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Prepared for the U.S. Department of Energy
under Contract EY-76-C-06-1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
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DISCLAIMER

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CONCEPTUAL DESIGN OF A NUCLEAR WASTE VITRIFICATION FACILITY

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Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

This document describes a conceptual high-level waste immobilization facility. The report is part of a study conducted for the U.S. Department of Energy to facilitate the analyses of various nuclear fuel cycles and their effects upon the environment as part of a generic environmental impact statement. The facility would have the capability to calcine and then vitrify high-level liquid waste (HLLW). The vitrification would be accomplished in a canister which is seal-welded, checked for integrity, and decontaminated for movement to storage. Included in the facility would be the capability to repair faulty canister-lid seal welds, overpack failed canisters, and treat the process off-gas and cell ventilation air prior to release to the fuel reprocessing plant (FRP) atmospheric protection system (APS).

The nuclear waste vitrification facility (NWVF) would be an integral part of the FRP structure. It would therefore use the services, utilities, warehousing, offices, operating personnel change areas, and maintenance areas of the FRP. The operations of the facilities would be centered in the waste vitrification cell (WVC) which performs most of the facility functions. The cell is a reinforced concrete hot cell, lined with stainless steel, with internal dimensions of 8.5 by 9.7 by 16 m high (28 by 32 by 53 ft high). Most operation and maintenance activities would be performed remotely using a crane equipped with an impact wrench or yoke. Other specialty activities would be performed by appropriate equipment such as master-slave manipulators, self-propelled dollies, and other items. The major facility equipment includes a feed tank, spray calciner, two melters, weld-inspection stations, canister storage rack, and a canister decontamination cubicle. Installation and removal of equipment in the cell would be done through shielding doors. The air lock system of the canister decontamination cubicle would permit placement and removal of the canister. Activities in the cell may be observed through four shielding glass windows and/or up to three periscopes. The operating, service, and pipe galleries which house operating personnel and equipment necessary for cell operations are located adjacent to the cell.

The NWVF would be designed and constructed according to Nuclear Regulatory Commission (NRC) licensing requirements to provide a licensable facility with a minimal impact on the environment. The siting and other facility requirements would be the same as requirements for the associated reprocessing plant. There would be no additional design or construction requirements.

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FIGURES

GLOSSARY

ALARA	as low as reasonably achievable
AMA	aqueous makeup area
APS	atmospheric protection system
CDC	canister decontamination cubicle
CSG	cell service gallery
CSR	canister storage rack
CVT	cell ventilation tunnel
DOE	Department of Energy
DST	decontamination solution tank
FRP	fuel reprocessing plant
HEPA	high efficiency particulate air
HLLW	high-level liquid waste
HMA	hot maintenance area
HPT	hot pipe trench
LWR	light water reactor
NRC	Nuclear Regulatory Commission
NWVF	nuclear waste vitrification facility
OA	operating area
PNL	Pacific Northwest Laboratory
SC/ICM	Spray Calcination/In-Can Melter
WSG	warm service gallery
WVC	waste vitrification cell

CONCEPTUAL DESIGN OF A NUCLEAR WASTE VITRIFICATION FACILITY

INTRODUCTION

This document describes a conceptual process and facility capable of solidifying high-level liquid waste (HLLW) by the Spray Calcination/In-Can Melter (SC/ICM) process. The document was prepared to support a generic environmental impact statement in which three alternative fuel cycles [light water reactor (LWR) once-through, LWR with U recycle, LWR with Pu/U recycle] are being evaluated.

The HLLW is an aqueous waste produced by the solvent extraction processing (first cycle) of spent nuclear fuels for uranium and plutonium recovery. The HLLW contains over 99% of the fission products and transplutonium elements contained in the spent fuel, and thus incorporates most of the radioactivity associated with reprocessing LWR fuel. A flow diagram indicating the origin, treatment, and disposition of the waste, including HLLW, is shown in Figure 1. This conceptual facility would be included as part of a fuel reprocessing plant that reprocesses 2000 metric ton of heavy metal (MTHM) of spent fuel per year. The facility described herein has the capability to solidify and encapsulate HLLW, then perform inspection and decontaminate the filled canister. Also, additional information is included describing the operations, maintenance, and materials utilization for facility operation. Waste and effluent generation rates are also included. The facility description is based on HLLW waste solidification development work being performed by Pacific Northwest Laboratory (PNL) for the United States Department of Energy (DOE).

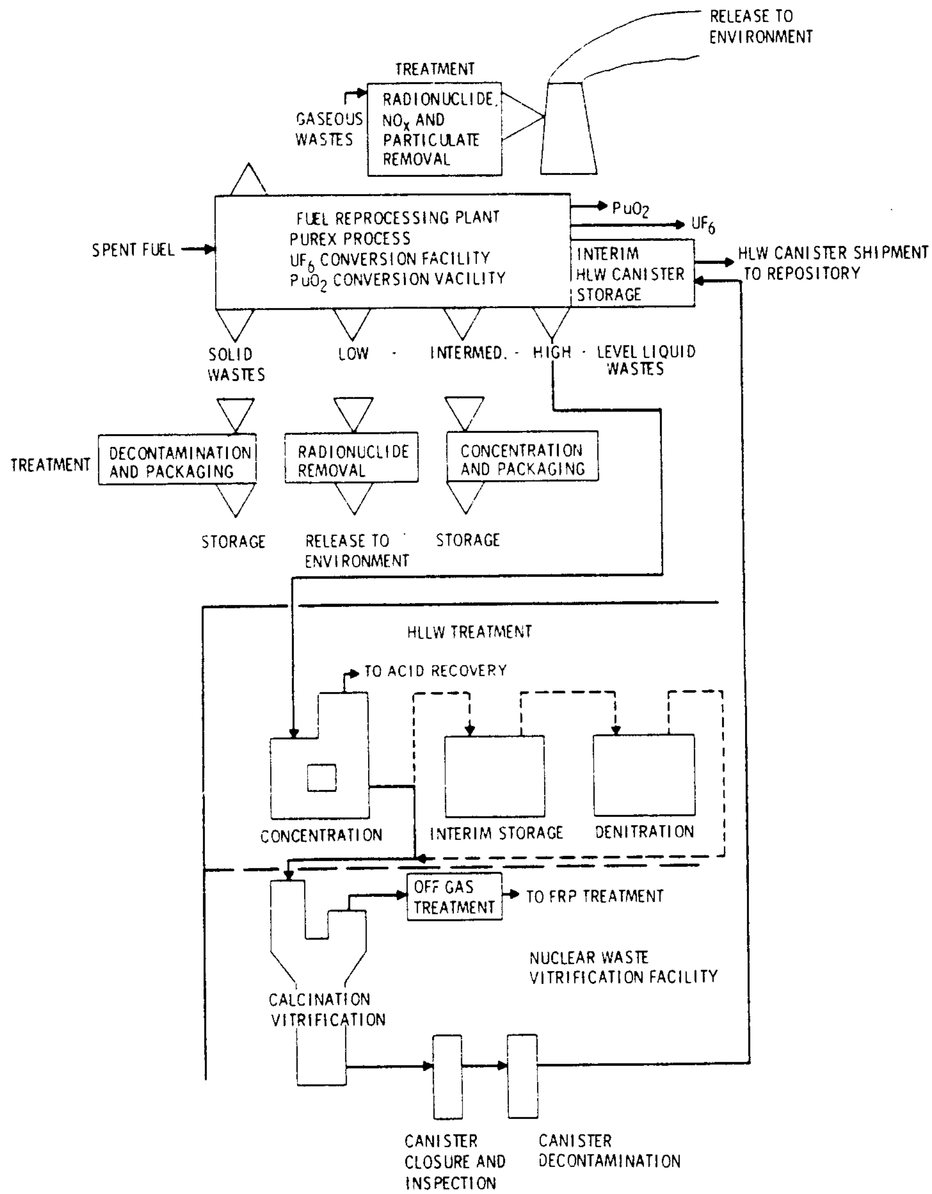


FIGURE 1. Source of High-Level Waste in the Fuel Cycle

PROCESS DESCRIPTION

The SC/ICM process[1-7] developed at PNL converts HLLW to a glass in a container that is then sealed for shipment to a Federal repository. The process consists of basically four steps: 1) calcination, 2) vitrification, 3) canister handling, and 4) effluent treatment. These steps are shown in the flow diagram in Figure 2. The process material balance is contained in Table 1.

CALCINATION

The calciner decomposes the chemicals in the HLLW to a process off-gas and a metal oxide calcine which is suitable for making waste glass.

HLLW at ≤40°C in the calciner feed tank is pumped at a controlled rate to the calciner through a pneumatic atomizing spray nozzle. Before the waste solution contacts the calciner wall, which is maintained at about 700°C (600-800°C) by a multizone furnace, it is dried and then converted to oxides and reaction gases including H_2O, HNO_3, air and NO_x. There may also be some CO_x and other gases from the degradation of organics that may be contained in the HLLW.

The calciner off-gas, at a temperature of about 350°C, is filtered by sintered stainless steel filters to remove entrained calcine. Only about 0.1 wt% of the calcine passes through the filters and is then retained in the off-gas system. Less than 2% of the ruthenium is volatilized and escapes the calciner, but this ruthenium is retained in the off-gas system. All iodine and tritium in the HLLW volatilizes and is included with the calciner off-gas. The balance of radionuclides remains in the calcine. The filters mounted on the calciner are periodically blown back with air to remove the accumulation of calcine.

Frit (a glass-forming additive) is metered into the calciner bottom at a rate proportional to the HLLW feed rate to the calciner. For most HLLW, about one part (by weight) of calcine is added to two parts of frit. The frit-calcine mixture drops from the calciner cone into a canister for melting. When one canister is full of glass, a diverter valve routes the calcine-frit mix to a second canister.

TABLE 1. High-Level Liquid

Solution, g/ℓ	(1) HLLW	(2) Calciner Condensate
H+	2.0	2.23
Na	0.147	N[e]
Fe	2.0	N
Ni	0.133	N
Cr	0.333	N
Gd	15.9	N
F.P.[a]	44.7	N
Act.[b]	1.96	N
U	8.43	N
Pu	0.105	N
A.P.[c]	0.520	N
PO_4	2.67	N
NO_3	199	138
Fission Products, Ci/ℓ		
^{90}Sr	105	0.116
^{106}Ru	319	3.54
^{129}I	4.90E-6[d]	N
^{137}Cs	161	0.178
^{144}Ce	417	0.460
Total	2,410	5.87
Properties		
SpG at 4°C	1.17	1.08
Temp., °C	≤40	≤30
Watts/ℓ	12.2	
ℓ/MTHM	567	510
ℓ/day	3,790	3,400

Gases, g-mole/day	
HNO_3	
H_2O	
Air	
NO_x	
CO_x	
NH_3	
N_2	
Solids, g/day	
Fission Products Ci/ℓ day	
^{90}Sr	
^{106}Ru	
^{129}I	
^{137}Cs	
^{144}Ce	
Total	
Properties	
Temp., °C	
Watts/ℓ	5
Std ℓ/MTU	6
ℓ/day at Temp	6
Std ℓ/day	
	m
	0°C

Solids (Oxides), kg/MTHM	(13) Calcine	(14) Frit	(15) Glass
Na_2O	0.112		0.112
Fe_2O_3	1.622		1.622
NiO	0.096		0.096
Cr_2O_3	0.276		0.276
Gd_2O_3	10.372		10.372
FP_xO_y	31.440		31.440
Act_2O_g	1.220		1.220
UO_3	5.741		5.741
PuO_2	0.068		0.068
AP_rO_t	0.400		0.400
P_2O_5	1.130		1.130
SiO_2	-	66.5	66.5
B_2O_3	-	18.4	18.4
TiO_2	-	7.35	7.35
Al_2O_3	-	1.83	1.83
Na_2O	-	15.6	15.6
K_2O	-	9.18	9.18
CaO	-	3.68	3.68
Total	52.5	122.5	175
Fission Products, Ci/ℓ			
^{90}Sr	1,360	-	1,130
^{106}Ru	4,120	-	3,440
^{129}I	N	-	N
^{137}Cs	2,080	-	1,740
^{144}Ce	5,400	-	4,500
Total	31,200	-	26,000
Properties			
SpG	1.2	1.6	3.0
Temp.	<500°C	Ambient	≤800°C
Watts/ℓ	157	-	131
ℓ/MTU	43.7	76.6	58.3
ℓ/day	292	510	389

(a) F.P. = Fission Products
(b) Act. = Actinides
(c) A.P. = Activation Products
(d) Quantity sufficiently small that it is assumed negligible. Appr
^{129}I in the Calciner Off-Gas would be included in the Calciner
(e) N = Negligible

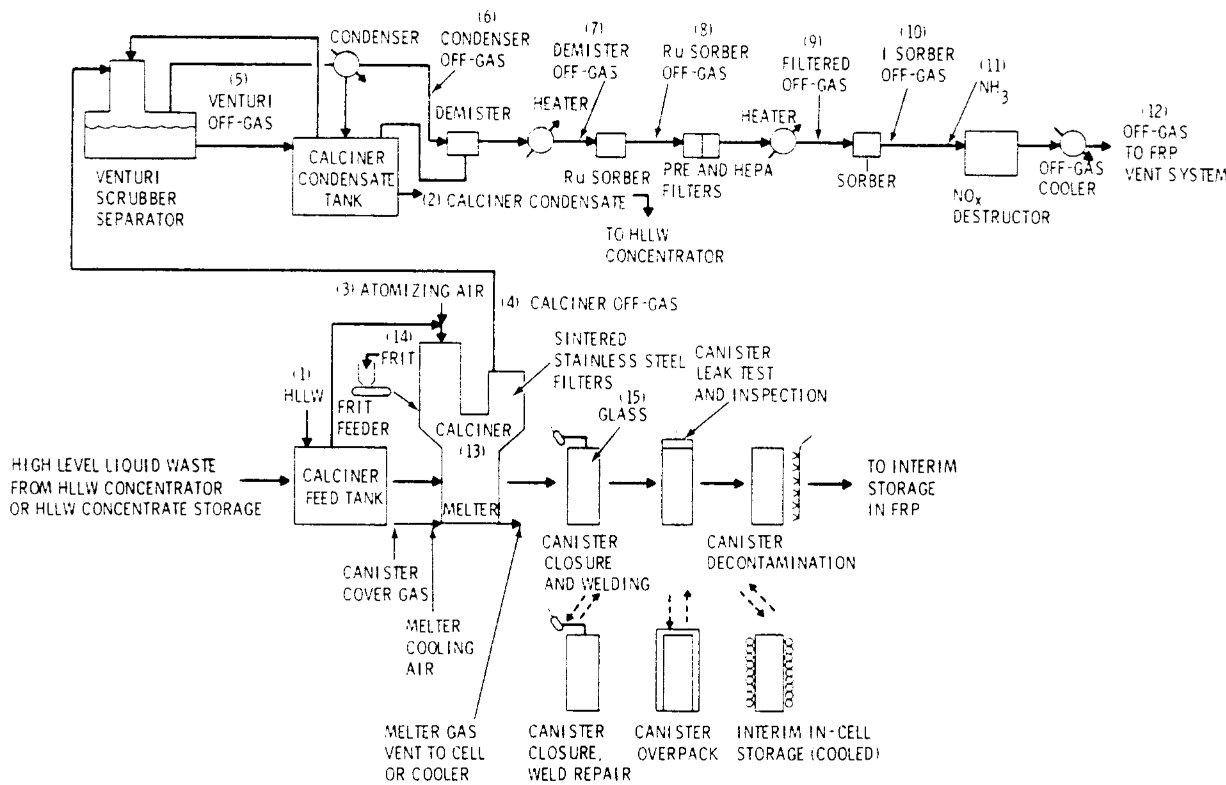


FIGURE 2. High-Level Liquid Waste Vitrification Flow Diagram

VITRIFICATION

The waste calcine vitrification is performed in a canister that is 30 cm in diameter by 300 cm high (12 in. in diameter by 10 ft high) which is contained in the retort of the melter furnace. The calcine-frit mixture from the calciner flows into the canister where it is melted at 1050°C to form glass at a rate of 16.2 ℓ/hr (0.57 ft^3/hr). Once the glass has formed, the heating is terminated, and cooling air is blown on the outer retort wall. This cools the wall and the canister to ≤800°C. The canister is filled to 80% of its volume (contains HLLW from 3.04 MTHM). The small volume of gas generated during the melting is routed to the calciner. Total time to fill the canister is about 11 hr for the reference flowsheet.

