-03	6.08E-02	7.41E+00	6.09E+00	3.65E+00	1.70E-01	2.07E+01	2.92E+00	1.02E+01	1.14E-01	1.39E+01	3.88E+00	6.86E+00	4.29E-01	5.23E+01	1.51E+00	2.57E+01
410	1.35E-03	6.28E-02	7.85E+00	5.85E+00	3.77E+00	1.76E-01	2.20E+01	2.80E+00	1.06E+01	1.20E-01	1.50E+01	3.68E+00	7.21E+00	4.51E-01	5.63E+01	1.43E+00	2.70E+01
420	1.38E-03	6.49E-02	8.30E+00	5.62E+00	3.89E+00	1.82E-01	2.32E+01	2.69E+00	1.09E+01	1.28E-01	1.61E+01	3.49E+00	7.58E+00	4.73E-01	6.05E+01	1.36E+00	2.84E+01
430	1.41E-03	6.70E-02	8.77E+00	5.40E+00	4.02E+00	1.87E-01	2.46E+01	2.58E+00	1.12E+01	1.32E-01	1.73E+01	3.32E+00	7.93E+00	4.96E-01	6.48E+01	1.29E+00	2.97E+01
440	1.44E-03	6.90E-02	9.26E+00	5.20E+00	4.14E+00	1.93E-01	2.59E+01	2.49E+00	1.16E+01	1.36E-01	1.85E+01	3.16E+00	8.30E+00	5.19E-01	6.90E+01	1.22E+00	3.11E+01
450	1.48E-03	7.12E-02	9.76E+00	5.00E+00	4.27E+00	1.99E-01	2.73E+01	2.40E+00	1.19E+01	1.45E-01	1.98E+01	3.01E+00	8.68E+00	5.43E-01	7.34E+01	1.17E+00	3.26E+01
460	1.51E-03	7.33E-02	1.03E+01	4.82E+00	4.40E+00	2.06E-01	2.87E+01	2.31E+00	1.23E+01	1.51E-01	2.12E+01	2.87E+00	9.07E+00	5.67E-01	7.80E+01	1.12E+00	3.40E+01
470	1.54E-03	7.54E-02	1.08E+01	4.65E+00	4.52E+00	2.11E-01	3.02E+01	2.23E+00	1.27E+01	1.55E-01	2.26E+01	2.74E+00	9.47E+00	5.92E-01	8.26E+01	1.06E+00	3.56E+01
480	1.57E-03	7.76E-02	1.13E+01	4.49E+00	4.65E+00	2.17E-01	3.17E+01	2.15E+00	1.30E+01	1.65E-01	2.41E+01	2.62E+00	9.88E+00	6.17E-01	8.73E+01	1.02E+00	3.70E+01
490	1.61E-03	7.97E-02	1.19E+01	4.34E+00	4.78E+00	2.23E-01	3.33E+01	2.08E+00	1.34E+01	1.72E-01	2.56E+01	2.51E+00	1.03E+01	6.43E-01	9.61E+01	9.74E-01	3.86E+01
500	1.64E-03	8.19E-02	1.25E+01	4.20E+00	4.91E+00	2.29E-01	3.49E+01	2.01E+00	1.38E+01	1.79E-01	2.72E+01	2.40E+00	1.07E+01	6.70E-01	1.02E+02	9.32E-01	4.02E+01

Attachment 7
Drag Coefficient for Bodies of Revolution

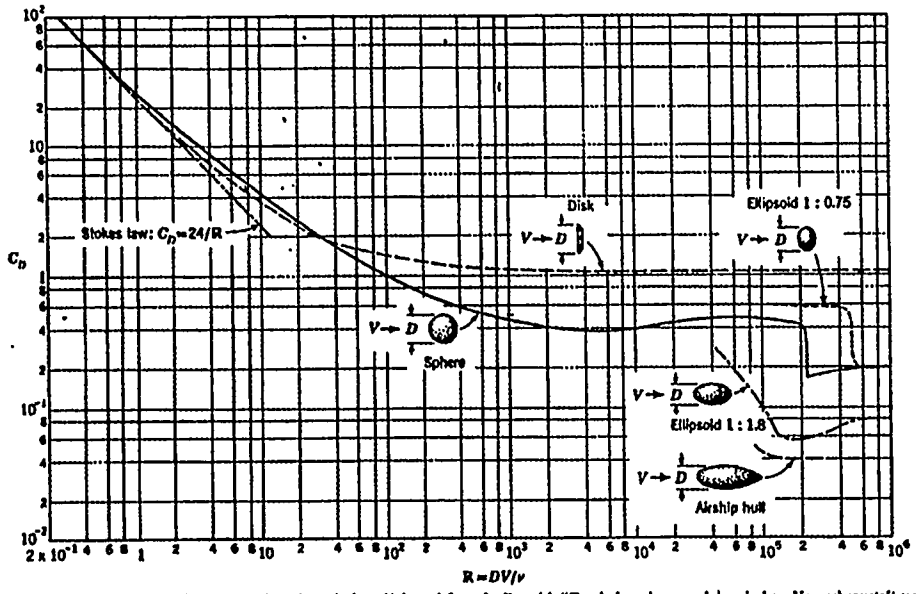


Figure 10.10 Drag coefficient for bodies of revolution. (Adapted from L. Prandtl, "Ergebnisse der aerodynamischen Versuchsanstalt zu Göttingen," p. 29, R. Oldenbourg, Munich and Berlin, 1923; and F. Eisner, "Das Widerstandsproblem," *Proc. 3d Internatn. Congr. Appl. Mech., p. 32, 1930.*)

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High Level Waste

3. Subtask High Level Waste Vitrification Facility

4. Title: Induction Melting

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

The purpose of this document is to describe the features of induction heated glass furnaces and compare them to the joule heated melters currently used for processing radioactive waste in the Department of Energy (DOE) complex.

DOE's are all based on the joule heated design. In this type of melter, electrodes are mounted directly inside the refractory-lined vessel, and a current is applied. In contrast, the French and Russians favor glass melters heated by induction. Such units are much smaller than typical joule heated melters, have lower glass production capacities, and are simpler in design and construction.

For the past 20 years, the French have used an unlined induction melter design to treat high level radioactive waste at their fuel reprocessing facilities. These "hot wall" units are small (55 centimeters in diameter), and they can produce only about 30 kg per hour of glass. At this production rate, the High Level Waste Vitrification Facility (HVF) would need to operate 9 melters in parallel. Finally, "hot wall" induction melters have a very limited operating life of 4,000 – 6,000 hours, due to the corrosivity of molten glass and the high operating temperature required (1,150°C).

The cold crucible induction melter design has the potential to overcome the limitations of the "hot wall" design while maintaining the cost and simplicity advantages. The French are beginning development work on cold crucible melters with capacities around 230 kg/hr. In addition, the cold crucible design makes its own refractory liner by freezing a thin layer of feed material next to the vessel wall. Therefore, operating life could be substantially increased.

The cold crucible development work has been on-going for more than 10 years. However, this design has not been yet been employed in the production facilities at La Hague and Marcoule, France. For this reason, the cold crucible induction melter design is considered less mature than the joule-heated melter design.

6. Distribution (complete package): D. J. Harrell, MS 3211, B.R. Helm MS3675, V.L. Jacobson MS 3211, M.S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only): J. McCarthy

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author R. R. Kimmitt	R	R. R. Kimmitt	R. R. Kimmitt	3/11/99
Independent Verification J. J. Quigley	R	J. J. Quigley	J J Quigley	3-11-99
Requestor D.A. Lopez	A	D. A. Lopez	D A Lopez	3/20/99

Induction Melting

1. Introduction

This paper describes the basic features of induction heated glass melters. The French have used induction melters at their nuclear fuel reprocessing facilities for more than two decades. However, DOE has chosen to use joule heated melters for processing radioactive waste in the United States. The design and operation of these two types of melters differ significantly. This paper also compares DOE's melters to the European designs.

2. Basics of Induction Heating

Induction heating has been used in the metal forming industry for decades. The main advantage of this method is the rapid rate of heating achievable. In addition, there are no physical connections between the piece being heated and the electric power supply. This speeds up the rate at which parts can be moved through the heater.

Induction heating has also been adapted for use in glass making. In this process electric coils carrying a high frequency alternating current are coiled around the container holding the glass. The current creates a fluctuating magnetic field within the glass, and this, in turn, generates a secondary current that actually heats the glass. Because the magnetic field is much stronger near the container wall than closer to the center of the container, the induced current is strongest near the container wall. This heats the glass near the walls more than the glass in the center. The lack of uniform heating sets up convective flow of glass that aids both mixing of components and overall heat transfer.

Special high frequency power supplies are required for induction melters. The French employ frequencies of 150 – 500 kHz for their glass melters at Marcoule and La Hague.[1] The "penetration depth" of the induced current is inversely proportional to the frequency of the current applied. For this reason, heating occurs primarily near the vessel wall. This phenomenon enhances mixing by natural convection, but it also limits the size of practical melter designs.

3. Two Types of Induction Melters

General
Induction melters have been used in Europe for processing high level radioactive waste for at least 20 years. The units are typically small with low production capacities. The French currently have production scale vitrification facilities at Marcoule and La Hague. The melters at Marcoule are cylindrical vessels with a diameter of 55 centimeters and a depth of about 70 centimeters. Output from each melter is around 1600 pounds of glass per day. The units at La Hague are oval in shape and have essentially the same capacity as those at Marcoule. Cogema is developing larger models, up to 1.2 meters in diameter; however, these units have not been placed in production yet.

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[1] Numatec, Inc., "ICPP Radioactive Waste HLW Immobilization Treatment Technologies – Numatec Comments and Recommendations, January, 1995, Section 2

"Hot Wall" Design

The French production melters incorporate a "hot wall" design. The molten glass is in direct contact with the high nickel alloy container. This limits the operating temperatures to about 1150 °C. Higher temperatures would result in deformation of the containers. This limits the melters to feed materials with relatively low concentrations of refractory oxides, such as alumina and zirconia.

Although the throughput of the French induction melter design is relatively low, it is high for its size. A typical joule-heated glass melter can produce 0.4 – 1.0 tons/day of glass for each square meter of melt cross-sectional area[2]. The French induction melter produces just over 3 tons/day-m^2.

In addition to the temperature limitation imposed by the "hot wall' design, the production melters in France have a very limited operating lifetime. They must often be removed from service after only 4,000 hours of operation. This is due to the highly corrosive nature of molten glass. This situation cannot be remedied by the addition of refractory lining, as is used in the joule-heated melters. The refractory would interfere with the generation of the induced current. The cold crucible melter design has the advantage of long operating life since the corrosive molten glass is not in direct contact with the metal vessel. In addition , the cold crucible vessel is kept much cooler than the hot wall vessel (<100°C vs. 1100°C).

Cold Crucible Design

To address the limitations of the "hot wall" design, the French and the Russians have both developed cold crucible induction melters. This design replaces the solid metal can with a vessel composed of tightly packed, water-jacketed ribs. Small spaces between the ribs allow the magnetic field to penetrate into the melt. The cooling water causes a thin layer of glass to freeze around the wall of the melter. The Russians have small cold crucible melters in operation at some of their research facilities (Khlopin Radium Institute and the Moscow Scientific and Industrial Association)[3].

Cogema in France has operated pilot-scale cold crucible melters for that last 10 years. The units tested range in size from 10 cm to 55 cm in diameter. The largest melter produces about 50 kg/hr (1.3 short tons per day) of product glass. Temperatures as high as 1,400 °C have been achieved[4]. Some recent work has been done with units as large as 1.2 meters in diameter.

With a water jacket carrying heat away from the melter, cold crucible units are far less energy efficient than the joule-heated, ceramic-lined alternatives. Whereas a joule heated unit requires about 1,000 kwh per ton of glass produced, the cold crucible design requires about 2,500 kwh for the same amount of glass.[5]

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[2] Envitco, Inc., Waste Vitrification Training Program, presented initially to Parsons Power, Inc., 1995, p. IX-20.
[3] Knecht, D.A., "Foreign Trip Report: October 11-25, 1996, Trip to St. Petersburg and Moscow, Russia, Sponsored by the Plutonium Focus Area", DOE/ID-10563(97)
[4] Letter, G.E. Stegan to C.A. Musick, "Induction Melter Technology Evaluation and Selection Information", 8/1/97
[5] FAX from Mr. Jouan of CEA (France) to Phyllis Shafer of PNL, 8/11/94

4. Peripheral Equipment

A source of auxiliary heat is needed for electrically powered glass melters. Glass does not conduct electricity well until it is molten. The frit and waste mixture must be heated by another method until it is molten and can conduct the induced electrical current. In DOE's existing joule heated melters, either propane or separate electric resistance heat is provided. These are used in the head space above the glass forming material. The French use microwave energy supplied by external equipment and delivered to the melter by a wave guide.

Mixing is important in glass melters. It results in better heat transfer and higher glass production rates. The French have tested both gas sparging (air or argon) and mechanical agitation systems to increase capacity.

Cold crucible melters are cooled by water flowing through coils. Significant thermal losses are incurred in this design. French work to date shows that around 60% of the energy applied to the melter is not transmitted to the melt (Reference 1). The cooling water stays below the boiling point, and feed material close the vessel wall does not melt. However, the thickness of the "frozen" material at the vessel wall is only a few millimeters[6]. Consequently, there is relatively little resistance to heat transfer, and much of the energy applied to the system is lost.

The French induction melter design includes an internal standpipe used for routine draining of glass. The standpipe assures that a small amount of molten glass remains in the vessel to conduct electricity and facilitate melting of the next batch. A bottom drain is also provided for use when the vessel is taken out of service for repair or replacement.

5. Operating Capacity

The hot wall induction melters currently in use in France have limited capacity. Capacity in cold crucible melters is higher, particularly if higher temperatures are employed. The table below shows glass production rates reported for some of the French melters induction melters.

Parameter	Cold Crucible	Hot Wall
Diameter , cm	55	55
Capacity, kg/hr	50	30
Temperature, °C	1350	1150

Reported capacity is significantly higher for larger units. For example, a 1.2 meter (diameter) cold crucible melter has produced 230 kg/hour of glass at 1,350°C.[7] At this rate, the processing of calcine into glass on a 20 –year schedule could be achieved with only two such melters[8].

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[6] Combret, C.G., "The Cold Crucible Glass Melter", presented at the Savannah River Center, 5/10-11/93
[7] Stegan, G. E., "Induction Melter Technology Evaluation and Selection Information and References", August, 1997.
[8] Lopez, D.A. and R. R. Kimmitt, "Vitrified Waste Option Study Report", November, 1997

6. Feed Equipment

As with joule-heated melters, induction melters can process both dry material and water slurries. However, there is a significant capacity penalty when slurries are fed to induction melters. The glass generation rate can be cut to half that obtainable with dry feed. The French feed their melters dry material directly from a calciner. In the HVF design, the feed slurry is spray dried prior to vitrification. The waste is prepared as a slurry to facilitate characterization and certification. It is then dried to allow maximum melter throughput. Cogema has recently suggested that dry mixing of frit and calcine is feasible for feed certification with appropriate development work[9]. At both Marcoule and La Hague the frit and the calcine are added separately to the melter. Mixing is sufficiently vigorous that acceptable product glass is made, even though the ingredients are not intimately mixed before they are fed to the melter.

7. Decommissioning and Equipment Replacement

Possibly the greatest advantage of cold crucible induction melters over joule heated melters is the ease with which the units can be taken out of service and prepared for disposal. The joule heated units used by DOE are typically two-stories tall, ten to twenty feet in diameter, and lined with refractory brick. Electrodes used for heating are integral with the melter. These factors make melter removal from the vitrification facilities a serious technical challenge. In addition, these units are highly radioactive, making dismantlement an even bigger problem.

By contrast, a cold crucible induction melter is no more than three or four feet in diameter, four or five feet tall, and has almost no internal components. There is no refractory material, since the cold crucible makes its own corrosion-resistent liner from the feed. The power supply is not in physical contact with the melter vessel, and this simplifies disassembly. The frozen feed material can easily be removed and fed back into the process, reducing the amount of waste material generated during decontamination.

8. Conclusion

The current feasibility study has been based on the use of induction melters rather than the joule heated designs in current use in the DOE complex. The cold crucible design offers several potential advantages over joule heated melters. Chief among these are lower capital cost and lower cost for decontamination and disposal of failed equipment. The disadvantages include relatively lower throughput compared to joule heated melters, and the lack of maturity of the technology. The cold crucible concept has been studied for years by the French and the Russians. However, the French production facilities still employ the hot wall induction melter design. Substantial development work would be needed to verify the suitability of cold crucible induction melting for treatment of INEEL calcine and liquid waste.

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[9] Letter, S. Ashworth to J. Valentine, "Idaho HLW & FD EIS Alternatives, Direct Vitrification Option", dated 1/5/99

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Fifteen Foot (15 ft) Canister Evaluation

5. Summary: The following discussion presents a study to determine if a 15-ft canister is a technical and economical alternative to the currently proposed 10-ft canister.

In the High Level Waste Vitrification Facility (HVF) it is currently planned to utilize 10-ft long stainless steel canisters for disposal of high level vitrified waste. The purpose of this EDF is to investigate the benefits and impacts of using 15-ft long stainless steel canisters for the same purpose. The 15-ft long canister has been proposed for Hanford processes and is technically acceptable to DOE[1]. The results of this EDF provide an initial investigation into the feasibility of 15-ft canisters and an order of magnitude cost comparison to that for 10-ft. canisters.

With the limited resources available for this EDF, the process for this study was to obtain recent documentation addressing a similar issue at the DOE Hanford site and develop a parametric comparison to the INEEL. Costs contained in this EDF are order of magnitude and are only suitable for preliminary decisions. A more detailed investigation will be required with future conceptual design efforts.

Conclusion:

The 15-ft canister appears to be a technically and economically feasible alternative to the 10-ft canister. Order of magnitude estimates indicate that the changing to 15-ft canisters results in a total cost savings, to the project, of approximately $655,870,000.00. There are operating efficiencies and potential operation cost improvements which have not been included in this EDF. Operating efficiencies include handling and welding fewer canisters; additionally, modification to incorporate the 15-ft canister and associated transportation and overpack equipment may have cost improvements through co-disposal efforts in conjunction with the national Spent Nuclear Fuel programs.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

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Independent Verification	R			3/16/99
Requestor	A	D. A. Lopez	D. A. Lopez	3/20/99

References (Attached)

1. Letter from J. 0. Honeyman of Westinghouse Hanford to W. J. Taylor of DOE Richland "Proposed Standard Canister for Tank Waste Remediation System High Level Waste Disposal", August 1, 1996.

2. Dept. of Energy Memorandum, Ronald A. Milner to Jackson Kinzer "Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement", July 6, 1996.

3. Report, Gary E. Stegen, "INEL High Level Waste Program Impacts Related To Disposal Fees and Ability of Repository To Accept Waste" SGN Eurisys Services Corporation, EN-RPT-001", June 1997.

4. Interdepartmental Communication D. R. James to E. C. Anderson "Vitrification Facility ", DRJ-08-98, July 20, 1998.

5. Engineering Design File, EDF-HVF-F-002, R. R. Kimmitt, "High Level Waste Vitrification Facility Process Calculations", March 11, 1999.

6. Personal communication, Dennis M. Kiser and R. R. Kimmitt, 3/16/99, and the attached spreadsheet entitled "Estimated Volumes of Vitrified Calcine and Newly Generated Liquid Waste".

Discussion

For the High Level Waste Vitrification Facility (HVF) process, it is currently planned to utilize 10-ft long canisters for disposal of vitrified waste. Within the last two years Westinghouse Hanford Disposal Programs Office (Hanford Site) and the Dept. of Energy Richland Operations Office have undergone investigation of canister options for Hanford's Tank Waste Remediation System High Level Waste Disposal. Reference 1 above is a confirmation letter to DOE Richland Operations that a 15 ft canister would be technically acceptable for vitrified high level waste, if the canister characteristics were similar to those for canisters developed for the Savannah River Site Defense Waste Processing Facility (DWPF). Reference 1 provides a basic description of the proposed canister. In general, the purpose of the investigation of Reference 1 was to develop a larger volume canister with dimensional characteristics consistent with current national high level waste disposal operations and storage. The volume of the 15-ft canister is 1.5 times that of the 10-ft canister.

In support of the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement, the DOE Office of Civilian Radioactive Waste Management developed disposal fee estimates for four waste container alternatives including 10-ft and 15-ft canisters (Reference 2). The disposal fee estimates include development costs, transportation costs, and repository costs. For the overall TWRS, with a total estimated cost of approximately $35 billion, use of the 15-ft canister was approximately a 2% total cost improvement (approximately $600 million in 1994 dollars) over that for the 10-ft canister. The majority of the cost improvement is due to a reduced total transportation and disposal cost. Transportation costs are considered roughly equal for each shipment of either type of canister. However, since the 15-ft canisters are 50% larger in volume than the 10-ft canisters, then there will be a cost savings due to making 1.5 times fewer shipments.

Reference 3 is a report which attempts to reconcile the various potential costing methodologies from Reference 2 to establish an order of magnitude "per canister" cost for the Hanford 10 ft and 15 ft canisters. The resulting transportation and disposal costs for Hanford high level vitrified waste are $330,000.00 for a 10-ft canister and $422,000.00 for a 15-ft canister. It is assumed that development costs for the 15-ft canister will only impact the Hanford development costs and will not impact to the INEEL HVF costs.

INEEL Parametric Cost Comparison[4]

The process for this study was to obtain recent documentation addressing costs for 15-ft canisters for HLW at the DOE Hanford Site and develop a parametric comparison to the costs for 15-ft canisters for HLW at the INEEL. The primary impacts of utilizing 15-ft canisters, in the INEEL HVF process, compared to utilizing 10-ft canister are as follows:

- **Facilities:** The impact to the current HVF floor plan and equipment is minor. The current building configuration and material handling systems include adequate clearance and capability to accommodate 15-ft canisters. Modifications necessary are to increase the clearance through the doorways from the canister staging room to the process area, from the process area to the loading and transfer tunnel, and from the loading and transfer tunnel to the Interim Storage Facility. Estimated costs for these modifications to the HVF design and facility are about $200,000.00[4].

- **Process:** The impact to the current HVF vitrification process is negligible. It is immaterial whether the canisters contain glass that is in one piece or not. The melters and other parts of the process still produce glass at the same rate as that for the 10-ft canister case and need only be utilized to fill the 15-ft canisters. The remaining capping, welding, decontamination, and decontamination smear processes are unaffected by the canister height.

- **Development:** As noted in the Discussion section, it is assumed that development costs for the 15-ft canister will only impact the Hanford development costs and will not impact to the INEEL HVF costs.

- **Transportation/Disposal:** As noted in the Discussion section, herein, and in Reference 3, the resulting transportation and disposal costs for Hanford high level vitrified waste are $330,000.00 for a 10-ft canister and $422,000.00 for a 15-ft canister. For the purpose of this EDF, the disposal costs discussed for the Hanford waste are assumed to be equivalent to those discussed for the INEEL waste.

The volume of glass produced in the current mass balance[5, 6] is based on a 25% loading for vitrification of calcine and a 50% loading of solids from newly generated liquid waste (NGLW). The volume of glass produced from calcine is 9,692 cubic meters and the volume of glass produced from NGLW is 12 cubic meters, as shown in Reference 6.

Canister Size	Volume Glass	Volume Canister	Quantity Canisters
10-ft	9704 m^3	0.72 m^3	13,478
15-ft	9704 m^3	1.08 m^3	8,985

The following table summarizes the cost comparison of HLW disposal with 10 ft. canisters and 15 ft canisters using Hanford's transportation/disposal cost estimate, per canister, and LMITCO's estimate of costs for modifying the HVF facility. These costs do not reflect operational savings for handling fewer canisters using the 15-ft design.

Canister	10-ft Canister (11,700 Canisters)	15-ft Canister (7,800 Canisters)
Vitrification Facility	Base	Minor Impact
Development	Base	Base
INEEL Storage/Tunnel	Base	$200,000.00[4]
Transportation/Disposal	$4,447,740,000.00	$3,791,670,000.00
TOTAL	$4,447,740,000.00	$3,791,870,000.00

The cost improvement for using 15-ft canisters is $655,870,000.00, un-escalated, and not including operating cost and canister procurement cost savings. This is a minor cost improvement of about 2.2% of the current total project cost estimate. However, there are operating efficiencies and potential operating cost improvements that have not been included in this EDF. Operating efficiencies include handling and welding fewer canisters. In addition, modification to the

process and facilities to incorporate the 15-ft canister and associated transportation and overpack equipment may have cost improvements through co-disposal efforts in conjunction with the National Spent Nuclear Fuel programs.

Reference 1

Proposed Standard Canister for Tank Waste Remediation System High Level Waste Disposal

United States Government Department of Energy

memorandum

DATE: JUL 01 1996

REPLY TO ATTN OF: RW-30

SUBJECT: Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS)

TO: Jackson Kinzer, Assistant Manager
Office of Tank Waste Remediation System

The Office of Civilian Radioactive Waste Management is pleased to transmit the information to address your request for disposal fee estimates to support the development of the Hanford TWRS EIS. This responds to your June 7, 1996, request for more rigorous cost estimates based on application of our Total System Life Cycle Cost (TSLCC) methodology. We have completed an analysis for the following four alternative scenarios and compared them against the 1995 TSLCC baseline:

1. Use of 23,000 "standard" canisters for the most probable quantity (14,260 m^3) of immobilized HLW for the reference "enhanced sludge wash" process.

2. Use of 12,200 "long" 0.61m D x 4.5m L canisters for the most probable quantity of Hanford HLW.

3. Use of 530 "long" canisters for 620 m^3 of HLW resulting from the "extensive separations" pretreatment process.

4. Use of 36,400 "very large" 1.68m D x 5.03m L canisters for 364,000 m^3 of HLW produced without any pretreatment.

Results of the analysis, including key assumptions, significant cost drivers, and limitations on the cost calculations, are provided in the attachment entitled "Cost Estimate Report on Disposal Costs for Tank Waste Remediation System Alternatives". It must be pointed out that the results presented are consistent with the assumptions documented in the 1995 TSLCC. In this regard, scenario 4 is so significantly outside the range of these assumptions that there may be other implications, beyond the large cost increase projected for disposal, which could affect our ability to license a repository or implement emplacement within the currently envisioned disposal system.

