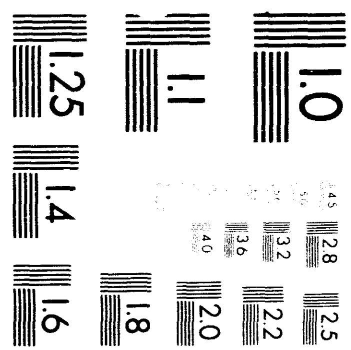
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DOE/NE/44139-67

# The Integrated Melter Off-Gas Treatment Systems at the West Valley Demonstration Project

Topical Report

By
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# ABSTRACT

The West Valley Demonstration Project was established by an act of Congress in 1980 to solidify the high level radioactive liquid wastes produced from operation of the Western New York Nuclear Services Center from 1966 to 1972. The waste will be solidified as borosilicate glass. This report describes the functions, the controlling design criteria, and the resulting design of the melter off-gas treatment systems.

## ACKNOWLEDGMENTS

The design of the melter off-gas treatment systems is the result of coordinated collective efforts of innumerable people from many and varied organizations. Within West Valley Nuclear Services, the Vitrification Design Engineering group and the Vitrification Test group were certainly instrumental. Major contributions were also made by subcontracted organizations including Battelle Pacific Northwest Laboratory of Richland, Washington; Ebasco Services Incorporated of New York, New York; Specialty Maintenance and Consultants of Lakeland, Florida; and Hunter Engineering-Architectural Services of Merritt Island, Florida.

Ron Shelson, Project Manager for Specialty Maintenance and Consultants, deserves special recognition. Ron coordinated finalization of the mechanical aspects of the designs for the equipment destined to be installed for remote operation inside the vitrification cell. This equipment was then fabricated under his supervision. He assured that the products manufactured under his direction were what his customer really needed. His work reflected a standard of personal integrity and professional excellence to which we should all strive, which few of us will ever be able to match, and which none of us can be expected to exceed. All of us who work at the West Valley Demonstration Project, and who live in western New York, are indebted to Ron for his relentless attention to detail.

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# 1.0 INTRODUCTION

The primary objective of the West Valley Demonstration Project (WVDP), located at the former nuclear fuel reprocessing plant at West Valley, New York, is to solidify the high-level radioactive waste stored in underground tanks into a form suitable for transportation and disposal. Vitrification has been chosen as the method of solidification. The purpose of this report is to describe briefly the systems used to treat the vitrification system off-gases for the purpose of protecting the environment.

## 1.1 Site History

The West Valley Nuclear Fuel Reprocessing Plant near Buffalo, New York, was constructed by W.R. Grace Company in 1966 and was operated by the Nuclear Fuel Services Company. During 1972, fuel processing operations at the plant were suspended for the purpose of making modifications to increase capacity. Changing government regulations, and economic considerations led to the decision to close the plant permanently. By that time, 640 Mg (700 tons) of spent nuclear fuel had been reprocessed.

As a result of reprocessing operations, about 2,100 $m^3$ (560,000 gal) of high level liquid Purex process waste was produced. This waste was neutralized with sodium hydroxide and stored in an underground carbon steel tank. A sludge layer of insoluble hydroxides, mostly ferric hydroxide, precipitated to the bottom of the tank, leaving a relatively clear liquid supernatant above the sludge. The primary radioactive isotope that remained in the supernatant was $^{137}Cs$. The other radioactive isotopes, mostly $^{90}Sr$, became part of the sludge. The supernatant contains about 590 PBq ($16 \times 10^6$ Ci) of activity, and the sludge contains an additional 590 PBq ($16 \times 10^6$ Ci).

From a special reprocessing campaign for fuel containing thorium, about 30 $m^3$ (8,000 gal) of acidic Thorex process waste was produced. This waste was stored in an underground stainless steel tank, and contains about 70 PBq ($2 \times 10^6$ Ci) of activity.

## 1.2 Project Background

In 1980, the United States Congress passed the West Valley Demonstration Act authorizing the United States Department of Energy (DOE) to conduct a nuclear waste management project at West Valley.

The DOE contracted with West Valley Nuclear Services Company, a subsidiary of Westinghouse Electric Corporation, to operate the WVDP. In 1983 the DOE selected borosilicate glass as the final high level waste form.

## 1.3 Pretreatment of the High Level Wastes

The high level wastes (HLW)) are pretreated bý the integrated radioactive waste treatment systems. These systems include the Supernatant Treatment System which separates non-radioactive ions from the high level wastes, the Liquid Waste Treatment System which concentrates the low level by-product solutions, and the Cement Solidification System which solidifies the concentrated solutions into drums of concrete. The drums of low level waste are temporarily stored in an above ground, concrete shielded, drum cell. Following pretreatment, the high level wastes will be vitrified into borosilicate glass and stored in a concrete cell of the old reprocessing building, until a federal repository is available.

The Purex waste supernatant contained a large quantity of non-radioactive sodium, about 300 Mg (330 tons). A reduction in the total amount of sodium to 40 Mg (44 tons) will allow the radioactive wastes to be vitrified in about 490 Mg (540 tons) of glass, or about one sixth the amount that would otherwise have been required.

To remove the sodium from the high level wastes, the supernatant was decanted and sent to the Supernatant Treatment System. There it was passed through ion exchange columns containing zeolite resins. The resin columns were designed to retain at least 99.9% (DF=1000) of the $^{137}Cs$, while allowing the water and sodium to pass. The water, with the sodium, was directed to the Liquid Waste Treatment System.

The Purex waste sludge contained interstitial liquids, similar to the supernatant, and about 30 Mg (33 tons) of sulfate as precipitated sodium sulfate salt. A reduction in the total amount of sulfate to 600 kg (1,300 $lb_m$) will allow a homogeneous glass to be produced.

To remove the sodium sulfate, the sludge will be washed. This will require three or four cycles of washing, settling, decanting and treatment of the wash solution by the Supernatant Treatment System. The decontaminated wash solutions will also be directed to the Liquid Waste Treatment System.

## 1.4 Vitrification Process Description

The zeolite resins and the Thorex wastes will be combined with the washed sludge, will be thoroughly mixed, and will be transferred by batches to a concentrator. While a batch of waste is concentrated, a sample from that batch will be analyzed to determine the proper amounts of glass forming and oxidation control ingredients to be added. Glass formers include silica, sodium tetraborate, potassium hydroxide, lithium hydroxide, aluminum hydroxide, and titanium dioxide. The additive for controlling oxidizing conditions in the melter is sugar. Following concentration and application of the additives, the resulting slurry will be thoroughly mixed and transferred to the melter feed tank.