If a stainless steel canister is used, an inert gas, such as argon, is used in the retort to control minor canister spalling during filling. Any spalled material is collected in a pan in the retort bottom and is removed for disposal, as necessary.

The filled canister is removed from the calciner connections, and the lid is placed on the canister. A prepackaged helium source may be placed in the canister prior to closure for use in later leak-testing. Then, the filled canister is moved on to seal-welding and inspection. The operating time cycle for filling a canister is shown in Table 2.

TABLE 2. Canister Operating Time Cycle

Operations	Time, hr
Place in Melter, Move Under Calciner, Connect	1
Heat Empty Can	2
Fill	11
Top and Allow Bubble Release	4
Cool	2
Disconnect, Move Away from Calciner, Remove from Melter	1
Time Lags	1
Total	22

CANISTER HANDLING

The canister lid is seal-welded, using the tungsten inert gas process, to isolate the waste and canister interior from the outside environment. The canister weld is helium leak-checked to ensure its integrity (ultrasonic testing may also be used for this purpose). The canister is also visually inspected. Medium pressure water and/or steam sprays are used to remove any loose contamination from the filled canister. It is then moved to interim storage in the FRP. The vitrification cell will also provide for storage of empty and filled canisters. Additional inspection and process quality control functions can be designed into the facility, if necessary.

EFFLUENT TREATMENT

There are four sources of process effluents: calciner off-gas, canister decontamination solution, canister cooling air, and canister cover gas. Other effluents from the process area include cell ventilation air, vessel ventilation air and periodic cell decontamination solutions.

The calciner off-gas from the sintered stainless filters is subjected to a series of process operations to remove particulates (including radionuclides), gaseous radionuclides, and NO_x. These steps, occurring prior to release to the atmospheric protection system (APS), include the following:

- quenching
- condensing
- mist elimination
- Ru sorption
- filtration
- I sorption
- NO_x destruction

The filled canisters are decontaminated with water and/or steam sprays to remove loose radioactive particulates such as calcine. The spray solution is accumulated in a tank and periodically recombined with HLLW prior to concentration.

There are multiple gaseous waste handling systems. The canister cooling air and the canister cover gas are vented to the cell. Cell ventilation air is filtered to remove radioactive particulates prior to release to the FRP APS. The cell air filtration system will include one stage of roughing filters followed by two stages of high efficiency particulate air (HEPA) filters. The filters are periodically tested to ensure their interity. The vessel ventilation air is routed to the FRP vessel ventilation system.

Periodically some cell or equipment decontamination will be required. Steam, water, nitric acid, caustic, potassium permanganate, or tartaric acid will be used for this purpose. Decontamination solutions will be collected in the cell sump or other tanks and jetted to a waste accumulation tank for sampling. They will then either be combined with the HLLW or routed for treatment as intermediate-level liquid waste (ILLW).

FACILITY DESIGN CRITERIA

The following design criteria provide guidance for appropriate, safe, and reliable functioning of the NWVF.

Regulations, Codes, and Standards

The facility would be licensed by the NRC and thus will comply with federal, state, and local regulations. The facility and equipment will be designed in accordance with nationally recognized codes and standards. The design will conform to applicable regulatory guides and criteria issued by NRC for nuclear reactors and fuels reprocessing plants.

Operating Functions

The following operations will be performed in the NWVF:

- Receive HLLW from a transfer tank
- Sample and adjust HLLW composition
- Feed HLLW to calciner
- Calcinate HLLW
- Vitrify calcine
- Place lid on canister
- Seal-weld lid on canister
- Integrity test seal weld
- Decontaminate filled canisters
- Interim storage of three empty and three filled canisters in cell
- Move canisters within, into, and out of cell
- Repair faulty seal welds
- Overpack failed canisters
- Treat calciner off-gas for release to APS
- Collect other waste, sump, and decontamination solutions for routing to further treatment
- Sample the sump collection and decontamination solution tanks.

Operating Methods

All WVC operations will be performed remotely. Operations will typically use any number of devices: the crane which may be equipped with special devices such as a rotating hook, yoke, or impact wrench; dollies, and devices designed for special operations such as the welding head, lid leak testing head, and canister coupler to the calciner loading chute. Typical uses of the master-slave manipulators may be limited to placement of helium sources in canisters, placement of canister lids, replacement of instrument sensors and adjustment of the welding head. All WVC operations will be performed and monitored from the control room by instrumentation, viewing through the shielding windows, or viewing through a periscope. Where practical for maximum efficiency, other NWVF operations should be performed and monitored from the control room.

Maintenance Methods

All WVC maintenance activities will be performed remotely with the in-cell crane which may be equipped with a yoke or an impact wrench. Use of the manipulators will be limited to replacing small, high frequency failure items such as parts on the canister-chute coupler or the welding head.

Other maintenance may be performed using contact, semiremote, or remote methods after the radiation and contamination hazards and available techniques have been assessed.

Functional Layout

The NWVF functions will be located in areas consistent with radiation and contamination criteria for personnel protection as indicated in Table 3.

TABLE 3. Nuclear Waste Vitrification Facility Personnel Access Zone Classifications

Function	Personnel Access
Waste Vitrification Cell and Hot Pipe Trench	None
Hot Maintenance Area	Limited
Warm and Cell Service Galleries	Controlled
Aqueous Make-Up and Operating Areas	Total

Process Capacity

The facility would be designed to operate for 300 d/yr and process waste at a rate of 5700 ℓ/d (1500 gal/d), although only a 3800 ℓ/d (1000 gal/d) flowsheet capacity is needed. The additional design capacity allows for process upsets and process variations. This capability would enable the processing of all the HLLW from an FRP reprocessing spent fuel at a rate of 2000 MTHM/yr.

Equipment

In general, in-cell equipment will be designed for simplicity of operation and maintenance. There will be minimal use of equipment with moving parts which are subject to high maintenance frequency. All equipment will be designed and selected on the basis of suitability for intended use and high reliability. Major pieces of process equipment will be fabricated from materials exhibiting high resistance to corrosion, radiation damage, and process operating conditions. Similarly, all of the equipment, piping and instrument tubing in radioactive areas will be fabricated of materials that can withstand existing and anticipated decontamination solutions and radiation exposure. To aid in remote operations, equipment will be arranged to permit unobstructed crane access and will be equipped with lifting devices (lugs, yokes, etc.).

Facility Design Basis Fuel

The fuel used as the basis for facility and equipment design has the following characteristics:

Type: Pressurized Water Reactor - Uranium Enriched
Enrichment: 3.3% ^{235}U
Burnup: 33,000 MWd/MTHM
Power Level: 30 MW/MTHM
Neutron Flux: 2.92E13 N/cm^2-sec
Time Out-of-Reactor: 180 d

HLLW Description

The HLLW will have the composition shown in Table 1. This HLLW may contain some organic material from entrainment of Purex process solvent or denitration processing, but it contains no other FRP wastes. Table 4 indicates the assumptions used to determine the HLLW radionuclide content. The HLLW would have a concentration of 568 liter/MTHM (150 gal/MTHM).

TABLE 4. Percentage of Reactor Fuel Products Appearing in High-Level Liquid Waste

Isotope	wt%
^{3}H	8.0
^{14}C	0.0
Kr	0.0
Xe	0.0
I	0.5
U	0.5
Pu	0.5
Other	100.0

Radiation

The facility will be designed so that personnel exposure will be controlled to "As Low As Reasonably Achievable" (ALARA) by area access control and by limiting personnel exposure in significant radiation zones. Facility areas will be designed so they will fall into one of the personnel exposure categories listed in Table 5.

TABLE 5. Personnel Exposure Categories

Personnel Access	Maximum Allowable Radiation Dose Rate, mrem/hr
Free	≤1
Limited	≤10
Controlled	≤100
Strictly Controlled or None	>100

Although personnel may be exposed to high radiation levels under non-routine conditions, these controlled times will not exceed the limits established in 10 CFR 20.[8]

Safeguards

Separation of the fissile materials contained in the HLLW for use in nuclear devices is impractical. The associated fission products and actinides will emit such an intense radiation field and will be so highly toxic as to prohibit handling of the material without heavily shielded and specialized facilities. Also, it would be very difficult to extract the plutonium from the other materials to make it useful as a fissile material because of the low concentrations.

The plant security force and controlled access techniques will also protect the HLLW from unauthorized movement.

Contamination Control

Radioactive contamination will be confined to appropriate facility areas such as process equipment and piping, the WVC niches and trenches. Confinement will be by several methods:

- Areas of higher contamination potential will be held at a negative pressure compared to areas of lower contamination potential.
- Ventilation air will flow from areas of lower contamination potential to areas of higher contamination potential.
- Potentially contaminated areas will be designed to either contain any solutions or solids spilled within the area itself or to send such spills to an area of higher potential contamination.

Sabotage

Since NWVF will be a part of the FRP it will be protected against acts of sabotage by the same methods and guard force that are used by the FRP to comply with 10 CFR 73.[8]

Accidents and Safety

The facility will be licensed for construction and operation by the NRC. A key concern of licensing requirements is the safety of operating personnel, local population, environment, and the facility. The facility will be designed to recover and resume operations after abnormal operations and accidents. Radionuclide releases from accident conditions will be controlled to within limits set by process technical specifications which are within federal regulations.

Criticality

The fissile material in the facility is not sufficient to be credibly assembled to make criticality a significant consideration.

Quality Assurance

A quality assurance program will be provided for the design and construction of the facility to assure it will meet all of the requirements. The program will comply to 10 CFR 50, Appendix B.[8]

Useful Life

The NWVF will be designed and constructed so that it will have a useful operational life of 30 yr based on the following design considerations:

- every component will be designed for maintenance under operating conditions;
- a quality assurance program will be developed for all aspects of design, procurement, construction and operation; and
- materials will be of known durability, and allowances will be made for radiation damage, corrosion and wear.

Decommissioning

Decontamination and decommissioning of the NWVF must be considered. Appropriate decontamination equipment and systems must be provided, and the monitoring and recording equipment must be incorporated to assess contamination levels. Materials and equipment will be selected for their ultimate ease of retirement and removal. A removable surface will cover facility structure surfaces which are highly susceptible to significant contamination with radionuclides that would be difficult to remove.

A decommissioning plan will be developed as part of the design. Guidance will be taken from the proposed standard, N 300-1974, Draft 7, August 28, 1974, of American National Standards Institute, Inc., "Design Criteria for Decommissioning of Nuclear Fuel Reprocessing Plants," or a later issue. A decommissioning plan will be developed as part of the design.

It is projected that at the end of the facility's operating life the WVC and associated equipment will have become contaminated with 10 kCi of mixed fission products that have been out of the reactor five years.

FACILITY DESCRIPTION

Calcination, vitrification, canister handling, and limited effluent treatment will take place in a single cell, which is described in this section. Some associated operating and service areas are partially included in the facility description. Services such as utilities, maintenance, air supply, final effluent treatment, personnel support, and other services which would support and/or be an integral part of the FRP are not described here. However, they are identified so they can be properly accounted for in the system requirements.

The NWVF will be a reinforced concrete structure (Figures 3 and 4) consisting of nine areas (see Table 6). This report describes in detail only the waste vitrification cell (WVC) and associated equipment since other indicated areas are dependent on the design and layout of the FRP. However, the operations and interfaces of these other areas with the WVC are described. Utilities such as cooling water, process water, steam, electricity, instrument air, ventilation air and emergency utilities will be provided to the areas listed in Table 6 from central sources for the FRP. Other services such as analytical capabilities, personnel comfort and change rooms, instrument and manipulator maintenance, and warm equipment maintenance will also be provided as part of the integrated FRP complex.

Filled canisters will be stored in the fuel receiving pool, or a waste canister storage pool, and the empty canisters will be stored in the FRP warehouse as will other equipment for the operations of the WVC. If a future decision is made that shipping a canister of vitrified HLLW to a Federal repository will normally require overpacking, then the necessary facilities will be installed in the FRP.