We appreciate the opportunity to assist you in the completion of the Hanford TWRS Final EIS. Please feel free to contact James Carlson of my staff at (202) 586-5321, if you have any questions regarding the report.

Ronald A. Milner

Ronald A. Milner, Director
Office of Program Management
and Integration
Office of Civilian Radioactive
Waste Management

Attachment

cc:
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D. Harrison, YMSCO
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D. Faust, TRW
C. Heath, TRW
D. Gibson, TRW
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Reference 2

Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement

WBS: 8.2.1
QA: N/A

Civilian Radioactive Waste Management System
Management & Operating Contractor

Cost Estimate Report on Disposal Costs for Tank Waste Remediation System Alternatives

June 28, 1996

WBS: 8.2.1
QA: N/A

Civilian Radioactive Waste Management System
Management & Operating Contractor

Cost Estimate Report on Disposal Costs for Tank Waste Remediation System Alternatives

June 28, 1996

Prepared for:

U.S. Department of Energy
Office of Civilian Radioactive Waste Management
1000 Independence Avenue SW.
Washington, DC 20585

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1. SUMMARY

This analysis was performed at the request of the Department of Energy Richland Operations Office to support analysis of alternatives for the TWRS as part of the development of the TWRS Environmental Impact Statement (reference 1, see Appendix A). Estimates of disposal costs were developed for four alternatives for the Hanford Tank Waste Remediation System (TWRS). Estimates of the total defense share of disposal costs were generated using a consistent methodology, as used by the Civilian Radioactive Waste Management Program in development of the Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program of September 1995 (95 TSLCC) (reference 2). Technical feasibility and the environmental effects of disposal are not within the scope of this study and are not addressed. Costs are presented in constant 1994 dollars to maintain consistency with the 95 TSLCC.

The 95 TSLCC base case and TWRS alternatives analyzed in this study are summarized in Table 1-1. The TSLCC assumed 9,860 standard canisters from Hanford would be disposed of in the repository. Scenario 1 would require disposal of 23,000 standard canisters from Hanford. Scenario 2 is based on the same volume of glass as Scenario 1, disposed of as 12,200 "long canisters" (4.5 meters in length versus 3.0 meters for the standard canisters). Scenario 3 assumes extensive separations resulting in less glass volume, to be disposed of as only 530 long canisters. Scenario 4 assumes 36,400 very large 10 cubic meter canisters are used to dispose of the very large volumes of vitrified waste which could result from a "no pretreatment" TWRS alternative.

Summary results are presented in Table 1-1. Each of four Hanford TWRS alternative scenarios are compared against the baseline assumed for the 95 TSLCC. Total Disposal Cost for the 95 TSLCC base case is $33.1 billion in constant 1994 dollars (94$s). The first three alternatives would result in a small variation in Total Disposal System Costs. Scenario 3 would save $0.5 billion (94$s) or 1.4 percent. Scenario 2 would increase Total Disposal System Costs by $1.4 billion (94$s) or 4.2 percent, and Scenario 1 would increase costs by $2.0 billion (94$s) or 6.0 percent. Scenario 4 would double the Total System Disposal Cost to over $66 billion (94$s) or 100 percent.

Scenario 1 has been identified by the TWRS program as the most likely current estimate of borosilicate glass canisters to be produced. Scenario 1 poses the disadvantage, from a disposal standpoint, of utilizing most available space between Spent Nuclear Fuel (SNF) waste packages. This could limit growth capacity to accept other wastes being considered for disposal, such as DOE SNF.

Scenario 4 is not a preferred alternative from a disposal standpoint. Scenario 4 would not only double the Total System Disposal Cost to over $66 billion (94$s), it would require approximately 35 additional years of geologic emplacement and extension of the planned disposal program completion from an assumed decommissioning in 2071 to 2102. Further, it would require characterization of additional area, suitability determination of the area, and associated licensing

Table 1-1 Repository Disposal Cost Evaluation Matrix

	Canister Size (OD x L)	Pretreatment Process	Volume of Glass, m^3	Number of Hanford Canister	Total No. of DHLW Canisters	Total Disposal Cost (94$s)	Allocated Defense Share (94$s)
Base Case (RW-0479)	0.61m x 3.0m	Enhanced Sludge Wash	6,100	9,860	18,046	$33.1B	$6.43B
Scenario #1 (most probable volume)	0.61m x 3.0m	Enhanced Sludge Wash	14,260	23,000	31,186	$35.1B	$10.3B
Scenario #2 (long canister)	0.61m x 4.50m	Enhanced Sludge Wash	14,260	12,200	20,386	$34.5B	$8.6B
Scenario #3 (minimum volume)	0.61m x 4.50m.	Extensive Separations	620	530	8,716	$32.6B	$4.0B[1]
Scenario #4 (very large canister)	1.68m x 5.03m	No Pretreatment	364,000	36,400	44,586	$66.2B[2]	$19.3B[2]

1 Share methodology understates defense share of unassigned costs due to extremely low piece counts. Actual share will be higher.
2 Scenario significantly in excess of repository planning basis. Requires assumptions which increase uncertainty of estimate. Scenario outside methodology validity for piece counts and disproportional waste package size.

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of a Hanford only section of the repository. A substantial portion of the Hanford wastes would require emplacement in the additional areas in a low thermal setting, following emplacement of some Hanford and all other HLW with all the available SNF in a high thermal setting in the primary area of the repository. This is in contrast to the 95 TSLCC assumption of emplacement of all HLW with SNF in the primary area in a high thermal loading setting. Excess quantities of Hanford HLW may exceed available areas in the repository. Disposition of remaining HLW would not be decided until DOE makes a recommendation on the need for a second repository.

The last column in Table 1-1 shows an estimate of the total defense share of each alternative. Estimates range from a reduction of $2.5 billion for Scenario 3 to an increase of $43 billion for Scenario 4. Estimates of defense share in Table 1-1 do not represent firm estimates of the full cost recovery for disposal of defense high level waste. The cost sharing allocation methodology was developed for a point estimate and design. Extreme case variations such as Scenario 3 and 4 fall outside the validity of the computational method. Differences between the cases appear to be exaggerated by the defense share allocation methodology bias.

2. SCOPE

This analysis was performed at the request of the Department of Energy Richland Operations Office to support analysis of alternatives for the TWRS as part of the development of the TWRS Environmental Impact Statement. The analysis was developed under an accelerated schedule, and of necessity provides scoping level detail, scaled from the detailed point estimate reported in the 95 TSLCC. It provides life cycle cost estimates for four alternative scenarios for disposal of vitrified high level waste (HLW) from Hanford. Scenarios vary HLW quantities and package sizes from the 95 TSLCC estimate basis. The scenarios and approach are described in Section 3. The analysis includes estimates for two new HLW waste packages, two new transportation casks, and estimates of changes to repository surface facilities, subsurface impacts, transportation, and other program costs.

Estimates of the total defense share, based on application of the 1987 Federal Register methodology, are provided in Section 4. Two cases, Scenarios 3 and 4, depart significantly from the base case. For these scenarios, quantitative estimates are provided, with qualitative discussion of impacts and limits of the analysis. Analyses are based on and consistent with the 1995 TSLCC.

A Hanford Multi-Purpose Canister (HMPC) is being considered by DOE for on-site storage at Hanford, followed by transportation to and disposal in a repository. An HMPC would be an overpack canister 4.65 meters in length by 1.61 meters outside diameter, sized to contain four of the long Hanford canisters of vitrified HLW such as those assumed for Scenarios 2 and 3 in this analysis. For transportation, each HMPC would be placed in a transportation overpack for shipment. At the repository, the unopened HMPC would be transferred to a disposal overpack, which, combined with the HMPC and its contents would comprise a four canister waste package. It is assumed that the HMPC would be licensed for storage, transportation, and disposal. The 95 TSLCC was not based on use of the HMPC. A qualitative discussion of the impacts of possible use of an HMPC is included.

3. APPROACH

3.1 TSLCC BASELINE

The 95 TSLCC forms the baseline for comparison of disposal costs for alternatives, and for estimation of the defense share for each alternative. The TSLCC assumes 9,860 standard canisters of HLW from Hanford are disposed of with 8,186 canisters of HLW from other DOE sites and the West Valley Demonstration Project, comingled with waste packages containing approximately 84,000 metric tons of Uranium (MTU) of commercial spent nuclear fuel (SNF). The 95 TSLCC does not include other wastes being considered for inclusion in the Civilian Radioactive Waste Management System (CRWMS), such as DOE SNF. The 95 TSLCC assumes disposal in a single repository, with the Yucca Mountain site in Nevada serving as a surrogate to allow estimation of total system life cycle costs. The Nuclear Waste Policy Act as Amended (NWPAA) (reference 3) establishes a 70,000 metric tons of heavy metal (MTHM) limit on a first repository, tied to opening of a second repository, and also specifies that the need for a second repository will be assessed between 2007 and 2010. This analysis assumes disposal in a single repository, consistent with the 95 TSLCC assumptions. Design concepts in the 95 TSLCC assume emplacement of waste packages, containing four HLW canisters each, in the spaces between SNF waste packages, in a spacial arrangement with a high thermal load. The 95 TSLCC assumptions were held constant, except as required for the scenarios. Costs reported in this analysis are reported in constant 1994 dollars to maintain consistency with the 95 TSLCC.

The 95 TSLCC baseline assumed use of Multi-Purpose Canisters (MPCs) for disposal of commercial SNF. HLW is assumed to be disposed of in waste packages containing four standard canisters each. Current Civilian Radioactive Waste Management System (CRWMS) planning does not assume MPCs for SNF and the TWRS program is planning use of HMPCs for HLW. This analysis maintains MPCs for SNF disposal, and shipment and disposal of individual HLW canisters in waste packages to maintain consistency with the 95 TSLCC. Future TSLCC reports will update the CRWMS baseline. A qualitative discussion of the impacts of an HMPC is provided in Section 4.

3.2 TWRS ALTERNATIVE SCENARIOS

Waste streams that minimized impact on repository capital costs were established for each alternative scenario. Delivery schedules were generated in discussion with the TWRS program to develop reasonable cases for evaluation of disposal costs without inordinate or unnecessary impact to the repository. Additional opportunity for optimization of total defense high level waste flows can result in capital cost reduction. Further improvement of waste stream flows was not possible within task schedule constraints. The schedules for emplacement of waste packages containing Hanford HLW are shown in Table 3-1.

Table 3-1 Waste Package Emplacement Schedule Assumptions for TWRS Alternative Scenarios

Year	All Scenarios	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Total Canisters Emplaced	Hanford WP's	Total Canisters Emplaced	Hanford WP's	Total Canisters Emplaced	Hanford WP's	Total Canisters Emplaced	Hanford WP's	Total Canisters Emplaced
2010									
2011									
2012									
2013									
2014									
2015									
2016									
2017									
2018		249		249		95		249	
2019		50		49		19		49	
2020		295		295		19		368	
2021		309		309				369	
2022		302		302				373	
2023		291		291				369	
2024		292		292				372	
2025		300		300				368	
2026		306		306				371	
2027		320		320				387	
2028		317		317				373	
2029		328		20				383	
2030		355						390	
2031		342						409	
2032		392						425	
2033		151						419	
2034		360						424	
2035		380						415	
2036		211						426	
2037								394	
2038								412	
2039								418	
2040								528	
2041								814	
2042								814	
2043								814	
2044								814	
2045								814	
2046								814	
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2064								814	
2065								814	
2066								814	
2067								814	
2068								814	
2069								814	
2070								814	
2071								814	
2072								814	
2073								814	
2074								814	
2075								28	
TOTAL	14,240	5,750	5,750	5,250	5,250	133	133	36,400	36,400

3.3 METHODOLOGY

3.3.1 Defense Share Methodology

The Nuclear Waste Policy Act as Amended requires full cost recovery from both defense and commercial users of the repository, with no cross-subsidization of program costs. Commercial SNF disposal costs are paid from receipts from a ratepayer fee charged on electricity generated and sold from nuclear power plants. Defense costs are paid from Defense Nuclear Waste Disposal appropriations. Costs are allocated among program participants according to a methodology published in the Federal Register (reference 4). This methodology has been applied to each case to estimate a total defense share for each scenario.

The methodology collects direct costs, allocates certain indirect costs based on piece count and areal dispersion factors, and then assigns remaining costs based on factors derived from relative direct and allocated costs. *Assignable direct costs* are incurred solely for the disposal of either HLW or SNF and are allocated in total to either the civilian program, defense program, or to West Valley. *Assignable common variable costs* are allocated among the civilian, defense, and West Valley programs by appropriately applying cost sharing factors, piece count, and areal dispersion to the specific individual cost accounts. *Common unassigned costs* are the remaining costs that cannot be either directly allocated or allocated on the basis of the cost sharing factors described above. Unassigned costs comprise a significant portion of the total system cost due to high development and evaluation costs compared to construction and operation.

The methodology was not developed to evaluate extreme variations from the base case such as the very low piece counts in Scenario 3 or the disproportionately large waste package sizes in Scenario 4. For these reasons, share allocation methodology may require modification if such alternatives are pursued, and respective cost shares may change as a result. This bias in methodology due to application of a method for a point estimate to a significant case variation tends to understate costs for Scenario 3, and may misrepresent costs for Scenario 4. A lesser degree of change also may be required for Scenario 2 to account for change in relative size of waste packages.

3.3.2 Mined Geologic Disposal System (MGDS) Cost Estimates

Analyses of Scenarios 1, 2, and 3 were able to maintain 95 TSLCC design assumptions for the repository thermal loading approach and emplacement of HLW waste packages in the space between hot SNF waste packages. Scenario 4 requires assumption of development of additional area(s) at the repository with a low thermal load setting which is dedicated to excess Hanford HLW. The HLW quantity exceeds the number of available openings in the high thermal load repository. Detailed engineering evaluations were not performed for this study. Waste package design verified sufficient corrosion allowances for the defense high level waste packages for

emplacement in a low thermal setting.

MGDS estimates were developed for each case using TSLCC models adjusted for changes in throughput capacity and additional underground excavation where required. Waste package dimensions and cost were developed consistent with the 95 TSLCC and 96 Advanced Conceptual Design bases. Repository estimates are based on the waste stream shown previously in Table 3-1, and are consistent with 95 TSLCC assumptions.

3.3.3 Transportation Cost Estimates

New HLW transportation cask designs would be required to support Scenarios 2, 3 and 4. An estimate has been made of changes required to the HLW cask design used in the 95 TSLCC to accommodate different size canisters compatible with the Hanford TWRS scenarios. No new thermal, mechanical, or radiological analyses were performed. The 95 TSLCC assumes a HLW rail cask with a capacity of five standard HLW canisters. The required cask types were scaled from the notional cask design used in the 95 TSLCC. Capacity of the transportation casks for the long canisters in Scenarios 2 and 3 was determined as four long canisters each, to meet national rail transportation system limits, assuming similar shielding as the TSLCC cask design basis (reference 5). This may be conservative. Design studies to optimize shielding for the low radiologic activities of HLW may permit a reduction in shielding which could increase the capacity for long canisters to five canisters. Scenario 4 was based on one very large canister per transportation cask. Capital costs for alternative casks were estimated based on data for the BR-100 rail cask. Shipping and related costs were estimated using the same methods as the 95 TSLCC.

3.3.4 Development and Evaluation and Other Program Costs

Development and evaluation (D&E) costs and other program costs were evaluated and are assumed to be essentially constant for Scenarios 1, 2 and 3. An addition for alternative cask development was identified for Scenarios 2 and 3.

Significant increases in development and evaluation, and other program costs would occur for Scenario 4 due to additional repository area characterization and licensing, and significant extension of waste acceptance and transportation operations. Costs were estimated based on notional schedules and throughput rates consistent with the capacity required for the high thermal loading repository. Estimates are based on 95 TSLCC costs for similar activities associated with a repository in the primary area, with a high thermal loading setting. Estimates for the new scope related to the Hanford only repository areas assume cost efficiencies gained from experience during the first phase of development and operations.

4. ANALYSIS

4.1 DEFENSE SHARE OF TOTAL SYSTEM COSTS

4.1.1 Results Summary

A summary of defense disposal costs for the TWRS alternatives is shown in Tables 4-1, 4-2, 4-3, and 4-4. From lowest to highest total system and defense share costs, the alternatives are ranked Scenario 3, 95 TSLCC Base Case, Scenario 2, Scenario 1, and Scenario 4. Scenario 3 reduces overall program costs by approximately $0.5B in 1994 dollars. Variation from the total system life cycle cost ranges from -1 percent to +6 percent for the first three alternatives. Scenario 4 doubles the total system disposal costs, and shifts the program from a civilian repository that is less than approximately 25 percent defense to a repository that is almost 75 percent defense on a total emplaced waste package count basis.

4.1.2 Limits of Analysis

Results should support evaluation of alternatives for TWRS but should not be taken as final estimates of the defense share. The estimates are consistent with the 95 TSLCC. Estimates are at a scoping level of detail, scaled from TSLCC data and estimated through use of TSLCC models. Results are not based on engineering studies of the specific alternatives and do not represent detailed point estimates. As noted in Section 3, the cost sharing methodology is limited in its application to cases which differ significantly from the base case. In particular, defense share is understated by the methodology for Scenario 3, and to lesser degrees for Scenarios 4 and 2, respectively. In addition, future TSLCC updates are required to incorporate developing changes to the CRWMS. Disposal of DOE SNF, accommodation of a variety of utility cask/canister systems for commercial SNF, and changes in funding profiles are current changes which will have system impact and will affect costs and cost shares.

4.1.3 Direct Costs

Tables 4-1 through 4-4 provided estimates of total disposal system costs and total defense share allocations of disposal costs for each scenario, based on a consistent methodology. Defense share estimates include disposal of all planned HLW from Hanford, Savannah River, and Idaho National Engineering Laboratory. Estimates of direct costs for Hanford HLW compared to total defense HLW are provided in Table 4-5 for use in further allocation of program indirect costs among the various defense programs. The Federal Register cost allocation methodology estimates total defense share compared to civilian to ensure no cross-subsidization of defense and civilian programs but does not address allocations among defense programs.

Table 4-1 Summary of Civilian, Defense, and West Valley Allocation (In Millions of 1994 Dollars) Scenario 1

Category	COST ALLOCATIONS											
	TSLCC95				Scenario 1				Delta			
	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total
Development & Evaluation	2,756	46	9,717	12,520	4,128	40	8,353	12,521	1,372	(6	(1,364)	1
Repository 1	2,817	47	7,932	10,796	4,868	47	7,652	12,566	2,050	0	(280)	1,770
Transportation	434	10	1,848	2,290	667	9	1,838	2,515	233	(1	(8)	225
MPCs	0	3	5,516	5,519	0	3	5,516	5,519	0	0	0	0
Waste Acceptance	238	5	1,005	1,246	331	5	912	1,247	95	(1	(93)	1
MRS	N/A				N/A				N/A			
Benefits	109	2	306	417	162	2	254	417	53	(0	(52)	(0
PETT	80	1	226	308	119	1	188	308	39	(0	(39)	(0
Total	$6,432	$114	$26,550	$33,096	$10,274	$106	$24,712	$35,093	$3,842	($0	($1,838	$1,997
Percentage %	19.43%	0.34%	80.22%	100.00%	29.28%	0.30%	70.42%	100.00%	9.64%	-0.04%	-9.60%	0.00%

Note: Totals may not add due to independent rounding

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Table 4-2 Summary of Civilian, Defense, and West Valley Allocation
(In Millions of 1994 Dollars)

Scenario 2

Category	COST ALLOCATIONS								Delta			
	TSLCC95				Scenario 2							
	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total
Development & Evaluation	2,756	46	9,717	12,520	3,482	52	9,010	12,543	726	5	(700)	23
Repository 1	2,817	47	7,932	10,796	3,816	56	7,986	11,858	999	9	54	1,061
Transportation	434	10	1,846	2,290	754	13	1,832	2,599	320	3	(15)	308
MPCs	0	3	5,516	5,519	0	3	5,516	5,519	0	0	0	0
Waste Acceptance	236	5	1,005	1,246	362	6	879	1,247	126	1	(126)	1
MRS	N/A				N/A				N/A			
Benefits	109	2	306	417	134	2	281	417	25	0	(26)	(0
PETT	00	1	226	308	89	1	207	308	19	0	(19)	(0
Total	$0,432	$114	$26,550	$33,096	$0,046	$133	$25,711	$34,490	$2,214	$19	($839)	$1,394
Percentage %	10.43%	0.34%	80.22%	100.00%	25.07%	0.39%	74.55%	100.00%	6.69%	0.04%	-5.67%	0.00%

Note: Totals may not add due to independent rounding

Table 4-3 Summary of Civilian, Defense, and West Valley Allocation (In Millions of 1994 Dollars) Scenario 3

Category	COST ALLOCATIONS											
	TSLCC95				Scenario 3				Delta			
	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total
Development & Evaluation	2,750	46	9,717	12,520	1,648	57	10,838	12,543	(1,108)	11	1,121	23
Repository 1	2,017	47	7,932	10,796	1,554	53	8,719	10,326	(1,263)	7	787	(470
Transportation	434	10	1,846	2,290	416	16	1,852	2,283	(18)	6	5	(7
MPCs	0	3	5,516	5,519	0	3	5,516	6,519	0	0	0	0
Waste Acceptance	236	5	1,005	1,246	227	9	1,011	1,247	(9)	3	6	1
MRS	N/A				N/A				N/A			
Benefits	109	2	306	417	63	2	352	417	(46)	0	46	(0
FETT	80	1	226	308	46	2	260	308	(34)	0	34	(0
Total	$6,432	$114	$26,550	$33,096	$3,954	$141	$28,549	$32,643	($2,478)	$27	$1,999	($453
Percentage %	19.43%	0.34%	80.22%	100.00%	12.11%	0.43%	87.46%	100.00%	-7.32%	0.09%	7.23%	0.00%

Notes: Share methodology understates defense share of unassigned costs due to extremely low piece counts. Actual share will be higher.
Totals may not add due to independent rounding

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Table 4-4 Summary of Civilian, Defense, and West Valley Allocation (In Millions of 1994 Dollars) Scenario 4

Category	COST ALLOCATIONS											
	TSLCC95				Scenario 4				DeHa			
	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total	Defense	WV	Civilian	Total
Development & Evaluation	2,756	46	9,717	12,520	12,868	26	3,487	16,389	10,110	(21)	(6,220)	3,869
Repository 1	2,817	47	7,932	10,796	31,221	61	5,317	36,599	28,404	14	(2,616)	25,802
Transportation	434	10	1,846	2,290	3,527	14	1,838	5,379	3,094	4	(9)	3,089
MPCs	0	3	5,516	5,519	0	3	5,516	5,519	0	0	0	0
Waste Acceptance	238	5	1,005	1,248	957	4	498	1,459	721	(2)	(507)	213
MRS	N/A				N/A				N/A			
Benefits	109	2	306	417	375	1	64	440	267	(1	(243)	23
PETT	60	1	226	306	316	1	54	370	235	(1	(173)	62
Total	$6,432	$114	$26,550	$33,096	$49,262	$108	$16,784	$66,154	$42,830	($6	$9,766	$33,058
Percentage %	19.43%	0.34%	80.22%	100.00%	74.47%	0.16%	25.37%	100.00%	55.03%	-0.18%	-54.85%	0.00%

Notes:
Scenario significantly in excess of repository planning basis. Requires assumptions which increase uncertainty of estimate.
Scenario outside methodology validity for place counts and disproportional waste package size.
Totals may not add due to independent rounding

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Table 4-5 Summary of Direct Disposal Costs for TWRS Alternatives (Millions of 1994$)

Category	1995 TSLCC		Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Hanford	Total Direct Defense	Hanford	Total Direct Defense	Hanford	Total Direct Defense	Hanford	Total Direct Defense	Hanford	Total Direct Defense
Repository										
Waste Packages	734	1,344	1,700	2,317	1,270	1,880	55	664	18,053	18,662
Emplacement	117	217	267	367	143	244	10	111	1,737	1,838
Transportation										
Shipping & Security (1)	123	264	294	435	204	345	15	156	2,241	2,382
Cask Purchases/Decom.	46	136	92	181	268	357	142	231	785	874
Total Direct	1,021	1,961	2,360	3,301	1,885	2,825	222	1,162	22,816	23,756

(1) Includes 180(c) costs

(2) Totals may not add due to independent rounding

4.2 COST ESTIMATE SENSITIVITIES

4.2.1 Repository

A summary of total repository costs is provided in Table 4-6 for the 95 TSLCC base case and the 4 TWRS scenarios, with a cost breakout by major cost element. The estimates are a subset of the total system costs shown in Tables 4-1 through 4-4. The values represent total repository costs for each scenario, without regard to allocation of costs to defense or civilian cost accounts. This data provides insight into the effect of each scenario on total system costs. For example, repository development and evaluation is constant for Scenarios 1, 2, and 3, but increases by $2.3 billion (94$s) for Scenario 4. The increase is a result of the cost of characterization of additional area, and associated licensing and development. This contrasts with defense shares of total D&E shown previously in Tables 4-1 through 4-4, which vary by scenario, dependent on sharing factors based on direct and assignable costs discussed in Section 3.3.1.

Major components of the repository estimate include waste package costs, the quantity of canisters, surface facility capital and operating costs, subsurface capital and operating costs, Nevada transportation capital and operating costs, and performance confirmation operations. Operating costs are driven primarily by years of emplacement. Capital costs are driven by either requirements for additional area or throughput capacity. Table 4-7 summarizes repository cost drivers. It identifies cost changes as a ratio relative to the 95 TSLCC for each of the Hanford TWRS scenarios.