From the melter feed tank, the waste slurry will be transferred into the slurry fed ceramic melter. The melter is operated at a temperature of about 1150 °C (2100 °F) to produce molten glass. The molten glass is air-lifted from the melter to a waiting canister that is positioned on a turntable.

The canisters into which the glass is poured are stainless steel cylinders 600 mm (2 ft) in diameter and 3050 mm (10 ft) tall. In the canisters, the glass cools and hardens with the radioactive materials atomically bonded in the glass structure. The canisters are capped, decontaminated, and transferred for interim storage into one of the existing shielded cells in the old reprocessing plant. They will remain there until a federal repository has been established to accept them. Approximately 300 canisters of high level waste will be produced.

The gaseous effluent from the melter, mostly water vapor and oxides of nitrogen, are scrubbed in a submerged bed scrubber, processed through a high efficiency mist eliminator, and filtered before leaving the shielded vitrification cell. Before the off-gases are released to the environment, they are further filtered through High Efficiency Particulate Air (HEPA) filters, and the oxides of nitrogen ($NO_x$) are eliminated by selective catalytic destruction.

## 2.0 FUNCTIONS AND DESIGN CRITERIA

The overall project approach was to incorporate the following principles:

(1) Make maximum use of existing technology, facilities and equipment.

(2) Minimize complexity.

(3) Produce a system that was safe, environmentally sound and cost effective.

### 2.1 Functions

The Vitrification Facility functional requirements that applied to the melter off-gas treatment systems are as follows:

(1) Remove radioactive particulate matter, toxic gases, and vapor from the process gases for release to the environment.

(2) Provide process solution re-use and recycle features to minimize derivative waste disposal demands.

(3) Provide process system redundancy and/or readily achievable remote removal and replacement capability for planned maintenance.

(4) Provide monitoring and control systems and maintain release levels below current state and fedeal regulatory limits.

(5) Use existing WVDP utility and support systems as far as practical.

(6) Provide design features to maintain internal and external radiation exposures to operating and maintenance personnel ALARA, and in no case exceed allowable design guidelines. Provide the capability to control contamination during routine and emergency operating conditions and during all hands-on and remote maintenance activities.

(7) Maximize the use of low maintenance process equipment in radioactive areas, and provide remotely operated decontamination capabilities for equipment to the extent necessary to support required maintenance.

(8) Provide alarm systems, and all other plant safety features essential to proper and safe plant operation.

(9) Evaluate remote equipment and components used in the vitrification facility for their service lives. Service lives may be enhanced, if required, by increased quality and reliability for the equipment, redundancy of equipment, and/or remote replaceability.

(10) Provide an alternate power supply and utilities as backup for essential equipment and systems.

## 2.2 Design Criteria

The primary design criteria applied to the melter off-gas treatment systems, excerpted from the design criteria document controlling the entire vitrification facility, are presented in the following paragraphs.

### 2.2.1 Operational Criteria

The process off-gas system blowers will maintain a negative pressure on the major tankage and melter within the vitrification facility and throughout the upstream process train to assure any leaks are into the system. An installed back-up off-gas blower and an alternate power source shall be provided.

### 2.2.2 Maintenance Criteria

Systems and components in contaminatd areas shall be designed to be either remotely maintainable in place, or remotely removable and replaceable.

Spares shall be provided for critical components or components that have a high probability of failure during operation.

Connectors, bolts, flanges, wrenches, sockets shall be standardized to the maximum extent practical.

Equipment shall be movable, maintainable, and replaceable with minimum disturbance of adjacent equipment.

The vitrification facility systems and structures are to be designed to facilitate post solidification decontamination.

### 2.2.3 Structural Criteria

Structures and components that are required to confine radioactive material shall be able to withstand the effects of natural hazards without loss of capability to perform safety function(s) or prevent the release of radioactivity and shall be designed to the "Operational Safety Design Criteria Manual," (ID-12044).

New confinement structures shall be designed to an acceleration of 0.1 g at ground level (horizontal loads).

The equipment shall be designed for a service life of seven years.

### 2.2.4 Safety Criteria

The principle of "As Low As Reasonably Achievable" (ALARA) shall apply to all aspects of radiation exposure. On-site personnel exposure levels less than one-fifth of the DOE Order 5480.11 dose equivalent limits should be used as a design objective.

The maximum radiation dose rate for a full-time access area shall be 2.5/t mRem/hr in which "t" is the maximum average time in hours per day that the area is expected to be occupied by any one individual. A full-time access area is one in which no physical or administrative control of entry exists.

### 2.2.5 Environmental Criteria

Gaseous releases shall be subject to applicable Environmental Protection Agency (EPA), New York State Department of Environmental Conservation (NYSDEC), and DOE regulations, Orders, and directives. These regulations shall include, but not be limited to, 40 CFR 61, 6 NYCRR Series 200, and DOE Order 5480.1A.

Where possible, radioactive liquid waste will be recycled

within the vitrification facility.

### 2.2.6 Quality Assurance

The Quality Assurance program will be based on ANSI/ASME NQA-1, and all supplements.

### 2.2.7 Decommissioning

The vitrification facility design shall incorporate features that facilitate future decommissioning of the facility.

### 2.2.8 Codes and Standards

**Commerical Codes and Standards**

| | |
|---|---|
| ANSI A58.1 | Minimum Design Loads for Buildings and Other Structures; NRC Adopted |
| ANSI/ASME-NQA-1 | Quality Assurance Program Requirements for Nuclear Facilities |
| ANSI B16.5 | Steel Pipe Flanges and Flanged Fittings |
| ANSI B31.3 | Chemical Plant and Petroleum Refinery Piping |
| ANSI N300 | Design Criteria for Decommissioning of Nuclear Fuel Reprocessing Plants |
| ANSI 509 | Nuclear Power Plant Air Cleaning Units and Components |
| ANSI 510 | Testing of Nuclear Air Treatment Systems |
| ASME B/PV Code, Pressure Vessels, Section VIII | |
| NFPA-70 | National Electric Code (NEC) |
| ISA Standard | Standards and Practices for Instrumentation |
| NFPA 101 | Life Safety Code |
| UL 586 | High Efficiency Particulate Air Filter Units |

**U.S. Department of Energy Documents**

| | |
|---|---|
| DOE ORDER 5480.A1 Chapter 1 | Environmental Protection, Safety and Health Protection Standards |
| DOE ORDER 6430.1A | General Design Criteria |

(This document was issued after the system design was completed. The design was checked to assure the intent of this document was met.)

| | |
|---|---|
| DOE-ID-12044 | Operational Safety Design Criteria Manual |

**Federal and State Standards**

| | |
|---|---|
| 40 CFR 61 | National Emmission Standards for Hazardous Air Pollutants |
| MIL-F-51068E | Military Specification, "Filter- Particulate, High-Efficiency, Fire Resistant" |
| MIL-F-51079C | Military Specification, "Filter Medium, Fire-Resistant High Efficiency" |
| 6 NYCRR 200 Series | Air Discharge |

# 3.0 PROCESS DESCRIPTIONS

The integrated melter off-gas treatment systems are depicted in Figure 1. The ALARA portion is located inside the vitrification facility cell and is identified as the In-Cell Off-Gas System. The atmospheric protection portion is located in the trench and in the 01-14 building and is identified as the Out-of-Cell Off-Gas system.