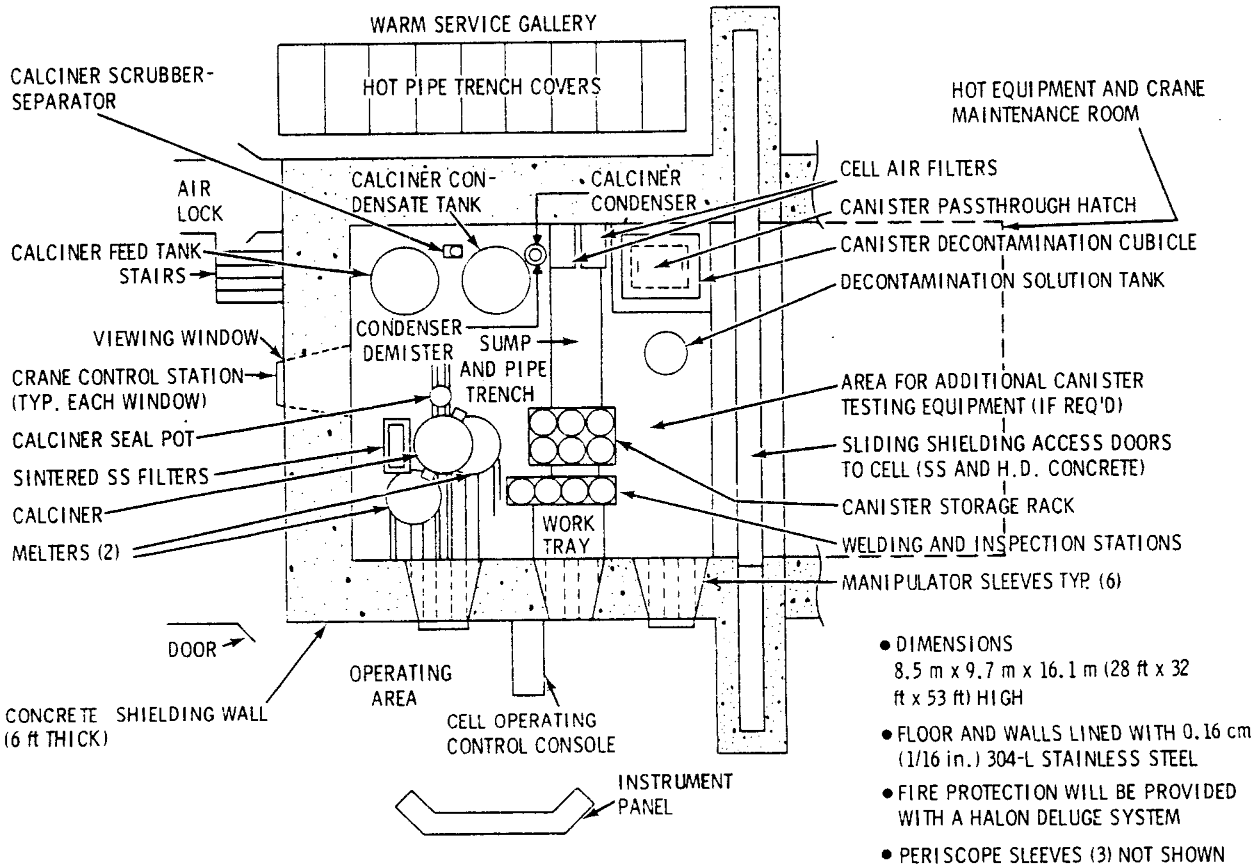


FIGURE 3. High-Level Waste Vitrification Cell Plan View

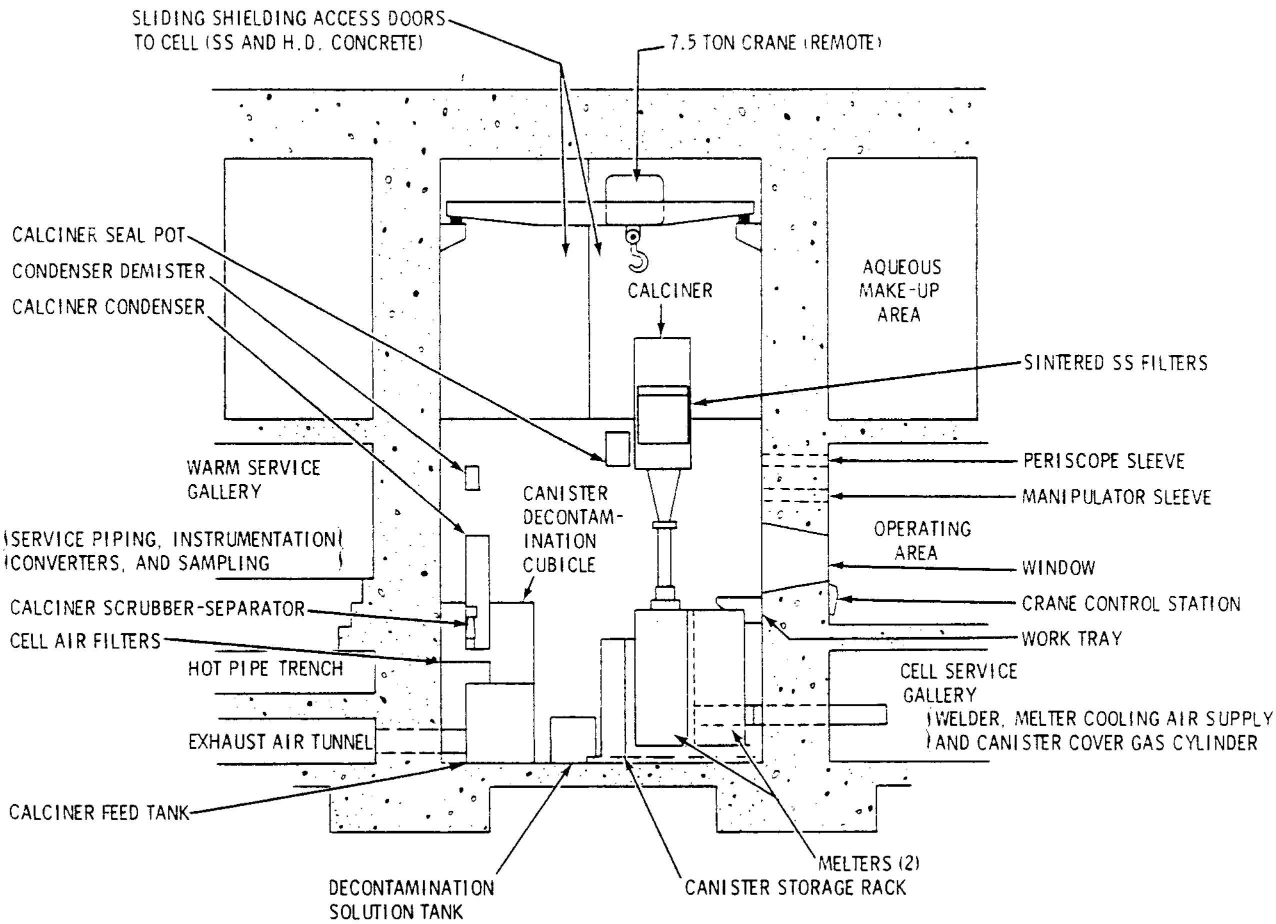


FIGURE 4. High-Level Waste Vitrification Cell Elevation View

TABLE 6. Nuclear Waste Vitrification Facility Areas and Associated Functions

Area	Function
Waste Vitrification Cell (WVC)	Receive, vitrify and package HLLW; inspect canister; limited process off-gas treatment; filter cell air; handle cell waste.
Canister Decontamination Cubicle (CDC)	Move canisters into and out of WVC, and decontaminate filled canisters.
Cell Ventilation Tunnel (CVT)	Route air from contaminated building cells to the FRP APS.
Hot Pipe Trench (HPT)	Route radioactive solutions between WVC and other FRP process areas.
Operating Area (OA)	Perform process control and monitoring.
Hot Maintenance Area (HMA)	Provides for equipment access and allows repairs to be made from WVC (access gained through shielding doors).
Warm Service Gallery (WSG)	Provides access to HPT, some WVC instrumentation converters and transmitters, samplers for WVC solutions, and service piping.
Cell Service Gallery (CSG)	Contains cold equipment, services and controls for WVC operations such as welder, melter cooling air supply, canister cover gas, and melter umbilical pipe drive.
Aqueous Makeup Area (AMA)	Contains frit storage and feed system, chemical solution makeup for use in WVC, and materials storage.

VITRIFICATION CELL

The vitrification cell will be a reinforced concrete structure with interior dimensions of 8.5 m wide x 9.7 m long x 16 m high (28 ft wide, 32 ft long and 53 ft high) as shown in Figures 3 and 4. The cell walls will be constructed of ordinary reinforced concrete. If it is deemed desirable to substitute high density concrete or other materials to accommodate cell penetrations or equipment, this may be done providing the shielding equivalence is maintained. The cell walls will be 1.8 m (6 ft) thick to reduce the radiation dose rate at the outer wall to ≤1 mrem/hr. The cell floor is assumed to be on or below the ground which will supply shielding and eliminate personnel access from this direction. Also, the roof may be less than 1.8 m (6 ft) thick if personnel access is limited. The entire cell will be lined with 304-L stainless steel which is about 0.16 cm (1/16 in.) thick. This liner will aid in cell decontamination and decommissioning and will also protect the cell walls from corrosive chemicals and vapors.

The floor structure will include a combination service trench and sump 0.61 m wide by 0.61 m deep by 8.5 m long (2 ft wide, by 2 ft deep by 28 ft long) covered with a 0.95-cm- (3/8-in.-) thick 304-L stainless steel, removable plate. The trench will contain a cell sump and service pipe running to the weld and inspection station (WIS), canister storage rack (CSR) and the decontamination solution tank (DST). The cell floor will be sloped toward the trench.

The main equipment access to the cell will be through the shielding doors leading to the hot maintenance area (HMA). The doors will be sealed when closed to minimize air in-leakage from this area. The second access will be through the canister decontamination cubicle (CDC). Through this cubicle, empty and full canisters will be moved into or out of the cell, and full canisters will be decontaminated upon removal from the cell. This cubicle cover will not be airtight, but in-leakage will be minimized. Ventilation air will be supplied to the cell from minor in-leakage and through a filtered air supply.

The CDC within the cell will have internal dimensions of 1.2 m wide x 1.5 m long x 3.7 m high (4 ft wide x 5 ft long by 12 ft high). The walls will be of 0.61-m- (2-ft-) thick concrete and lined with 0.16-cm (1/16-in.)

304-L stainless steel. The cubicle will be equipped with spray bars supplied with decontamination solution from a medium pressure pump in the DST and a sump equipped with a steam jet to move decontamination solution back to the pump tank.

The cell wall will contain four shielding windows to enable viewing and guiding operations within the cell. Penetrations in the cell wall that will accommodate services such as master-slave manipulators, periscopes, a pre-packaged helium source pass-through, two melter umbilical pipes, cell monitoring instrumentation, and equipment operation instrumentation. Service piping from the hot pipe trench to the adjacent cell remote heads will be cast into the cell wall. Service piping required from the hot pipe trench or cold side to the cell side walls will be routed through recesses in the cell wall behind the cell liner. There will also be a sump on the cell floor under the liner which will drain to a cell sump header.

Cell equipment will be mounted on ears, yokes, or racks on the walls and guides or supports on the floor. The crane will move on rails built into the cell walls. The melters will move on rails mounted on the cell floor.

Some empty floor space will be left in the cell to accommodate any additional canister test equipment required by federal waste acceptance criteria. If federal repository waste acceptance criteria require that all canisters be overpacked prior to shipment to a federal repository, this operation will be performed in another facility in the FRP.

EQUIPMENT

Major equipment for the SC/ICM process is described in this section and in Figures 5-22. Table 7 lists the equipment. All major process equipment will be remotely operated and maintained. With the exception of the calciner off-gas heaters, ruthenium sorber, off-gas filters, iodine sorber, NO_x destructor, and off-gas cooler, this equipment will be contained in the WVC. The pieces of equipment that are not in the WVC will be located in cells (such as the HLLW storage cell, HLLW concentration cell, or FRP vessel ventilation cell) to separate them from an area with significant airborne contamination. Except for the ruthenium sorber and perhaps the off-gas

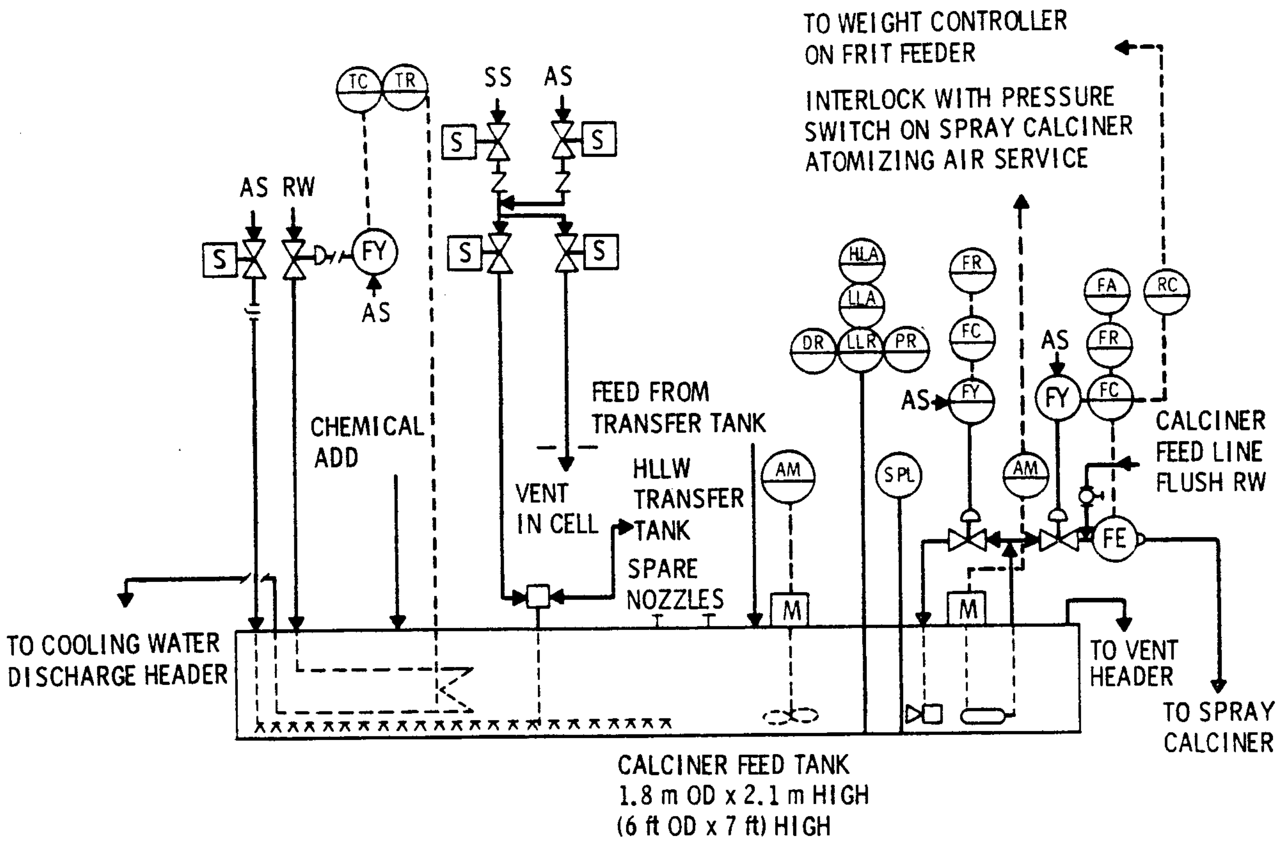
TABLE 7. Process Equipment

Process Equipment	Figure
(Legend)	(Table 8)
Calciner Feed Tank	5
Calciner	6
Melter	7
Frit Feeder	8
Calciner Condensate Tank	9
Decontamination Solution Tank	10
Canister Storage Rack	11
Cell Air Filters	12
Welding and Inspection Stations	13
Calciner Condenser	14
Calciner Scrubber-Separator	15
Off-Gas Demister	16
I and Ru Sorber Feed Heaters	17
Ruthenium Sorber	18
Pre- and HEPA Off-Gas Filters	19
Iodine Sorber	20
NO_x Destructor	21
Off-Gas Cooler	22

TABLE 8. Legend for Figures 5 Through 22

- RACK OR PANEL MOUNTED
- LOCALLY OR IN-LINE MOUNTED
- TWO MEASURED VARIABLES
- FLOW ELEMENT
- MOTOR
- DIAPHRAGM OPERATED VALVE
- SOLENOID OPERATED VALVE
- BALL VALVE
- NEEDLE VALVE
- REVERSE FLOW CHECK VALVE
- RESTRICTING FLOW ORIFICE
- JET MIXER
- PROCESS SERVICE LINES
- PNEUMATIC INSTRUMENT LINES
- PRIMARY PROCESS LINES
- ---- ELECTRONIC WIRES OR HIDDEN LINES

AM	AMMETER
AS	AIR SUPPLY
ATM	ATMOSPHERE
CI	CIRCUIT INTERRUPTER
DPA	DIFFERENTIAL PRESSURE ALARM
DPI	DIFFERENTIAL PRESSURE INDICATOR
DPR	DIFFERENTIAL PRESSURE RECORDER
DPT	DIFFERENTIAL PRESSURE TRANSMITTER
DR	DENSITY OR SPECIFIC GRAVITY RECORDER
ETM	ELAPSED TIME METER
FA	FLOW ALARM
FC	FLOW CONTROLLER
FE	FLOW SENSING ELEMENT
FI	FLOW INDICATOR
FR	FLOW RECORDER
FT	FLOW TRANSMITTER
FY	CONVERTER
HLA	HIGH LEVEL ALARM
ΔHWA	HIGH WEIGHT RATE CHANGE ALARM
IAS	INSTRUMENT AIR SUPPLY
IC	IONIZATION CHAMBER
IS	CURRENT SWITCH
IY	RELAY
JR	ELECTRICAL POWER RECORDER
JS	ELECTRICAL POWER SWITCH
KJC	TIMER
LC	LOAD CELL
LLA	LIQUID LEVEL ALARM
LLI	LIQUID LEVEL INDICATOR
LLR	LIQUID LEVEL RECORDER
ΔLWA	LOW WEIGHT RATE CHANGE ALARM
PCV	PRESSURE CONTROL VALVE
PE	PRESSURE SENSING ELEMENT
PGM	PROGRAMMER
PI	PRESSURE INDICATOR
PR	PRESSURE RECORDER
ΔPR	CHANGE IN PRESSURE RECORDER
PS	PRESSURE SWITCH
RC	RATIO CONTROLLER
REF	REFERENCE PRESSURE HEADER
RR	RADIATION RECORDER
RW	RAW WATER (UNSANITARY)
SE	SENSING ELEMENT
SPL	SAMPLE
SS	STEAM SUPPLY
SUM	SUMMER
SW	SELECTOR SWITCH
TA	TEMPERATURE ALARM
TC	TEMPERATURE CONTROLLER
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
TR	TEMPERATURE RECORDER
TRC	TEMPERATURE RECORDER CONTROLLER
TT	TEMPERATURE TRANSMITTER
VC	VALVE CONTROLLER
VIB	VIBRATOR
ΔWA	WEIGHT RATE CHANGE ALARM
WC	WEIGHT CONTROLLER
ΔWC	WEIGHT RATE CHANGE CONTROLLER
ΔWI	WEIGHT RATE CHANGE INDICATOR
ΣΔWI	WEIGHT TOTAL AND RATE CHANGE INDICATOR
WR	WEIGHT RECORDER
ΔWR	WEIGHT RATE CHANGE RECORDER
WS	WEIGHT SUPPLY