4.2.2 Transportation

Transportation operations costs are primarily direct costs accrued by specific shipments. The defense share of transportation operations for the alternatives is most affected by the number of canisters per transportation cask, quantities of shipments, and cask fleets required to support the shipping schedule. Mileages are addressed in the modeling of costs but are constant for all Hanford alternatives.

The defense shares of transportation operations increased by 54 percent for Scenario 1, 74 percent for Scenario 2, and 713 percent for Scenario 4. Scenario 1 had a high number of shipments but these costs were offset in part by reduced cask fleet costs due to the commonality of casks for all DHLW. Cask costs increased only 34 percent to support the increased operational tempo. Scenario 2 had fewer shipments than Scenario 1, but defense cask fleet costs increased 163 percent due to multiple cask types and high system throughputs. Scenario 4 increases are due to the extremely large number of shipments over a long period of time, and dedicated transportation fleets. Scenario 4 cask costs increased 549 percent. Scenario 3 costs decreased by 4 percent overall. Savings that resulted from fewer trips were offset by a 67 percent increase in cask fleet costs due to use of different types for DHLW. There may be approaches to reduce this impact by adjusting the assumed delivery schedules.

Table 4-6 Repository Cost Summary (millions of 94$s)

Cost Category	1995 TSLCC	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Rail Spur & Performance Confirmation	926	926	926	926	1,159
Surface Facilities	3,312	3,918	3,774	3,607	7,681
Subsurface Facilities	2,748	2,897	2,775	2,642	6,491
Waste Package	3,876	4,786	4,354	3,133	21,145
Development and Evaluation (Yucca Mountain only)	6,532	6,532	6,532	6,532	8,819
Totals (1)	17,394	19,059	18,361	16,840	45,295

(1) Totals may not add due to independent rounding

Table 4-7 Repository Cost Drivers

Source of Change		Ratio (scenario/95 TSLCC)
Waste Package		
	Unit cost due to glass pour canister sizes	
	Scenario 1	1.00
	Scenarios 2,3	1.41
	Scenario 4	1.67
	Waste Package quantity variation	
	Scenario 1	1.71
	Scenario 2	1.40
	Scenario 3	0.50
	Scenario 4	13.69
Surface Facilities		
	Capital costs	
	Scenarios 1,2,3	1.19
	Scenario 4	1.28
	Operating labor	
	Scenario 1	1.2
	Scenario 2	1.15
	Scenario 3	1.08
	Scenario 4	2.59
Subsurface Facilities		
	Capital and operating affected by excavation lengths and waste package quantities	
	Scenario 1	1.05
	Scenario 2	1.01
	Scenario 3	0.96
	Scenario 4	2.36

4.2.3 Development and Evaluation and Other Program Costs

4.2.3.1 Scenarios 1, 2, and 3

Development and evaluation (D&E) costs and other program costs were evaluated and are assumed to be essentially constant for Scenarios 1, 2 and 3. The only change identified for Scenarios 2 and 3 is an addition for alternative cask development.

4.2.3.2 Scenario 4

In Scenario 4, repository D&E would increase to characterize additional repository areas required to accommodate excess Hanford HLW which can not be emplaced within the primary area. Characterization is assumed to start in 2026, followed by license application in 2032 and construction authorization in 2035. Costs are assumed to be approximately 50 percent of 95 TSLCC costs for characterization and licensing of the repository primary area. Repository surface operations and emplacement, along with supporting transportation and waste acceptance operations, would continue 35 years after completion of emplacement of all commercial SNF and other HLW. Allowing for a caretaker period ending 50 years after start of emplacement in the additional area, program duration would be extended from the 95 TSLCC case completion in 2071 to closure and decommissioning in 2102.

Other D&E, waste acceptance operations, and other program costs were adjusted to the increased scope. These activities also assume efficiencies over similar activities in development of the initial repository primary area, and make adjustments for system simplification since there is only one source of wastes to be disposed of in the Hanford HLW only period of operations.

4.3 EVALUATION OF ALTERNATIVES

The following identifies quantitative and qualitative discriminators for the scenarios determined in the course of this cost analysis for each alternative. This analysis does not take in to account other additional wastes such as DOE SNF which may be required to be emplaced in a repository, or potential variation in HLW canister quantities from other sites. Technical feasibility and environmental effects of disposal are not within the scope of this study and are not addressed.

4.3.1 Scenario 1

Scenario 1 significantly increases the quantity of HLW waste packages over the 95 TSLCC base case. The 95 TSLCC design approach of emplacing HLW waste packages in spaces between the higher thermal output SNF packages requires matching the incoming HLW and SNF waste stream. A disadvantage of this alternative is that it requires an efficient use of most available spaces between SNF packages. Defense HLW waste packages fill approximately 74 percent of the available spaces between SNF waste packages in the period from 2015 through 2040. This

could limit growth capacity in the primary area of the repository. This analysis also does not take in to account other additional wastes such as DOE SNF which may be required to be emplaced in a repository, or potential variation in HLW canister quantities from other sites. For these reasons, this alternative could compete with other wastes being considered for disposal. A more efficient (lower quantity of HLW packages) utilization of repository space would be preferred. This alternative is ranked third in terms of overall cost.

4.3.2 Scenario 2

Scenario 2 is closest to the base case in terms of the number of canisters and repository utilization, given Hanford expectations of higher glass production identified in reference 1 (14,260 m^3 vs. 6,100 m^3 assumed for TSLCC). It is a cost effective alternative and is compatible with the design concepts utilized in the 95 TSLCC. Some modification to cost share methodology may be required to account for disproportionate changes in waste package size, however the methodology bias is much less than for Scenario 3.

4.3.3 Scenario 3

Scenario 3 is a favorable alternative from standpoint of maximizing the efficient use of repository capacity. This alternative has the lowest overall defense waste disposal cost, and reduces total disposal program costs slightly. The cost sharing methodology requires modification to achieve legal requirements for full cost recovery as noted in the discussions in Section 3.3.1 above. The low piece counts of this scenario fall outside the validity of the computational method. Following such adjustment, costs for this alternative would increase, however this would still be the lowest cost alternative from the standpoint of disposal.

4.3.4 Scenario 4

Scenario 4, a no separations alternative, is not preferred from a disposal standpoint. Scenario 4 far exceeds other alternatives in total costs for disposal. This alternative requires substantial disposal area beyond what is being characterized by the Civilian Radioactive Waste Management Program. Scenario 4 would require characterization of secondary areas in addition to the primary area being characterized, suitability determination of the area, and associated licensing of a Hanford only section of the repository. It would require an alternate thermal strategy from that being planned for the repository. Seventy six percent of the Hanford wastes would require emplacement in the additional areas in a low thermal setting, following emplacement of the first twenty four percent of the Hanford HLW and all other HLW with all the available SNF in a high thermal setting in the primary area of the repository. This would require a license update for additional area in an alternate thermal setting. The requirement for both high and low thermal loading areas in Scenario 4 would complicate the licensing process. This is in contrast to the 95 TSLCC assumption of emplacement of all HLW with SNF in the primary area in a high thermal loading setting. Excess quantities of Hanford HLW may exceed available areas in the repository.

Disposition of remaining HLW would not be decided until DOE makes a recommendation on the need for a second repository, required by the NWPAA to be in the period from 2007 to 2010.

The cost sharing methodology may require modification to achieve legal requirements for full cost recovery as noted in the discussions in Section 3.3.1 above. The very high piece counts and large relative size of waste packages in this scenario fall outside the validity of the computational method. Further, uncertainties due to Scenario 4 assumptions may result in delays which could require prolonged on-site storage of excess canisters at Hanford. Uncertainties in assumptions also may increase disposal costs for this scenario.

4.4 QUALITATIVE IMPACTS OF USE OF HANFORD MULTI-PURPOSE CANISTER

4.4.1 Repository

Use of an HMPC which satisfies disposal requirements would result in a small cost saving at the repository for Scenarios 1, 2, and 3. In each case, HLW canisters are already planned to be disposed of in waste packages containing 4 canisters each, as is planned for the MPC. An HMPC would simplify surface facility handling operations. Repository cost savings would be small if any.

4.4.2 Transportation

The HMPC being considered in current TWRS planning is most analogous to Scenario 2 in this analysis. Use of an HMPC would have negligible effect on transportation for Scenario 2, which assumes a HLW transportation cask with a capacity of four long canisters each. Shipping costs would be reduced slightly due to a lower empty weight for return shipments because any basket structure to hold the canisters is part of the HMPC. Cask capital costs would be lower due to absence of the basket structure and reduction in shielding thickness to account for shielding provided by the HMPC canister wall.

The efficiency of an HMPC for Scenario 3 would depend upon the availability of suitable casks required for other purposes. Acquisition of dedicated casks would not be cost effective.

Use of an HMPC for Scenario 1 would require development of alternative transportation casks if not developed for other requirements, and would increase the number of shipments by 25 percent due to the capacity change of five canisters per cask to four.

An HMPC would have no effect on transportation for Scenario 4 since these very large canisters would be transported one per cask and there is no basket in either case.

REFERENCES

1. U.S. Department of Energy, *Request for Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement*, letter Ser WDD:PL 96-WDD-069 of Jun 7, 1996.

2. U.S. Department of Energy, *Analysis of the Total System Life Cycle Cost for the Civilian Radioactive Waste Management Program* (DOE/RW-0479), September, 1995.

3. Nuclear Waste Policy Amendments Act of 1987, Pub. L. No. 100-203, December, 1987

4. U.S. Department of Energy, "Civilian Radioactive Waste Management; Calculating Nuclear Waste Fund Disposal Fees for Department of Energy Defense Program Waste", pp. 31508-31524, *Federal Register*, Vol. 52 No. 161, August 20, 1987.

5. Jones, Robert H. and Nickell, Robert E., *Final Report, MRS-to-Repository Transportation System Design Characterization and Capacity Study*, Los Gatos, CA, December, 1989

APPENDIX A

Request for Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement, dated Jun 7, 1996.

Westinghouse
Hanford Company

P.O. Box 1970 Richland, WA 99352

August 1, 1996

9653251

Post-it™ Fax Note 7671	Date 1/8/97	# of pages ▶ 4
To Gary Steger	From Steve Schaus	
Co./Dept.	Co. LMHC	
Phone #	Phone # 509 372-1149	
Fax # 208-526-4560	Fax #	

Mr. W. J. Taylor, Director
Waste Disposal Division
U.S. Department of Energy
Richland Operations Office
Richland, Washington 99352

Dear Mr. Taylor:

PROPOSED STANDARD CANISTER FOR TANK WASTE REMEDIATION SYSTEM HIGH-LEVEL WASTE DISPOSAL

References: 1) Letter, J. E. Kinzer, RL, to President, WHC, "Office of Tank Waste Remediation System (TWRS) High-Level Waste (HLW) Canister Projection Assessment and Project Baseline Guidance," 96-WDD-029, dated April 23, 1996.

2) Letter, R. A. Milner, RW-30, to J. E. Kinzer, RL, "Evaluation of Hanford Longer High-Level Waste Product Canister Option for Acceptance by the Civilian Radioactive Waste Management System," dated April 5, 1996.

3) Letter, J. E. Kinzer, RL, to S. Rousso, RW-40, "Evaluation of Hanford Longer High-Level Waste Product Canister Option for Acceptance by Civilian Radioactive Waste Management System," 96-RTI-017, dated February 2, 1996.

The purpose of this letter is to propose a preliminary concept for a 4.5 meter long canister to serve as the "TWRS standard canister." The canister would be used for TWRS baseline planning purposes in the interim until a final design is available. It would also be used in negotiations with the private vendors to ensure that the long canister option is maintained in the vendor's plant design, and in discussions with DOE-RW concerning incorporation of the longer canister into the Waste Acceptance Systems Requirements Document (E00000000-00811-1708-00001, Revision 2).

This canister would be 1.5 meters longer than the standard canisters currently being used at the Defense Waste Processing Facility (DWPF) and West Valley Demonstration Project (WVDP), but would retain the same 0.61 meter outer diameter. In Reference 3, Hanford requested an evaluation of this option by the Department of Energy -- Office of Civilian Radioactive Waste Management (DOE-RW). In Reference 2, DOE-RW stated that "...a longer canister, not to exceed 4.5m (nominally 15 feet), for vitrified HLW that has

characteristics similar to the Savannah River Site Defense Waste Processing Facility product would be technically acceptable."

A description of the proposed TWRS standard canister is provided in Attachment 1. An engineering sketch showing dimensions and configuration is provided in Attachment 2. The canister concept incorporates many of the features found in the DWPF and WVDP standard canisters in order to make maximum use of the development, fabrication, qualification and early operating experience with these canisters. The concept requires verification and optimization through future design, testing and evaluation activities.

If design and testing activities confirm the viability of the concept, the median value for the canister count for HLW could be reduced from 23,000 (Reference 1) to approximately 13,000.

If you have any questions please call me at 376-7402, or contact D. J. Washenfelder (373-2641) for technical questions, or R. W. Powell (376-9618) for program-related questions.

Very truly yours,

J. O. Honeyman, Director
Disposal Programs Office
Tank Waste Remediation System

kge

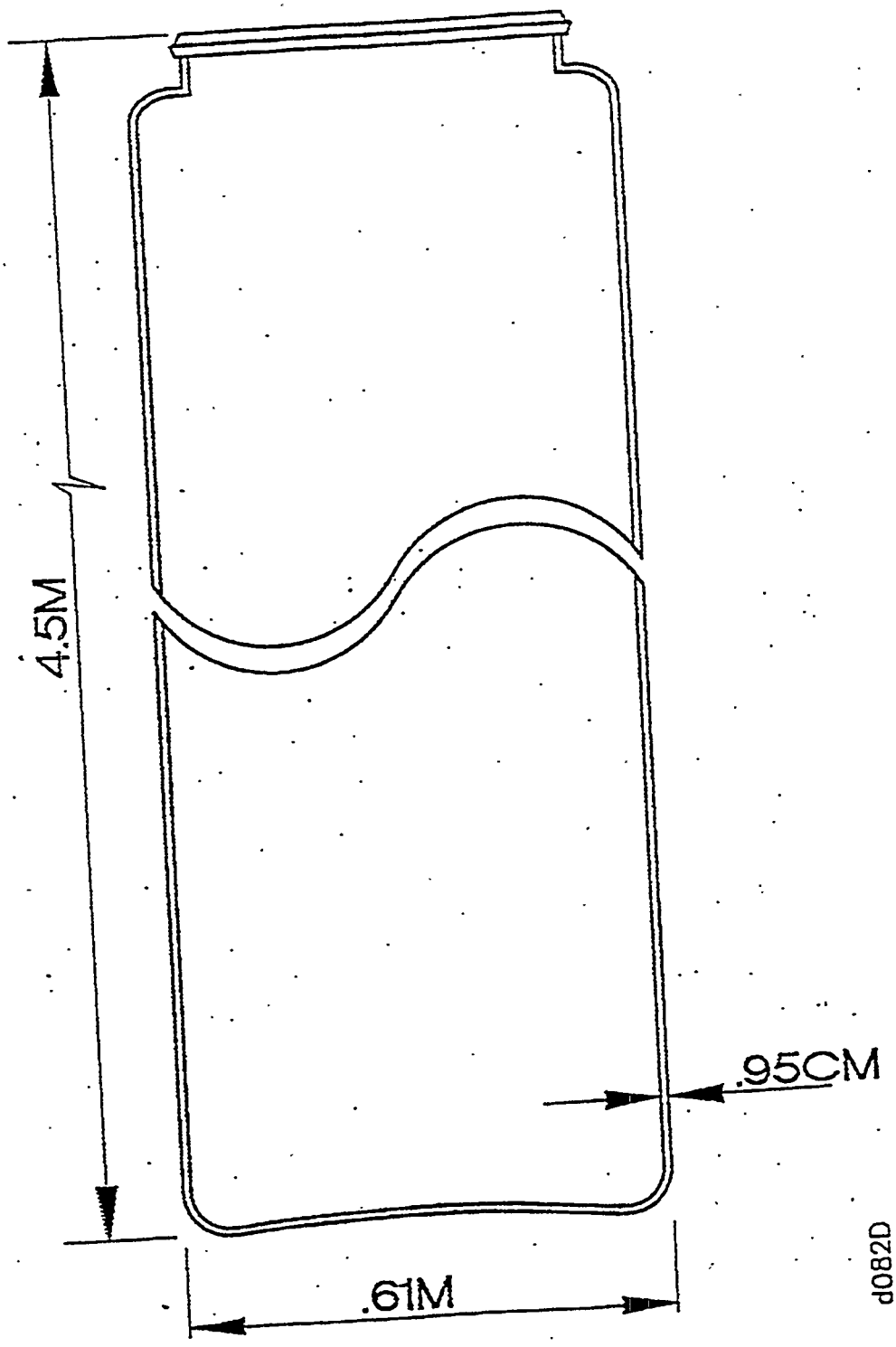
Attachments 2

RL - A. H. Wirkkala (w/o attachment)

Description of the proposed "TWRS Standard Canister" for Hanford HLW Disposal

Length:	4.50 m	(1.5 m longer than DWPF and WVDP canister - nominal 15 feet length)
Outer Diameter:	0.61 m	(same OD as DWPF and WVDP canister)
Wall Thickness:	0.95 cm	(same as DWPF)
Canister Weight:	715 kg	
Flange Opening:	0.41m	(same as WVDP--large opening)
Dished Bottom:	Yes	(same as DWPF and WVDP)
Available Volume:	1.214 m^3	
Nominal % Fill:	90%	(provides approx. same void volume as WVDP)
Glass Volume:	1.08 m^3	
Glass Weight:	2,870 kg	
Total Weight:	3,590 kg	

An engineering sketch of the proposed TWRS standard canister concept



TWRS STANDARD CANISTER
Figure 1

Reference 3

**INEL High Level Waste Program Impacts Related To Disposal Fees and Ability of Repository To Accept Waste"
SGN Eurisys Services Corporation, EN-RPT-001**

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APPROVAL: Originator: G. E. Stegen Date 6/5/97

Manager: L. A. Fort Date 6/5/97

Director of Engineering D. W. Hamilton Date 7/15/97

Director of ESQ&H D. W. Duncan N/A Date / /

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Document No.: EN-RPT-001 **Revision No.:** 0

Key Words: High-Level Waste, Disposal Cost, Disposal Fee, Repository, Waste Quantity, Canister Size, Idaho National Engineering Laboratory, Hanford

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INEEL HIGH-LEVEL WASTE PROGRAM IMPACTS RELATED TO DISPOSAL FEES AND ABILITY OF REPOSITORY TO ACCEPT WASTE

Gary E. Stegen
June, 1997

Prepared for Lockheed Martin Idaho Technologies Company under Subcontract C95-175006 Task Order F97

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INEEL HIGH-LEVEL WASTE PROGRAM IMPACTS RELATED TO DISPOSAL FEES AND ABILITY OF REPOSITORY TO ACCEPT WASTE

1.0 OBJECTIVE AND SCOPE

A substantial quantity of radioactive waste is currently stored at the Idaho National Engineering and Environmental Laboratory (INEEL) Chemical Processing Plant (ICPP) as liquid in tanks and as solidified calcine in bins. The high-level waste (HLW) portion of this waste will be treated, immobilized, and packaged in canisters for offsite disposal in a federal repository. Immobilized HLW must be accepted by the repository program, which is managed by the U. S Department of Energy (DOE) Office of Civilian Radioactive Waste Management (OCRWM).

The objective of this report is to provide information on repository disposal of HLW requested by the INEEL HLW program for use in evaluating HLW processing options. This information includes estimated disposal fees for DOE HLW disposed in a Federal repository and identification of other considerations related to repository acceptance of the waste that could constrain program options. Due to limited resources, scope of this task was confined to compiling and assessing readily available information.

2.0 SUMMARY AND CONCLUSIONS

2.1 HLW Disposal Fees

A disposal fee will be assessed for DOE for the transportation and repository disposal of immobilized HLW produced by DOE sites. The INEEL HLW program approach ultimately selected for processing HLW will affect the quantity of HLW to be disposed, and the DOE disposal fee. Total DOE HLW disposal fees are determined by the total repository program costs multiplied by the fraction of those costs allocated to DOE HLW. Changes in HLW quantity were found to have a much smaller impact on repository program cost than on the DOE disposal fee (typically by a factor of about two). This is because the fee calculation method allocates a larger fraction of general and fixed costs to DOE as the amount of HLW disposed increases. The following are recommended as nominal or best estimate values for changes in DOE disposal fees resulting from changes in the number of DOE HLW canisters disposed at the repository: $300,000 per canister for 2-foot by 10-foot canisters and $400,000 per canister for 2-foot by 15-foot canisters. The stated fees are in constant 1994 dollars, and are incremental fees as opposed to average fees, which are higher. These values should be considered as rough approximations, and it may be appropriate to evaluate the sensitivity of program decisions to changes in disposal fee assumptions.

For sensitivity analyses, it is recommended that a lower disposal fee assumption be considered, based on the estimated change in repository program costs from changes in HLW quantity. There are lower than the nominal values because they do not include changes in the DOE allocation of general and fixed costs that result from cost allocation formulas currently assumed. Repository cost and DOE fee allocation could also increase above current estimates due to a number of factors, such as: development of two repositories versus the single repository assumed for current estimates, program delays, new requirements, surprises in site characterization, reductions in future commercial spent fuel quantities, problems during construction or startup, etc. No specific studies were identified that evaluate or quantify potential areas of cost growth. However, for preliminary sensitivity studies, consideration of potential incremental disposal fees that are 20 to 50 percent or more above the nominal values wouldn't be unreasonable. Nominal incremental fee estimates above are based on data from a recent study of repository costs and DOE disposal fees for different HLW quantity and package configuration assumptions. The above values are considered to be suitable for preliminary evaluations. However, it is recommended that input be obtained from the OCRWM before finalizing major program decisions that are dependant on DOE disposal fee assumptions.

2.2 Alternative Immobilized HLW Package or Waste Forms

Evaluation of program options that require changes to issued waste form specifications and package requirements should consider possible disposal fee impacts and the time and resources required to get such changes approved. Operating waste treatment facilities in the United States currently produce borosilicate glass in 2-foot diameter by 10-foot canisters. This waste form and package configuration are the only ones currently approved by the repository program. However, Hanford is attempting to obtain approval for a larger 15-foot canister.

Use of a different canister design than planned for other DOE sites will result in added disposal fees if there are additional costs to the repository program for setting up to handle a different package. There may also be cost and schedule impacts to the HLW program because of the need to design, qualify, and obtain acceptance of the revised design. If Hanford proceeds with the 15-foot canister, use of either this design or the 10-foot design by INEEL should result in little or no additional cost for design, qualification, or repository set-up. Estimates of direct program impacts and disposal fees for other canister designs must be made on a case-by-case basis.

Options that use alternatives to borosilicate glass for HLW immobilization should consider the time and resources required to obtain approval of the alternate waste form, together with risk to the program if approval is substantially delayed or rejected. Unusual or unfamiliar waste forms and options with debatable merits may require a number of years and substantial resources to bring them to the point where a decision on acceptability can be reached.

2.3 Options Requiring Large Quantity HLW Disposal

The INEEL may consider options such as direct vitrification of calcine that require repository disposal of relatively large quantities of HLW. From available information, it does not appear that such program options can be ignored simply because they require repository disposal of relatively large quantities of waste. However, options that are substantially above current planning bases need to be discussed with the repository program to verify that they are acceptable.

2.4 Schedule Considerations

Schedule interface with the repository program is an important consideration for some INEEL HLW program options. A schedule mismatch could increase costs and could conceivably affect ability of the repository to accept INEEL HLW. The current planning basis is that all HLW (calcine and tank waste) will be processed and ready to ship to a repository by 2035. This schedule is reasonably in line with current planning for the first repository. However, it is not clear that INEEL canisters can go to the first repository. Actual (versus plan) schedules for the first and second repositories also have significant uncertainty. The INEEL HLW program planning bases are likewise subject to change (the Environmental Impact Statement (EIS) and record of decision have not yet been issued, and funding to achieve the current planning base is not yet provided). One implication of these uncertainties is that significant buffer storage for immobilized HLW will likely need to be provided at the INEEL. Another implication is that as repository waste receipt schedules are firmed up and finalized, there may be some influence or constraints on selection of preferred INEEL HLW program options. Examples:

1. If current repository program schedules hold, and there is a decision to build only one repository, immobilized HLW produced after about 2040 may have no home, or may cost substantially more to dispose if it requires a new dedicated repository expansion. Under this scenario, options such as deferred calcine processing, which substantially delay immobilization of all INEEL HLW, appear less desirable.

2. If there is a substantial delay in the dates that the repository can accept INEEL HLW, it may be desirable to consider a similar delay in schedules for calcine retrieval and immobilization. Such a delay should provide some areas of cost savings such as reduced interim storage facilities for immobilized HLW canisters, improvements in technology over time, and delay in making expenditures (time value of money), and may result in some reduction in cost and hazard to workers as well as the environment because of additional decay of radionuclides prior to retrieval and processing of the waste.

3.0 INFORMATION SOURCES

Readily available information was collected on disposal fees and repository waste acceptance for DOE HLW. References discussed below provide the most pertinent information found relative to report objectives.

References 1 and 2 provide results of a recent study performed under the direction of the U. S. OCRWM. This study, issued in July 1996, was prepared to provide HLW disposal cost information for the Hanford Site Tank Waste Remediation System (TWRS) EIS. Immobilized HLW package size and quantity options were included that bracket most options that might be considered for ICPP waste.

The Civilian Radioactive Waste Management Program (CRWMP) Total System Life Cycle Cost Estimate (TSLCC) issued in September 1995 (Reference 3) was used as a base case in developing the study reported in Reference 2. Other cases in Reference 2 maintained assumptions used for Reference 3 with the exception of the defense HLW quantity and package configuration. Even though some programmatic and design concept assumptions inherent in the cost estimates have already changed, References 1, 2, and 3 appear to be the most recent reliable sources of information on immobilized HLW transportation and disposal cost.