## 3.1 ALARA Process

The ALARA melter off-gas treatment system, and associated vessel ventilation system, are depicted in Figures 2 and 3, and include all vessels, piping, valves, and associated equipment required to collect, treat, and transfer process gases and vapors from the melter and other in-cell equipment to the atmospheric protection off-gas treatment system.

### 3.1.1 Vessel Ventilation

Ventilation gases and vapors from the concentrator, the vitrification cell sample station, the feed hold tank, the canister turntable, canister decontamination station, and the vitrification cell waste header, are continuously collected into the vessel ventilation header. In the event that vacuum is lost in the melter, melter gases and vapors are also directed into the vessel vent header to re-establish the vacuum. The gases and vapors from the vessel vent header are directed into the shell side of the condenser. Closed loop cooling water is directed into the tubes, counterflow with the gases and vapors in the shell. The condensate from the condenser flows by gravity through a calibrated weir, and a liquid seal, to a header which directs the liquid to the tank farm (Tank 8D-3) for subsequent processing. Gases and uncondensed vapors are directed into the in-cell melter off-gas treatment system.

### 3.1.2 Quenching/Scrubbing

The submerged bed scrubber is designed for the first stage scrubbing of melter off-gases, cooling and condensation of melter vapor emissions, and interim storage of condensed fluids.

The scrubber is a passive device that uses water to remove particulate and to quench the off-gases. It functions by bubbling the off-gases through the water in a bed packed with ceramic spheres. The rising bubbles of off-gas cause the liquid to circulate up through the packing. This simultaneously causes downward flow in the annular space outside the packed bed as liquid from the annular space replaces the liquid that which is rising through the bed. The packing breaks larger bubbles into smaller ones to increase the gas to water contacting surface, thereby increasing the particulate removal and heat transfer efficiencies. The liquid circulation helps to prevent a buildup of captured material in the bed by constantly washing the materal away. As the off-gases cool, water vapor condenses and increases the liquid water inventory. The excess water spills into the receiver, thereby maintaining a constant liquid depth in the scrubber. Heat absorbed by the water from the off-gases is removed by the cooling coils as the water flows downward in the annular space.