OPERATING CONDITIONS

VOLUME: 1200 GAL (4500 ℓ)

PRESSURE: 0.97 atm

TEMPERATURE: 40°C

CALCINER FEED FLOW RATE: 2.6 ℓ/min

DESIGN PARAMETERS

VOLUME: 1500 GAL (5700ℓ)

PRESSURE: 0.5-1.5 atm

TEMPERATURE: 0-110°C

HEAT REMOVAL: ≤ 120 kW

CALCINER FEED FLOW RATE: 0.4-4 ℓ/min

AGITATION: AIR SPARGE RING
PROPELLER AGITATOR
MIXING JET

TRANSFER JET CAPACITY (TYPE-STEAM):

25 gpm (~100 ℓ/min)

MATERIAL: 304-L STAINLESS STEEL

NOTES:

FEED SYSTEM:

PUMP: TYPE: CANTILEVER

CAPACITY: 200 gpm (757 ℓ/min)

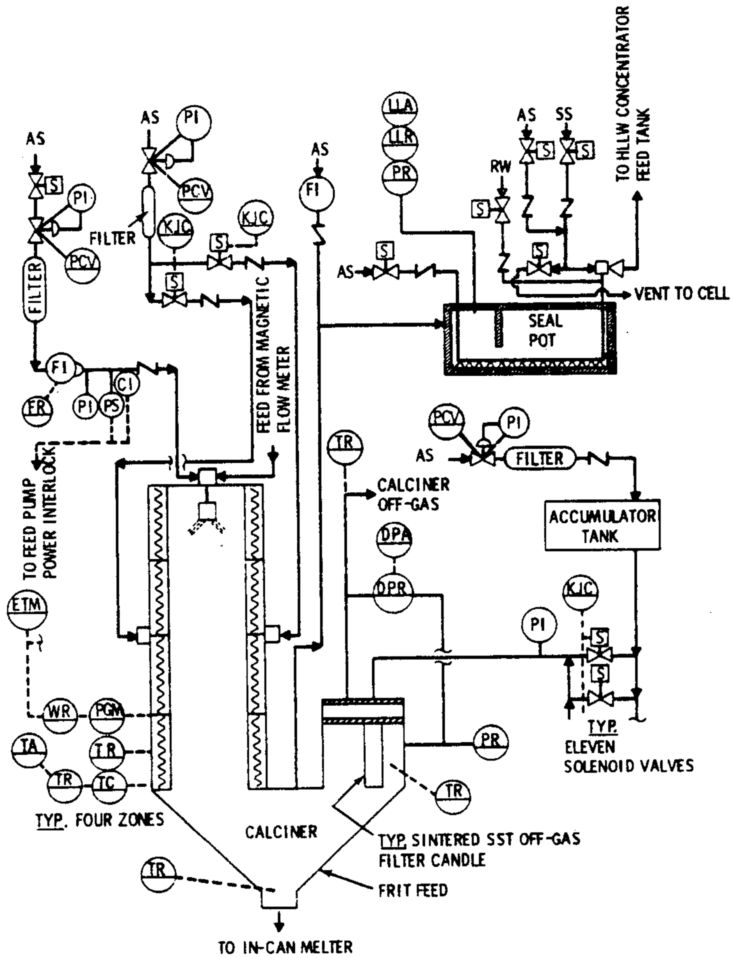
HEAD: 160 ft H_2O (4.7 atm)

FLOWMETER: MAGNETIC

FLOW CONTROL VALVE: HAMMEL-DAHL DIAPHRAGM CONTROL VALVE WITH SPLINE PLUG OR EQUIVALENT

TANK MATERIAL THICKNESS: 0.64 cm (1/4 in.)

FIGURE 5. Calciner Feed Tank



OPERATING CONDITIONS

CAPACITY: 160 ℓ HLLW/hr
TEMPERATURE: 700°C - CHAMBER
350°C - FILTERS
PRESSURE: 0.97 atm

DESIGN PARAMETERS

CAPACITY: 24-240 ℓ/hr
TEMPERATURE: 0-1000°C
PRESSURE: 0.5 - 2 atm

CALCINER CHAMBER

TYPE	RIGHT CYLINDER
INSIDE DIAMETER	0.91 m (36 in.)
HEIGHT	3 m (10 ft)
TOTAL HEAT TRANSFER AREA	8.7 m^2 (94 ft^2)
MATERIAL	310 SS
WALL THICKNESS	0.64 cm (0.25 in.)
BOTTOM	$\geq$60 SLOPE

FURNACE

TYPE	ELECTRICAL RESISTANCE 3 PHASE, 480Y
NUMBER OF ZONES	4
CONTROL	SILICON CONTROLLED RECTIFIER
MAXIMUM POWER (TOTAL)	280 kW AT 70 kW/ZONE
NORMAL OPERATING TEMPERATURE	800°C
MAXIMUM OPERATING TEMPERATURE	1000°C

ATOMIZING NOZZLE

TYPE	PNEUMATIC, INTERNAL MIX SUCH AS MFG. SPRAY SYSTEMS CO. MODEL SETUP NO. 72 OR EQUIVALENT
FLUID ORIFICE	TYPE 304 SS, 0.95 cm (0.375 in.) ID
AIR CAP ORIFICE	TYPE 303 SS WITH A 96% ALUMINA INSERT, 0.64 cm (0.25 in.) ID
ATOMIZING GAS	AMBIENT TEMPERATURE AIR
AIR TO LIQUID VOLUMETRIC FLOW RATIO	300

FILTERS

TYPE	SINDERED POWDERED METAL CYLINDER
TOTAL FILTER AREA	$\geq$150 ft^2
MEAN PORE SIZE	65 μ
MATERIAL	316 SS
NUMBER CANDLES	68
CANDLE DIMENSIONS (156 FT^2)	7 cm (2-3/4 in) OD, 0.91 m (36 in.) LONG AND 0.16 cm (1/16 in) THICK (REINFORCED)

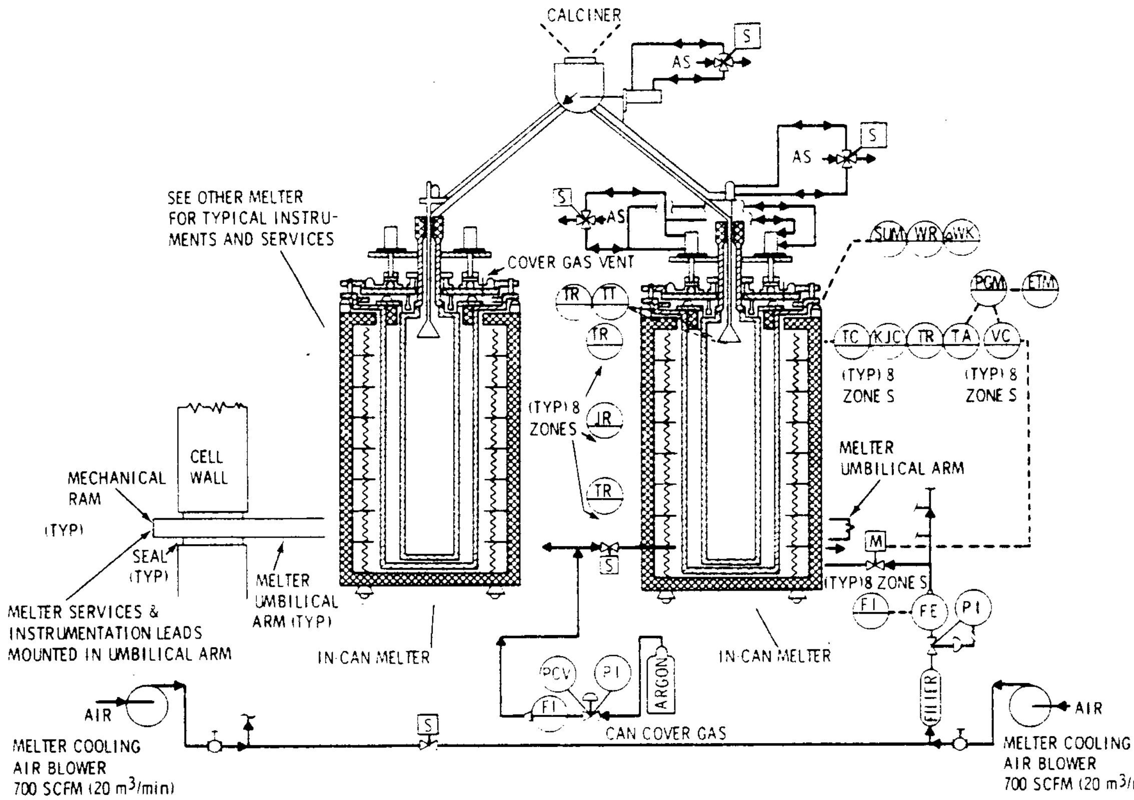
FILTER BLOWBACK SYSTEM

TYPE	VENTURI
BLOWBACK AIR PRESSURE	4.1 TO 6.8 atm (60 TO 100 psig) AT BLOWBACK
BLOWBACK NOZZLE SIZE	NOZZLE 0.38 TO 0.46 cm (0.15 TO 0.18 in) ID
PERCENT OF FILTERS CLEANED SIMULTANEOUSLY	20%
BLOWBACK CYCLE	2 TI 100 min
PULSE DURATION	0.25 sec

VIBRATORS

TYPE	PNEUMATIC DRY LUBRICANT SUCH AS MFG. CLEVELAND VIBRATOR CO. MODEL: 1300 AC VIBRAMIGHT OR EQUIVALENT
MOTIVE AIR PRESSURE	40 psig (2.7 atm)
LOCATION	SIDE MOUNTED, 180° APART
NUMBER	2

FIGURE 6. Calciner



OPERATING CONDITIONS

- CAPACITY: 50 kg GLASS/hr
- TEMPERATURE: 1050°C
- PRESSURE: ~1 atm

DESIGN PARAMETERS

- CAPACITY: 0 TO 75 kg/hr
- TEMPERATURE: 0 TO 1200°C
- PRESSURE: NOT APPLICABLE

MELTER

- TYPE: RESISTANCE HEATING
- SIZE OF FURNACE EXTERIOR - 3.6 m HIGH x 1.5 m dia (12 ft HIGH x 5 ft) dia
- SIZE OF HEATED CHAMBER - 3.3 m HIGH x 0.91 m dia (10-3/4 ft HIGH x 3 ft) dia
- NUMBER OF ZONES - PRESENT EXPERIENCE SUGGESTS USING 8 ZONES EACH APPROXIMATELY 38 cm (15 in.) HIGH
- POWER REQUIRED - 30 kW/ZONE OR 240 kW TOTAL
- COOLING REQUIRED - 7 kW/ZONE OR 56 kW TOTAL
- MAXIMUM OPERATING TEMPERATURE - 1200°C
- MATERIALS - LOW THERMAL INERTIA, UNAFFECTED BY THERMAL CYCLING, THERMAL SHOCK, AND RADIATION

SIZE OF RETORT - 3.2 m HIGH x 71 cm max ID (10-1/2 ft HIGH x 28 in. max ID)

RETORT - RESISTANCE AT 1200°C. IT MUST BE UNAFFECTED BY THERMAL CYCLING AND THERMAL SHOCK. IT MUST HAVE GOOD STRENGTH AND OXIDATION. HASTELOY X WAS SUCCESSFULLY USED IN BOTH INDUCTION AND RESISTANCE FURNACES IN WSEP. TEMPERATURE WAS LESS THAN ~1000 TO 1050°C.

LOAD CELL RANGE - 0 - 2,500 kg

LOAD CELL TOTAL CAPACITY - MAY NEED TO SUPPORT SUSCEPTOR/RETORT AS WELL AS CAN AND MELT.

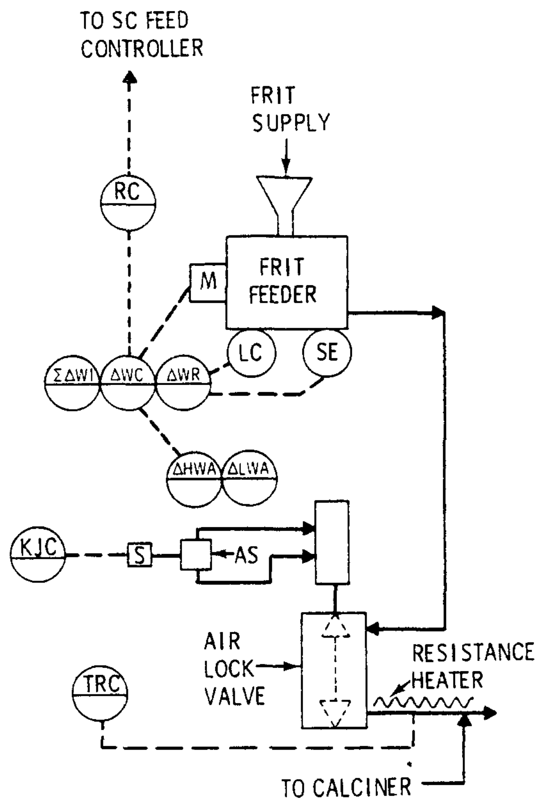
LOAD CELL MATERIALS - SHOULD BE RESISTANT TO RADIATION OR APPROPRIATELY SHIELDED AND SHOULD BE RESISTANT TO TEMPERATURE.

MELTER SERVICES - ALL POWER, COOLING AIR, COVER GAS, AND THERMOCOUPLE LEADS WHICH SERVICE THE MOVING MELTER WILL BE SUPPLIED THROUGH THE MELTER UMBILICAL ARM.

COUPLING SECTION

- DUCT SIZE - 10 cm (4 in.) INSIDE DIAMETER MINIMUM
- MINIMUM SLOPE - 60° FROM HORIZONTAL
- OPERATING TEMPERATURE - 300°C (CALCINE TEMPERATURE) NORMAL AND 100°C MINIMUM
- DURABILITY - INSIDE MUST BE ABRASION, NITRIC ACID AND RADIATION RESISTANT. (STAINLESS STEEL MAY NOT RESIST ABRASION WELL ENOUGH.)
- PERFORMANCE - TOTAL SECTION MUST BE LEAK RESISTANT. INSIDE SURFACES SHOULD BE SMOOTH WITH NO LEDGES FOR FRIT/CALCINE TO COLLECT.