Methods used to allocate repository program costs are defined in Reference 4. Current plans are to place defense HLW in the same repository to be used for disposal of commercial spent fuel. The Nuclear Waste Policy Act as Amended requires full-cost recovery from both defense and commercial users of the repository, with no cross-subsidization of program costs. The DOE evaluated various cost allocation methods for meeting this requirement and defined methods to be used in the Federal Register in 1987 (Reference 4). Reference 4 cost allocation methods were used as the basis for disposal fee estimates reported in References 2 and 3.

Reference 5 provides additional background information on cost allocation methods considered by DOE, and also provides earlier estimates of repository costs and DOE disposal fees. Disposal fee estimates in Reference 5 were reviewed and found to be reasonably consistent with estimates in Reference 2 when adjusted for inflation.

References 6 and 7 provide information on the 15-foot canister proposed for use at Hanford, and additional information on the status of the Hanford HLW program.

Reference 8 is the Waste Acceptance Systems Requirements Document (WASRD) issued by the DOE office of civilian radioactive waste management. It provides programmatic, design, and performance requirements for acceptance of HLW and spent fuel by the repository program.

4.0 DEFINITIONS

Several cost-related values are discussed in presenting information on HLW disposal costs. In order to clearly understand terms used herein, the following definitions are provided.

CRWMP TSLCC is the CRWMP total system life-cycle cost (TSLCC) estimate for a particular option under consideration, also referred to herein as total "repository program cost." All past and future direct and indirect costs are included, such as: development, characterization, and evaluation of candidate repositories; development and evaluation of transportation systems for delivery of waste packages to the repository; construction, operation, and closure of the repository, waste handling, and transportation system; waste acceptance activities; program management and technical support; and miscellaneous expenses, fees, and payments. The various cost categories and recent base case estimates for each category are described in more detail in Reference 3. Costs presented herein are consistent with References 2 and 3, which are stated in constant 1994 dollars, with no adjustment for future inflation or discounting for the time value of money.

Disposal Fee is the total transportation and disposal fees assessed to DOE to cover the share of CRWMP TSLCC allocated to immobilized DOE defense HLW. Values presented herein are in constant 1994 dollars, with no adjustment for date the fees are actually paid (consistent with References 2 and 3). Reference 4 page 31510 indicates that DOE intends to eventually make an adjustment for the time value of money when the fees are eventually paid. This adjustment as well as the adjustment for future inflation are expected to increase the actual dollar value of fees assessed.

Average Disposal Fee Per Canister is the disposal fee divided by the total number of canisters of immobilized DOE defense HLW assumed for a particular case under consideration.

Incremental Disposal Fee Per Canister is the difference in disposal fee between the two cases under consideration divided by the difference in number of immobilized HLW canisters for the same two cases.

Incremental Repository Program Cost per Canister is the difference in CRWMP TSLCC between the two cases under consideration divided by the difference in number of immobilized HLW canisters for the same two cases.

5.0 KEY COST ESTIMATE ASSUMPTIONS

A large number of programmatic and technical assumptions were used in developing the base case cost estimates in Reference 3, which were in turn used as the basis for cost estimates developed in Reference 2, and are reported herein. Assumptions of particular interest are discussed below.

Waste Quantity. The CRWMP TSLCC is based on using a single repository to dispose of the total estimated civilian spent nuclear fuel (SNF) quantity of 84,000 Metric Tons Uranium (MTU), plus 18,046 canisters of defense HLW, and 300 canisters of HLW from the West Valley Demonstration Project. It is noted in Reference 3 that the assumed waste quantity exceeds the current legal limit of 70,000 MTU total waste in the first repository. It is not clear if this implies an assumption that the Nuclear Wastes Policy Act will eventually be amended to allow a larger quantity of waste in the first repository.

No Other Waste Types. The design concept does not include any allowance for other waste types; e. g., spent nuclear fuel from defense or research reactors, failed equipment containing HLW, and other nonstandard HLW forms.

High Heat Loading Design. The repository design concept is based on high-heat loading, and assumes a high-thermal loading license will eventually be granted.

Co-location of SNF and HLW packages. The design concept calls for HLW packages to be placed between SNF packages to better equalize heat distribution. Incremental cost calculations assume this concept will be used. If HLW options do not allow this concept to be efficiently used, incremental costs HLW may increase.

No Temporary Storage. The design and cost estimate assume that no temporary retrievable storage for SNF or HLW is provided by the repository program. With the cost allocation methods used, SNF retrievable storage costs are charged to SNF only. Therefore, there is no direct effect of SNF storage assumptions on reported HLW disposal fee estimates. However, the lack of any temporary storage for SNF could affect the ability to efficiently balance delivery schedules required to achieve efficient co-packing of SNF with HLW. This is more important for high-volume HLW cases that need to efficiently use most of the spaces between SNF packages.

Schedule. The cost estimate assumes SNF emplacement in the repository starts in 2010, HLW emplacement starts in 2015, and that all waste emplacement is completed by 2040. The waste emplacement schedule requires SNF and HLW to be received and emplaced at complementary rates. If any HLW is received after all SNF is emplaced, it would presumably be more costly to dispose.

6.0 COST AND FEE ESTIMATES

Cost estimates based on References 2 and 3 are summarized in Table 1. Case 1 is the base case reported in Reference 3. The CRWMP TSLCC is estimated at $33.1 billion, and the allocated DOE disposal fee for defense HLW is $6.43 billion for Case 1. This case assumes 18,046 canisters (2-foot diameter by 10-foot) of defense HLW, giving an estimated average disposal fee of $356,300 per canister.

Case 2 assessed the effect of increasing the number of defense HLW canisters to 31,186, while retaining the standard 2-foot by 10-foot canister. The estimated DOE defense HLW disposal fee for this case is $10.3 billion, an increase of $3.87 billion over the base case ($295,000 per incremental canister). Estimated repository program cost is increased by $2.0 billion or $152,000 per incremental canister as compared to the base case. The incremental disposal fee per canister is significantly larger than the incremental repository program cost because a larger fraction of general and fixed costs are allocated to HLW, based on increased numbers of disposal packages, and the increased fraction of repository area filled by defense HLW packages.

Cases 3 and 4 assess cost impacts of increasing the waste package (canister) size and reducing total immobilized defense HLW volume below the base case, respectively. Case 3 assumes that Hanford waste is packaged in a reduced number of larger 2-foot diameter by 15-foot canisters (see Reference 6). This change is estimated to reduce the repository program cost by $600 million compared to Case 2, which has roughly the same glass volume. The reduction results from the reduced cost of handling a lower number of waste packages and is partially offset by increased costs to qualify and set up for an additional waste package type, and increased unit costs for shipping, handling, and disposing the larger/heavier packages. The allocated DOE disposal fee is reduced by $1.7 billion, which is almost three times the reduction in repository program cost. This results from the formula for allocating general and fixed costs based on piece count and repository area required for disposal.

TABLE 1

TABLE 1. DEFENSE HIGH LEVEL WASTE DISPOSAL COST SENSITIVITY CASES

CASE	DESCRIPTION	HANFORD CAN SIZE DIA x HEIGHT	HANFORD CANS	TOTAL DHLW CANS	CRWMP TSLCC 1994 $	DISPOSAL FEE-DHLW 1994 $	TSLCC DELTA 1994 $	DHLW FEE DELTA 1994 $	AVG. DIS. FEE $K/CAN	INC. TSLCC $K/CAN	INC. DIS. FEE $K/CAN	COMMENTS
1	BASE CASE	2 ftX 10 ft	9,860	18,046	$33.1 B	$6.43 B.	—	—	356	—	—	
	DOE/RW-0479											
2	INCREASED	2 ftX 10 ft	23,000	31,186	$35.1 B	$10.3 B	$ 2.0 B	$3.87 B	330	152	295	CASE 2 VS CASE 1
	GLASS VOLUME											
3	INC GLASS VOL +	2 ftX 15 ft	12,200	20,386	$34.5 B	$8.6 B	$-0.6 B	$-1.7 B	422	56	157	CASE 3 VS CASE 2
	INC. CAN SIZE						(VS 2)	(VS 2)				
4	REDUCE GLASS	2 ftX 15 ft	530	8,716	$32.6 B	$4.0 B	$-1.9 B	$-4.6 B	459	163	394	CASE 4 VS CASE 3
	INC. CAN SIZE					(NOTE 1)	(VS 3)	(NOTE 1)	(NOTE 1)	(VS 3)	(NOTE 1)	
5	NO SEPARATION	5.5 ftX 16.5 ft	36,400	44,586	$66.2 B	$49.3 B	$ 33.1 B	$42.9 B	1106	1247	7	CASE 5 VS CASE 1
	JUMBO CASKS				(NOTE 2)	(NOTE 2)	(VS 1)	(VS 1)	(NOTE 2)	(VS 1)	(NOTE 2)	PROG. IMPACTS

NOTES: 1. Due to the very low HLW canister count, the cost allocation model may be outside the range of validity. Actual cost allocation to defense HLW expected to be somewhat higher for this case.

2. Glass volume well exceeds current repository design concepts. Major program impacts would result from this case including substantial delay to repository program (35 years estimated). Cost estimates for this case are also very tentative.

3. All cost estimates based on Reference 2. For definitions see text section 3.0.

Case 4 assumes the same larger (15-foot) canister for Hanford waste as Case 3, but glass volume is drastically reduced by employing highly efficient separations for Hanford waste. This case is estimated to reduce total repository program costs by $1.9 billion or $163,000 per incremental canister compared to Case 3. The calculated disposal fee for this case is reduced by $4.6 billion total or $394,000 per incremental canister compared to Case 3. Reference 2 also indicates that the very low canister count for this case is outside the range of validity for the fee allocation model used. Actual fee allocation is expected to be higher, thus the fee reduction per canister may be less than indicated by this calculation. It is assumed that this fee allocation problem is primarily related to the extremes, i.e., the last canisters reduced, therefore the calculated fee reduction of $394,000 per canister is expected to be reasonably valid for relatively small changes in canister count.

Disposal fee for cases 1 through 4 were fit to the following equations.

If only 10-foot canisters are used: $DF = 1.11\ E{+}09 + (2.95\ E{+}05)(N10)$.

If both 10-foot and 15-foot canisters are used:

$DF = 1.408\ E{+}09 + (2.95\ E{+}05)(N10) + (3.94\ E{+}05)(N15)$.

Where DF is the total estimated disposal feet in 1994 dollars, N10 is the number of 10 foot HLW canisters and N15 is the number of 15 foot HLW canisters. These equations imply a $1.11 billion fixed fee plus $295,000 per canister incremental fee if only 10 foot canisters are used. If both 10-foot and 15-foot canisters are used, the incremental disposal fee is $394,000 per canister fee for 15-foot canisters, and the implied fixed fee is increased by $298 million, to $1.408 billion. The $298 million increase an apparent fixed fee is not fully explained in Reference 2. However, it appears to result from the increased cost to set up for transportation and handling of an additional size (larger) canister. Note that the above equations are illustrative only. The actual incremental fee per canister is probably not completely constant, and the apparent fixed fee may not be valid for cases that deviate substantially from cases studied in Reference 2.

Reference 5 issued in 1986 provides an earlier estimate of HLW disposal fees and repository costs. For the area/piece fee allocation method, average and incremental disposal fees were estimated at about $220,000 and $200,000 per canister respectively (in 1985 dollars) for standard 2-foot by 10-foot canisters. Despite substantial differences in programmatic and design assumptions, these are roughly comparable to current estimates when adjusted for inflation. The incremental CRWMP TSLCC cost estimate of about $87,500 per 2-foot by 10-foot canister in 1985 dollars, is moderately lower than current estimates even after adjustment for inflation. The current estimate of $152,000 (1994 dollars) is likely more reliable since it is based on more detailed repository design information and more current programmatic assumptions.

The disparity between incremental repository program cost per canister and incremental disposal fee per canister creates the potential for anomalies in evaluating program options. The following example illustrates this point:

> Assume a decision is made to implement efficient separations (Case 4); increasing total cost of waste processing (pretreatment and immobilization) by $3 billion over Case 3; and that Case 3 and Case 4 cost estimates and fee allocations are accurate. Results of the example assumptions are that DOE spends an additional $3 billion in treatment costs to reduce repository program costs by $1.9 billion. However, DOE actually saves $1.6 billion because of the $4.6 billion disposal fee reduction. Allocated civilian share of the repository program cost increases by $2.7 billion even though there is no change in the amount of civilian waste.

The example shows the cost allocation method could result in non-optimum program decisions. Because of the significant difference between incremental repository program cost and incremental disposal fee, and the large magnitude of costs affected by these decisions, it is worthwhile to consider both values in evaluating the options.

It may also be desirable to consider the possiblility of future cost growth in evaluting program options. Repository cost and fee allocation could increase above current estimates due to a number of factors, such as: the requirement to develop two repositories versus the single repository assumed for current estimates, the possible need to provide additional temporary waste storage, program delays, new requirements, surprises in site characterization, reductions in future commercial spent fuel quantities, problems during construction or startup, etc. No specific studies were identified that evaluate or quantify potential areas of cost growth. Based on past experience, consideration of the possibility for disposal fee growth in the range of 25 to 50 percent or possibly more, plus inflation as sensitivity cases, would not appear unreasonable.

Past experience has shown that preferred options for many program decisions are not affected by changes to the disposal fee assumptions . This is in part a result of relatively high costs to immobilize and store high-level waste. When these costs are combined with even the low end of the potential disposal fee range, there is a strong incentive to minimize the quantity of immobilized HLW. However, in some cases it may be found that major program decisions will be different for the low versus high end of the potential disposal fee range. In this event, a refined disposal fee estimate and/or a program policy decision may be needed to resolve the issue. For important program decisions that depend on DOE HLW disposal fee assumptions, input and concurrence from OCRWM would be highly desirable.

7.0 REPOSITORY ABILITY TO ACCEPT HLW

Several issues were identified related to the ability of the repository to accept HLW from INEEL. These include physical capacity, legal limits on waste quantity in the first repository, and program schedules. Information identified on these subjects is discussed in this section.

Some INEEL HLW program options, such as direct vitrification of calcine would result in relatively large HLW quantities to be disposed at the repository. The question is sometimes asked: Is it feasible or conceivable that the repository could accept these large quantities, or can these options be simply ruled out? Two scenarios included in Reference 2 provide some insight into this issue as discussed below.

A scenario evaluated in Reference 2 included no separation for Hanford tank waste and use of 36,400 jumbo 5.5-foot diameter by 16.5-foot casks for disposal of the immobilized Hanford HLW (Case 5 of Table 1). It was indicated that this case would require the repository to be expanded beyond current areas being characterized and licensed. Compared to the base case, this option would require a substantial increase in time for characterization and licensing the repository as well as for operations. Reference 2 estimates that primary operations would be extended about 35 years and final closure would be delayed 31 years. This scenario well exceeds HLW disposal quantities for any case that could be reasonably envisioned for INEEL. However, Reference 2 did not indicate that accommodation of such a large quantity of waste in the first repository was infeasible.

Another scenario evaluated in Reference 2 provides information on the maximum quantities of defense HLW that can be accommodated if the 1995 repository design concepts are maintained. This scenario (Case 2 of Table 1) included a total of 31,186 standard 2-foot by 10-foot canisters for all defense HLW. From the following comments in Reference 2, it appears that this option is feasible, but is straining the limits of the co-placement concept: "defense HLW packages fill approximately 74 percent of available spaces between SNF waste packages in the period from 2015 through 2040." "A more efficient (lower quantity of HLW packages) utilization of repository space would be preferred." Reference 2 also indicates that this quantity of HLW canisters may constrain the ability of the repository to accept other wastes such as DOE spent fuel (apparently no allowance for DOE SNF or other wastes was included in the 1995 baseline design concept). Cost estimates for this scenario assume that the relatively efficient packing concept is achieved, and that schedule constraints and delivery coordination for the different waste types do not result in additional costs.

The ability of the repository to accept increased quantities of INEEL immobilized HLW depends, in part, on quantities of HLW from other DOE sites. As previously discussed, Case 2 is near the limit for the 1995 repository design concept. This case assumes that Hanford, Savannah River, and INEEL produce 23,000, 5,453, and 2,733 canisters, respectively. Hanford would use the standard 2-foot diameter by 10-foot canisters for this case. Reference 2 indicates Case 2 "has

been identified by the TWRS [Hanford] program as the most likely current estimate of borosilicate glass canisters to be produced." However, Hanford is pursuing the option of using a 15-foot canister design. Use of this larger canister reduces the median estimate for Hanford HLW canisters from 23,000 to about 13,000 (Reference 6). Recent discussions with Hanford HLW program personnel (Reference 7) indicates the 15-foot canister is now believed to be the most likely option. If INEEL implements a no separations/direct vitrification option for tank and calcine wastes, required glass production should be no more than 18,000 to 20,000 metric tons or 6,200 to 7,000 of the 2-foot diameter by 15-foot canisters (unpublished estimates by this author). These quantities might be further reduced by use of a high temperature melter. Thus, it appears that if Hanford and INEEL both implement the 15-foot canisters, the 1995 repository design can likely accommodate the maximum INEEL canisters, even under the ICPP no-separations case.

The information discussed above does not guarantee that the repository will have the capacity to accept waste from high waste volume options, however, it does suggest that these options cannot be ruled out simply because of the physical inability of the repository to accept the waste. Note that this conclusion is tentative, and would need to be confirmed by discussions with the repository program prior to any decision to implement high waste volume options such as direct vitrification.

An additional question is the legal limit on quantity of waste that can be accepted by the repository. The Nuclear Waste Policy Act requires that OCRWM "shall not accept in excess of 70,000 MTU [metric tons uranium] or equivalent for disposal in the first repository prior to operation of a second repository." (Reference 8, page 33) Reference 8 also states that the planning basis limits the vitrified HLW share of this to 2/3 of 7,000 MTU or 4667 MTU [equivalent]. The method for calculating the MTU equivalent for HLW is not clearly established. A value of 0.5 MTU per canister of glass has been used for some planning estimates. However, as discussed in Reference 5, this value is not universally applicable. Thus, there is some uncertainty as to how the MTU limit applies to INEEL HLW. Page 36 of Reference 8 states:

> "For planning purposes, the 4,667 MTU includes the vitrified HLW from West Valley Demonstration Project and the Savannah River Site. Any additional space within the current 2/3 vitrified HLW allocation will be filled with vitrified HLW from Hanford and the Idaho National Engineering Laboratory. The waste from these sites will also be considered for any additional allocation that becomes available."

Within the uncertainties of the above discussion, it appears possible that the repository could have the physical capacity to accept INEEL HLW, but would be legally barred from accepting INEEL HLW until a second repository is in operation. If and when a second repository will be in operation are highly questionable.

Waste processing schedules may also affect costs and the ability of the repository to accept INEEL HLW. Program schedules and cost estimates for the first repository assume that SNF placement starts in 2010, HLW placement starts in 2015, and all waste placement is completed by 2040. The waste placement schedule requires SNF and HLW to be received and placed at complementary rates. For example, HLW received after all or most SNF is placed would presumably be more costly because the benefit of placing HLW packages between SNF packages at the time they are initially placed would be lost. If INEEL HLW were to be delivered after SNF placement is completed and placement operations and facilities have been shut down, there could be substantial impacts in terms of both cost and ability of the repository to accept the waste.

Relative to INEEL program and process decisions over the next few years, the uncertainty in time spans when the repository will be able to accept the INEEL immobilized waste should be considered in program decisions. For example this should be considered in defining requirements to provide storage for immobilized HLW. Storing for a long period of time followed by eventual disposal in the repository results in additional costs for construction and operation of storage facilities. While these costs are only a fraction of the estimated repository disposal fee, the increase in total cost that will result if waste shipments are substantially delayed is not negligible and should be considered in selecting process and program options. Once they are firmed up, the actual schedules that the repository can accept INEEL HLW may be an important consideration for some INEEL HLW program options, such as preferred schedule for calcine retrieval and processing.

8.0 ALTERNATE HLW WASTE FORMS AND PACKAGE DESIGNS

Evaluation of program options that require changes to issued waste form specifications and package requirements should include consideration of the time and resources required to get such changes approved. All waste to be disposed at the repository must first be accepted by the repository program. The only Immobilized HLW form currently specified in the repository Waste Acceptance System Requirements Document (Reference 8) is borosilicate glass in 2-foot diameter by 10-foot canisters. Requirements have been defined for this product and package type, including some performance specifications (leach test requirements, drop test requirements, etc.). Repository design concepts and evaluations have been developed concerning this product and package type.

Alternate waste forms and package design concepts may be approved and included in future revisions of Reference 8. For example, Hanford is pursuing changes to Reference 8 to allow use of a larger canister (Reference 6). However, it can be safely assumed that substantial schedule time and resources will be required to gain any such approvals. The magnitude of time and resources required depend on the specific changes proposed. Radical changes that have wide ranging implications and debatable merits may require a number of years and substantial

resources to bring to a point when decision can be reached. In the meantime, the program may be substantially delayed while waiting for a decision, or alternatively, a path may be pursued that has not yet been approved, which ultimately may or may not be found acceptable.

9.0 REFERENCES

1. Memorandum, Ronald Milner to Jackson Kinzer, *"Repository Disposal Fee Estimates for the Hanford Tank Waste Remediation System (TWRS) Environmental Impact Statement (EIS),"* U. S. Department of Energy (RW-30), dated July 1, 1996.

2. TRW Environmental Safety Systems Inc., *"Cost Estimate Report on Disposal Costs for U. S. Department of Energy Tank Waste Remediation System Alternatives,"* Civilian Radioactive Waste Management System Management & Operations Contractor WBS: 8.2.1, dated June 28, 1996.

3. U. S. Department of Energy, *"Analysis of the Total System Life Cycle Cost of the Civilian Radioactive Waste Management Program,"* DOE/RW-0479, dated September 1995.

4. Federal Register Notice, *"Civilian Radioactive Waste Management; Calculating Nuclear Waste Disposal Fees for Department of Energy Defense Waste Program Waste,"* pp. 31508-31524, Vol. 52, No. 161, dated August 20, 1987.

5. U. S. Department of Energy, *"Perspective on Methods to Calculate a Fee for Disposal of Defense High-Level Waste in Combined (Civilian/Defense) Repositories,"* DOE/RL-86-10, dated December 1986.

6. Letter, J. O. Honeyman, Westinghouse Hanford Company, to W. J. Taylor, DOE, "Proposed Standard Canister for Tank Waste Remediation System High-Level Waste Disposal," 9653251, dated August 1, 1996.

7. Personal communication between P. S. Schaus, Lockheed Martin Hanford Company, and G. E. Stegen, SESC, January 6, 1997.

8. U. S. Department of Energy, *"Waste Acceptance Systems Requirements Document,"* DOE/RW-0351P Revision 02 DCN 02, dated December, 1996.

Reference 4

Vitrification Facility

LOCKHEED MARTIN

Lockheed Martin Idaho Technologies Company

INTERDEPARTMENTAL COMMUNICATION

Date:	July 20, 1998		
To:	E. C. Anderson	MS 3650	6-1572
From:	D. R. James	MS 3655	6-7139
Subject:	VITRIFICATION FACILITY – DRJ-08-98		

Pursuant to your request, we have evaluated the cost affects in relation to the canister size change. As a result of our cursory review, we anticipate cost changes in the Transfer Tunnel and Interim Storage Facility only.

The overall change to the Total Estimated Cost (TECH) is an increase of $200,000.

If you have additional questions or need further detail, please do not hesitate to contact me at 526-7139 or Lotus Notes ID – NIE.

mlc

cc: Estimate File 2443-AB/2421
R. D. Adams, MS 3655
D. R. James File

Reference 5

High Level Waste Vitrification Facility Process Calculations

Reference 6

Estimated Volumes of Vitrified Calcine and Newly Generated Liquid Waste

Calcine Type	Calcine Volume, m^3	Calcine Density, kg/m^3	Calcine Mass, kg				
Zr	3057	1,600	4,891,200				
Na - Na/Fl	340	1,200	408,000				
Al	918	1,090	1,000,620				
Totals	4315		6,299,820				
Total Mass of Al-Na and Al-Na/Fl (assume 25% Al in calcine blend)							
Mass of Na and Na/Fl =		408,000	kg				
Total Mass of Mixture =		544,000	kg				
Mass of Al Used =		136,000	kg				
Remaining Unused Al Calcine =		864,620	kg				
Mass of Glass Made =		2,176,000	kg				
Volume of Glass Made (SG 2.6) =		836.92	m^3	Note 1			
Total Mass of Al-Zr (assumes 25% Al in calcine blend)							
Mass of Al Used =		864,620	kg				
Total Mass of Mixture =		3,458,480	kg				
Mass of Zr Calcine =		2,593,860	kg				
Remaining Unused Zr Calcine =		2,297,340	kg				
Mass of Glass Made =		13,833,920	kg				
Volume of Glass made (SG 2.6) =		5,320.74	m^3	Note 1			
Total Remaining Mass of Zr (assume 100%)							
Mass of Zr Calcine =		2,297,340	kg				
Mass of Glass Made =		9,189,360	kg				
Volume of Glass Made (sg 2.6) =		3,534.37	m^3	Note 1			
Total Volume of Glass Made from Calcine =		9,692	m^3				
Glass Made from Direct Vitrification of NGLW:							
From liquid vitrification material balance, mass of glass made =				651	lbs/day		
Liquid is vitrified 5 days/yr for 20 yrs, so mass of glass =				65,100	lbs total		
Volume of glass made from NGLW (SG 2.5) =				417	ft^3 =	12	m^3
Total number of canisters made =		13,478					
Note 1:							
Specific gravity values from Vinjamuri (Vitrification of Calcine, letter dated April 22, 1998)							

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Sampling Study

5. Summary: The following discussion summarizes the sampling processes, and their costs, for the High Level Waste Vitrification Facility Feasibility Study.