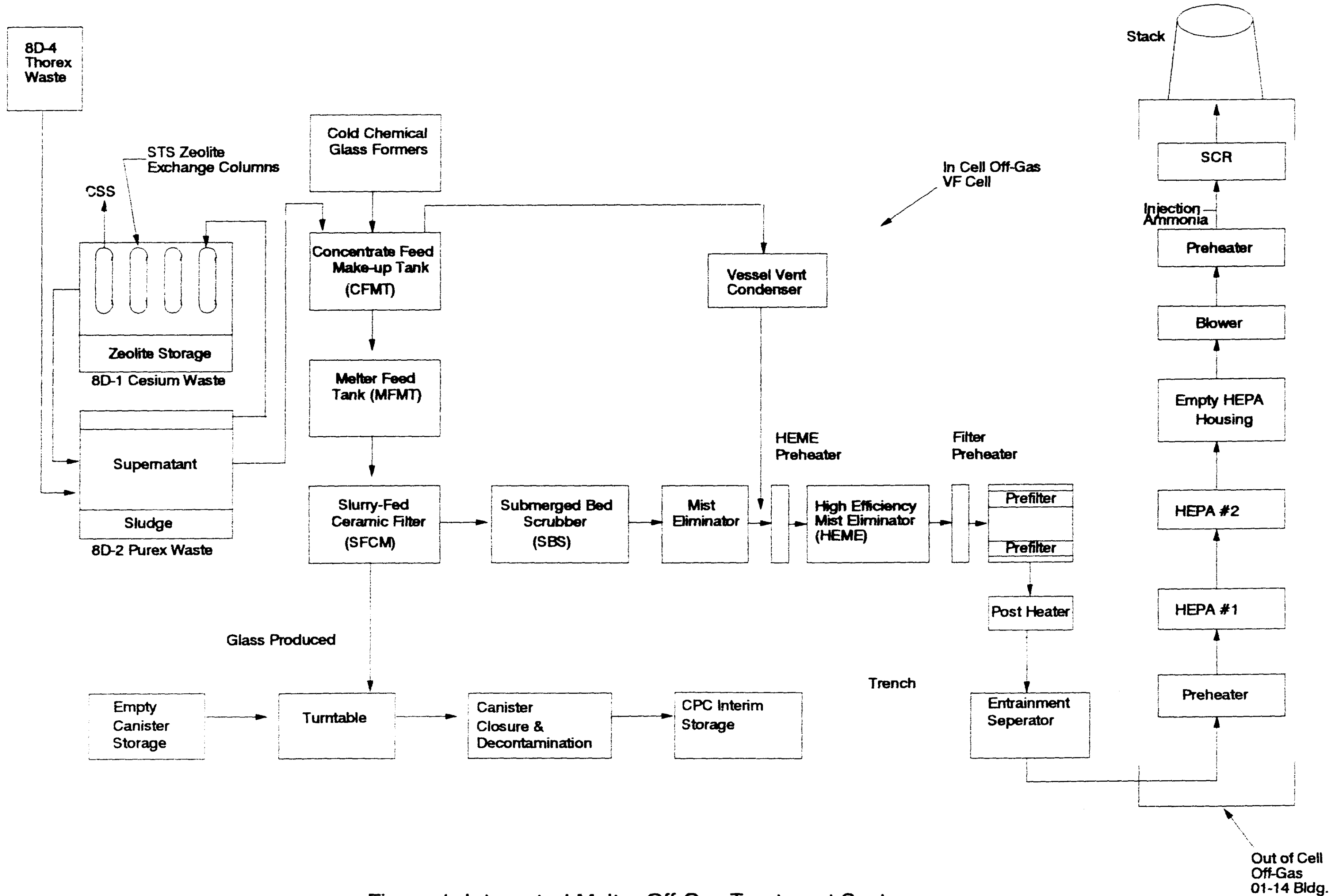


Figure 1: Integrated Melter Off-Gas Treatment Systems

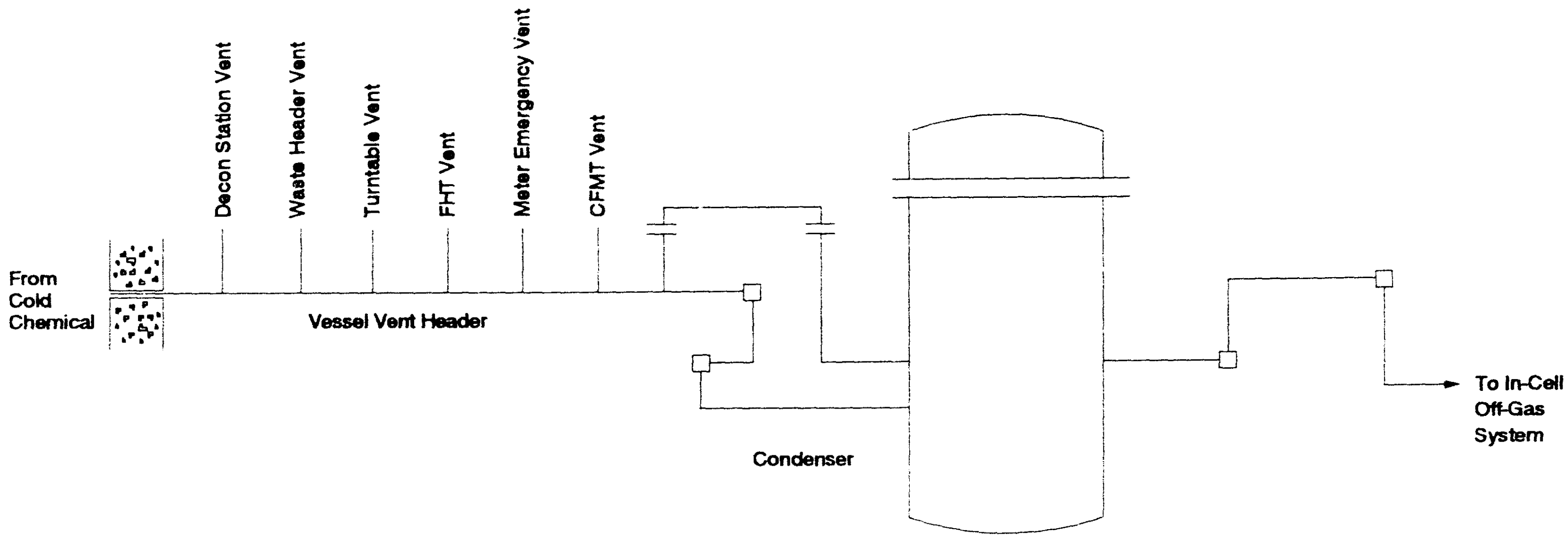


Figure 2: Vessel Ventilation System

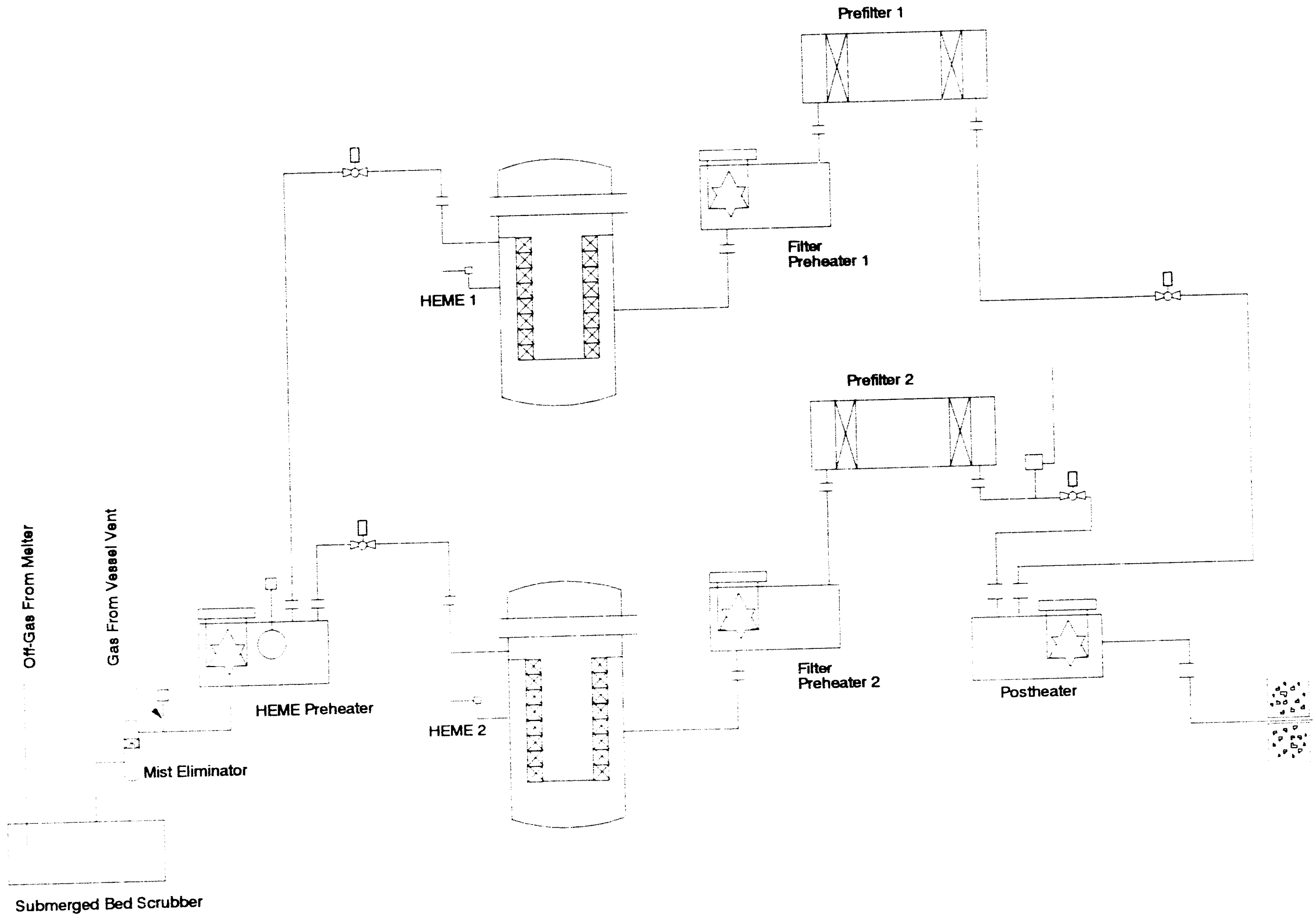


Figure 3: ALARA Off-Gas Treatment System

The mist eliminator consists of a mesh pad in a housing mounted directly on the submerged bed scrubber off-gas exit nozzle flange, plus a jumper that provides demineralized spray water to flush the pad, and pressure differential measurement across the pad during operation.