FIGURE 7. Melter



FRIT FEEDER

FRIT FEEDER

OPERATING CONDITIONS

NOMINAL FEED RATE: 34 kg/hr
TEMPERATURE: ROOM
PRESSURE: 1 atm

DESIGN PARAMETERS

TYPE - VARIABLE SPEED, CONTINUOUS WEIGHT BELT

FEED RATE - 0-55 kg/hr

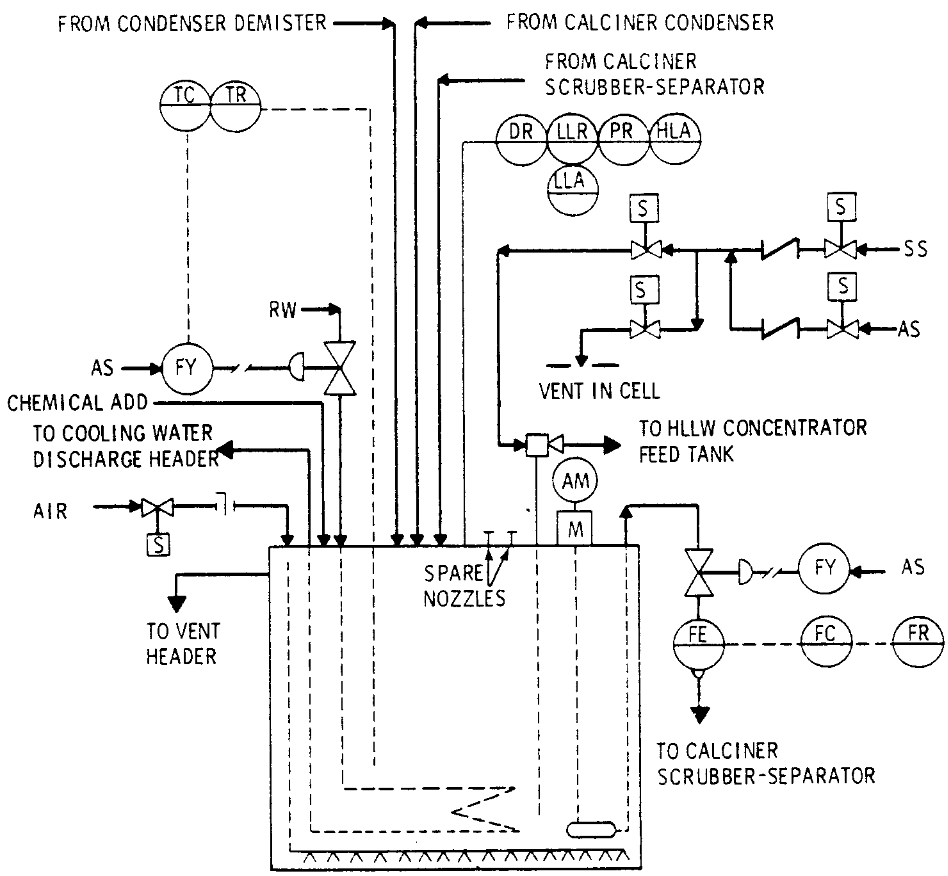
BIN SIZE - 1225 kg OF FRIT (510 ℓ/DAY)
(FRIT: SIZE - -20/+80 MESH; SPECIFIC GRAVITY: 1.6)

CONTROL - THE FEEDER MAY OPERATE AS A SLAVE FEEDER BY METERING FRIT AT A RATE PROPORTIONAL TO THE FLOW RATE OF LIQUID WASTE TO THE CALCINER.

MAINTENANCE - THE BIN, SCALES, AND FEEDER WILL BE OUTSIDE THE HOT CELL SO THAT THEY NEED NOT BE RADIATION RESISTANT AND HANDS-ON MAINTENANCE IS POSSIBLE. THE DUCTS AND AIRLOCK(S) SHOULD BE MADE OF ABRASION RESISTANT MATERIALS.

PERFORMANCE - THE AIRLOCKS MUST MINIMIZE BACK MIGRATION OF CONTAMINATION. A DUCT ANGLE OF 45° FROM VERTICAL IS ADEQUATE FOR GRAVITY FLOW OF THE FRIT THAT IS -20/+80 MESH.

FIGURE 8. Frit Feeder



CALCINER CONDENSATE TANK
1.7 mΦ x 1.5 m (5 ft 6 in. Φ x 5 ft)

OPERATING CONDITIONS

VOLUME: 2650 ℓ (700 GAL)

PRESSURE: 0.97 atm

TEMPERATURE: ~29°C

SCRUBBER FLOW RATE: 190 ℓ/min

DESIGN PARAMETERS

VOLUME: 3400 ℓ (900 GAL)

PRESSURE: 0.5-1.5 atm

TEMPERATURE: 0-110°C

HEAT REMOVAL: ≤ 130 kW

SCRUBBER FEED FLOW RATE: 40-320 ℓ/min

AGITATION: AIR SPARGE RING

TRANSFER JET CAPACITY (TYPE: STEAM): ~100 ℓ/min (25 gpm)

MATERIAL: 304-L STAINLESS STEEL

NOTES:

SCRUBBER FEED SYSTEM

PUMP: TYPE: CENTRIFUGAL

CAPACITY: 320 ℓ/min

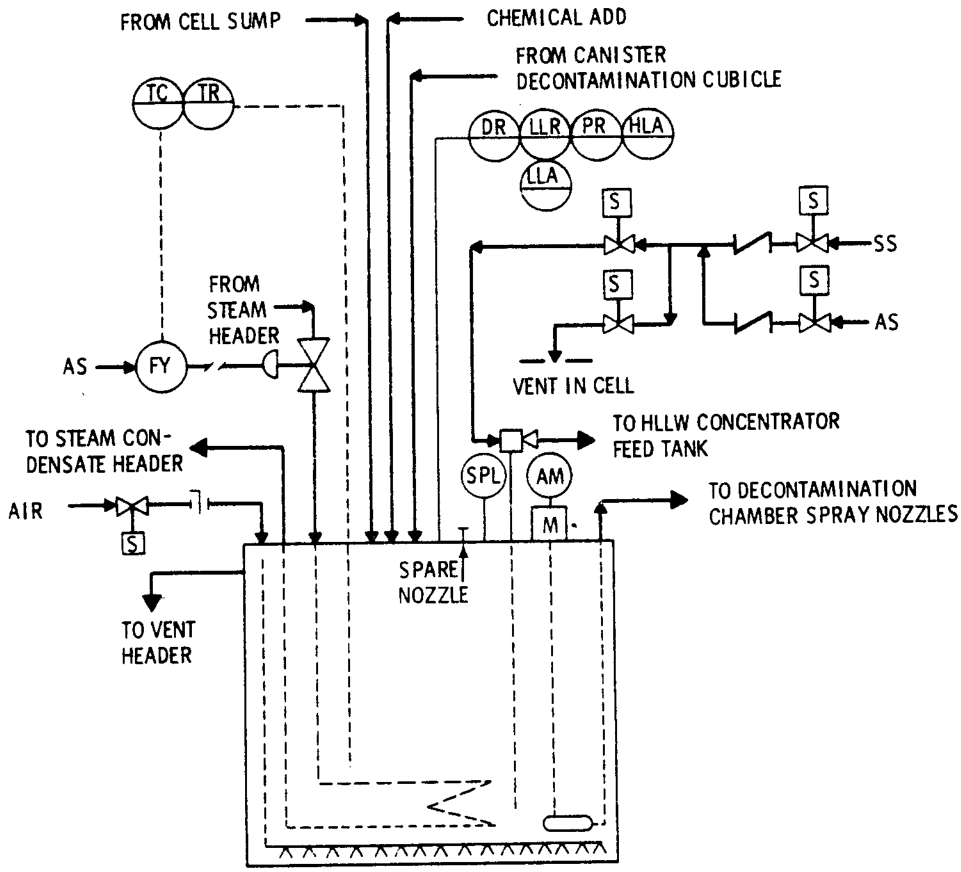
HEAD: 4 atm (60 psig)

FLOWMETER: ORIFICE

FLOW CONTROL VOLUME: HAMMEL DAHL DIAPHRAM CONTROL VALVE OR EQUIVALENT

TANK MATERIAL THICKNESS: 0.64 cm (1/4 in.)

FIGURE 9. Calciner Condensate Tank



DECONTAMINATION SOLUTION TANK
1.2 mΦ x 1.2 m (4 ft Φ x 4 ft)

OPERATING CONDITIONS

VOLUME: 1135 ℓ (300 GAL)

PRESSURE: 0.97 atm

TEMPERATURE: 50°C

DECONTAMINATION SOLUTION FLOW RATE: 100 ℓ/min

DESIGN PARAMETERS

VOLUME: 1420 ℓ (375 GAL)

PRESSURE: 0.5-1.5 atm

TEMPERATURE: 0-110°C

HEATING: 100 kW

DECONTAMINATION SOLUTION FLOW RATE: 20-200 ℓ/min

AGITATION: AIR SPARGE RING

TRANSFER JET CAPACITY (TYPE-STEAM): ~100 ℓ/min (25 gpm)

MATERIAL: 304-L STAINLESS STEEL

NOTES:

DECONTAMINATION SOLUTION PUMP SYSTEM

PUMP: TYPE: CENTRIFUGAL

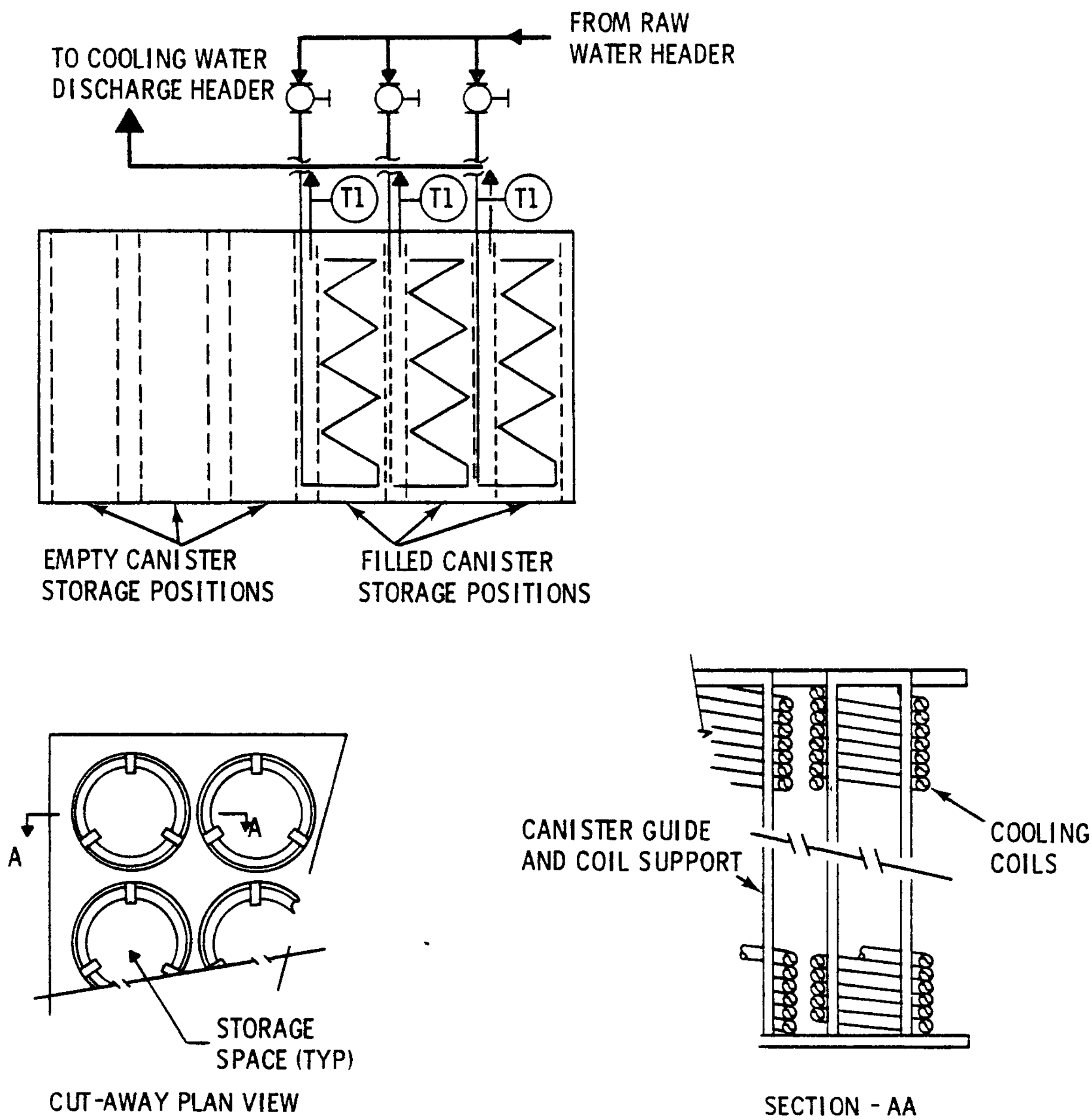
CAPACITY: 200 ℓ/min

HEAD: 4.8 atm (70 psig)

FLOWMETER: NONE

FLOW CONTROL: NONE

FIGURE 10. Decontamination Solution Tank



TYPE: OPEN WELDED FRAME

CAPACITY: THREE EMPTY CANISTERS
THREE FULL CANISTERS

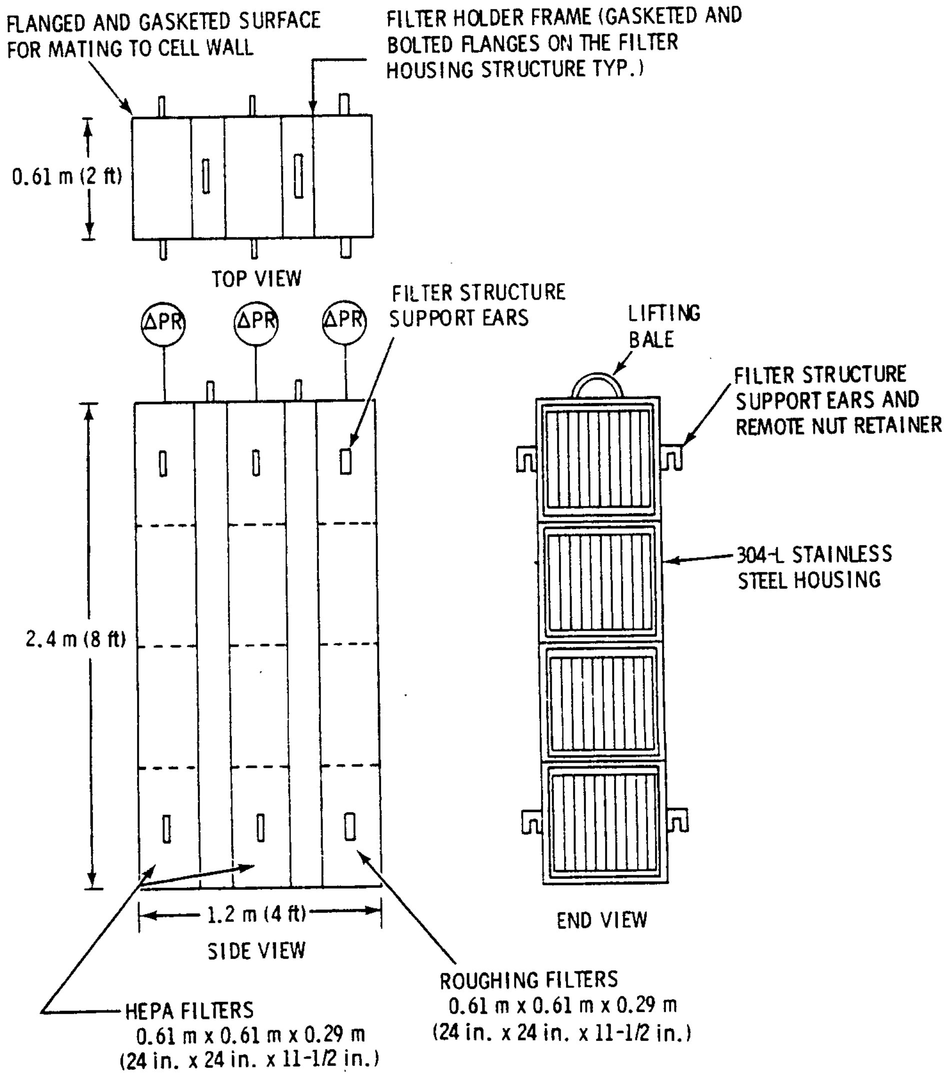
MATERIAL: 304-L SS

COOLING: WRAPPED 304-L SS TUBING
(A TUBE COIL IS PLACED OUTSIDE OF CANISTER GUIDES IN STORAGE POSITION)

COOLING CAPACITY: 50 kW/COIL

RACK DIMENSIONS: (~6 ft x 6 ft x 11 ft)