Sampling processes, and their costs, for the High Level Waste Vitrification Facility can be divided into three types, which are:

1. **Process Sampling:** Sampling the calcine or newly generated liquid waste (NGLW), before the vitrification-melter process, must be done in order to determine the amount of aluminum and other metals that are present. This will determine the amount and composition of the frit to be mixed with the waste that will form a certifiable borosilicate glass. The estimated costs are:

- $7,260,000.00 for 3630 laboratory tests, statistical modeling, building the feed system sampling database;
- $25,000,000.00 for engineering and installing 3 remotely operated sampling apparatus, the necessary instrumentation and the ICP emissions spectroscopy equipment;
- $35,000,000.00 for operating costs of feed sampling ($2000.00/sample, 1.3 samples/canister, 13,478 canisters);
- $3,786,000.00 for operating costs of vitrified core sampling ($3,000,000.00 robotic core drill, core drilling $1000.00/sample, analysis $2000.00/sample, 262 macro-batch samples)
- **$71,046,000.00 total process sampling costs.**

2. **Waste Canister Sampling for Surface Contamination:** Sampling of HVF canister surfaces per NRC and DOE standards for decontamination.

- **$15,500,000.00, total estimated costs for taking and analyzing swab samples** (13,478 canisters, 2.3 samples/canister, $500.00/sample)

3. **Off-Gas Sampling System:** Sampling the HVF off-gas per EPA stack emissions standards.

- $157,000.00 for engineering and installing a required shielded-probe stack emissions monitoring system.
- $628,000.00 additional costs for 4 shielded-probe-sampling systems monitoring the exits of 4 main process points.
- $80,000.00 sampling costs for 40 samples over 20-yr life of HVF.
- **$865,000.00 total estimated cost for 5 shielded probe off-gas-sampling systems.**

4. **Grand Total: $87,411,000.00**

The above costs were developed from the attached discussion, entitled " High-Level Waste Vitrification Facility Sampling Study".

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	D. M. Kiser	D. M. Kiser	4/2/99
Independent Verification	R	R.E Dafoe	R.E Dafoe	4/5/99
Requestor	A	D. A. Lopez	D A Lopez	4/5/99

High-Level Waste Vitrification Facility Sampling Study

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Process Sampling

In the process[1] for producing vitrified high level waste (HLW) in the HLW Vitrification Facility (HVF), either radioactive calcine plus water or newly generated liquid waste (NGLW) is mixed with glass "frit", which produces a slurry. This slurry is then agitated, which keeps it uniformly mixed, fed into a dryer and finally fed into a melter where the mixture is melted, forming a molten borated silicon glass. This mixture is then poured into a stainless steel canister where it cools and the molten material solidifies. This glass filled canister then becomes the final form of vitrified HLW that is ready for transport to a HLW repository.

The design of the process specifies that the HLW will be fed into a waste-receiving tank that will feed each of three mix-tanks, in which either calcine, frit and water, or NGLW and frit are mixed to form the process slurry. This slurry is agitated, sampled, analyzed, and qualified before it is fed to one of three melter feed-tanks. The slurry is then fed, on demand, to one of four dryer/glass melters. The third mix-tank/feed-tank system is required to eliminate process interference caused by awaiting sample analysis or feed tank maintenance. Sampling of each slurry mixture is required because each waste stream contains varying amounts of aluminum (Al), and if too much Al is present in the slurry mixture then the amount of frit in the mixture must be increased. The Savannah River Site Defense Waste Processing Facility (DWPF) is currently producing vitrified high level waste with a qualified process which incorporates slurry mixing, transport, and sampling systems similar to those proposed herein for the HVF.

The sampling requirements for the HVF will be similar to those for the DWPF. In general, the DWPF process utilizes a rigorous sampling plan[2] that closely controls the composition of the waste stream and frit mixture, before the slurry is fed to the melter. The DWPF sampling plan is described in Reference 2. This process assures that a certified glass is produced. Molten vitrified waste is sampled on a less frequent basis, which is once per "macro-batch" (about once every four- (4) months). A "macro-batch", in DWPF terms, is a batch of liquid waste material that was generated by one or more of the DWPF process streams and consists of several thousand liters of waste. This macro-batch is reasonably uniform in chemical composition, and the volume of waste is quite large. Therefore, a fairly large number of vitrified waste canisters are filled while vitrifying this waste. This molten macro-batch sample is taken at the throat of the canister protector that is located at the outlet

of the melter as molten glass is poured from the melter into the canister. This sampling apparatus is a specially designed and manufactured fixture that is described in Reference 2.

Control of the production of certified glass by sampling and analyzing the process feed mixture is heavily dependent on a complete database that contains qualified data, to which the sample analysis can be compared. Extensive pilot scale testing must develop this database. The purpose of the tests is to determine how varying the waste and frit compositions can be bounded for producing a certifiable vitrified waste. In general, the DWPF has achieved this and has demonstrated that controlling the composition of melter feed material can produce certifiable vitrified waste. Because the HLW at the INEEL is different than that at the DWPF then the INEEL must build a similar database that is unique to the INEEL waste stream. Thus, extensive laboratory tests must be performed by producing vitrified samples from various combinations of existing calcines and NGLW with varying compositions of frit, and testing the samples for certification. Comparison of HVF production samples to this database will then assure that a canister contains a certifiable vitrified waste. This kind of process control, by monitoring and controlling the feed stream of a production process in order to govern the product produced is a method that is commonly used in industrial applications[3]. In particular, this method is referred to in Reference 3, as a "Variable Control Chart" method.

In discussions[4] with the LMITCO Nuclear Operations Analysis Unit at the INTEC, the control of various nuclear-fuel-reprocessing processes by controlling the input feed composition is a common method of control used at INTEC in the past. Based on these discussions and the methods described in Reference 3, a rough plan was developed for building the HVF process control database (PCDB) and production process sampling procedure. This plan is outlined as follows:

1. If the estimated distribution of different calcines is considered, as discussed in the "Bin-Set Inventories" section of Reference 9, then there are about 214 regions of existing calcine, that are of different chemical composition, that are stored in the storage bins at INTEC. Each of these different regions can be considered a "macro-batch" in the context that a macro-batch is a region of waste material that is of reasonably consistent chemical composition. Also there are at least two batches/yr, of calcine, made from sodium bearing waste[1], that will be processed during the years 1998-2012 (14-yr), and at least 1 batch/yr of NGLW[1] that will be generated during the life of HVF (20-yr). Thus, there will be about 214 sub-regions of existing calcine combined with 28 batches of sodium bearing calcine, giving about 242 batches of calcine, and 20 batches of NGLW that will be produced during the production life of the HVF. Combining these batches of HLW gives a total of about 262 potential "macro-batches" that will be processed during the life of the HVF.

2. The initial preprocess sample database can be built by formulating and testing about 15 different calcine-frit compositions representing each of the 214 different calcine regions that characterize the storage bin inventory discussed in Item 1, above, and the 28 batches of sodium bearing waste, that will be calcined by 2012. Selection of 15 samples as the initial number necessary is based on the discussions on process control methods used in the past at INTEC[4]. One of the purposes of these tests is to vary the concentrations of aluminum bearing calcine and frit in each sample, because the amount of aluminum present affects the resultant certifiability of the resulting

glass. This amounts to about 3630 samples. Characterization of the NGLW batches must be done as each batch is generated and therefore will not be part of this initial sampling stage.

3. Each of these samples can then be analyzed both before and after they are vitrified. The calcine sample will be tested, prior to vitrification, by utilizing inductively coupled plasma (ICP) emission spectroscopy in order to determine the metal concentrations. The calcine will then be mixed with frit in varying concentrations and vitrified. This vitrified sample will then be tested in order to determine its certifiability according to the requirements of Reference 5. The results of these analyses will then become the initial HVF process control database (PCDB). Hence, the initial database will contain information on 3630 feed composition samples that produce both certifiable and non-certifiable vitrified glass.

4. According to the LMITCO Nuclear Operations Analysis Unit[4] the cost of formulating and analyzing samples will be about $2000.00 per sample. At this cost per sample, the cost of building the PCDB for 3630 initial samples is about $7,260,000.00.

5. During production, in the HVF calcine vitrification process, the calcine will be transferred from the calcine receiving-tank to one of the three- (3) mix-tanks[1] where it will be mixed with water and a sample obtained. The sample will be tested utilizing inductively coupled plasma (ICP) emission spectroscopy in order to determine the metal concentrations, as in Item 3. The purpose of sampling is to determine the amount of aluminum in the mixture. Based on the aluminum content determined by the sample analysis, the proper amount of frit is added to the mixture and agitation continues. Taking a second ICP sample is not considered necessary because the first ICP sample analysis will determine with a high degree of certainty the amount and composition of frit that must be added to the slurry in order to produce a certified glass. If the mixture is within specification as defined by the PCDB then that mixture is transferred to the melter feed-tank. It is estimated that about 25%, by weight, of Al-bearing calcine to frit will make-up a proper mixture for certification[1]. Agitation continues in the feed-tank until the mixture is transferred to the dryer and subsequently to the melter.

6. During production, in the HVF NGLW vitrification process, the NGLW is transferred from one of the two- (2) NGLW receiving-tanks[1] to one of the three- (3) mix-tanks described in Item 5, above. Since the NGLW already contains water, then no water will be added. The same sampling scheme as that described in Item 5, above, is then used to qualify the mixture for vitrification. However, the amount of solid waste is greater for the NGLW process than for the calcine process because the amount of Al in the NGLW is much less than that in the calcine. It is expected that about 50%, by weight, of NGLW solid material to frit will make-up a proper mixture for certification[1].

7. It is unclear how much the costs will be for the apparatus making up the sampling system that will actually draw the samples discussed in Items 5 and 6, above. A study[6] is currently underway to develop the configuration of such a system for the HVF. For the purposes herein, a rough estimate[4] of the costs for three (3) remotely operated mechanical sampling systems (i.e. one for each mix-tank), the necessary instrumentation, and the ICP emission spectroscopy equipment is about $25,000,000.00. It is assumed that, as per Item 4, above, the cost of obtaining and

analyzing samples during production will be about $2000.00 per sample. Assuming that 13,478 canisters (10-ft long) will be filled[1] and that 1.3 samples per canister (average) will be required to qualify each melter feed, then a total cost of about $35,000,000.00 is estimated as the total operating costs for process sampling. The assumption in arriving at 1.3 samples/canister was determined as follows:

- A minimum of 1 sample/canister is required
- It is unknown what the standard deviation in sampling frequency will be. However, assuming plus or minus 1 standard deviation in sampling frequency, gives about 68% confidence[7], which is equivalent to a probability[7] of about 0.25. In physical terms, the probability is equivalent to the fraction of samples that lie within the confidence interval. Thus rounding the probability to the first decimal point, and adding the known minimum-sampling rate of one gives the result of 1.3 samples/canister average sampling frequency.

8. No in-melter or post-melter sampling is planned[1]. However, this will actually be determined by certification of the HVF sampling and control process and the PCDB according to the HLW Vitrified Waste product specifications[5]. If samples of vitrified waste are required, then the most cost effective part of the process in which to take the samples is during the waste/canister cooling stage, just after the canister is filled by the melter. At this stage either a molten sample or a solidified core sample can be taken before the canister cap is placed and welded into place. The process to be used will be the most cost-effective approach. However, if it is assumed that the core sample approach is the more expensive of the two approaches, then a conservative cost estimate can be developed. If a core sample approach is used, then the costs of developing and manufacturing a remotely operated core drilling apparatus would be about $3,000,000.00[8]. The cost of drilling and extracting the sample is estimated to be $1000.00[8] per sample. The cost of crushing and analyzing the core samples is about the same as that for the feed sampling process discussed in Item 4 above, which is about $2000.00 per sample. Thus the cost of about $3,000.00 is estimated for drilling, extracting, and analyzing each core sample. Combining the estimated 242 macro-batch samples of calcine with the 20 macro-batch samples of NGLW discussed in Item 1, above, gives 262 total macro-batches for which a vitrified sample might be taken. This amounts to an estimated cost of about $262,000.00 for core drilling and extraction of the samples and about $524,000.00 for crushing and analyzing the samples. This amounts to a total cost for taking vitrified samples of $3,786,000.00. This number should be considered the upper bound for the vitrified samples to be taken. The current plan[1] is to require about 2 or 3 samples per year by carefully blending different calcines together and requiring a vitrified sample only if the chemical composition of a calcine blend changes significantly. This would amount to a minimum cost of about $3,180,000.00 for the remotely operated core drilling apparatus and 60 samples. It should be pointed out that no remote controlled core drilling apparatus is currently being marketed. Thus some or all of the costs for developing and manufacturing the core drilling apparatus discussed herein might be recoverable by marketing the apparatus to the U. S. Space program or for use in other hazardous environments.

Waste Canister Sampling for Surface Contamination

After a waste canister has been filled with vitrified waste, and the cap welded in place, the surface of the canister will be decontaminated by spraying with a slurry of water and glass frit. The frit, thus used, is then recycled through the vitrification process. In order to prove that the canister surface has been decontaminated, the surface will be swabbed and the swab will be analyzed to detect the presence of radioactive contaminants. If the swab shows contamination then the spraying-swabbing process is repeated until either no contaminants are found or the quantity of contaminants found are less than 1000 disintegrations per minute (dpm) of beta or gamma radiation or less than 20 dpm of alpha radiation[10]. The repository acceptance criteria requirements for allowable surface contamination are yet to be determined. After decontamination is completed then the canister is transferred to the HVF transfer tunnel and transported to the Interim Storage Facility. The cost estimate for the decontamination and swabbing apparatus is already included in the HVF facility design and will therefore not be discussed here. However, the cost of performing the swab and analysis is about $500.00 per sample[10]. Assuming conservatism in that every canister will contain at least one spot of external radioactive contamination, then one swab sample will be required to detect the contamination and one swab will be required to verify that the canister has been decontaminated. Thus a minimum of two swab samples will be required. Assuming that the probability of taking more than two samples per canister is about 0.3, then an average sampling rate of about 2.3 samples per canister will be required (i.e. refer to the discussion of sampling frequency in Item 7 of the section entitled "Process Sampling" above). Since there will be about 13,478 canisters[1] produced, then the total cost of performing the swab sampling is about $15,500,000.00.

Off-Gas Sampling System

Sampling of the melter, and other process off-gases will be achieved by utilizing a shielded probe sampling system, in the HVF exhaust stack, that is similar in design and configuration to that of the Transuranic Storage Area - Retrieval Enclosure (TSA-RE) at the INEEL[11]. The shielded probe system was selected over an isokinetic sampling system with continuous emissions monitors (CEM)s because it has been demonstrated that the shielded probe system outperforms the isokinetic and CEM systems and is more highly cost effective[12]. On November 21, 1994, the United States (US) Environmental Protection Agency (EPA) approved the use of Alternate Reference Methodologies (ARM) for sampling stacks and ducts at all US Department of Energy (DOE) facilities[13, 14, 15]. Reference 11 explains how the shielded probe system, of the TSA-RE stack at the INEEL, achieves this. Since the HVF stack is similar to that of the TSA-RE stack then a shielded probe sampling system is assumed to be adequate for the needs of the HVF emissions stack.

The shielded probe system, in the HVF stack, will operate continuously and will therefore perform the same functions as both a CEM and sampling system. The requirement for implementing a shielded probe system is that the airflow in the stack to be monitored must be characterized so that the probe can be located at the most representative position[16]. In particular, the probe must be located at least 9 stack diameters from the nearest inlet duct so that the air and off-gas flow will be fully developed turbulent flow. This will ensure that a uniform gas-stream velocity profile will be formed over more than 67% of the stack center flow-area. This will, in turn, ensure that the variation of tracer gases and aerosol particles will vary less than 20% at the sample point. Equipment platforms and sampling ports

must then be provided for shielded probe sampling at that position. The estimated costs for a system of this type is based on the cost of the system for the TSA-RE stack[11], which was $157,000.00. This cost includes some laboratory tests conducted by the manufacturer in order to qualify the system. Operating costs must include the cost of personnel that obtain and analyze the samples. However, this is part of the normal operating costs of the HVF and will not be included herein.

The legal requirement for meeting EPA[13, 14, 15] standards for stack emissions monitoring will be met by utilizing a shielded probe system. Additionally, a similar system is also recommended for use at each of the exits of the three main sources of process off-gas and the exit of the process heating, ventilating and air-conditioning (HVAC) system, in order to isolate the locations of unforeseen emissions from one of the processes. These systems are:

1. At the exit of the melter off-gas ducting.

2. At the exit of the ducting that surrounds the tank, vessel, and process venting system.

3. At the exit of the ducting that surrounds the vitrifier feed and dryer systems.

4. At the exit of the process heating, ventilating and air conditioning system.

In order to assign an order of importance to these additional shielded probe sample systems a risk analysis will have to be performed for each system. If it is so determined, then a sampling system should be purchased and installed. In any case for the purposes herein, if it is assumed that each system is necessary, then the total cost of the recommended systems is $628,000.00.
For each shielded probe sample system it is estimated that the cost of changing sample filters and collectors and analyzing them for RCRA, mercury, radionuclide, and organic emissions is about $2000.00/sample. It is currently anticipated that the HVF process will be quite clean and will therefore require sample analysis about twice per year. Thus, over the 20-yr life of the HVF 40 off-gas samples will cost a total of $80,000.00. The resulting total cost is $865,000.00 for the recommended HVF off-gas sampling system.

ENGINEERING DESIGN FILE

Project File Number 02204

Project/Task High Level Waste Project

Subtask Vitrified Waste Option

Title: Electrical Study

Summary: This EDF evaluated the electrical requirements for the Vitrification Facility. The connected loads were estimated to be 4.7 MVA, an evaluation of the usage indicated that the demand would be approximately 4.1 MVA. The majority of the demand is from the HVAC equipment. The Bath Electrode requires a source of standby power. The estimated standby requirement is 2.6 MVA. The standby power system at the ICPP is presently undergoing a complete redesign and the final configuration and spare capacity is not known. It would be safe to assume that a new standby generator will be required. This generator would be installed in the existing standby generator building and would be connected to the Substation 60, which distributes standby power to the ICPP. Normal power would be supplied from Substation 15 via two existing Power Sectionalizing Switches. These switches are located in the northeast quadrant of the ICPP and would supply a 13.8kV feed to the new load centers. One load center will supply a secondary voltage of 480 Volts for building and process loads and one will supply 4160 Volts for the large HVAC motors. Standby power would be supplied through this load center from Substation 60.

Distribution (complete package):

Distribution (summary package only):

Author	Dept.	Reviewed	Date	Approved	Date
J.D. Zolynski J.D.Z 1-19-99	Facility Engineering		1/19/99		2/3/99
		LMITCO Review	Date	LMITCO Approval	Date

See Management Control Procedure (MCP) 6 for instructions on use of this form.

VITRIFIED WASTE OPTION

1.0 ELECTRICAL REQUIREMENTS

1.1 EXISTING AND PLANNED ELECTRICAL UTILITIES AT ICPP

The ICPP ties into the 138kV INEEL loop at Substation 2 which is located outside the area fence to the south. Substation 2 transforms the 138kV to 13.8kV and provides power to Substation 10 which is located within the ICPP complex. Power at 13.8kV is than distributed from Substation 10 through the complex. The Electrical and Utility System Upgrade (EUSU) project is currently under construction. The EUSU project will install a new 13.8kV electrical distribution system throughout the complex. This new system will provide greater safety, additional capacity and greater reliability.

Currently, standby power is provided by each facility. Standby generators are located at various facilities and operate as an island of power during a normal power outage. The EUSU project will construct a standby power plant, install new standby generators and tie existing generators into the standby power system. Standby power will than be distributed through the complex by the new 13.8kV distribution system. The Utility Control System (UCS) will control the usage of standby power.

1.2 POWER REQUIREMENTS

1.2.1 NORMAL POWER

The electrical requirements of the Vitrification Facility were analyzed and determined to be 4,708 kVA connected, with a demand projected to be 4,147 kVA. The results of the analysis are shown in Tables 1 and 2. The major loads with the Vitrification Facility are the HVAC equipment, and lighting.

Normal power will be supplied to the Vitrification Facility by 13.8 kV feeders from Substation 15. A combination of new and existing duct banks will be used to route the feeders.

1.2.2 STANDBY POWER

The requirements for standby power for the Vitrification Facility were analyzed and determined to be 2,656 kVA. The results of the analysis are shown in Table 3. The standby loads for the Vitrification Facility will consist of the following:

- UPS Normal and Bypass feeders
- Selected lighting and miscellaneous loads
- HVAC equipment
- Spray dryer system
- Other loads as determined in later designs

Standby power to the Vitrification Facility will be provided over the normal power distribution system from Substation 60, the Standby power plant substation via Substation 15. The standby power system is at or near capacity. Upon completion of the EUSU project, an evaluation of the spare capacity will be performed. A 2000 kVA generator will be required to meet the standby requirement for this facility. A 2000 kVA diesel generator and associated equipment will be installed in the space available in the standby generator plant. The UCS will perform shedding of the non-essential loads. The UCS will control the operation of circuit breakers and equipment to assure that only those loads requiring standby power remain in operation.

1.2.3 DISTRIBUTION SYSTEM

Both normal and standby power will be provided by one set of redundant feeders. The EUSU project will install a redundant pair of sectionalizing switches in the north east quadrant of the complex. These switches, PSS-NCE-1507A and PSS-NCE-1557A are supplied by one set of 500KCMIL cables each. These switches are fed directly from Substation 15 and are very lightly loaded. New duct banks will be run from these switches to new load centers. The load centers will be double ended and will provide a redundant source of power to the Vitrification facility.

1.2.4 UNINTERRUBTABLE POWER SUPPLY (UPS)

A solid state UPS with a static transfer switch will be provided. The UPS will be provided with 20-minute battery backup. Both the normal feed and the bypass feed to the UPS will be on standby power. The UPS will feed a 208Y/120 Volt panel. The UPS and the panel will be located in the electrical room. The UPS will support the following loads: voice paging/evacuation systems, environmental monitoring system and other critical loads.

1.3 LIGHTING

1.3.1 INTERIOR LIGHTING

Lighting in office areas and other low ceiling areas will be supplied by recessed of pendant mounted fluorescent fixtures. These fixtures will be operated at 277 Volts and will be locally switched. Motion detectors will be utilized areas of low occupancy. Lighting in high bay areas will be will be supplied by metal halide fixtures operating at 277 Volts. The metal halide fixtures will be switched at the lighting panel.

1.3.2 CELL LIGHTING

Lighting in the cells will be designed to allow for remote operation of the equipment via an in cell CCTV system or by operation through cell windows. Lighting of the cells will be provided utilizing fixtures mounted in "K" plugs. The number, location, and size of the fixtures and associated "K" plugs will be coordinated with the cell design during the conceptual phase. The fixtures will be designed and fabricated to facilitate installation

and removal for replacement of the light source. Metal Halide light sources are desired and will be given preference during the final design. The lighting design will take into account light loss through the translucent panels as well as the light lost in viewing operations through the cell windows.

1.3.3 EXTERIOR LIGHTING

The exterior of the building will be illuminated with high pressure sodium wall pack fixtures mounted over each personnel door. Loading areas will be provided with high pressure sodium wall pack fixtures on each side of the doors. The need for area lighting in maneuvering areas will be evaluated during the conceptual and final designs.

1.3.4 EMERGENCY AND EXIT LIGHTING

Emergency egress lighting will be in accordance with NFPA 101, Life Safety Code. In areas where illumination is provided by fluorescent fixtures, selected fixtures will be provided with integral battery back up. In areas where illumination is provided by metal halide fixtures, selected fixtures will be provided with a quartz lamp which will be used for emergency lighting. The quartz lamp will be connected to the UPS system or will be provided with an integral battery.

1.4 DESIGN DESCRIPTION

1.4.1 SITE CONDITIONS

Electrical equipment will be rated for continuous operation at an elevation of 5,000 feet above sea level.

1.4.2 HAZARDOUS LOCATIONS

Several areas within the facility will be used for storing or handling of hazardous materials. An evaluation will be performed during the conceptual design and the final design to determine the effects of these materials on the installation of electrical equipment. Flammable and Combustible Liquids Codes NFPA 30: National Electrical Code, NFPA 70; and Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Process Areas, NFPA 497A will be used in making the determination.

1.4.3 SERVICES

1.4.3.1 PRIMARY SERVICE

Two 13.8 kV feeders will provided the primary service to the site. The feeders will originate from Substation 2 located outside the fence. Power for Vitrification Facility will be carried over existing feeders up to the Sectionalizing Switches. From the Sectionalizing Switches, new feeders will be routed through new and existing duct banks.

1.4.3.2 STANDBY POWER

Standby power will be provided at 13.8kV over the existing primary distribution system. The existing UCS in conjunction with the Plant Control System which will be installed in the Vitrification Facility will control selected circuit breakers to limit the standby power distribution only to those loads deemed important.

1.4.3.3 UTILIZATION VOLTAGES

Three and possibly four utilization voltages will be provided for the Vitrification Facility. Transformers and load centers located near the facility will transform the 13.8kV to 480Y/277 Volt, transformers down stream will transform the 480 Volts to 208Y/120 Volts. The third and fourth utilization will be determined during the conceptual and title designs. 4160Y/2400 Volts is desired as the third utilization however, the ICPP currently utilizes 2400Y/1386 Volts. Preferably, only one will be used. Equipment selection and operating personnel preference will determine the voltage to be utilized.

Electrical loads will be assigned voltages as follows:

- Motors 100 HP and larger - 4160V, 3 phase or 2400V, 3 phase
- Resistive loads 100 kVA and larger - 4160V, 3 phase or 2400V, 3 phase
- Motors ½ HP to less than 100 HP - 480V, 3 phase
- Resistive loads 1 kVA to less than 100 kVA - 480V, 3 phase
- Motors less than ½ HP 120V, single phase
- Miscellaneous loads less than 1 kVA - 120V, single phase
- Lighting – 277V single phase.

In certain circumstances, 480 volt, 3 phase will be utilized for motors over 100 HP and loads over 100 kVA. This will be determined on an individual basis after the effects have been evaluated.