Off-gases enter from below the pad and exit from above. The mist eliminator pad collects entrained droplets by impaction against the pad fibers where they adhere and coalesce. The coalesced liquid flows by gravity back into the submerged bed scrubber.

### 3.1.3 High Efficiency Mist Elimination

Should the operations organization decide to employ the high efficiency mist eliminator as a dry filter, the 480 V electric preheater would be used to elevate the temperature of the off-gases above their dew point. The reference use for the high efficiency mist eliminator is mist elimination, and this preheating option is not expected to be employed when treating radioactively contaminated off-gases.

Impact wrench operated isolation valves in the jumpers to the high efficiency mist eliminators are used to select which of the two installed parallel off-gas trains (high efficiency mist eliminator, filter preheater and prefilter) are used.

The high efficiency mist eliminator receives off-gases from the preheater. It collects and coalesces entrained liquid droplets, and is 99.8 weight percent efficient for droplets 3 microns in diameter and larger. Simultaneously it removes submicron particulate from the gases.

Off-gases enter the center of the cylindrical pad from the top and pass through the pad to the outside. Because the pad is so large, the velocity of the gas through the pad is slow. Due to Brownian movement, droplets and particles contact the fibers of the pad where they collect and coalesce. Collected particulate is carried to the high efficiency mist eliminator drain lines either by the gravity flow of the coalesced liquids, or by demineralized water spray.

The high efficiency mist eliminator vessel has a drain line which directs coalesced liquids, and spray water, to the submerged bed scrubber.

### 3.1.4 Prefiltration

The filter preheaters operate by the same principles described for the high efficiency mist eliminator preheater.

The filter preheaters are used to elevate the temperature of the off-gases above the dew point to assure that no condensation occurs on the prefilter elements downstream.

The prefilter assemblies capture dry particulate to retain radioactive contamination inside the vitrification cell. This prevents significant contamination from reaching off-gas treatment equipment located downstream, outside the vitrification cell, thereby allowing hands-on maintenance there.

### 3.1.5 Heating

The off-gases from the parallel off-gas trains are directed through jumpers, with impact wrench operated isolation valves, to a common electric "postheater."

> **NOTE**
> The original purpose of the postheater was to elevate the temperature of the off-gases above the dew point sufficiently to assure that no condensation occurred in the duct from the vitrification cell to the 01-14 Building. Insulation, an entrainment separator, and reheaters installed to protect the HEPA filters rendered the "postheater" redundant.

## 3.2 Atmospheric Protection Process

The Atmospheric Protection Off-Gas Treatment System is depicted in Figure 4, and includes all vessels, piping, valves, and associated equipment required to collect, treat, and transfer process gases from the vitrification cell to the base of the plant stack.

### 3.2.1 HEPA Filtration

The off-gases from the vitrification cell are directed through an insulated duct to the atmospheric protection off-gas treatment equipment. The insulation is intended to protect the HEPA filter elements by mitigating condensate formation between the vitrification cell and the final HEPA filters. Immediately upstream from the HEPA filters the off-gases are processed through an entrainment separator, and one of two redundant electric reheaters connected in parallel, which restore the off-gases to above the dew point.

The off-gases then pass through the HEPA filters. In each of two parallel filter trains are two HEPA filter elements arranged in series. The gases pass through one filter train while the other remains available as an installed back-up. The purpose of the HEPA filters is to provide final atmospheric protection against dispersion of radioactive particulate. The integrity of the filter elements, and the seals between the elements and the housing, is verified by in-place DOP testing.

Following HEPA filtration, the off-gases pass through another, empty, filter housing. One housing is located immediately downstream from each HEPA filter. These previously existing housings were retained for possible future use.

### 3.2.2 Motivation

Following filtration, the off-gases pass through one of three redundant, positive displacement, off-gas blowers installed in parallel. One blower operates while the others provide reliable, full capacity, backup service. (The first backup is electric and the other is driven by a diesel motor.) The blower provides the motive force to maintain all of the vitrification equipment upstream under a slight vacuum for the purpose of contamination control. It also provides the motive force to discharge the treated off-gas into the base of the previously existing plant stack.