FIGURE 11. Canister Storage Rack



OPERATING CONDITIONS

AIR FLOW RATE: 113 m^3/min (4000 cfm) PER ASSEMBLY

TEMPERATURE: ~65°C

PRESSURE: ~1 atm

HUMIDITY: ≤30% RELATIVE

DESIGN PARAMETERS

CAPACITY (2 ASSEMBLIES): 226 m^3/min (8000 cfm)

TEMPERATURE: ≤ 100°C

PRESSURE: ~1 atm

FILTERS:

CAPACITY: 28 m^3/min (1000 cfm)

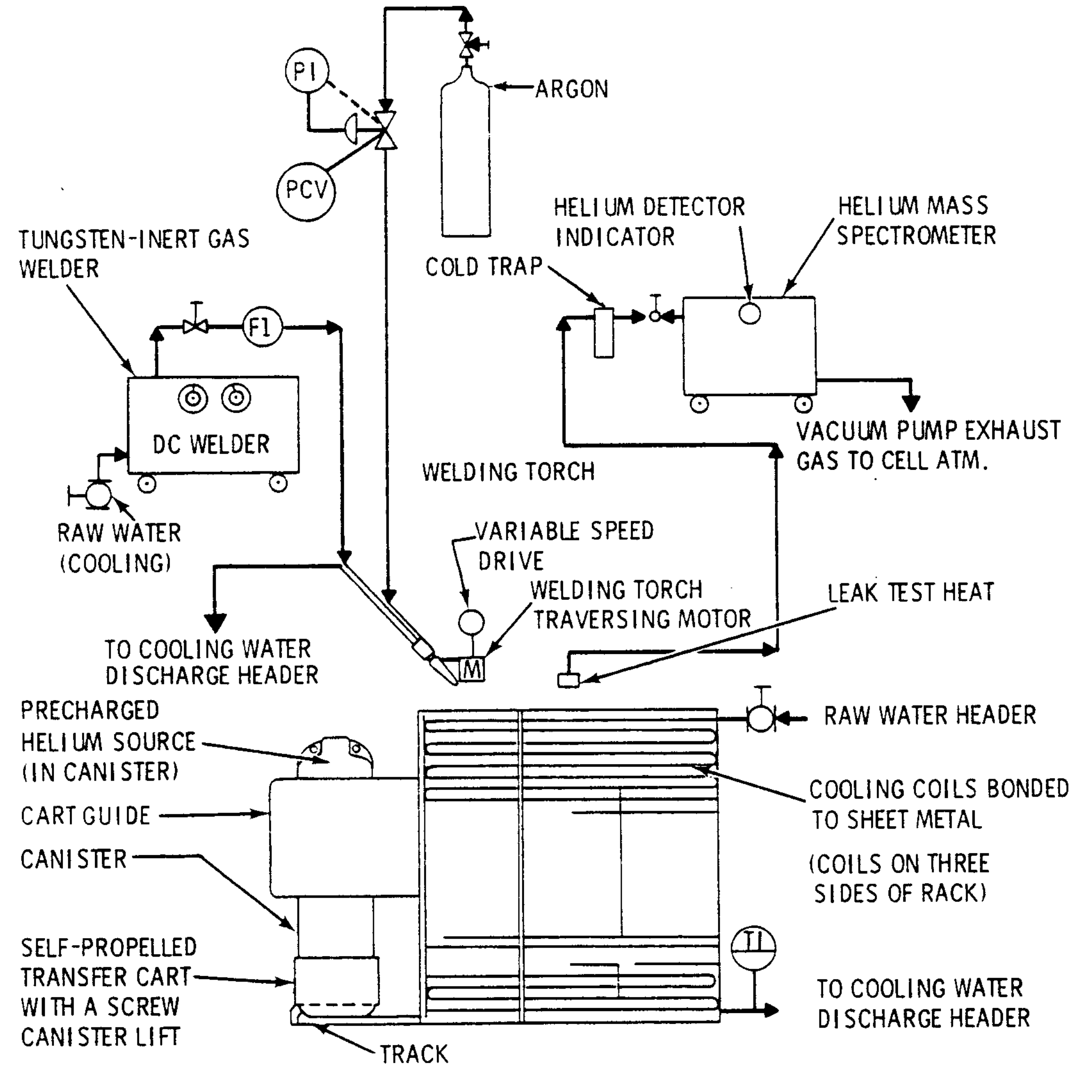
DIMENSIONS: 0.61 m x 0.61 m x 0.29 m (24 in. x 24 in. x 11.5 in.)

FRAME: FIRE RETARDENT WOOD

HOUSING: 304-L STAINLESS STEEL

TESTING: AN IN-PLACE FILTER TEST CAPABILITY WILL BE SUPPLIED WITH THE ASSEMBLY

FIGURE 12. Cell Air Filters



CANISTER CART SYSTEM

TYPE: SELF-PROPELLED ELECTRIC

FEATURE: WILL BE ABLE TO LIFT CANISTER ~30 cm (~12 in.) TO FIT INTO REMOTE PLACEMENT FIXTURE

RACK STRUCTURE

TYPE: FRAME STRUCTURE OF SAME TYPE CONSTRUCTION AS "CANISTER STORAGE RACK"

MATERIAL: 304-L SS

COOLING: A METAL SHEET WILL BE ATTACHED TO THE RACK SIDES WITH THE COOLING COIL BONDED TO THE SHEET

COIL COOLING CAPACITY: 50 kW

SIZE: 0.61 m x 2.4 m x 3.2 m (24 in. x 96 in. x 126 in.)

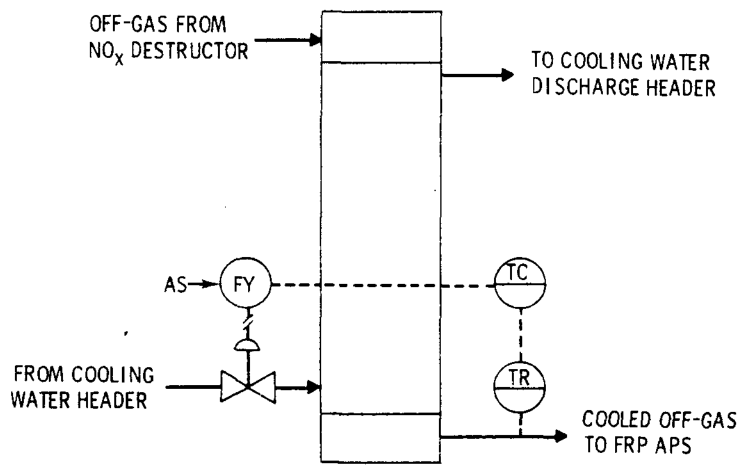
WELDER

TYPE: TUNGSTEN-INERT GAS USING A REMOTE HEAD

INSPECTION

TYPE: He LEAK CHECK USING He MASS SPECTROMETER WITH A REMOTE BELL HEAD OR ULTRASONIC SEAL WELD INTEGRITY CHECK

FIGURE 13. Welding and Inspection Stations



OPERATING CONDITIONS

CAPACITY: ~100,000 g-moles OF GAS (TABLE 1, 12. OFF-GAS TO FRP) PER DAY AT ~500°C IS COOLED TO ~55°F

TEMPERATURE (OFF-GAS): SEE ABOVE

PRESSURE: ~0.95 atm

DESIGN PARAMETERS

CAPACITY: FROM 0-200,000 g-moles OF GAS (TABLE 1, 12. OFF-GAS TO FRP) PER DAY AT ~500°C IS COOLED TO ~55°C

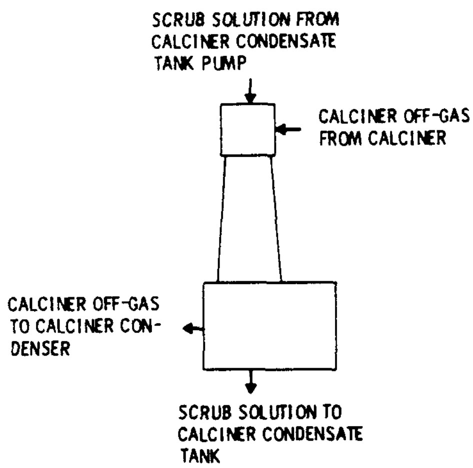
TYPE: SHELL-TUBE
SINGLE PASS
BAFFLED
FLOATING HEAD
AIR ON TUBE SIDE
WATER ON SHELL SIDE

HEAT TRANSFER AREA: ~11 m^2 (~120 ft^2)

HEAD LOAD: ~21 kW (~72,000 Btu/hr)

MATERIAL: 304-L STAINLESS STEEL

FIGURE 14. Calciner Condenser



OPERATING CONDITIONS

CAPACITY: 4250 std ℓm in (150 SCFM) OF CALCINDER OFF-GAS (TABLE 1, (4) CALCINDER OFF-GAS) AT ≤350°C COOLED TO ≤110°C

PRESSURE (CALCINER OFF-GAS): ~0.97 atm

DESIGN PARAMETERS

TYPE: VENTURI SCRUBBER-SEPARATOR

CAPACITY: 6370 std ℓm in (300 SCFM) OF CALCINDER OFF-GAS (table 1, (4) CALCINDER OFF-GAS) AT ≤350°C COOLED TO ≤110°C

TEMPERATURE: 0-400°C

PRESSURE (CALCINER OFF-GAS): 0.5-1.2 atm

MATERIAL: 304-L STAINLESS STEEL

NOTE: THE FOLLOWING SYSTEM, EQUIVALENT, OR BETTER CAN BE CONSIDERED FOR DESIGN PURPOSES.

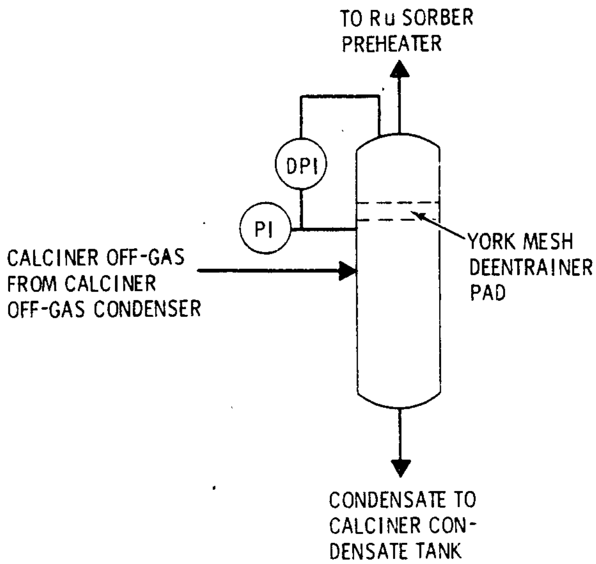
S&K TYPE 7014 SCRUBBER-SEPARATOR SYSTEM. THE FOLLOWING COMPONENTS WILL BE SUPPLIED:

1. EJECTOR-VENTURI SCRUBBER, TYPE 7010, 15 cm (6 in.) 316 STAINLESS STEEL. THE SCRUBBER WILL HAVE A 3.2 cm (1-1/4 in) (EXTRA LARGE) 316 STAINLESS STEEL FIG. 622-L SPRAY NOZZLE AND 316 STAINLESS STEEL SPIRAL.
1. SEPARATOR, TYPE 7040, 15 cm (6 in.) 316 STAINLESS STEEL, THE SEPARATOR WILL HAVE AN SK DESIGNED IMPACT BAFFLE SEPARATOR ELEMENT.

PERFORMANCE: THE 15 cm (6 in.) TYPE 7014 SCRUBBER-SEPARATOR SYSTEM IS DESIGNED TO HANDLE 15.6 m^3/min (500 ACFM) OF GAS AT 400° C, (25 in W.C.) 0.061 atm 14 m^3min VACUUM, CONSISTING OF 14 m^3 500cfm OFSTEAM WITH NITRIC ACID AND 0.26 Gr/DCFM. WHEN THE SPRAY NOZZLE IS SUPPLIED WITH 180 /min 48 gpm OF FRESH WATER AT 29° C (85° F) AT 4.1 atm (60 psig) PRESSURE, THE SCRUBBER-SEPARATOR SYSTEM WILL HAVE A 0.012 atm, 5 in. W.C. DRAFT. AT THESE OPERATING CONDITIONS THE SCRUBBER-SEPARATOR SYSTEM WILL CONDENSE AND COOL THE GAS TO LESS THAN 60°C (140°F) AND REMOVE 90% of 1 MICRON SIZE PARTICLES.

THE EJECTOR VENTURI MAY BE CHANGED TO A HIGH ENERGY VENTURI TO ACHIEVE A MORE EFFICIENT SCRUBBING SYSTEM.

FIGURE 15. Calciner Scrubber-Separator



OPERATING CONDITIONS

CAPACITY: 57.4 cfm (1625 ℓ/min) OF CONDENSER OFF-GAS (TABLE 1, (6) CONDENSER OFF-GAS)

TEMPERATURE: ~50°C

PRESSURE: ~0.95 atm

DESIGN PARAMETERS

TYPE: YORK MESH DEENTRAINER IN-PIPE OR EQUIVALENT

CAPACITY: 2435 /min (≤86.1 cfm) OF VAPOR SATURATED AIR @ ≤50°C,
ENTRAINED LIQUID ~2.2 M HNO_3, AND AIR WILL CONTAIN SOME NO_x

ENTRAINMENT LOAD = UNKNOWN

MATERIAL: 304-L STAINLESS STEEL

NOTE:

DEMISTER: TYPICAL DESIGN
AT 2435 min(86.1cf m) ≤ @ 50°C WANT LINEAR FLOW RATE ≤4.5 m/sec (15 ft/sec)

10 cm (4 in.) THICK YORK MESH DEMISTER

EFFECTIVE AREA = 75.5 cm² (0.081 ft² = 11.7 in.²)

EFFECTIVE DIAMETER = 10 cm (3.9 in.)

PIPE ID = 10 cm (4 in.)

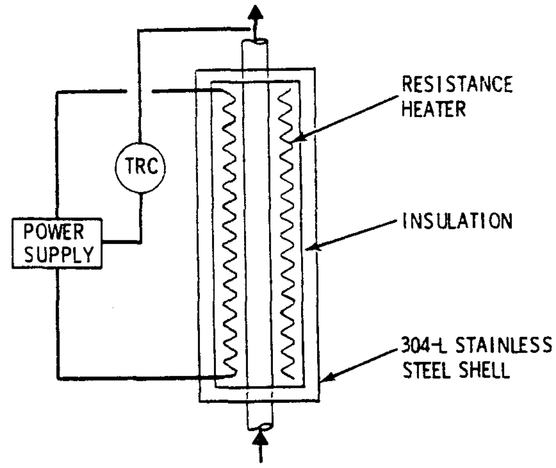
PIPE THICKNESS ≈ 0.64 cm (1/4 in.)