1.4.4 EQUIPMENT

1.4.4.1 LOAD CENTERS

Two load centers will be provided. Both load centers will be located outside the Vitrification Facility and will be a NEMA 3R Walk-in type similar to the load centers currently in use at the ICPP. One load center will provide 4160 Volts, for the large HVAC motors, and one will provide 480/277 Volts. Each load center will be double ended. Each transformer will be sized to provide service to all loads on the load center. The load centers will be provided with all equipment and wiring to insure that it is fully compatible with the existing UCS System.

1.4.4.2 TRANSFORMERS

Transformers 5,000 kVA and below will be cast coil, dry type transformers. Transformers over 5,000 kVA will be oil filled.

1.4.5 LIGHTING

Lighting levels will conform to the Illuminating Engineer's Society (IES) handbook and standard practices at the ICPP. In general, the design will provide the following illumination levels:

- Work Stations 70 to 90 foot candles depending on activity
- Work Areas 30 to 50 foot candles depending on activity
- Non-Work Areas 10 foot candles, 50 where data is obtained

1.4.6 GROUNDING

Grounding at the ICPP is accomplished with bare copper conductors installed in all duct banks and ground rods installed in every manhole this in turn is solidly connected to the casing of the deep wells. Facilities and structures throughout the ICPP are connected to this ground system. As well, the Vitrification Facility will be connected to the ground system. Grounding within the facility and at the out door load centers and other structures will be accomplished in accordance with the National Electrical Code and IEEE Standard 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems.

1.4.7 LIGHTNING PROTECTION

Lightning protection will be provided in accordance with NFPA 78, Lightning Protection Code.

TABLE 1

WASTE TREATMENT PROJECT

CONNECTED LOAD
VITRIFIED WASTE OPTION

LOAD	kVA
General Building Lighting 308,000 sq. Ft @ 1.75 Watts per sq. Ft = 539,000 Watts	539
Miscellaneous Loads 308,000 sq. Ft. @ 1.0 Watts per sq. Ft = 308,000 Watts	308
HVAC Loads: Supply Fan Motors 4@ 125 HP 9@ 50 HP Exhaust Fan Motors 10@150 HP Miscellaneous HVAC 50 HP small Motors	 500 450 1500 50
Process Equipment: Glass Melters 4@ 185 kW Spray Dryer System 4@ 24 kW Pumps, Agitators, Scrubbers, Blowers and Conveyors 455 HP Cranes 70 HP	 740 96 455 70
Total connected kVA	4,708

TABLE 2

WASTE TREATMENT PROJECT

DEMAND
VITRIFIED WASTE OPTION

LOAD	DEMAND	kVA
General Building Lighting 308,000 sq. Ft @ 1.75 Watts per sq. Ft = 539,000 Watts	539,000 Watts @ 90% Demand = 485,100	485
Miscellaneous Loads 308,000 sq. Ft. @ 1.0 Watts per sq. Ft = 308,000 Watts	308,000 Watts @ 50% demand = 154,000	154
HVAC Loads: Supply Fan Motors 4@125 HP 9@50 HP Exhaust Fan Motors 10@150 HP Miscellaneous HVAC 50 HP small Motors	 4 @ 125 HP 9 @ 50 HP 10 @ 150 HP 50 HP @ 75%	 500 450 1500 38
Process Equipment: Glass Melters 4@ 185 kW Spray Dryer System 4@ 24 kW Pumps, Agitators, Scrubbers, Blowers, and Conveyors 455 HP Cranes 70 HP	 4 @ 185 kW 4 @ 24 kW 25% of 455 HP 1 @ 70 HP	 740 96 114 70
Total Demand kVA		4,147

TABLE 3

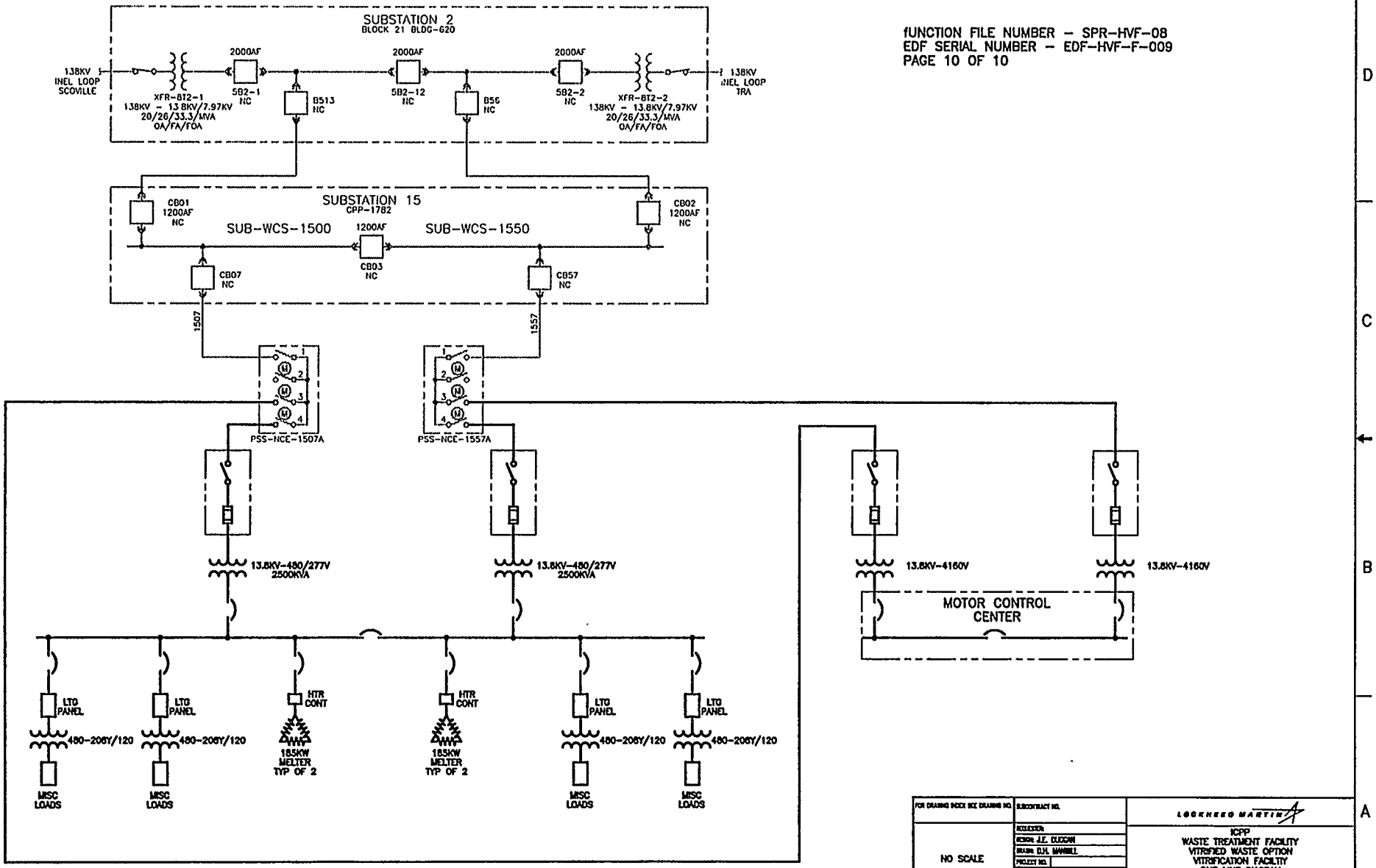
WASTE TREATMENT PROJECT

STANDBY POWER REQUIREMENTS
VITRIFIED WASTE OPTION

LOAD	STANDBY POWER	kVA
General Building Lighting	10% of 539,000 = 53,900	54
Miscellaneous Loads	10% of 308,000 = 30,800	31
HVAC Loads		
Supply Fan Motors 4 @ 125 HP	4 @ 125 HP	500
9 @ 50 HP	9@ 50HP	450
Exhaust Fan Motors 10 @ 150 HP	10 @ 150 HP	1500
Miscellaneous HVAC 10 % of 50 HP	5 HP	5
Process Equipment	20 HP	20
Spray Dryer System	4@ 24 kW	96
Total Standby kVA		**2,656**

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE

FUNCTION FILE NUMBER – SPR–HVF–08
EDF SERIAL NUMBER – EDF–HVF–F–009
PAGE 10 OF 10



FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
NO SCALE	DESIGN J.E. DUGGAN DRAWN D.H. MANNELL	ICPP WASTE TREATMENT FACILITY VITRIFIED WASTE OPTION VITRIFICATION FACILITY ONE LINE DIAGRAM
DESIGN PHASE	FOR BUYER/APPROVAL SIGNATURES	SIZE D · CAGE CODE 01MF3 · DRAWING NUMBER 200-10-530 · REV
QUALITY LEVEL	EFFECTIVE DATE	SCALE NONE · SHEET E–1

ENGINEERING DESIGN FILE

1. Project File No. 02204v 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: : HLW Vitrification Facility Feasibility Study Canister Flow Diagram

5. Summary: This Engineering Design File (EDF) presents the waste canister flow diagram, HVF-M-01, which is attached and which shows a schematic of the movement of the waste canisters through the HLW Vitrification Facility processes. The following discussion summarizes the flow diagram.

The flow diagram begins at the left-hand side of the drawing and shows a representation of the two operations floors at the –32-ft level and ground level. It should be noted that each labeled room might not be physically located adjacent to the labeled room shown successively on the flow diagram. The diagram only shows rooms or facilities in the succession of the process through which the canister moves during the vitrification and canister filling processes.

Beginning at the left-hand side of the drawing, the clean canisters are off-loaded, at ground level, from a truck into a transfer cart utilizing a polar overhead crane. After off-loading, the transfer cart, containing canisters, is moved from the truck airlock through a corridor and into the clean canister storage room where the canisters are placed into a canister storage unit. As the canisters are needed each is moved, utilizing a polar overhead crane, to a floor hatch and lowered through the hatch to the canister staging room at -32-ft below ground level. At this point the canister is staged for lifting the canister using the filling and capping cell polar overhead crane in order to begin the process of filling the canister with vitrified waste. The canister is then moved to one of four canister lift stations. At the canister lift station the canister is raised by a lifting mechanism until the canister top engages that station melter hatch. Upon engaging the melter hatch the melter then extrudes its contents of molten vitrified waste and fills the canister. The canister is then lowered back to the -32-ft floor and again picked-up by the polar overhead crane. The polar overhead crane then moves the filled and hot container to the canister cooling station, where the canisters are cooled. After the canisters are sufficiently cooled, the crane then moves the canister to the canister capping station where a cap is placed on the canister top. The canister is then lifted by the welding cell polar overhead crane, located at the cell ceiling near the +45-ft level, through a floor hatch to the GTAW station, at ground level, where the canister cap is welded into place. This seals the vitrified waste inside the canister. The weld is then leak checked. The welding cell polar overhead crane is then utilized to lower the canister through a floor hatch into the decon cell, at the -32-ft level. The outside of the canister is then decontaminated and lifted through a floor hatch, utilizing the smear cell polar overhead crane, at the cell ceiling near the +45-ft level, into the smear station, where the entire surface of the canister is sampled for radioactive contamination using a smear system. The canister then waits until the analytical laboratory tests the smear for contamination. Upon completion of the smear test verifying that the canister in free of contamination, the canister is lowered through a floor hatch, utilizing the smear cell polar overhead crane, into a canister transport cart that will move the canister through the transfer tunnel to the Interim Storage Facility.

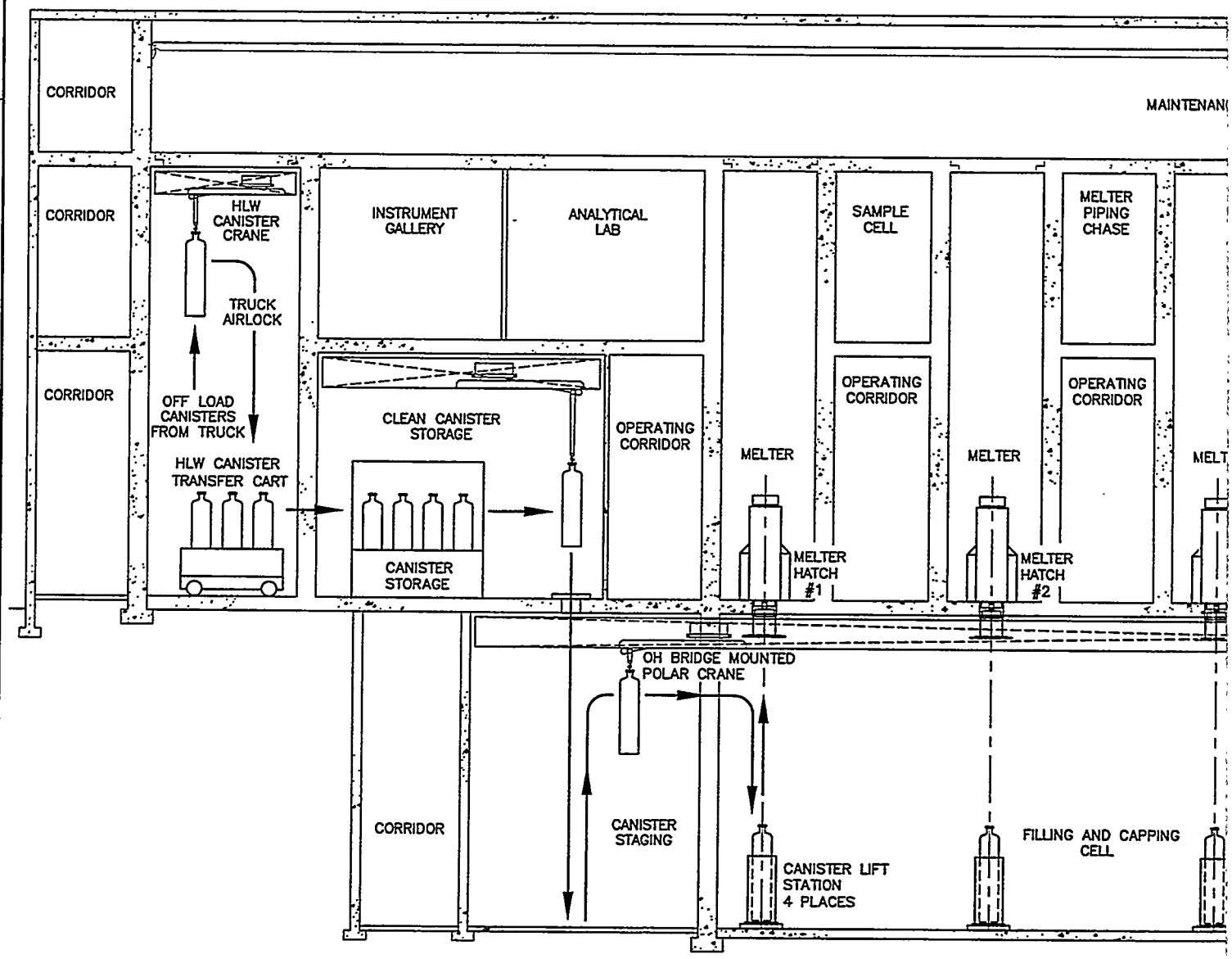
6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	D. M. Kiser	Kenneth M. Kiser	2/1/99
Independent Verification	R	R. E. Dafoe	R E Dafoe	2/3/99
Requestor	A	D. A. Lopez		

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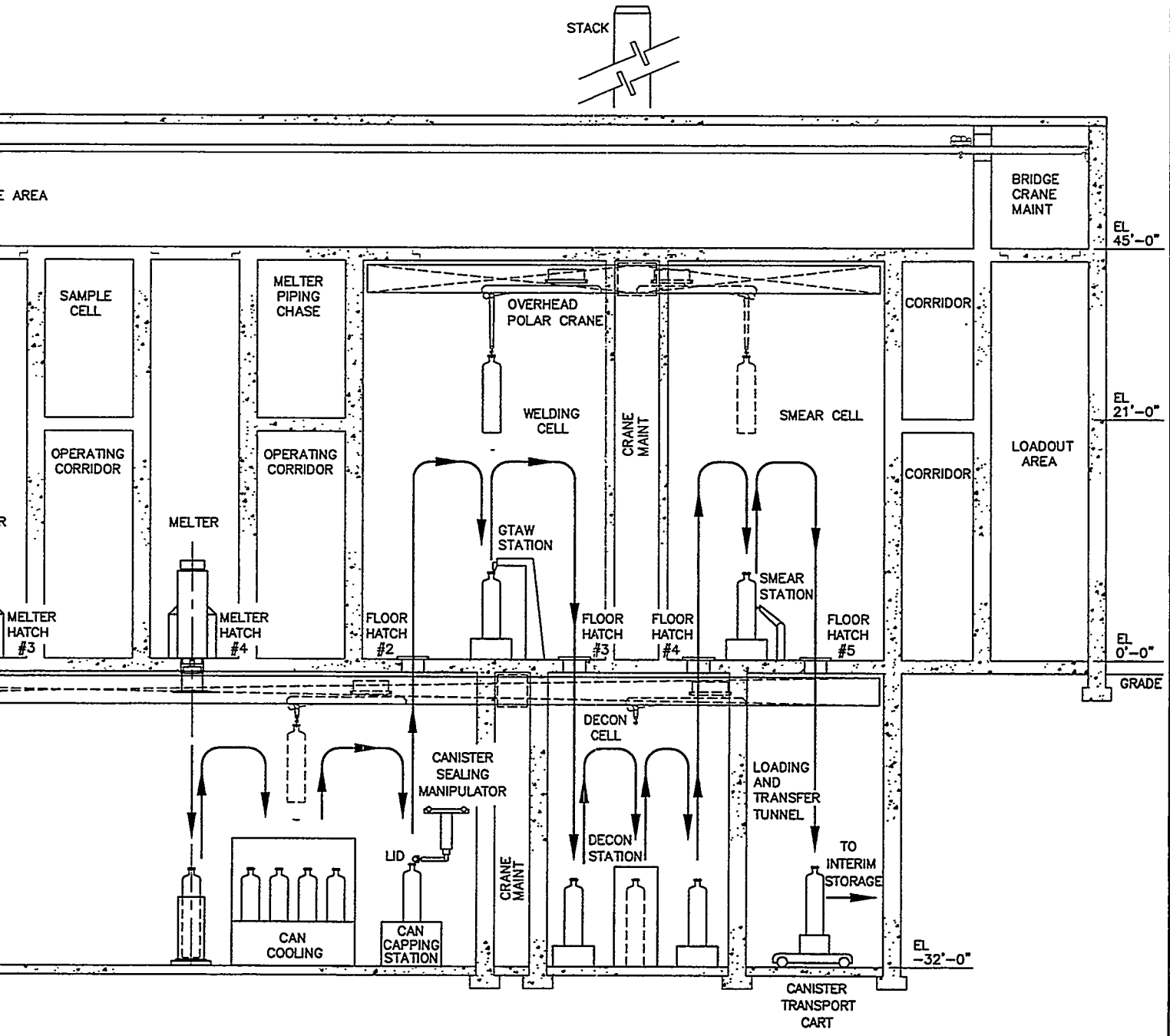
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REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:



W DIAGRAM

NG SECTION

FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
NO SCALE	REQUESTER: D HARRELL DESIGN: E ANDERSON DRAWN: RMHall PROJECT NO. SPEC CODE	HLW VITRIFICATION FACILITY FEASIBILITY STUDY FOR THE HIGH LEVEL WASTE PROGRAM CANISTER FLOW DIAGRAM
DESIGN PHASE: FEASIBILITY	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE: D; CAGE CODE: 01MF3; INDEX CODE NUMBER: AREA 200, TYPE, SL, ORG 24 530; DWG-; REV
QUALITY LEVEL: 3	EFFECTIVE DATE:	SCALE: NONE; SHEET HVF-M-01

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Utilities Study

5. Summary: Utility needs for the HVF have been identified and are summarized in the following subsections. The scope and cost for new facilities or upgrades to existing facilities for these utilities have not been included in this study, but are included in the Utilities and Infrastructure Study[1].

References

1. Russell S. Garcia, "Utilities and Infrastructure Report", INEEL/EXT-97-01398, February 1998.

2. J. D. Zolynski, "High Level Project, Vitrified Waste Option, Electrical Study", EDF-HVF-F-009, (undated).

3. M. E. Van Sickle, "High Level Waste Vitrification Facility - HVAC Study", EDF-HVF-F-012, 1/29/99.

4. Email note, M. E. Van Sickle to Dennis M. Kiser, "HVAC Fan Motor and Steam Usage for the Vitrification Facility", 1/19/99.

5. W. J. Prendergast, "High Level Waste Vitrification Facility - Offgas Treatment Study", EDF-HVF-F-004, 2/1/99.

6. R. R. Kimmitt, Engineering Design File EDF-HVF-F-002, "High Level Waste Vitrification Facility Process Calculations", March 11, 1999.

7. W. J. Prendergast, "Non-Separation Alternatives - Vitrified Waste Option", EDF-VWO-004-REV 1, 1/21/98.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	D. M. Kiser	Dennis M. Kiser	4/9/99
Independent Verification	R	R. S. Garcia	Russell S. Garcia	4/13/99
Requestor	A	D. A. Lopez	D. A. Lopez	4/13/99

HVF Utilities Study

Electrical Power

The estimated connected load[2] is 4,708 kVA with projected demand[2] at 4,147 kVA for the HVF facility.

Standby Electrical Power

The estimated standby power requirements[2] are 2,656 kVA for the HVF facility.

Steam

Steam is required for the HVF facility HVAC[3, 4] and the vitrification offgas treatment system[5]. The HVF HVAC requirements are for 27,600 lbm/hr at 150-psig during peak steam usage, with 5708 lbm/hr at 150 psig during average steam usage. The HVF offgas treatment system consists of four- (4) slurry spray dryer systems that each requires about 1,100 lbm/hr at 150 psig, which results in a total steam usage of 4,400 lbm/hr. The steam thus used is required to heat the offgas treatment system air stream that dries the slurry mixture. The steam required is dry saturated steam such as that generated by the existing ICPP steam plant (150 psia at approximately 181°C).

Breathing Air

The use of breathing air has been identified and is discussed in EDF-HWO-006. Specific equipment for the facility breathing air system has not been identified due to the scoping level of this study. However, it is deemed necessary and is included the cost estimate.

Plant Air

The only process equipment identified that uses plant air are the four- (4) calcine pulverizers that feed the slurry mix tanks. Each pulverizer will use about 1,653 scfm of plant air at 100 psig, which results in a total requirement of 4959 scfm. Other specific equipment that uses facility plant air has not been identified due to the scoping level of this study. However, it is deemed necessary and is included in the cost estimate.

Raw Water

Raw water is required in order to supply the three- (3) vitrification slurry mix tank water make-up requirements, the four- (4) melter cooling jackets and slurry dryer condensers, and the HVF fire suppression systems. The initial requirement[6] for start-up of the mix-tank processes requires about 21,000 lbm of raw water at a rate of about 1.75 gpm. After this initial charge the slurry mixing/drying processes form a closed loop in which the water is used, vaporized, condensed, and recycled, so that only make-up water will be required to compensate for leakage of evaporated water into the offgas treatment system. It is estimated[6] that about 100 g/day, at a rate of about 0.07 gpm, will be required for make-up water. Raw water requirements as a coolant for the melter cooling jackets will be about 200 gpm, total, and for the slurry dryer condensers[5] will be about 40 gpm, total. Specific raw water requirements for the HVF fire suppression systems have not been identified at the time of this investigation. However, raw water requirements are discussed for fire suppression in Reference 1.

Potable Water

About 124 personnel will operate the HVF during normal operations[7]. Thus, assuming that each person will require about 25 g/day of potable water, then a total of about 3,100 g/day of potable water will be required during HVF operations.

Process Waste

No facilities for process waste will be required as all process waste will be recycled and included in subsequent slurry mixtures. Water used to cool the melters is recirculated and cooled by an air-cooled heat exchanger. Water evaporated during the slurry drying process will be condensed and recycled in subsequent slurry mixtures. It is estimated that about 100 g/day of evaporate will be lost and channeled into the offgas treatment system which eventually vents into the atmosphere through the HVF stack.

Sanitary Waste Water

About 124 personnel will operate the HVF during normal operations[7]. Thus, assuming that each person will produce about 25 g/day of waste water, then a total of about 3,100 g/day results, which will flow through a sewage drain system to the ICPP sewage treatment and settling pond area.

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task Non-Separations Alternative

3. Subtask High Level Waste Vitrification Facility

4. Title: HVAC Study

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

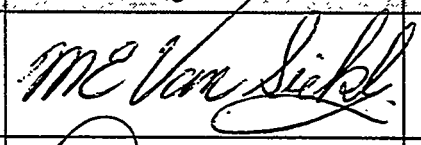
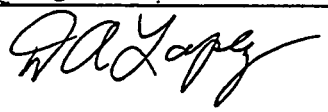
This EDF takes a preliminary look at the required air flow for the facility to minimize the spread of radioactive contamination between different rooms in the building. Room volumes and recommended air changes were used to determine the air flow for each room. Rooms were grouped into like contamination areas. Similar contamination areas are then ventilated and filtered using the same HVAC (fan, duct and HEPA) system.

The attached drawing (HV-1) shows the HVAC air flow diagram for the facility. This is by no means the only configuration in which the air flow may be distributed but is given as one method in order to get a grasp of the order of magnitude of the HVAC for the facility.

6. Distribution (complete package): D. J. Harrell MS 3211; B. R. Helm MS 3765, V. L. Jacobson MS 3211; M. S. Spinti MS 3650, WTP EIS Studies Library; Project File.