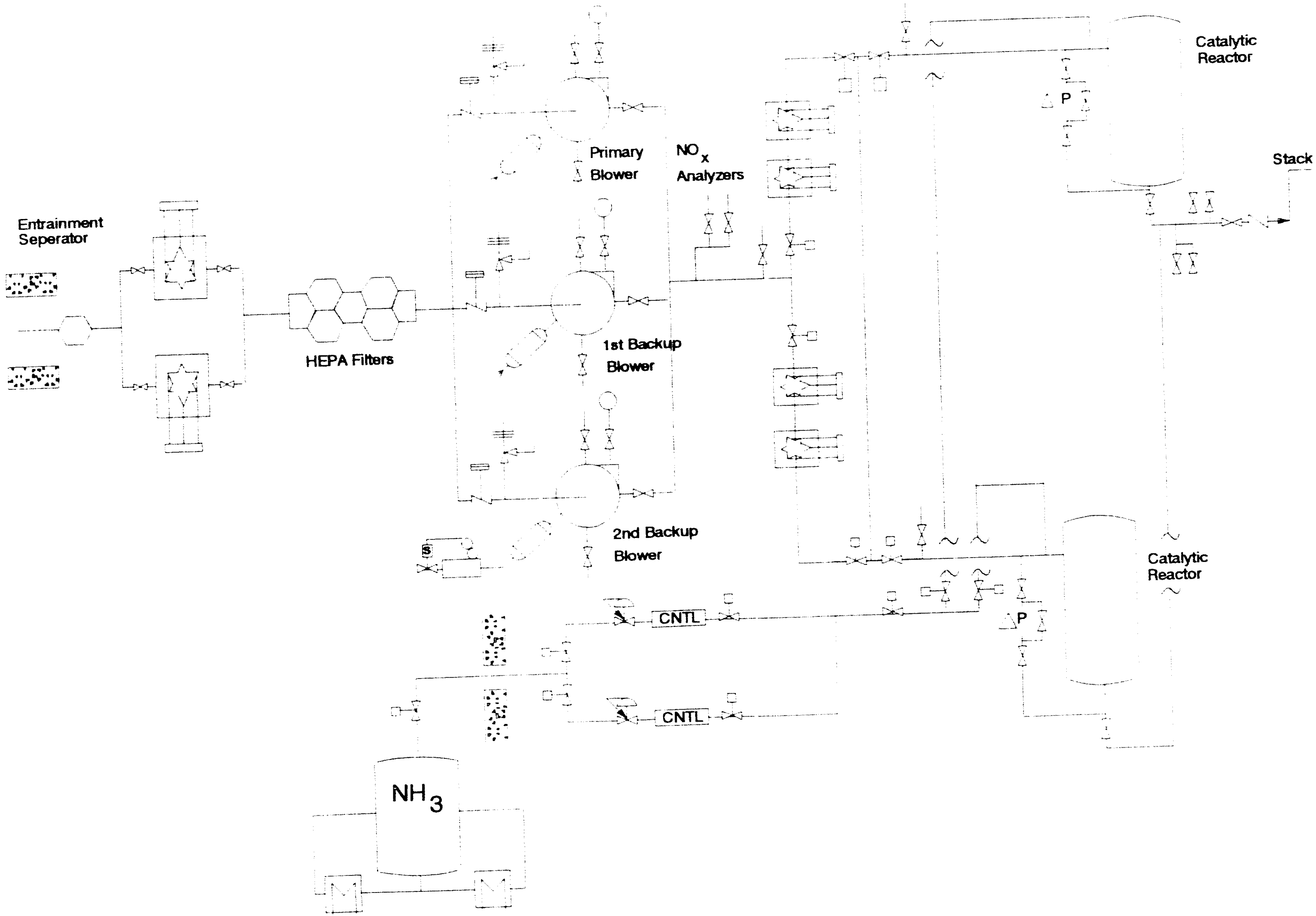


Figure 4: Atmospheric Protection Off-Gas Treatment System

### 3.2.3 $NO_x$ Destruction

From the blower, the off-gas pass through a $NO_x$ abatement system to destroy the noxious oxides of nitrogen ($NO_x$) The oxides of nitrogen are reacted with ammonia at an elevated temperature, and in the presence of a catalyst, to produce harmless water vapor and nitrogen.

The $NO_x$ destruction equipment includes redundant off-gas preheaters, an ammonia supply system, and redundant catalytic reactors. The preheaters elevate the off-gas temperature to promote the desired reaction, the ammonia supply provides the necessary reactant, and the catalytic reactor accelerates the desired reaction.

The $NO_x$ gases are destroyed by several competing chemical reactions involving $NO_2$, NO, $N_2O$, $NH_3$ and $O_2$. Test results indicate that, at WVDP operating conditions, the following reactions dominate.

$$2\,NO + O_2 \rightarrow 2\,NO_2$$

$$8\,NO_2 + 6\,NH_3 \rightarrow 7\,N_2O + 9\,H_2O$$

$$2\,N_2O + \rightarrow 2\,N_2 + O_2$$

These reactions are all exothermic. Therefore, the off-gases become hotter as they pass through a $NO_x$ reactor.

Following $NO_x$ destruction, the treated off-gas is directed to the previously existing plant stack.

# 4.0 EQUIPMENT DESCRIPTIONS

## 4.1 ALARA Equipment

The vitrification cell environment which the melter off-gas treatment equipment must endure is tabulated below.

| | | |
|---|---|---|
| Temperature | 16 to 35 °C | (60 to 95 °F) |
| Pressure | 0 to -1 kPa | (0 to -4 InWC) |
| Relative Humidity | 30 to 80 % | |
| Nitric Acid Fumes | 100 ppm | |
| Radiation (SBS) | 50 Gy/h | (5 x $10^3$ Rad/hr) |
| (other) | 1 Gy/h | (100 Rad/hr) |

For corrosion resistance against nitric acid fumes and solutions, the fabrication materials used for surfaces of equipment exposed to the vitrification cell environment, and to process fluids, is generally Type 304L stainless steel. The structural supports are made from carbon steel, and are painted for corrosion resistance.

Many items are fastened together by the process and electrical Purex connectors shown in Figures 5 and 6.

The impact wrench shown in Figure 7 is used to connect and disconnect the Purex connectors, and to open and close the isolation valves in the system. The wrench is suspended horizontally or vertically from a crane hook, employs a 50 mm (2 in) hexagonal socket, and applies 750 N-m (550 ft-$lb_f$) of torque.