MESH SUPPORT - WELDED IN ANNULAR PLATES

TOTAL HEIGHT ≤30 cm (1 ft) (EXCL. CONNECTOR HEADS)

MESH ΔP ≤0.0037 atm (1.5 in. H_2O)

FIGURE 16. Off-Gas Demister



OPERATING CONDITIONS

CAPACITY: 1375 std/min (48.5 SCFM OF DEMISTER)-GAS OFF-GAS (TABLE-1, (7) DEMINSTER OFF-GAS) AT $\leq 80^oC$ ARE HEATED $\leq 60^oC$

TEMPERATURE (OFF-GAS)

	INLET	EXIT
I FEED HEATER	$\leq 80^oC$	$\sim 130^oC$
Ru FEED HEATER	$\leq 50^oC$	$\sim 80^oC$

PRESSURE (OFF-GAS) $\sim$0.95 atm

DESIGN PARAMETERS

CAPACITY: $\sim$0-3 kW

TYPE: ELECTRICAL RESISTANCE

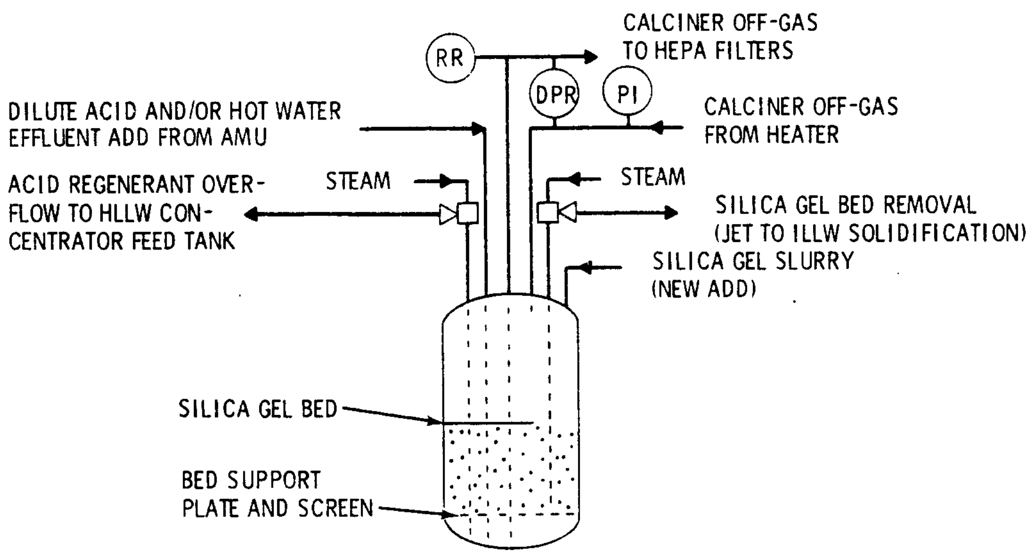
TEMPERATURE: $0\text{-}200^oC$

PRESSURE: 0.5-1.5 atm

MATERIAL: 304-L STAINLESS STEEL EXCEPT FOR HEATING ELEMENTS AND INSULATION AND OTHER ITEMS AS MAY BE APPROPRIATE

NOTE: FOR PRELIMINARY DESIGN ASSUME $\sim 0.37\ m^2$ ($\sim 4\ ft^2$) OF HEAT TRANSFER AREA IS NEEDED AND THIS IS SUPPLIED BY 5 cm (2 in.) DIAMETER PIPE THAT IS 2.4 m (8 ft) LONG. THE HEATING ELEMENT SUPPORT STRUCTURE AND INSULATION ARE PLACED IN A 15 cm (6 in.) PIPE.

FIGURE 17. I and Ru Sorber Feed Heaters



OPERATING CONDITIONS

CAPACITY (AIR HANDLING):
1375 std ℓ/min (48.5 SCFM) OF DEMINSTER OF GAS
(TABLE-1, (7) DEMISTER OFF-GAS)

TEMPERATURE (OFF-GAS): 80°C

PRESSURE: ~0.95 atm

DESIGN PARAMETERS

CAPACITY (AIR HANDLING):
2070 std ℓ/min (73 SCFM) OF DEMISTER OFF-GAS
(TABLE-1, (7) DEMISTER OFF-GAS)

TEMPERATURE: 0-150°C

PRESSURE: 0.5-1.5 atm

TYPE: PACKED SILICA GEL BED

MATERIALS: VESSEL - 304-L SS
BED - 12-40 MESH SILICA GEL

VESSEL SIZE: 66.5 cm (26.2 in.) ID
1.8 m (70 in.) HEIGHT

THICKNESS: 0.64 cm (0.25 in.)

BED SUPPORT: 0.48 cm (3/16 in.) 304-L SS PLATE DRILLED FULL OF 0.64 cm (0.25 in.) HOLES SUPPORTING A 304-L SS HEAVY SCREEN WHICH IS ≤ 80 MESH

HEADS: STANDARD DISHED

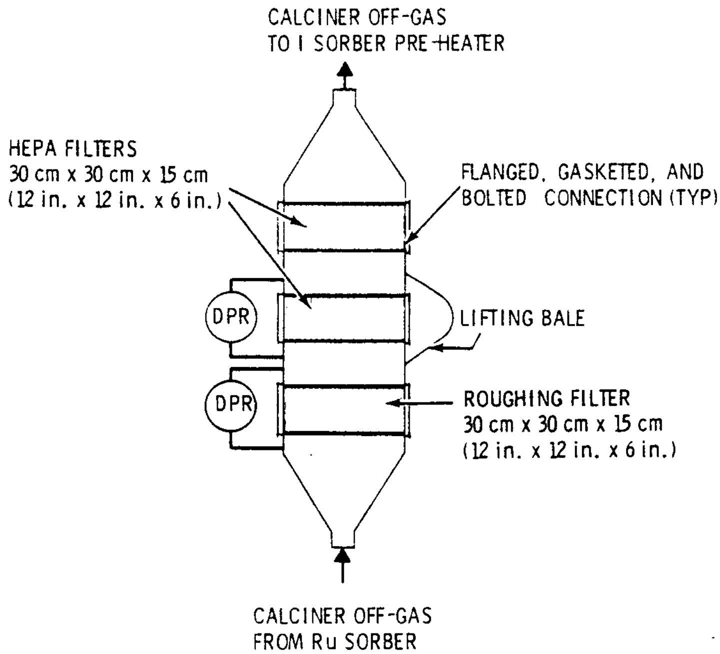
BED: DAVIDSON GRADE 40 SILICA GEL OR EQUIVALENT

SIZE: 41 cm (16.2 in.) dia
76 cm (30 in.) DEPTH

PARTICLE SIZE: 12-40 MESH

JETS (TYPE-STEAM): ~100 ℓ/min (25 gpm)

FIGURE 18. Ruthenium Sorber



OPERATING CONDITIONS

CAPACITY: 1375 std ℓ/min (48.5 SCFM) OF Ru SORBER OFF-GAS (TABLE 1, (8) Ru SORBER OFF-GAS)

TEMPERATURE: $\leq 80^0$C

PRESSURE: ~0.95

DESIGN PARAMETERS

CAPACITY: 3580 std ℓ/min (125 SCFM)

TEMPERATURE: 0-150^{0}C

PRESSURE: ~0.95 atm

TYPE: CUSTOM FILTER ASSEMBLY

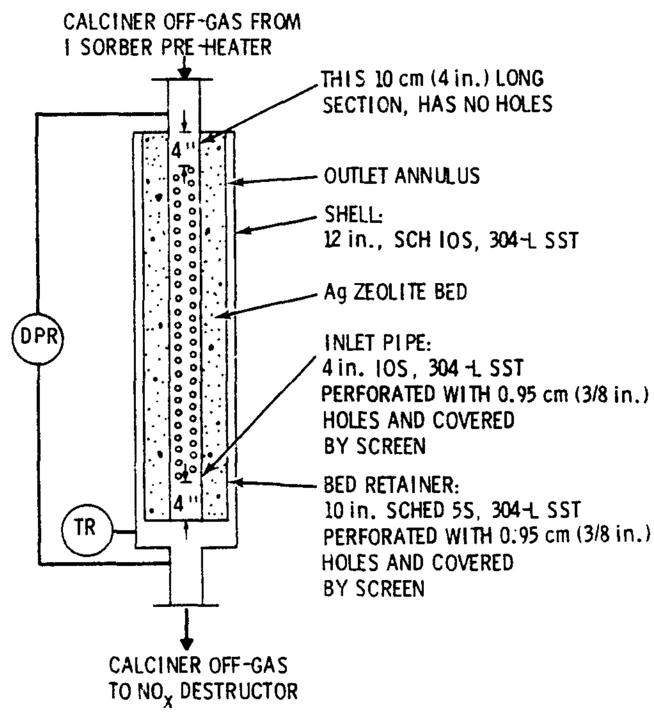
MATERIALS: FILTER CASE: 304-L SS AND FLANGES

GASKETS: ASBESTOS OR SILICONE

FILTERS: STANDARD HEPA AND PRE FILTERS WITH FIRE RESISTENT CASE

DIMENSIONS: ~35 cm x 35 cm x 1.5 m (~14 in. x 14 in. x 60 in.)

FIGURE 19. Pre- and HEPA Off-Gas Filters



OPERATING CONDITIONS

CAPACITY: 1375 std ℓ/min (48 SCFM) OF FILTERED OFF-GAS (TABLE 1, (9) FILTERED OFF-GAS)

TEMPERATURE: 130°C

PRESSURE: ~0.95 atm

DESIGN PARAMETERS

CAPACITY: 2070 std ℓ/min (73 SCFM) OF FILTERED OFF-GAS (TABLE 1, (9) FILTERED OFF-GAS

TEMPERATURE: 0-200°C

PRESSURE: 0.5-1.5 atm

TYPE: CUSTOM ANNULAR SORBER BED

MATERIALS: VESSEL: 304-L SS

BED: 12-14 MESH SILVER ZEOLITE GRANULES

VESSEL: CONCENTRIC ANNULI CONSTRUCTION

SIZE: 32 cm Φ x 1.5 m (12-3/4 in. Φ x 5 ft)

END PLATES: 0.64 cm (0.25 in.) (BED AND VESSEL)

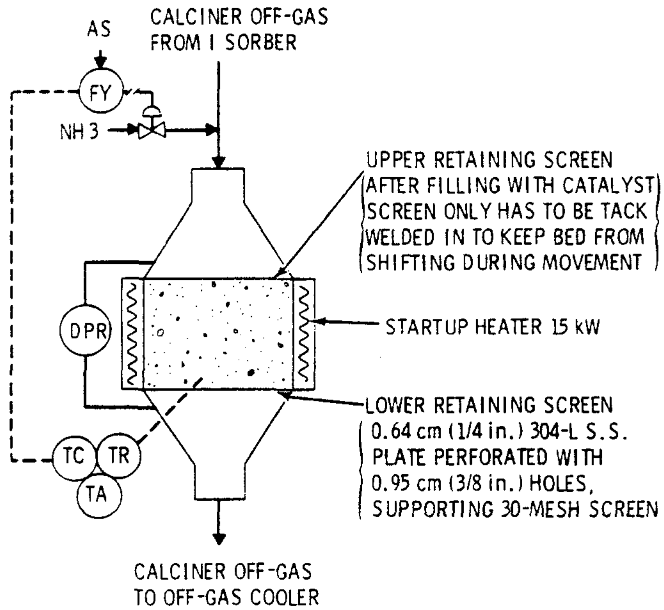
SCREEN: HEAVY, 30 MESH

BED: LINDE 13X ZEOLITE IN AG FORM

ANNULUS BED DIMENSIONS

ID = 11.4 cm (4.5 in.)
OD = 26.5 cm (10.4 in.)
DEPTH = 1.36 m (4.5 ft)
MESH = 12-14

FIGURE 20. Iodine Sorber



OPERATING CONDITIONS

SEE TABLE 1, MATERIAL BALANCE

DESIGN PARAMETERS

OPERATING PARAMETERS: SEE TABLE 1

TYPE: CUSTOM DESIGN CYLINDRICAL BED REACTOR

MATERIAL: VESSEL: 304-L SS, 0.64 cm (1/4 in.) THICK

BED: 0.16 cm (1/16 in.) ZEOLON 900 EXTRUDATE PELLETS

VESSEL: CYLINDRICAL WITH TAPER CONE ENDS

SIZE: 0.3 mΦ x 0.91 m (12 in. Φ x 3 ft)

BED: 0.16 cm (1.16 in.) EXTRUDATE ZEOLON 900

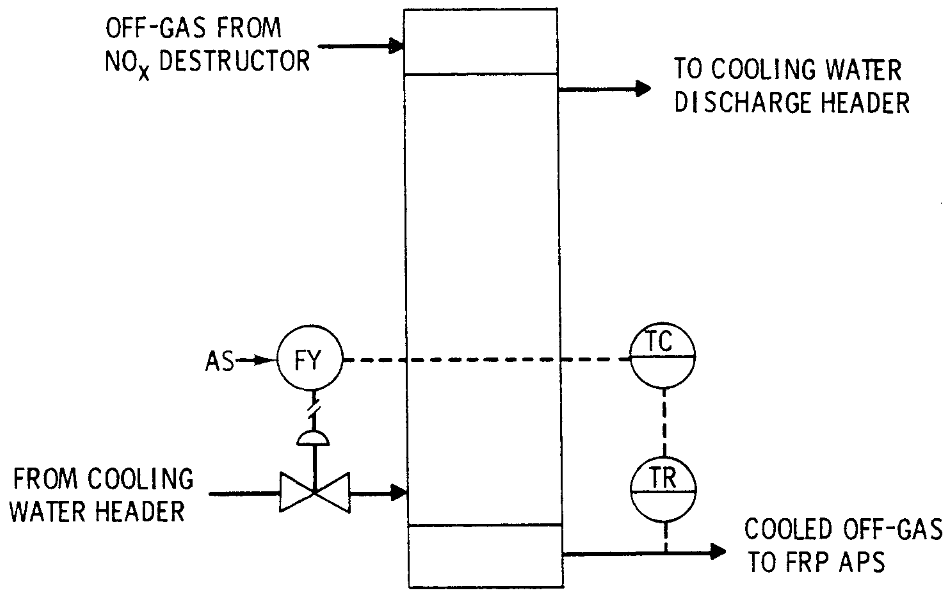
SIZE: 20 cm (8 in.) DEEP
30 cm (12 in.) DIAMETER

HEATER: 15 kW RESISTANCE HEATER USED FOR STARTUP

INSULATED OUTSIDE OF ELEMENTS

HEATER COVERED WITH 304-L SHELL

FIGURE 21. NO_x Destructor



OPERATING CONDITIONS

CAPACITY: ~100,000 g-moles OF GAS (TABLE 2, 12. OFF-GAS TO FRP) PER DAY AT ~500°C IS COOLED TO ~55°F

TEMPERATURE (OFF-GAS): SEE ABOVE

PRESSURE: ~0.95 atm

DESIGN PARAMETERS

CAPACITY: FROM 0-200,000 g-moles OF GAS (TABLE 2, 12. OFF-GAS TO FRP) PER DAY AT ~500°C IS COOLED TO ~55°C

TYPE: SHELL-TUBE
SINGLE PASS
BAFFLED
FLOATING HEAD
AIR ON TUBE SIDE
WATER ON SHELL SIDE

HEAT TRANSFER AREA: ~11 m^2 (~120 ft^2)

HEAD LOAD: ~21 kW (~72,000 btu/hr)

MATERIAL: 304-L STAINLESS STEEL

FIGURE 22. Off-Gas Cooler

filters, the contamination of the equipment located out of the WVC will be less than that of equipment pieces located further upstream.

Much additional nonprocess equipment will be required to operate the waste vitrification process, including:

- Remote-operated bridge crane
  Number: 1
  Capacity: 7.5 Tons
  Number of Remote Operating Stations: 4

- Master-Slave Manipulators
  Number: Up to 3 pair
  Model: To be determined, but will be heavy duty, able to lift up to 23 kg (50 lb), and to perform limited maintenance operations

- Periscopes
  Number: Up to 3
  Model: To be determined

- Prepackaged Helium Sources
  Number: 1 per canister
  Type: Steel sponge filled with liquid helium

- Helium Source Wall Pass-Through Mechanism
  Number: 1
  Type: To be designed.

UTILITIES, MATERIALS AND WASTES

Utilities required to operate the NWVF, the design load, and the average consumption rate are indicated in Table 9. Only utilities used in the NWVF and provided from the FRP are shown in Table 9. Any emergency utilities required, such as electricity and cooling water, will be supplied from the FRP emergency services.

Essential materials used in NWVF operations and their average consumption rates are also shown in Table 9. Maintenance and replacement materials are not shown. Only chemicals used for periodic facility decontamination and cleanup are included in Table 9.