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	M. E. Van Sickle		1/29/99
Independent Verification	R	L. E. Guillen		1/29/99
Requestor	A	D. A. Lopez		2/9/99

In addition to the offgas system, the VF will be required to have two ventilation confinement zones per DOE Order 6430.1A. This section will deal with the two confinement zones, and the non-confinement area. A ventilation confinement system will be provided, which, in conjunction with the physical barriers, maintains a continuous airflow pattern from areas of low potential contamination to areas of high potential contamination. The objectives of the confinement systems are to prevent the spread of radioactive and other hazardous materials to occupied areas; and to minimize the release of radioactive and other hazardous materials in facility effluents. The primary confinement consists of the process hot cells and hot maintenance areas, which will be exhausted through two stages of HEPA filters. The primary confinement boundary will be comprised of hot cell walls, welded stainless steel ductwork and HVAC equipment designed to maintain its structural integrity during and after operational and natural-phenomena design basis accidents (DBAs). The secondary confinement boundary consists of the operating corridors and other building structures that surround the primary confinement. The secondary confinement boundary contains all ventilation system equipment such as HEPA filter units and exhaust fans. The non-confinement boundary consists of offices, control rooms and support areas outside the secondary confinement boundary. The non-confinement zones do not require unique ventilation systems and will be maintained at a slight positive pressure with respect to ambient. HEPA filters will remove contaminated particulates, but no carbon absorber beds will be provided in the primary filter trains, because semivolatile fission products and iodine will be removed by the offgas system.

Drawing HV-1 depicts the air flow diagram of the HVAC system for the VF, and the HVAC requirements are attached here with. Two air handling units (AHU) will supply 184,200 cfm of conditioned air to the operating corridor at levels -32 ft, 0 ft 0 in., -+21 ft and +45 ft. An additional 2 air handlers will supply 123,800 cfm of 50F air to primary confinement areas. Air from the operating corridors will be cascaded into the hot cells via AHUs, each consisting of a supply blower and a single stage testable HEPA filter. Each set of air handler supply units will be sized so that one bank of HEPA filters may be closed off for changeout with out affecting the remainder of the unit, and each set of filters will be equipped with a redundant fan. Air from the hot cells will be exhausted to the stack through two stages of testable HEPA filter units and exhaust fans. HEPA filter sets will be sized so that one bank may be closed off for changeout with out affecting the remainder of the units and a redundant exhaust fans will be provided for each set of HEPA filters.

The control room will be provided with an independent HVAC system. Air from the room will be recirculated. Supply AHUs will have 100% redundancy. Administrative offices will be provided with an independent HVAC system. Air from these rooms will be recirculated.

The facility will be provided with an independent chilled water system consisting of central chillers and pumps, delivering chilled water to various cooling coils. This system removes built-up heat from process equipment because cooling will not be required for personnel comfort in the operating corridor. The facility will obtain steam for comfort heating from an INTEC central steam supply facility (see the Utilities and Infrastructure Report).[10] The HVAC system will be controlled by a central electronic system located within the facility.

Redundancy will ensure proper ventilation confinement during HEPA filter changeout or fan maintenance. Exhaust ductwork will be located in areas that will not be normally occupied. HEPA filter housings will have the capability to be leak tested and tested for filter efficiency in place. Single stage HEPA filtration will be provided at the hot cell intakes to prevent possible contamination from momentary back flow to the occupied areas. HEPA filters units will be designed per the American Society of Mechanical Engineers (ASME), N509, Nuclear Power Plant Air-Cleaning Units and Components, and tested per ASME N510, Testing of Nuclear Air Treatment Systems. Confinement boundaries will be sealed to maintain isolation when pressure differentials fall below normal conditions. Exhaust systems for the primary and secondary confinements will be round stainless steel welded joint ductwork designed and installed in accordance with applicable Sheet Metal

and Air Conditioning Contractors National Association, Uniform Mechanical Code, and American Conference of Governmental Industrial Hygienists standards.

Confinement zones will be supplied by once through ventilation. All the airflow from these zones will be HEPA filtered and discharged to the exhaust stack, with no air recirculation. Each HEPA filter unit includes a stainless steel plenum housing, a deluge system, demister, prefilter, one or two stages of side-bagout HEPA filters, DOP test sections and ports, and a fan. The exhaust fans have integral adjustable flow control. The supply and exhaust fans for the hot cells can be powered from the INEEL site standby power grid (see the Utilities and Infrastructure Report).[10] This allows the ventilation confinement to be maintained in the hot cells during a loss of off-Site power condition.

Automatic local stand-alone controllers will be provided with the HVAC equipment. Graphic displays mimicking the HVAC system will be available in the control room for monitoring and for remote manual override control. The HVAC system will have local operator stations. However, the control room operator will have supervisory control capability to start and stop the HVAC system and to change setpoints. Alarms and out-of-tolerance conditions will be annunciated in the control room. It is assumed that a shielded probe air monitor system can be used in the VF exhaust stack to monitor the discharge from the ventilation system and offgas exhaust.

This facility will be designed with the following ventilation parameters:

- Eight air changes per hour for primary confinement
- Four air changes per hour for secondary confinement
- One cfm per square foot for administrative areas
- Two cfm per square foot for the control room
- One stage of testable HEPA filters for hot cell inlet
- Two stages of testable HEPA filters for hot cell exhaust
- One stage of testable HEPA filters for secondary confinement exhaust
- Once through ventilation for primary and secondary confinement zones
- Room pressures maintained in accordance with Table 1.

It is assumed that areas with large in-cell heat loads, which exceed normal nuclear ventilation capability, will have additional fan coil cooling units installed. These units will recirculate the air for cooling purposes only and will have no filtering capabilities. An example of this would be auxiliary room cooling for removing heat from canister cooling station in the canister filling and capping cell.

Table 1. HVF HVAC Data

Room	Room Volume (1000 ft3)	Required Air changes per hour	Static pressure required (in-wg)	Flow Rate required (1000 cfm)	Room grouping
1. Office	74.7	1 CFM/FT2	0.1	8.3	A
2. Electrical Equipment Room, Telephone Room, Fire Protection Room, Elevator Equipment Room, Mechanical Equipment Room	139.3	2	0.1	4.6	A
3. North Truck Air Lock	20	4	0.1	1.3	A
4. South Truck Air Lock	34.1	4	0.1	2.3	A
5. Decon Makeup Room, Decon Distribution Room	72.6	4	0.1	4.8	A
6. Operating Floor (-32)	341.5	4	-0.25	22.8	B
7. Operating Floor (00)	475	4	-0.25	31.7	B
8. Operating Floor (+21)	444.9	4	-0.25	29.7	B
9. Operating Floor (+45)	522.6	4	-0.25	34.8	B
10. Hatch Floor	950.5	8	-0.75	126.7	C
11. Crane Maintenance Room	49.3	8	-0.75	6.6	C
12. P & V Corridor	178.4	8	-0.75	23.8	D
13. Pre Decon Room, Decon Room, Hands-on Room	16.5	8	-0.75	2.2	D
14. Cut Up Cell (+21)	15.1	8	-0.75	2	D
15. Process Equip. Canyon	177.3	8	-0.75	23.6	D
16. Jumper Storage Room	33.4	8	-0.75	4.5	D
17. Instrument Gallery	33.1	8	-0.75	4.4	E
18. Analytical Lab	35.3	4	-0.25	2.4	B
19. Melter Room #1	32.8	8	-0.75	4.4	F
20. Melter Room #2	32.8	8	-0.75	4.4	F
21. Melter Room #3	32.8	8	-0.75	4.4	F
22. Melter Room #4	32.8	8	-0.75	4.4	F
23. North Sample Cell	5.9	8	-0.75	0.8	F
24. South Sample Cell	5.9	8	-0.75	0.8	F
25. North Sample Collection Rm	6.3	8	-0.75	0.8	F
26. South Sample Collection Rm	6.3	8	-0.75	0.8	F
27. North Storage (+21)	13.4	4	-0.25	0.9	B
28. South Storage (+21)	13.4	4	-0.25	0.9	B
29. Weld Cell	72.1	8	-0.75	9.6	E
30. Smear Cell	62.3	8	-0.75	8.3	E
31. Crane Maintenance Rm	16	8	-0.75	2.1	E

Room	Room Volume (1000 ft3)	Required Air changes per hour	Static pressure required (in-wg)	Flow Rate required (1000 cfm)	Room grouping
32. Loadout Room	74	8	-0.75	9.8	E
33. Electrical Room (+21)	99.2	2	0.1	3.3	A
34. Clean Canister Storage Rm	28.1	4	-0.25	1.9	B
35. AX Room (+21)	11.4	8	-0.75	1.5	F
36. Decon Cell (00)	7.5	8	-0.75	1	D
37. Cut-Up Cell (00)	20.2	8	-0.75	2.7	D
38. Hands-on Cell (00)	13.7	4	-0.25	0.9	B
39. Canister Lowering Rm	64.4	8	-0.75	8.6	E
40. Canister Filling Cell	231.8	8	-0.75	30.9	E
41. Crane Maintenance (-32)	8.9	8	-0.75	1.2	E
42. Decon Cell (-32)	45.8	8	-0.75	6.1	E
43. Liquid collection Cell	41.7	8	-0.75	5.5	E
44. Loading Cell	45 .9	8	-0.75	6.1	E
45. HVAC Supply Room	436	4	-0.25	29.1	B
46. HVAC Exhaust Room	436	4	-0.25	29.1	B

The following is a list of the primary design requirements for the VF HVAC system:

- Maintain office and operational areas at temperature recommended by the appropriate codes and standards specified to assure personnel comfort and safety and to protect instruments and equipment during normal and off-normal conditions.

- Detect and monitor ventilation flows and pressure differentials throughout the facility as required to prevent the possible spread of potential hazards. All ventilation air flows and pressure differentials will be alarmed if out of compliance.

- Assure facility airflows are from areas of less contamination potential to areas of greater contamination potential. Means should be provided to seal all containment boundaries in case of loss of ventilation or pressure differentials or both.

- Confine radioactive materials as close as practicable to the point of release.

- Maintain ALARA release of the radioactivity to the environment as required by DOE Order 5400.5.

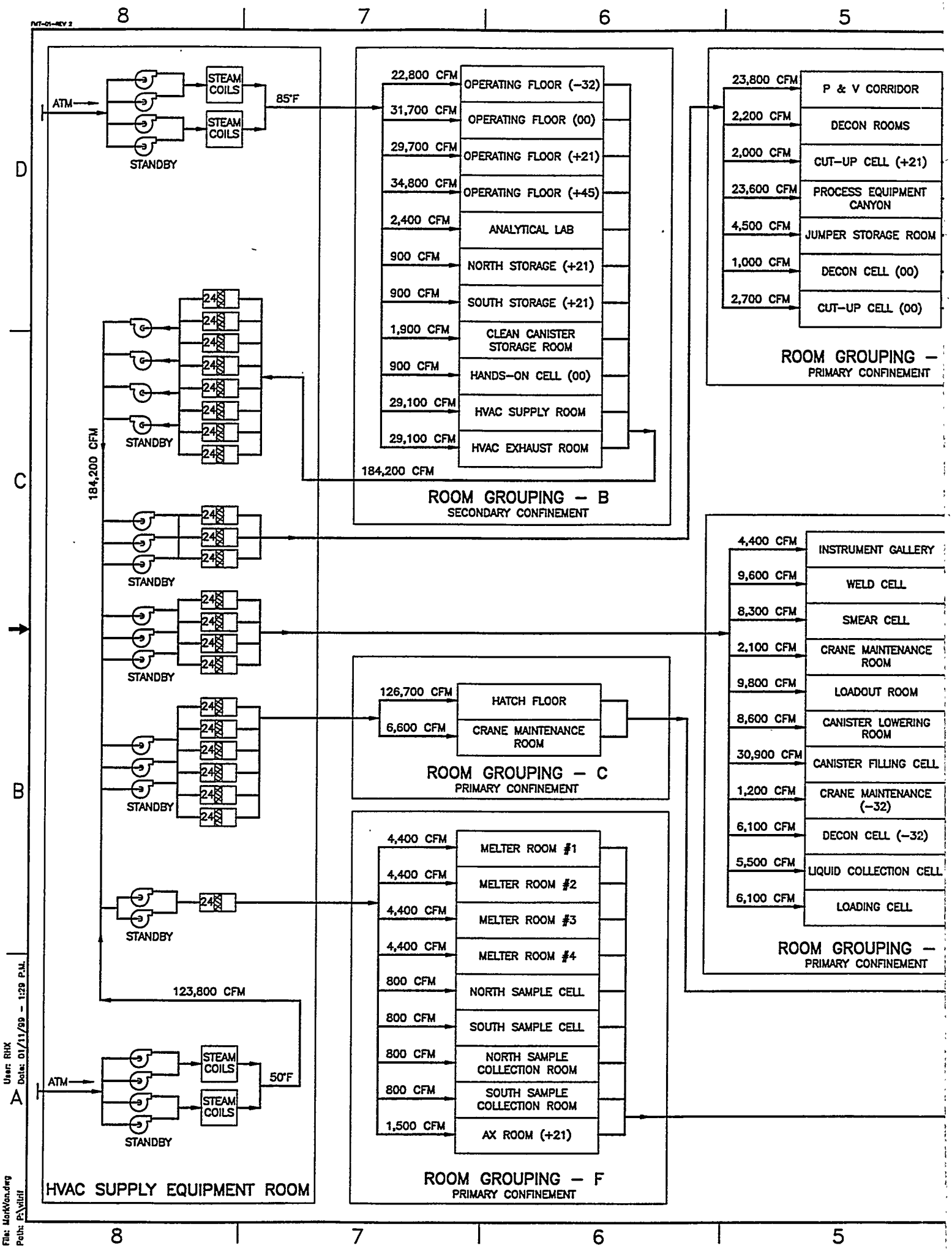
- Provide redundant or backup equipment in all exhaust systems serving contaminated areas as needed to assure contamination control.

- Provide sampling ports in the individual branches of supply and exhaust ducting for testing to verify system performance, operability, and in-place filter component leakage.

- Provide air changes sufficient to remove heat, hazardous and particulate gases, and other contaminants. The system will be designed to provide proper distribution of airflow throughout the facility during normal, off-normal and maintenance activities.

- Provide an interlocked HVAC barrier system so that reversed airflow patterns cannot be established.

- Provide a stack to exhaust all contaminated or potentially contaminated air. The exhaust stack will be monitored using a shielded probe system. As a minimum, the system will monitor for Beta/Gamma particulate, Alpha particulate, and tritium. The system will allow for both local and remote readout and alarm annunciation.


8
7
6
5
D
C
B
A
ATM
STEAM COILS
STEAM COILS
85°F
STANDBY
22,800 CFM
OPERATING FLOOR (–32)
31,700 CFM
OPERATING FLOOR (00)
29,700 CFM
OPERATING FLOOR (+21)
34,800 CFM
OPERATING FLOOR (+45)
2,400 CFM
ANALYTICAL LAB
900 CFM
NORTH STORAGE (+21)
900 CFM
SOUTH STORAGE (+21)
1,900 CFM
CLEAN CANISTER STORAGE ROOM
900 CFM
HANDS–ON CELL (00)
29,100 CFM
HVAC SUPPLY ROOM
29,100 CFM
HVAC EXHAUST ROOM
184,200 CFM
ROOM GROUPING – B
SECONDARY CONFINEMENT
23,800 CFM
P & V CORRIDOR
2,200 CFM
DECON ROOMS
2,000 CFM
CUT–UP CELL (+21)
23,600 CFM
PROCESS EQUIPMENT CANYON
4,500 CFM
JUMPER STORAGE ROOM
1,000 CFM
DECON CELL (00)
2,700 CFM
CUT–UP CELL (00)
ROOM GROUPING –
PRIMARY CONFINEMENT
24
184,200 CFM
STANDBY
126,700 CFM
HATCH FLOOR
6,600 CFM
CRANE MAINTENANCE ROOM
ROOM GROUPING – C
PRIMARY CONFINEMENT
4,400 CFM
INSTRUMENT GALLERY
9,600 CFM
WELD CELL
8,300 CFM
SMEAR CELL
2,100 CFM
CRANE MAINTENANCE ROOM
9,800 CFM
LOADOUT ROOM
8,600 CFM
CANISTER LOWERING ROOM
30,900 CFM
CANISTER FILLING CELL
1,200 CFM
CRANE MAINTENANCE (–32)
6,100 CFM
DECON CELL (–32)
5,500 CFM
LIQUID COLLECTION CELL
6,100 CFM
LOADING CELL
ROOM GROUPING –
PRIMARY CONFINEMENT
4,400 CFM
MELTER ROOM #1
4,400 CFM
MELTER ROOM #2
4,400 CFM
MELTER ROOM #3
4,400 CFM
MELTER ROOM #4
800 CFM
NORTH SAMPLE CELL
800 CFM
SOUTH SAMPLE CELL
800 CFM
NORTH SAMPLE COLLECTION ROOM
800 CFM
SOUTH SAMPLE COLLECTION ROOM
1,500 CFM
AX ROOM (+21)
ROOM GROUPING – F
PRIMARY CONFINEMENT
123,800 CFM
ATM
STEAM COILS
STEAM COILS
50°F
STANDBY
HVAC SUPPLY EQUIPMENT ROOM
User: RHK
Date: 01/11/99 – 1:29 P.M.
File: MarkVan.dwg
Path: P:\vitif

REVISIONS		
REV	DESCRIPTION	EFFECTIVE DATE:

59,800 CFM — 24 24 24 — STANDBY

92,600 CFM — 24 24 24 24 — STANDBY

133,300 CFM — 24 24 24 24 24 24 — STANDBY

22,300 CFM — 24 — STANDBY

HVAC EXHAUST EQUIPMENT ROOM

308,000 CFM

STACK

OFFICES
HEATED TO 68°F
COOLED TO 72°F
8,300 CFM ATM → 8,300 CFM

ELECTRICAL EQUIPMENT ROOM
HEATED TO 50°F
COOLED TO 72°F
4,600 CFM ATM → 4,600 CFM

NORTH
TRUCK AIR LOCK
HEATED TO 50°F
1,300 CFM ATM → 1,300 CFM

SOUTH
TRUCK AIR LOCK
HEATED TO 50°F
2,300 CFM ATM → 2,300 CFM

DECON MAKEUP ROOM
HEATED TO 50°F
4,800 CFM ATM → 4,800 CFM

ELECTRICAL ROOM
HEATED TO 50°F
COOLED TO 72°F
3,300 CFM ATM → 3,300 CFM

LEGEND

24 — 6 X 4 SINGLE HEPA FILTER

24 — 6 X 4 DOUBLE HEPA FILTER

ROOM GROUPING – A

FOR DRAWING INDEX SEE DRAWING NO.	SUBCONTRACT NO.	LOCKHEED MARTIN
NO SCALE	REQUESTER: D LOPEZ DESIGN: M VANSICKLE DRAWN: RM HALL PROJECT NO. SPEC CODE	INTEC WASTE TREATMENT FACILITY VITRIFICATION WASTE OPTION HLW INTERIM STORAGE FACILITY HVAC AIR FLOW DIAGRAM
DESIGN PHASE:	FOR REVIEW/APPROVAL SIGNATURES SEE DAR NO.	SIZE D · CAGE CODE 01MF3 · INDEX CODE NUMBER AREA 200 TYPE CL 20 OBSC 530 · DWG- · REV
QUALITY LEVEL:	EFFECTIVE DATE:	SCALE: NONE · SHEET HV–1

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Instrumentation and Control

5. Summary:

This EDF estimates the Instrumentation and Control (I&C) requirements for the HVF. There are 1940 instruments listed. One central control room will be used. The Raytheon Direct Vitrification Option Feasibility Study Report[1] baseline design was used for this I&C estimate. Additional instrumentation has been identified and added to comply with the proposed Maximum Achievable Control Technology (MACT) rule.

Reference 1:

Raytheon Engineers and Constructors, Inc. Western Operations, Idaho Chemical Processing Plant Waste Immobilization Facility Direct Vitrification Option Feasibility Study Report, MS528.163, October 25, 1994.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	R. H. Averill		22 JAN 99
Independent Verification	R	J. L. Hanson		22 JAN 99
Requestor	A	D. A. Lopez		1-22-99

The Raytheon Direct Vitrification Option Feasibility Study Report[1] baseline design was used for this I&C estimate, for I&C system requirements, and for subsequent material and installation costs. Differences between the baseline design and the HVF were used to ratio the number of instruments from the baseline design. The following assumptions allowed estimation of the instrument types and quantities required for the HVF design (as with the baseline facility and process cells, the HVAC I&C cost estimate is included in the HVAC estimate). Air monitors were ratioed by the area of floor space between the baseline design and the latest design. (baseline = 70,000 ft square; latest design = 90,000 ft square.)

HVF process I&C measurements increase due to adding one melter train (including melting cell) from 3 to 4. It was estimated that the referenced report had approximately 52 measurements per melter so the total number of melter instruments were increased by the ratio 4/3. This includes the Instrument Bulks Allowance, Control and Safety Valves, Electronic Instruments, and Pneumatic Instruments. The process I&C measurements used in conjunction with the slurry mix, evaporation, and storage of the liquid feed will be consistent with the baseline.

A shielded probe sampling system will be used in the HVF exhaust stack to monitor stack effluents. The electrical estimate includes telephones, facility public address systems, fire alarm systems, local control stations, and lighting protection systems consistent with the baseline. The process I&C system downstream of the melters will be the same as the baseline design (for example: filling, cooling, capping, smearing, welding, decontaminating, and associated canister transfer and handling equipment); therefore, the estimate is identical to the baseline estimates for these areas. I&C for the offgas treatment system design in this report is the same in the baseline design.

The canister filling monitoring I&C cost for each melter system will be the same as in baseline design (a government-funded equipment (GFE) cost of $2 million per unit); therefore, the HVF cost for four melter systems will be $8 million. The canister leak check system I&C, located in the welding cell, will cost the same as the baseline design (a GFE cost of $1 million).

Table 1 lists I&C system estimates for both the baseline Vitrification Facility I&C, and the HVF I&C, based on the above assumptions.

Additional instrumentation has been identified and added to comply with the proposed Maximum Achievable Control Technology (MACT) rule, which includes more stringent emission limits than currently allowed for a number of pollutants. These instruments are to be used to supplement the normal stack monitors emission instrumentation.

The report titled "Feasibility Study Report for NWCF MACT Compliance Facility", INEEL/INT-97-00992, dated November 1997, was the baseline design used for this section of I&C estimate, to include I&C system requirements, and subsequent material and installation costs.

Since the proposed MACT rule has not finalized, several assumptions were made in the report. These same assumptions were used for this estimate but without tabulating them here. Briefly, the assumptions in the report were based on a review of the April 19, 1996 and May 2, 1997 MACT rule proposal and revision, and current available information on emissions. Table 2 lists MACT instrument estimates, based on the above information. Refer to figure 1, News CEMS for complying with the proposed MACT rule, in Volume II of the report identified above.

Table 1. I&C Quantities

Description	Baseline Quantity HVF	(Ref Only) Quantity
Alpha Continuous Air Monitors	20	26
Beta Continuous Air Monitors	20	26
Remote area Monitors	16	20
Frisker	26	33
Personnel Contamination Monitor	8	10
Air Sample Probe	56	71
Plant Control System Hardware	9	9
Plant Control System Software	9	9
Entrance Warning Signs	56	56
Local Area Warning	32	32
Data Management System Hardware	9	9
Data Management System Software	9	9
Closed-circuit television (CCTV) System in Control Room	1	1
Instrument Bulks Allowance	350	402
Control and Safety Valves	350	402
Electronic Instruments	350	402
Pneumatic Instruments	350	402
	sub-total	1919

Table 2. MACT Instrumentation

Description	HVF Quantity
Oxygen Monitor	2
Carbon Dioxide Monitor	2
Carbon Monoxide Monitor	2
Total Hydrocarbon Monitor	2
Gas Conditioner and Pump	2
Heated Sample Line	1
Flow splitter	2
Stripchart Recorder	2
Offgas Flowmeter	2
Pressure Transducer	2
Insitu Particle Matter Monitor	2
sub-total	21

Assumptions

The HVF will use the baseline Control System and utilize state-of-the-art process control and data acquisition equipment throughout the facility. The control system will consist of distributed process controllers, multiple control room operator consoles, local operator station, and interconnecting communication network. Reference Figure 2 and 3, WIF Addendum 1- LWHVF/LVA WIF Control System Black Diagram, Raytheon drawings.

The baseline control system will satisfy the following requirements:

- Monitoring and control of facilities and utilities
- Data acquisition and analysis
- Management report generation
- Health Physics monitoring

The baseline control system will utilize one Main Control Room. It will control and monitor all systems including the following areas:

- Receiving and Pretreatment area
- HLW Direct Vitrification area
- HLW Interim Storage area

- Mixed LLW Interim Storage area
- Bulk Chemical Storage area.

The Control System will in general satisfy the following requirements:

- Analog transmitter signals from process variables will be indicated in the Main Control Room.
- Digital equipment status (pump on, valve open, etc.) and alarms will be indicated in the Main Control Room.
- The Control System will supply closed loop control of process variables as well as digital on/off control.
- Local operator stations will be provided for local control through the Control System with automatic interlock, permissive and /or emergency shutdown functions.
- Key lock protected LOCAL/REMOTE switch over stations will be provided for local, hard-wired override control of equipment in case of Control System failure. Control System interlocks and permissives will not be in effect during local override operation.
- Automatic operations from each Satellite Control Room and the Main Control Room will be provided to the maximum extent as deemed practical.

The baseline Control System that controls the facilities systems will meet the following specific requirements:

1. Bulk Chemical Storage and Transfer

   - Analog transmitter signals from process variables will be indicated in the Main Control Room.
   - Digital equipment status (pump on, valve open, etc.) and alarms will be indicated in the Main Control Room.
   - The Control System will supply closed loop control of process variables as well as digital on/off control.
   - Local operator stations will be provided for local control through the Control System with automatic interlock, permissive and /or emergency shutdown functions.
   - Key lock protected LOCAL/REMOTE switch over stations will be provided for local, hard-wired override control of equipment in case of Control System failure. Control System interlocks and permissives will not be in effect during local override operation.

2. Remote Handling Systems

   The remote handling systems will be operated locally, be equipped with interlocks and safety systems, and will be controlled by dedicated control mechanisms supplied with the remote handling equipment.

The only interface between the control system and the remote handling system will be the capability to select a camera mounted on a remote handling device for viewing operations at CCTV monitors in the control room.

3. Sampling System

Sampling operations will be performed locally and manually.

4. Pneumatic Sample Transfer System

The Control System will supply closed loop control of process variables as well as digital on/off control.