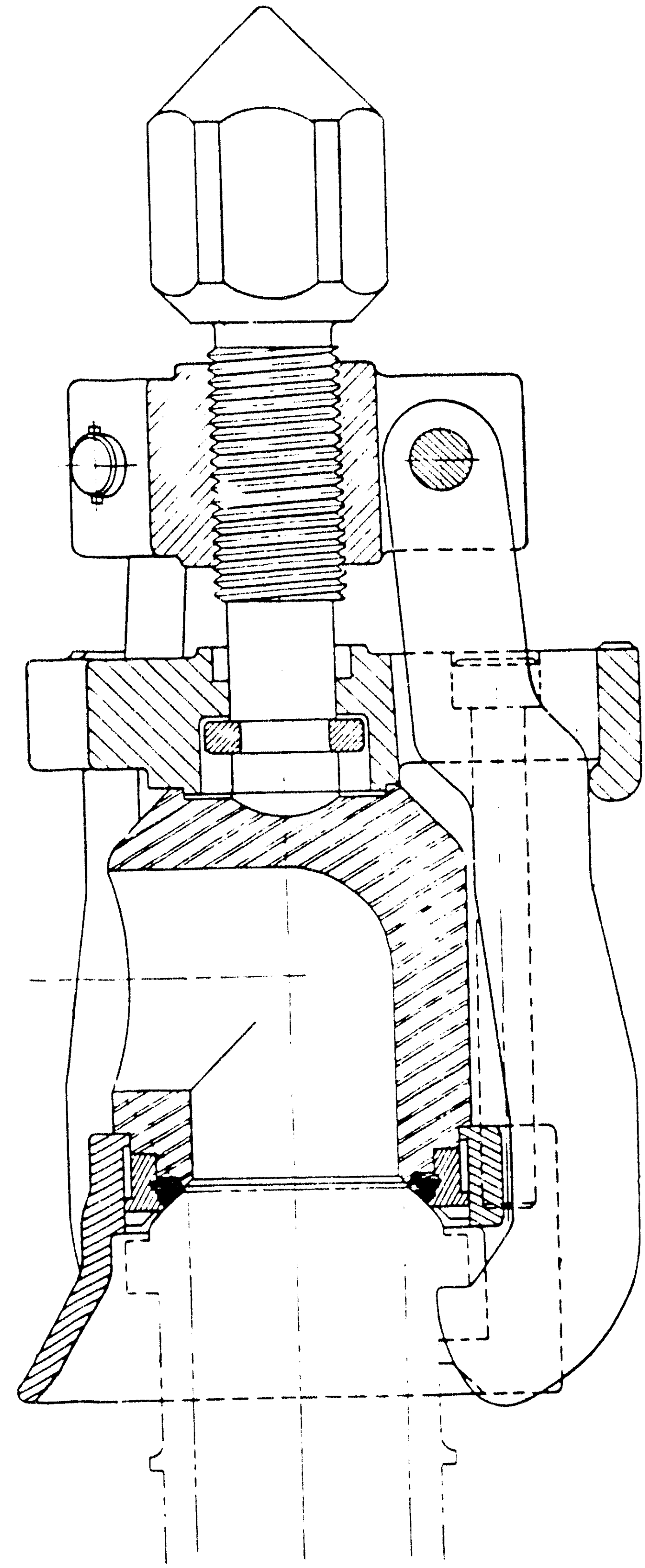

**Figure 5: Purex Process Connector**

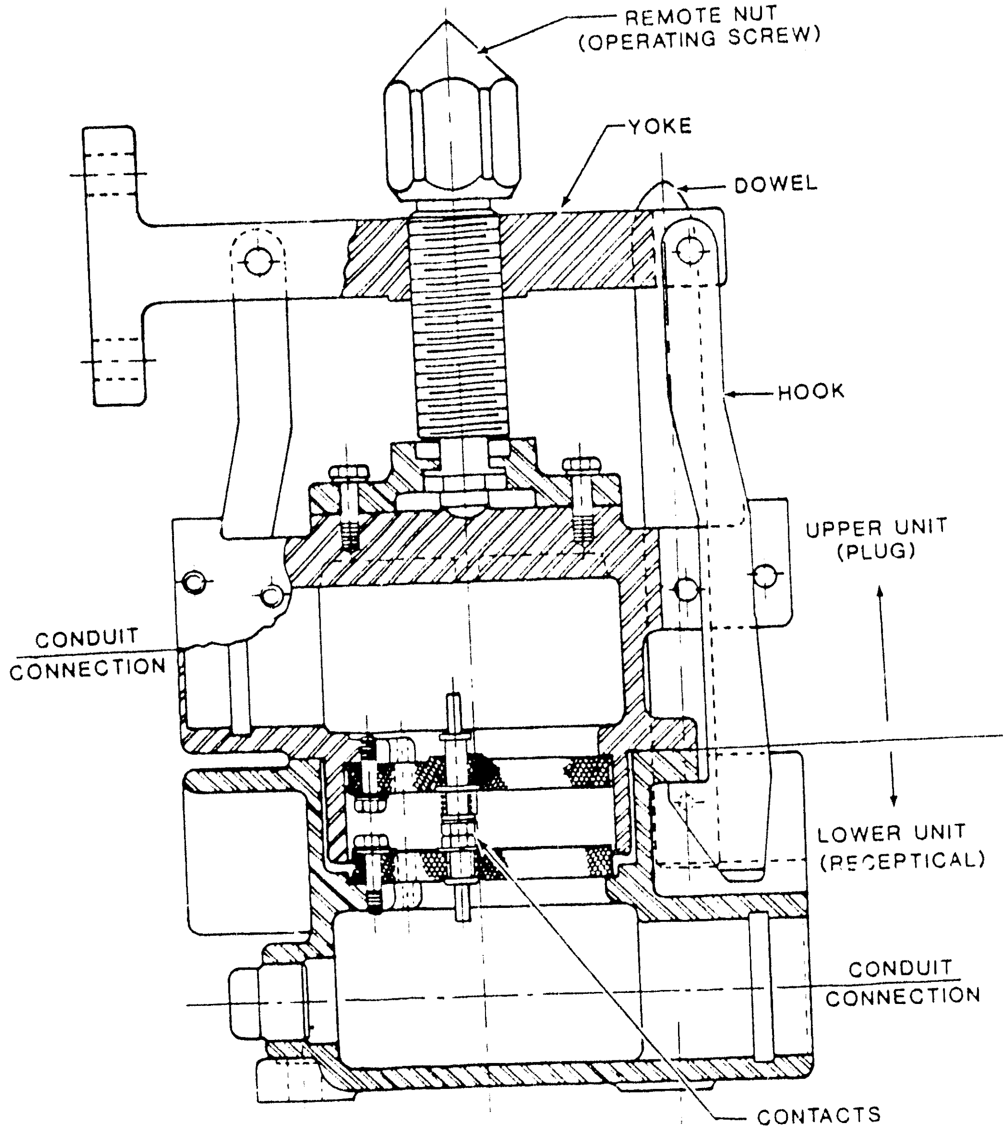


**Figure 6: Purex Electrical Connector**

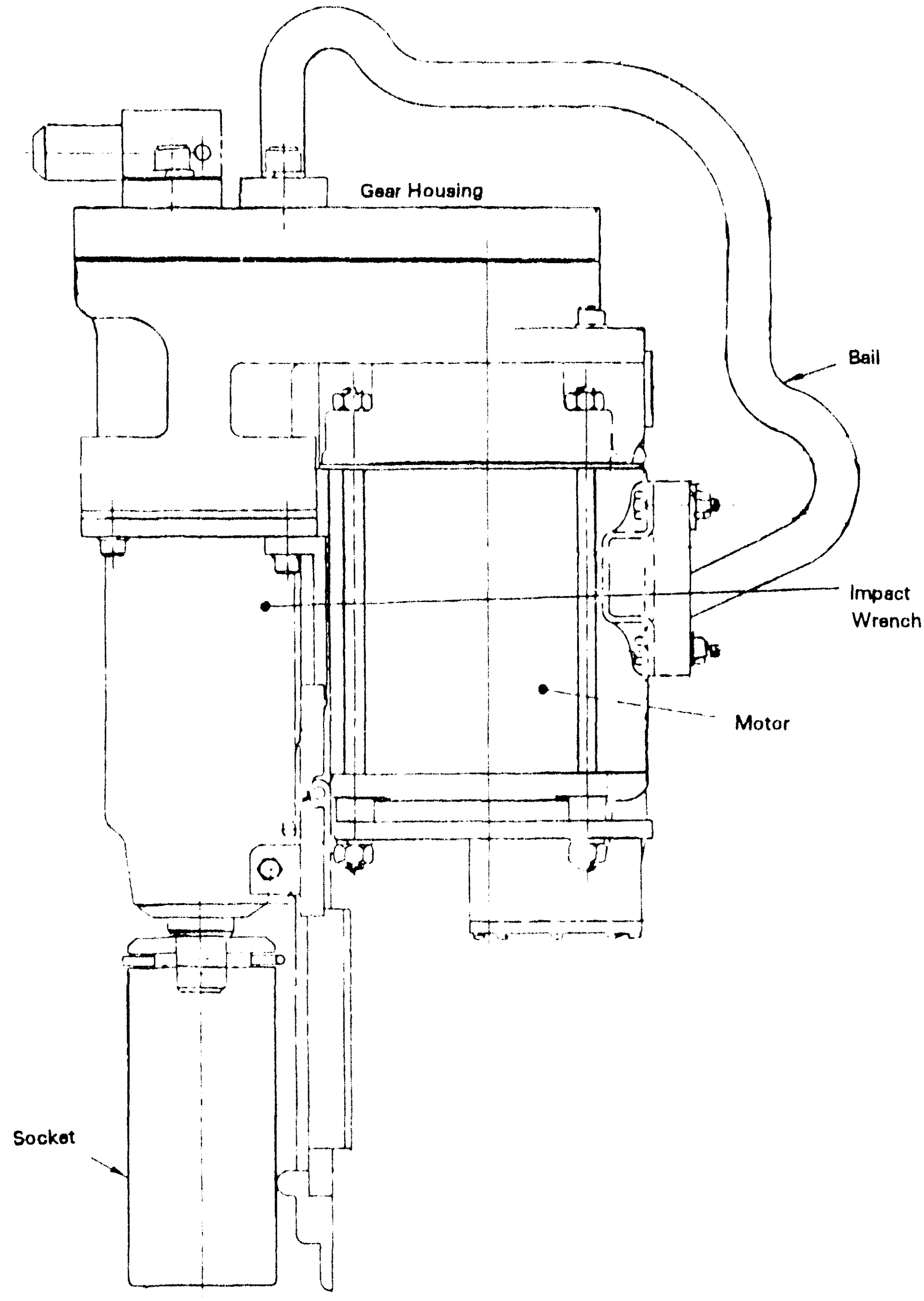


Figure 7: Impact Wrench

### 4.1.1 Vessel Ventilation

**1) Vessel Ventilation Header**

The vessel ventilation header is located on a ledge below the crane rails near the top of the vitrification cell walls. It rests on supports at a slope of 10 mm/m (1/8 in/ft) so liquids will drain to the condenser.

The header is made from seamless 150 mm (6 in) Schedule 40, Type 304 stainless steel pipe, with a corrosion allowance of 1.6 mm (1/16 in).

Stresses in the header due to thermal expansion and contraction over the design temperature range are accommodated by six, permanently installed, expansion joints made from Type 304L stainless steel. They are physically protected by external covers, and from accumulations of particulate by internal sleeves.

The header is designed for the following conditons:

| | | |
|---|---|---|
| Temperature | 13 to 260 °C | (55 to 500 °F) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Flow | 45 $m^3$/min | (1600 ACFM) |

**2) Condenser**

The vessel ventilation condenser, shown schematically in Figure 8 is a vertical, 3.2 GJ/h ($3.0 \times 10^6$ Btu/hr), shell and U-tube heat exchanger.

The shell is made of Type 304L stainless steel with a corrosion allowance of 1.6 mm (1/16 in), is 760 mm (30 in) in diameter, is 3400 mm (11 ft) high, and rests on a 1200 mm (4 ft) skirt.

The condenser is self supporting on a circular, 1300 mm (52 in) diameter lower base plate made from 50 mm (2 in) Type 304L stainless steel plate. Guide pins and studs in the lower base plate facilitate remote installation and fastening of the condenser. The lower base plate is welded to a floor embedment.