TABLE 9. Nuclear Waste Vitrification Facility Utilities and Essential Material Requirements

Utility	Required Capacity	Average Use Rate	Disposition
Electricity, kW			
Calciner	240	140	--
Melter: No. 1	120	30	--
No. 2	120	30	--
HVAC (Cell) Blowers and Air Conditioning	150	100	--
Welder	25	1	--
Vessel Vent and Melter Cooler Blowers	60	50	--
Lights	100	80	--
Motors	50	30	--
Vessel Vent O.G. Heaters (total of two)	6	5	--
Instrumentation	50	30	--
Miscellaneous	100	70	--
Total	1021	566	--
Water, liter/min			
Raw (Cooling Water ΔT = 15°F)			
Calciner Feed Tank	240	60	Recycle or Environment
Canister Storage Rack	280	40	Recycle or Environment
Welding and Inspection Stations	200	20	Recycle or Environment
Calciner Off-Gas Condenser	44	28	Recycle or Environment
Calciner Condensate Tank	240	80	Recycle or Environment
NO_x Destructor Off-Gas Cooler	48	32	Recycle or Environment
Welder	<4	Negligible	Recycle or Environment
Miscellaneous	200	60	Recycle or Environment
Total	1256	400	
Process			
Canister Decontamination	(a)	(a)	HLLW
Cold Process Solutions	(a)	(a)	HLLW
Equipment Flushes	(a)	(a)	HLLW or ILLW
Cell Decontamination	(a)	(a)	HLLW or ILLW
Ru Scrub Solutions	(a)	(a)	HLLW
Seal Pot Solutions	(a)	(a)	HLLW
Miscellaneous	(a)	(a)	HLLW or ILLW
Total	400	10	
Sanitary			
Fountains and Sinks	(a)	(a)	Sanitary Sewer-Tile Field
Lavatory and Shower	(a)	(a)	Sanitary Sewer-Tile Field
Cleaning	(a)	(a)	Chemical Sewer-Tile Field
Miscellaneous	(a)	(a)	Sanitary or Chemical Sewer-Tile Field
Total	20	12	
Air, SCMM			
Instrument: General	0.3	0.15	As Appropriate
Atomizing	1.0	0.6	Calciner Off-Gas
Melter Cooling (two 700 SCFM Blowers)	39.7	14.0	Cell → APS
Cell Ventilation	225.0	225.0	Treatment → APS
Process and Vessel Ventilation	0	0	APS
Facility Ventilation: Operating Areas	~150.0	~100.0	Atmosphere
Warm Areas	~300.0	~200.0	APS
Total	716.0	539.75	
Steam, kg/min			
Facility Heating	0.5	0.35	Recycle
Decontamination Solution Heating	10.0	1.0	HLLW or ILLW
Transfer Jets	6.0	Negligible	HLLW
Total	16.5	1.35	

Essential Materials Requirements[b]

Frit	820 kg/day
Canisters	2.2 canisters/day
Caustic HC (19 M)	8,000 liter/yr
Nitric Acid HC (12.2 M)	12,000 liter/yr
Helium Sources	2.5 sources/day
Argon	4250-5660 liter/day
Detergent (Example: Tide)	225 kg/yr
Ammonia	120,000 kg/yr

(a) No breakdown

(b) Excludes maintenance materials and apparel

There are a variety of wastes generated from NWVF operation, maintenance, and shutdown activities. The waste types and their dispositions, characteristics, and average generation rates are estimated in Table 10. Particulates contained in gaseous effluents are assumed to be calcine. The physical properties of the calcine particulates are shown in Figure 23.

The estimates in Tables 9 and 10 are based on engineering calculations and operations of similar facilities.

The facility will handle toxic materials and/or materials that present other (chemical or radioactive) hazards. These materials are identified in Tables 9 and 10 by a superscript "H". If chemical, a "C" follows the "H"; if radioactive, an "R" follows the "H"; and if both, a "CR" follows the "H".

TABLE 10. Nuclear Waste Vitrification Facility Waste Generation

	M³/yr	Activity Ci/yr, Type	Disposal Method	Characterization
RADIOACTIVE[HR]				
Liquids				
Canister Decontamination		, MFP[(a)]	HLLW	Water
Cell & Equipment Decontamination		, MFP	HLLW & ILLW	Water, HNO_3, NaOH, Detergent, Complexant
Calciner Off-Gas Condensate	3E3	1E5, MFP	HLLW	Table 1, (2) Calciner Condensate
Ru Scrubber Regeneration Solution		, Ru[(b)]	HLLW	Hot Water or 0.1 M HNO_3
Miscellaneous		, MFP	HLLW & ILLW	Water, HNO_3, NaOH
Gases				
Process Off-Gas	1E5	3, MFP	APS	Table 1, (12) Off-Gas to FRP (Includes process upsets)
Vessel Ventilation	2E5	1, MFP	APS	Air with small amounts of NO_x and HNO_3
Cell Ventilation	1.2E8	2, MFP	APS	Air with trace particulates, NO_x and HNO_3
Solids				
Failed Equipment	50	2E4, MFP	Burial	Mostly stainless steel
Trash	100	500, MFP	Burial	Paper, plastics, cloth, metal, glass and chemicals
NONRADIOACTIVE				
Liquids				
Processing Cooling Water	2.1E5	Negligible	Environment or Recycle	Warm Water
Cleaning Solutions and Chemical Wastes (Chemical Sewer)	1E3	Negligible	Tile Field	Water with detergent, HNO_3, NaOH or Complexant
Sanitary Wastes (Sanitary Sewer)	6.5E3	Negligible	Tile Field	Showers, Toilets, Wash Basins, Drinking, etc.
Gases				
Operating Area Ventilation Air	~8E7	Negligible	Environment	Warm Air, ≤80°F
Warm Area Ventilation Air	~1.6E8	Negligible	APS	Warm Air, ≤80°F
Solids				
Failed Equipment	20	Negligible	Sanitary Landfill	Mostly stainless and mild steel
Trash	1000	Negligible	Sanitary Landfill	Paper, plastics, cloth, metal, glass and chemicals

HEAT RELEASES	kW, Average
Ventilation Air Systems	300
Cooling Water	230
Miscellaneous (includes Building Losses)	70
Total	~600

(a) MFP = Mixed Fission Products
(b) Ru = Ruthenium
(c) APS = Atmospheric Protection System

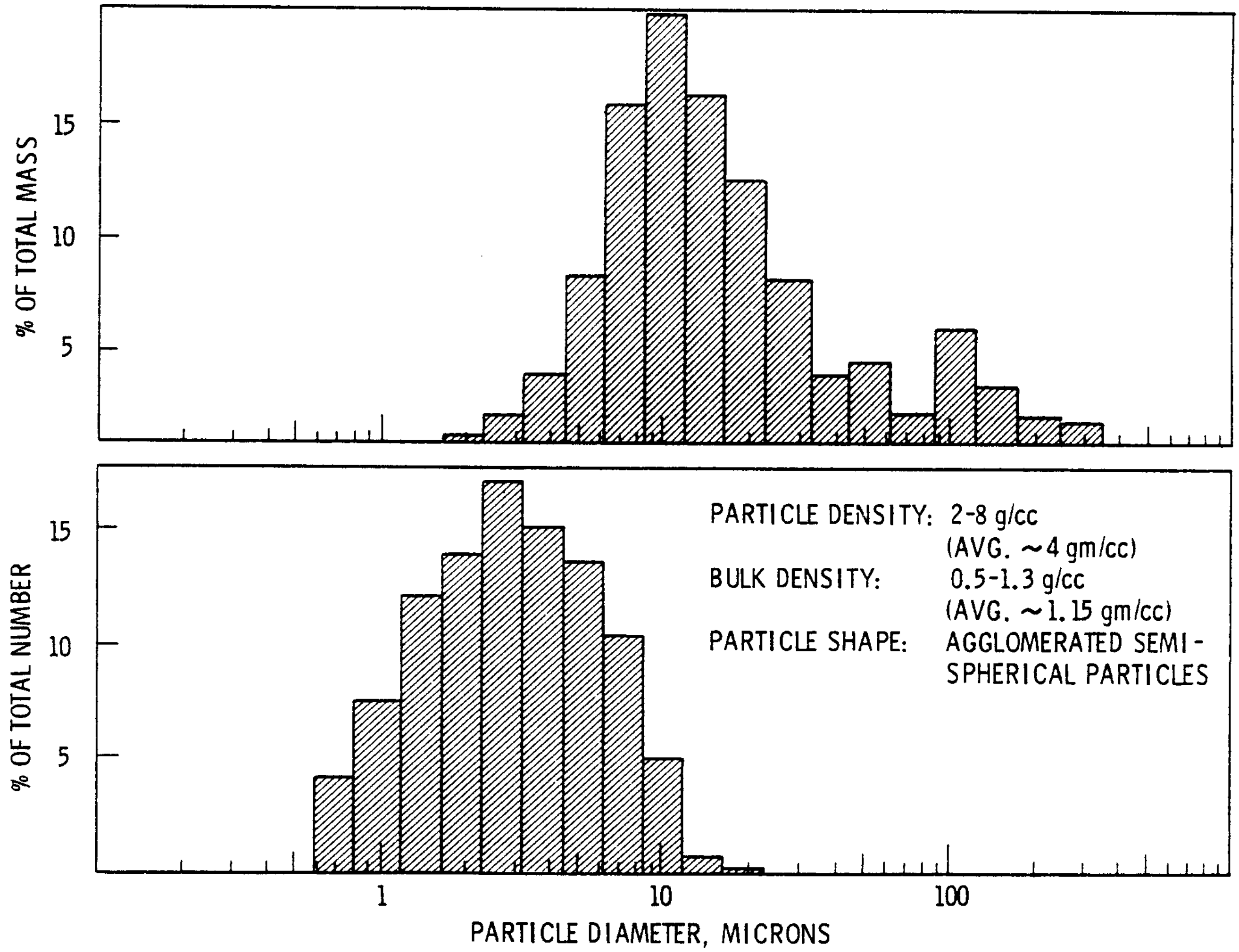


FIGURE 23. Spray Calcine Properties

SITING

The nuclear waste vitrification facility will be constructed as an integral part of a nuclear FRP. Economy and efficiency of integration with other plant operations will determine the location of the NWVF within the plant. Thus, it will have to conform to criteria for the FRP siting. Since the NWVF does not possess unique characteristics as related to the FRP, it will not require additional siting criteria.

The amount of land necessary for dedication to the NWVF will be negligible compared to the amount of land required for the FRP. The vitrification facility, including the waste operating area and other service areas, will occupy a ground space of roughly 460 m^2 (5000 ft^2).

OPERATIONS

The routine operating sequence will be performed in the facility as outlined below:

- Move up to three empty canisters with lids, into the CDC on a dolly, and then shut the cubicle door to the aisle or tunnel.
- Remove the cubicle cover block and move the canisters with the crane to empty the canister storage rack positions with the crane. Replace the cover block.
- Remove the lid from the canister with the crane hook or manipulator, as the design requires.
- Pick up the melter top with the crane, then raise the empty canister with the melter top yoke and place it in the melter.
- Move the melter with the empty canister into position under the calciner with the melter umbilical pipe.
- Connect the melter to the calciner using electro-pneumatic devices.
- Heat the canister to the melting temperature.
- When the canister in the companion melter is filled, move the calciner diverter valve to fill the heated canister.
- As the melt level rises in the canister, discontinue heating and start cooling below the melt level to prevent excessive system temperatures.
- When the canister is full, allow it to sit at operating temperature for several hours to allow final glass melting and out-gassing.
- Disconnect the canister, and move it from under the calciner.
- Place a prepared helium source in the canister with manipulator (or the source may be attached to the canister lid). Then place the lid on the canister using the crane or manipulator, as designed.
- Move the canister to the WIS.
- Place canister in position under the remote welding head and seal weld.

- Move the canister into position under the remote helium leak test head and check the canister seal weld for leaks.
- Move the filled canister with the crane to a full-canister position in the CSR where it is maintained at a desirable temperature.
- As appropriate, move the filled canisters by crane through the hatch onto the dolly in the CDC and replace the hatch cover.
- Decontaminate the full canister or canisters in the dolly with medium pressure steam or decontamination solution passed through spray nozzles mounted on the cubicle walls.
- After allowing the canister to dry, move it by dolly through the door for transfer to interim storage in the FRP.

There are also other periodic operations that will be performed. These include:

- removing calciner condensate from the calciner condensate tank (CCT) to the HLLW concentrator feed tank,
- changing decontamination solution in the DST and routing the expended solution to the HLLW concentrator feed tank,
- jetting the sump solutions to a waste collection tank for sampling,
- regenerating the ruthenium sorber with dilute nitric acid or hot water and routing strip solution to the HLLW concentrator feed tank,
- flushing equipment for decontamination and routing the decontamination solution to the HLLW concentrator feed tank,
- repairing occasional seal weld leaks or overpacking a breached canister, and
- flushing a calciner seal pot to the HLLW concentrator feed tank and filling it with water.

Other NWVF operations are described in the "Process Description" or are maintenance activities.

The staffing requirements to operate this facility are shown in Table 11. This table shows full-time operating personnel and indicates the

TABLE 11. Allocated Facility Staffing Requirements[a]

Job Description	Number of Staff
Operations	
Process Operators	11
Radiation Monitors	1
Supervisors	1
Managers	0.25
Others	4
Maintenance and Services (Plant Forces)	
Craft Workers	5
Planners and Supervisors	1
Managers	0.25
Others	4
Technical	
Process Engineers	1
Facility Engineers	1
Safety	1
Technicians	3
Managers	0.5
Others (Including Analytical)	4
Administrative	
Others	4
	42.0

Totals:	Nonexempt	31
	Exempt	7
	Supervisors	3
	Managers	1
		42

(a) Assume NWVF is integrated with other FRP operations.

equivalent personnel that would spend part of their time associated with the facility. Except for an instrument technician, a pipefitter, a millwright, and a welder, who would be on shift to perform minor equipment upkeep duties, maintenance personnel are excluded from the table.

As indicated previously, the NWVF will be incorporated into the reprocessing plant structure. It is not anticipated that it will add any noticeable incremental noise, visual presence, or other undesirable features to the site or local population. A very small amount of NO_x and NH_3 will be added to the FRP stack air. It is not anticipated that the local population will notice these incremental gases.

MAINTENANCE

The vitrification equipment is designed for total remote operation with minimum aid of master-slave or electro-mechanical manipulators. Supporting equipment that requires contact maintenance, such as the frit feeder, welder and the mass spectrometer, will be located out-of-cell. Appropriate air locks, anti-backflow devices, and block valves will be provided between the in-cell and out-of-cell equipment to ensure safe operation.

To keep personnel exposure low, all major in-cell equipment pieces are designed for remote replacement. In addition, components that may wear out or fail can be remotely replaced without removing the major equipment. Lifting lugs on the equipment will facilitate remote handling with the in-cell crane. Alignment dowels and fixed mounting trunions will be used to ensure exact positioning of equipment and components. For the most part only the in-cell crane and an impact wrench will be required for remote maintenance, although master-slave manipulators will be provided at locations where they could be required. Hanford-type piping and electrical connectors will be used for most service and process connections. Hanford-type remote tank flanges will also be used to install pumps, agitators, and filter assemblies. Vee flanges and other quick connective devices will be used where Hanford-type connections are not appropriate. Certain high-maintenance items will be located in shielded wall niches. These items include the spray calciner filter blowback valves and frit feeder air lock valves which, although normally nonradioactive, could become contaminated. Contact maintenance will also be employed on all out-of-cell supporting equipment.

Equipment will be moved into or out of the cell through the shielding doors to the hot maintenance area (HMA). When the door is open, air will flow from the HMA into the cell at a rate that minimizes the escape of radioactivity from the cell. Equipment will be internally and externally decontaminated prior to removal from the cell. The equipment may be maintained in the HMA, if desired and the radiation level is sufficiently low, or the equipment may be placed in a shielded container for storage. The crane will also be maintained in the HMA. Should the crane become immobilized in the cell a small remote service crane or another crane on the same rail may be used to retrieve it.

Special precautions will be observed in removing and replacing equipment which penetrates the cell wall, such as the shielding windows, melter umbilical pipe, manipulators, and periscope. Special procedures will be required to ensure minimal exposure to maintenance personnel and to prevent the spread of radioactive contamination to cold or warm areas.

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