5. Canister Handling

Canister handling will be performed locally by use of hardwired bridge cranes, individual forklifts, trucks, and dollies.

6. Sumps and Drains

Leaks into sumps and low points in drain lines will be remotely monitored and enunciated in the control room. Sump levels will be indicated in the control room.

7. Stack Monitors

A shielded probe exhaust stack monitoring system will be provided at the ventilation exhaust stack to monitor plant emissions as required by RCRA. The stack monitoring system will be supported by the Uninterruptible Power Supply (UPS) system. As previously mentioned, MACT instrumentation will be added to the stack monitoring in order to comply with the MACT rule.

8. Health Physics Monitors

Health Physics Systems, including all equipment necessary to monitor and control alpha, beta, and gamma radiation for the areas which could be potentially contain radioactive material, will be provided.

Concentration and radiation levels will be indicated and recorded in the control room. High concentration and/or radiation levels and/or analyzer trouble alarms will be enunciated in the control room and in the Health Physics office.

Continuous Air Monitoring (CAM) and Radiation Area Monitoring (RAM) alarms will be enunciated locally by the detecting instrument. Area and entrance warning beacons will be provided and controlled by the Main control System. Personal survey stations and surface wipe sample counter will be operated locally and manually. On/off status and system trouble and process variables from the central air sampler vacuum systems will be monitored at the main control room.

9. HVAC

The HVAC systems will be controlled automatically by local stand-alone controllers provided with the HVAC equipment. Graphic displays mimicking the HVAC system will be available in the central Control Room for monitoring and for remote manual override control. The HVAC system will be operated locally from local operator stations. However, the control room operator will have supervisory control capability to start and stop the HVAC system and to change setpoints. Alarms and out-of-tolerance conditions will be enunciated in the control room.

10. Utilities

The electrical systems will not be under the control of the main control room. Power loss alarms and/or indications will be routed to the control room. The fire Detection System will be a stand-alone system. Alarms and indications will be routed to the control system for monitoring. Compressed air systems will be operated locally through hard-wired control panels. Alarms and indications will be routed to the control system for monitoring. Vacuum systems will be operated locally through hard-wired control panels. Alarms and indications will be routed to the control system for monitoring. Treated and chilled water temperature, system status, and high/low temperature alarms will be monitored in the control room. Steam pressure and high/low pressure alarms will be monitored in the control room.

11. Communications

The Control system communication network will integrate all distributed process controllers, multiple control room operator consoles, and any local operator stations with in the HVF.

Reference 1:

Raytheon Engineers and Constructors, Inc. Western Operations, Idaho Chemical Processing Plant Waste Immobilization Facility Direct Vitrification Option Feasibility Study Report, MS528.163, October 25, 1994.

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Remote Maintenance and Equipment Sizing

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

This EDF provides the basic philosophy for performing remote maintenance activities and remote sizing (cutting) tasks within the High-Level Waste Vitrification Facility. Component configuration and essential features for performing remote maintenance activities are discussed in this EDF.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	S. M. Berry	S. M. Berry	3/17/99
Independent Verification	R	M. J. Ross	M. J. Ross	3/17/99
Requestor	A	D. A. Lopez	D. A. Lopez	3/20/99

The HVF design will include provision for remote replacement of process equipment, which past experience has shown to be prone to failure. Equipment such as tanks, vessels, and columns which have anticipated maintenance intervals of greater than 10 years will be designed for hands-on maintenance.

General

The terms "remote maintenance" and "remote replacement" are generally used interchangeably. Items requiring maintenance at the HVF will be remotely removed from service, and decontaminated, and maintenance on the item will then be performed hands-on.

Component Configuration and Essential Features for Remote Maintenance

The features of the HVF that will facilitate the remote handling capabilities of the facility include the following:

- Remote Handling and Replacement Cubicle or Corridor (P&V)- A shielded and enclosed area designed and equipped to provide remote handling and replacement for those items that must be isolated from the main process cells due to their high maintenance frequency and radiation hazard. Features required for direct maintenance will also be provided.

- Manipulator/Crane Parking and Maintenance Areas - Shielded areas designed for maintenance of major in-cell remote handling equipment. These areas will have the capability of being isolated and shielded from the P&V corridor during maintenance operations and will permit removal of the major remote handling equipment from the high radiation and contamination areas when the equipment is not being used.

- Remotely Operated Manipulators – Electro Mechanical manipulators with extended reach and intermediate handling capability that can be controlled from a number of locations in the operating corridor.

- Remotely Operated Cranes – Conventional cranes for lifting and transport of heavy items inside the shielded areas of the facility controlled stations adjacent to shielded viewing windows with control transferable from one window to another.

- Master-Slave Manipulators – Mechanical arms directly operated by personnel located at viewing stations when highly dexterous remote manipulation is required.

- Shielded Viewing Windows – Stations that permit direct viewing of operational areas inside the shielded cells.

- Remotely Replaceable Lighting – Removable lighting units which provide adequate lighting in the shielded areas. Lighting units are replaced using remote handling equipment.

- Filtered Exhaust Ventilation - A remotely changeable system designed to achieve maximum contamination control by filtering cubicle and corridor ventilation air at its exhaust point. Provisions for increased airflow during hatch removal will be provided. The preferred approach is the top-loading filter system for handling the changeout

- Smear Cell - A shielded area for limited decontamination, packaging, and transfer of failed equipment to other decontamination or waste disposal facilities/area. This area will be designed so that it can be intermittently isolated from the remote corridor to allow hands-on repair/smear of slightly contaminated equipment. This cell will be adjacent to or part of the decontamination cell.

- Decontamination Cell - A shielded area for decontamination, packaging, and transfer of failed equipment to other waste disposal facilities/areas.

- Hands-On-Maintenance (Repair) Area – A minimally shielded area for repair of decontaminated equipment.

The following will also be provided to permit in-cell remote handling operations and to reduce operator exposure:

- Permanently located lifting devices and scaffolding to aid in direct or remote maintenance operations.

- Tool ports, in-cell tool racks, and tables.

- Decontamination system for external and internal equipment surfaces as well as cell surfaces.

- Quick-disconnect piping Connections/remote flanging with captive bolts.

- Controlled entry for personnel access.

- Remotely controlled video-viewing systems.

- Stainless steel lining for the inside corridor surfaces to facilitate decontamination.

- Remote maintenance service stations with remote connectors for utilities needed inside the shielded areas, including air, fluids (water, decontamination solutions) electric and video.

Equipment Items

High maintenance equipment items include valves, pumps, heat exchangers, cell, vessel off-gas HEPA filters, centrifugal contactors, etc. These items will be grouped into common shielded areas and the areas provided with remote equipment, (e.g., cranes, manipulators, and viewing windows). The remote areas must also be adequately illuminated with remotely replaceable lights, remote maintenance service stations (RMSS)[1], tool-drop ports and worktables. Closed circuit video capability will also be provided if supplemental viewing is required.

Equipment which is not prone to failure such as tanks, vessels, columns, and airlifts will also be located in shielded cells, but the cells will not be equipped to permit remote replacement of these items. Rather, maintenance of these items will be hands-on. These areas will be equipped for maintenance access and equipment removal without interference from adjacent equipment. Permanently installed working platforms with ladders for maintenance access will be considered on a case-by-case basis. Although certain equipment items are identified as hands-on maintenance items, to reduce operator exposure remote features such as quick-disconnects, remote flanges, captive bolts, and lifting bales may be incorporated into their design if such

[1] A centralized grouping of selected utilities located in process cells that can be accessed (connected/disconnected/used) by manipulators and used to support in-cell remote activities.

features are determined to be necessary. The purpose of these features is twofold: a) to permit potential hands-on maintenance activities to proceed more rapidly, and b) to permit remote or partially remote (i.e., overhead crane and overhead manipulator) operations to take place if the radiation fields are expected to be excessively high.

"Skyrights" will be provided to assure equipment accessibility with overhead equipment. In addition, visibility, accessibility, and interferences must be considered during facility design. Center-of-gravity lifting bails will be provided on all remotely removable process equipment (e.g., valves). Remotely removable valves, pumps, and other equipment will be installed on self-aligning jumper assemblies to enhance remote removal and replacement.

Throughout the facility, remote concepts and equipment must be "proven" technology. Development items and unproven state-of-the-art items will not be included in the production facility unless the concepts/equipment can be proven by demonstration prior to incorporation. Remote tooling and equipment provisions must be maintained as practical, straightforward, and simple as possible. Standardization (sizes, shapes, arrangement) will also be maximized.

To provide remote handling in the HVF certain remote capabilities are required:

- The capability for viewing and remotely transferring radioactive items and materials as required to maintain personnel radiation exposures to as-low-as-reasonably achievable levels.
- Remote process equipment will be accessible for ease of operation and maintenance.
- All in-cell mechanical and electrical equipment (windows, video equipment, manipulators, electrical enclosures, etc.) will be sealed or otherwise protected from penetration of corrosive solutions and gases.
- In-cell lights for remote cells will be designed for remote replacement.
- Provision will be made for tool storage and worktables as required.
- Closed circuit video will be provided for supplemental viewing with both fixed and movable in-cell support assemblies as necessary.
- Ladders, piping and platforms will provide minimum interference with equipment replacement and will be remotely removable where necessary.
- Remote cell cranes and manipulators will be equipped with retrieval systems. Remote cell cranes will be equipped with remote load lowering devices
- To assure maximum ease and efficiency of remote maintenance of jumpers, inspection ports and equipment, each operation will be defined and described in detail. Exact location of remote flanges, bolts and other disconnect devices relative to manipulator operation and viewing will be studied in front, top and side views to verify impact wrench clearances, equipment installation and removal clearances and potential interference problems.
- Clearances for standard operation and removal of master-slave manipulators will be provided.
- Decontamination capability will include remotely controlled sprays and wash-down techniques.

- Remote connectors, bolts, flanges, wrenches, sockets, extensions, and other tooling should be standardized to the extend possible to reduce the need for wrench changes and varied operating envelopes during equipment replacement.
- Equipment will be movable, maintainable and replaceable without disturbing adjacent equipment whenever possible.
- Design of in-cell equipment supports and concrete embedments will consider possible retrofit of alternate process equipment.
- Equipment components and subsystems will be of modular design, where possible, to facilitate removal and replacement.
- All remotely serviced equipment will be checked for dimensional fit and proper operation prior to installation.

Facility Requirements

To accommodate remote requirements, the HVF building will include the following requirements:

- Incorporation of embedments for viewing windows and master-slave manipulators.
- Complete ceiling hatch access to all cells.
- Incorporation of a bridge crane and electro-mechanical manipulator in the maintenance area.
- Labyrinth cell entryways with utility maintenance service stations (UMSS). [2]
- A sufficient number of crane and electro-mechanical manipulator control station outlets will be adjacent to viewing windows and other operating locations to permit unrestricted remote operation.
- Sufficient clearances will be provided both ends of all master-slave manipulators to permit unrestricted movement and easy removal and replacement of the arms. Manipulator counterweight motions must also be considered.
- Dedicated shielded areas, which can be isolated from any radioactive sources, will be provided for parking/maintenance in-cell cranes and electro-mechanical manipulators, to permit hands-on maintenance.

Operational Requirements

A remote handling and replacement corridor, commonly known as a pump and valve (P&V) corridor, will be provided near those processing areas where radiation exposure and radiological hazards justifies the additional facility cost. Failure prone equipment will be located within this corridor. Basic equipment and process design will minimize the total amount of maintenance that will be required. When maintenance or vessel inspection is required, the facility design will provide features that will reduce radiation exposure to personnel. The operational features of such philosophy will include both remote and direct maintenance and

[2] A centralized grouping of selected utilities located in process cell entryways that will be available for use during cells entries

will include less emphasis on remote capabilities as the process proceeds with purification of the product stream.

Some of the operational features of this philosophy would include the following remote capabilities:

- Draining and flushing capabilities of all equipment that can contain process solutions. Remote replacement of failed equipment.
- Transporting tools, failed equipment, and/or HEPA filters to a shielded decontamination, packaging, and transfer area.
- Packaging of contaminated items in an area separate from the maintenance area and preparing for transport to a specified decontamination area.
- Maintenance of radiation and contamination control at all times
- Arrangements of equipment to facilitate remote and direct maintenance operations.
- Collection of decontamination and process solutions for recycle to salvage or waste disposal collection systems.
- Remote replacement of exhaust HEPA filters for the calcine receipt vessels and the off gas system in the P&V corridor.
- Adequate lighting, viewing, and utility systems to support remote handling and replacement operations.

Remote Equipment

Standard remote handling equipment will include master-slave manipulators, wall-mounted electro-mechanical manipulators, bridge-mounted electro-mechanical manipulators, bridge cranes, and jib cranes, etc. The primary usage of this equipment will be the remote replacement of components. All in-cell remote handling equipment will be provided with redundant features and retrieval systems to minimize the effect of failures.

Shielded viewing windows will be used to provide unrestricted viewing of remote operations, and will provide additional viewing angles from adjacent windows. Remote operating and maintenance tasks will be located within the normal viewing angle of the windows. Remotely replaceable hot-side shields will be provided for the viewing windows where necessary.

Mockups

All HVF remote equipment, and major remote operations, will be mocked up in full scale at the Remote Mockup and Test Facility (RMTF) and tested prior to design completion and procurement. Mockups will include mechanical equipment, remote handling equipment, viewing, and cell sizes and arrangements. Items being checked will include accessibility, interference, visibility, maintainability, operability, transfer routes, and lifting mechanisms and devices.

Maintenance Requirements

The facility will be designed to provide for repair or replacement of any process component while minimizing personnel radiation or contamination exposures, maintenance cost, and downtime. All mechanical equipment, windows, video cameras, and other equipment in potentially radioactive or contamination areas will be sealed or otherwise designed to prevent penetration by contamination and/or decontamination solutions. Materials such as plastics and insulation that degrade in radiation environments will be excluded whenever possible. If used, they will be encased and shielded or otherwise protected from excessive radiation exposure. These materials will be installed for periodic inspection and replacement.

The maintenance philosophy for radioactive process equipment in the HVF will be to replace high maintenance items such as pumps and valves. These components will be isolated from the system (if required), uncoupled from the system, and removed to a decontamination area. The repaired or replacement component will then be reinstalled and returned to service. In selected cases, spare components will be available for service. Direct contact maintenance will be used, for items that are not expected to fail more than once every 10 years and in areas where the component can be decontaminated and expected radiation levels will be minimal.

Equipment will be designed to permit decontamination, inspection, replacement, and/or repair with minimum radiation exposure to personnel. Cells will have provisions for visual inspection or radiation monitoring without exposing the inspector to radiation or contamination hazards. Access ports for transfer of small tools and equipment will be provided in areas requiring remote replacement or repair operations. RMSS will be located in selected remote maintenance cells and will be equipped with remote connectors for electrical, video, air and water utilities.

Remote Equipment Change/Cut-up/Disposal Scenarios

Equipment in the P&V corridor approach requiring routine change out will be able to be connected & disconnected, handled, and moved remotely. The basic philosophy for a typical jumper change out would involve the use of an in-cell electro-mechanical manipulator and in-cell crane to remove the defective jumper from the P&V corridor and transport it to the decontamination cell. These areas need to be adjacent to each other and in succession to afford adequate crane coverage in order to perform initial decontamination activities. The crane maintenance and decontamination areas allow movement of equipment from higher contamination /rad-level environments to that of a lower level environment. After a jumper is repaired in the hands-on maintenance room and surveyed to be clean, this unit may then be transported to a clean storage area for reuse.

A jumper storage room will also be provided for clean and/or refurbished jumpers to be stored for future replacements of defective process jumpers. Jumpers would be re-introduced into the P&V corridor via the jumper storage cell and crane maintenance area at the opposite end of the P&V corridor. The crane maintenance areas, decontamination cell, and hands on maintenance areas will be provided with shield doors to allow isolation between successive areas.

The philosophy will be to use redundant wall mount manipulators in the P&V corridor to provide back-up capability in order to minimize impact on process operations and to provide retrieval capability for a failed

manipulator. The P&V corridor will also have a small bridge crane running the full length, including into respective maintenance areas. This crane will be used to bring routine maintenance equipment into the P&V corridor and move defective equipment into the pre-decontamination cell area for the cleanup and repair process.

The basic philosophy will be to take contaminated equipment first to the decontamination cell, and then to the hands on maintenance cell for repair. Remote maintenance may be conducted in the decontamination cell using master-slave manipulators to perform various repair tasks on remotely maintainable equipment without having to use the hands-on maintenance cell.

If equipment cannot be refurbished, then disposal of this material will be required. After decontaminating to appropriate levels, this equipment will be placed in proper disposal containers for transfer through the load out area. Disposal of melter cell components will require a different approach to the standard P&V corridor concept. A bottom loading shield type container (cask) will be used to interface with the melter cell to allow the components to be withdrawn up into this container for transport to a cutup cell and minimize the spread of contamination. The cut-up cell will include equipment for dismantling of large, failed components. A plasma torch is preferred in the cut-up cell for reducing the size of metal components to that compatible with standard load out boxes.

The HVF melter cells pose unique remote maintenance problems due to their, number (four), and the amount and complexity of associated equipment located within. To adequately address remote maintenance activities, each melter cell will be equipped with an overhead crane and an electro-mechanical manipulator to facilitate equipment changeout of failed components. These in cell remote handling units will be used in conjunction with the large overhead crane in the overhead maintenance area to remove and install equipment in the melter cell.

ENGINEERING DESIGN FILE

1. Project File No. 02204 2. Project/Task High-Level Waste Project

3. Subtask High-Level Waste Vitrification Facility

4. Title: Cell Equipment Decontamination

5. Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

This EDF provides the basic philosophy for performing cell equipment decontamination activities within the High-Level Waste Vitrification Facility. The items discussed in this EDF are component configuration/essential features, cell decontamination, cell and equipment/vessel decontamination systems, and operational requirements.

6. Distribution (complete package): D. J. Harrell MS 3211, B. R. Helm MS 3765, V. L. Jacobson MS 3211, M. S. Spinti MS 3650, WTP EIS Studies Library, Project File

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	S. M. Berry	S. M. Berry	3-17-99
Independent Verification	R	M. J. Ross	M. J. Ross	3/17/99
Requestor	A	D. A. Lopez	D. A. Lopez	3/20/99

Components Configuration and Essential Features

The basic components for the HVF decontamination capability shall include the items described in the following paragraphs. Materials of construction shall be resistant to radiation damage and the corrosive effects of the various decontamination solutions (e.g., oxalic, citric, tartaric, and nitric acids, and caustic solutions.

- Decontamination Cell - An area shall be provided within the HVF to decontaminate failed process equipment. This area shall be located near the Crane Maintenance area and shall be equipped with remote handling capability and equipment. Remote equipment will include master-slave manipulators, an electro-mechanical manipulator if necessary, an overhead crane, and viewing windows.

- Cell Decontamination System - Spray nozzles and piping networks shall be designed and located throughout the HVF process cells and remote handling and replacement areas to provide adequate surface wetting and will not interfere with remote or direct maintenance activities, cell lighting or vessel removal. Special attention shall be given to assuring sprays are directed at potential collection "dead spots" or points such as cell corners. Capability shall also be provide to "spot decon" as required using master-slave or electro-mechanical manipulators.

- Equipment/Vessel Decontamination System - The Equipment/Vessel Decontamination System shall deliver decontamination solutions to the interior surfaces of process vessels and equipment. Where effective, these solutions shall be distributed by sprays. However, such situations will also require access and provisions for nozzle removal and replacement. Agitation for decontamination solution shall also be provided (e.g., sparges).

- Decontamination Distribution System - A piping system shall be provided to deliver heated decontamination solutions to process cells and equipment. Piping shall be insulated in normally occupied areas.

- Decontamination Solution Makeup Area - An area shall be provided which will be equipped with multi-purpose vessels and used for makeup of decontamination solutions. This area may be part of a cold chemical makeup area that is also used for other purposes.

Decontamination Cell

The HVF Decontamination cell will provide the equipment and services required to remove contaminates from equipment retrieved from the P&V corridor area and surrounding process cells. Remote decontamination and disassembly of the equipment will be performed to reduce the radiation level on the components to levels that will permit hands-on maintenance. Small waste items shall be removed through a shielded loadout port; larger items shall be transferred to the crane maintenance area, then to a waste transfer container at ground level. Items to consider during design include:

a) Cleaning and decontamination techniques, materials, and equipment should be as simple as possible. Dry or damp methods are preferable to wet methods in most cases, since wet methods generate secondary waste streams that are harder to handle. Recycling and/or reuse of decontamination solutions should be practiced.

b) Capability to decontaminate to hands-on level.

c) Capability to remotely disassemble equipment as necessary to be able to decontaminate to a hands-on level.

d) Containment of contamination and decon solutions from external areas.

e) Capability to transfer equipment into and out of the cell.

f) Full viewing of all decontamination operations using either windows or auxiliary viewing methods.

g) Any decontamination or cleaning technique should minimize the amount of secondary waste created.

h) Techniques that tend to spread contamination beyond the immediate area being cleaned should be avoided.

i) The choice of techniques should accommodate a goal of no liquid discharge. All liquids should be recycled or solidified.

j) The decontamination area and access points shall be sized to accommodate anticipated equipment.

k) Provide design for ease of cleanup.

l) Capability to monitor equipment without cell entry by personnel.

m) Provisions for cutting and packaging solid wastes for disposal.

The basis for design of the decontamination cell is to provide a shielded area where radioactive contaminates can be removed by remote operations that permit maintenance of the equipment by contact methods. The decon cell shall require shielding windows located to visually observe decon operations and remote handling equipment such as master-slave manipulators, electro-mechanical manipulators and overhead cranes that will permit disassembly and transport of various equipment items.

Cell and Equipment/Vessel Decontamination System

The Cell and Equipment/Vessel decontamination system shall consist of makeup and injection of heated decontamination solutions into process areas and process vessels, and a method where solutions within vessels can be recirculated. Recirculation of the decontamination solution is necessary to minimize waste generation.

An area shall be designed to permit decontamination solutions to be made up in a safe and controlled manner. Equipment shall be provided to blend and heat decontamination solutions, while pumps and insulated piping shall deliver the solutions under pressure to the process areas. Curbed and stainless steel lined collection areas shall be provided in the makeup area to permit operators to wash down chemical spills. Emergency showers and eye wash stations shall also be located in the makeup area for personnel safety. A combination of directly and remotely controlled sprays and wipe-down techniques shall be used to decontaminate cell walls and the exterior surfaces of equipment within the equipment cells. The decontamination piping system shall permit spraying, flushing, and flooding the inside surfaces of equipment in contact with contaminated process liquids and solids.

To facilitate cleanup and/or decommissioning, critically safe sumps, if required, will be provided with transfer jets shall be installed in all decontaminable areas so that decontamination solutions can be collected for sampling, recycling, and transferring to the appropriate system.

The HVF and equipment installed in the HVF shall include features to reduce the duration and frequency of decontamination efforts. Experience gained from decontamination efforts in existing INTEC Facilities indicates many areas for improvement. Included are:

a) "Dead" areas in vessels and piping must be eliminated to the maximum extent practical. Areas that could contribute to radiation fields (reducers, flanges, and orifices) shall not be located near the bottom of a vessel.

b) Process piping or vessel construction shall not allow non-draining low points or pockets.

c) Heat exchangers shall have vertical or inclined tubes.

d) Vessel design shall enhance the complete removal of process and decontamination solutions and the associated undissolved solids and shall include sloped bottoms to allow free draining. Interior and exterior crevices must be excluded.

e) Equipment with high failure potential shall be located in common areas and be remotely replaceable.

f) Flat plates mounted on flat surfaces on equipment located in contaminated areas (pump bases, etc.) shall be avoided. Valves shall be provided with flushing and draining capabilities.

g) Cell walls shall be stainless steel lined, normally to a height of four feet, or have other finished surfaces, e.g. epoxy coatings [see ANSI-N5. 12-74 "Protective Coatings (Paints) for the Nuclear Industry" and ANSI-NIO1. 2-72 "Protective Coatings (Paints) for Light Water Nuclear Reactor Containment Facilities].

h) Cell floors shall be adequately sloped and a means of decontaminating sump areas included.

i) Electro-polishing of component and cell liner surfaces shall be considered where cost compared to benefit is effective.

j) Strippable coatings may be used in areas of frequent expected decontamination and should be considered on a case-by-case basis. Any coatings used must be compatible with waste disposal systems.

Cell and Equipment/Vessel Decontamination System Operational Requirements

The Cell and Equipment/Vessel Decontamination System will consist of two basic operational functions: (1) to deliver heated decontamination solutions to process cells (for cell walls and external equipment and piping surfaces) and process equipment (internal surfaces) to achieve "the first cut" of gross reduction in radiation levels; (2) to continue the decontamination process without generating large volumes of radioactive waste. This will be accomplished by recycling decontamination solutions through the contaminated process equipment. This process will continue until the radiation fields are reduced to levels that will permit contact maintenance. Process areas serviced by this decontamination system will be evaluated individually according to costs and reduction in potential radiation risks. The basic operational requirements shall be to:

a) Provide tankage in a multi-purpose zone of the PM area for preparing and feeding all the required decontaminating solutions to any area or equipment item in the facility requiring such service.

b) Provide heating of the solutions and insulated piping for delivering heated solution to the process area or equipment item.

c) Provide a remote decontamination spray system in each process cell (or separated area) which will enable thorough flushing of cell walls, ceilings, floors, and external surfaces of each piece of equipment and piping.

d) Provide a system in each cell to remove solutions from the floor and process equipment; the solutions shall be transferred to the waste sampling tanks, or the waste collection tanks.

e) Provide means to recirculate decontamination solutions within each piece of equipment or through portion of the process (i.e., remove from the bottom of vessel and recirculate back through the vessel inlet).

f) Provide uranium accountability features if required.

g) Provide contamination control for all operational phases of the decontamination system.

Personnel Decontamination

An area shall be provided on each level of the facility to monitor and decontaminate personnel. This area shall contain a shower, sink and provide storage space for collecting contaminated personnel protective clothing.