The shell is ASME "U" stamped, and is designed for the following conditons.

| | | |
|---|---|---|
| Temperature | 185 °C | (365 °F) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Pressure Diff. (max.) | 7 kPa | (1 psid) |
| Flow (inlet) | 45 $m^3$/min | (1600 ACFM) |

The tube bundle head is ASME "U" stamped, and the bundle is designed for the following conditons.

| | | |
|---|---|---|
| Temperature | 185 °C | (365 °F) |
| Pressure | 690 kPa | (100 psig) |
| Pressure Diff. (max.) | 30 kPa | (5 psid) |
| Flow (max.) | 500 L/min | (130 gpm) |

3) **Non-Condensibles Jumper**

The non-condensibles jumper from the condenser is 100 mm (4 in) in diameter, is made from Type 304L stainless steel, and has a corrosion allowance of 1.6 mm (1/16 in). It holds a diaphram-operated pressure control valve and a temperature sensor for temperature indication and condenser control.

The jumper is designed for the following conditions.

| | | |
|---|---|---|
| Temperature | 177 °C | (350 °F) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Flow | 20 $m^3$/min | (700 ACFM) |

4) **Condensate Drain**

The condensate drain includes the jumper from the bottom of the condenser which connects to a seal loop jumper, and a demineralized water jumper to the seal loop.

The jumper from the condenser has an isolation valve which is operated from overhead by the impact wrench. The seal loop jumper provides a 10 kPa (40 InWC) liquid seal between the condenser and the tank farm to isolate the condenser from the tank farm ventilation system. The seal loop has a demineralized water inlet to allow flushing toward the tank farm (Tank 8D-3) when the isolation valve is closed.

The condensate drain is designed for the following conditions.

| | | | |
|---|---|---|---|
| Temperature | 170 °C | (338 °F) | |
| Pressure | 690 kPa | (100 psig) | |
| Flow | | 1100 L/h | (300 gph) |

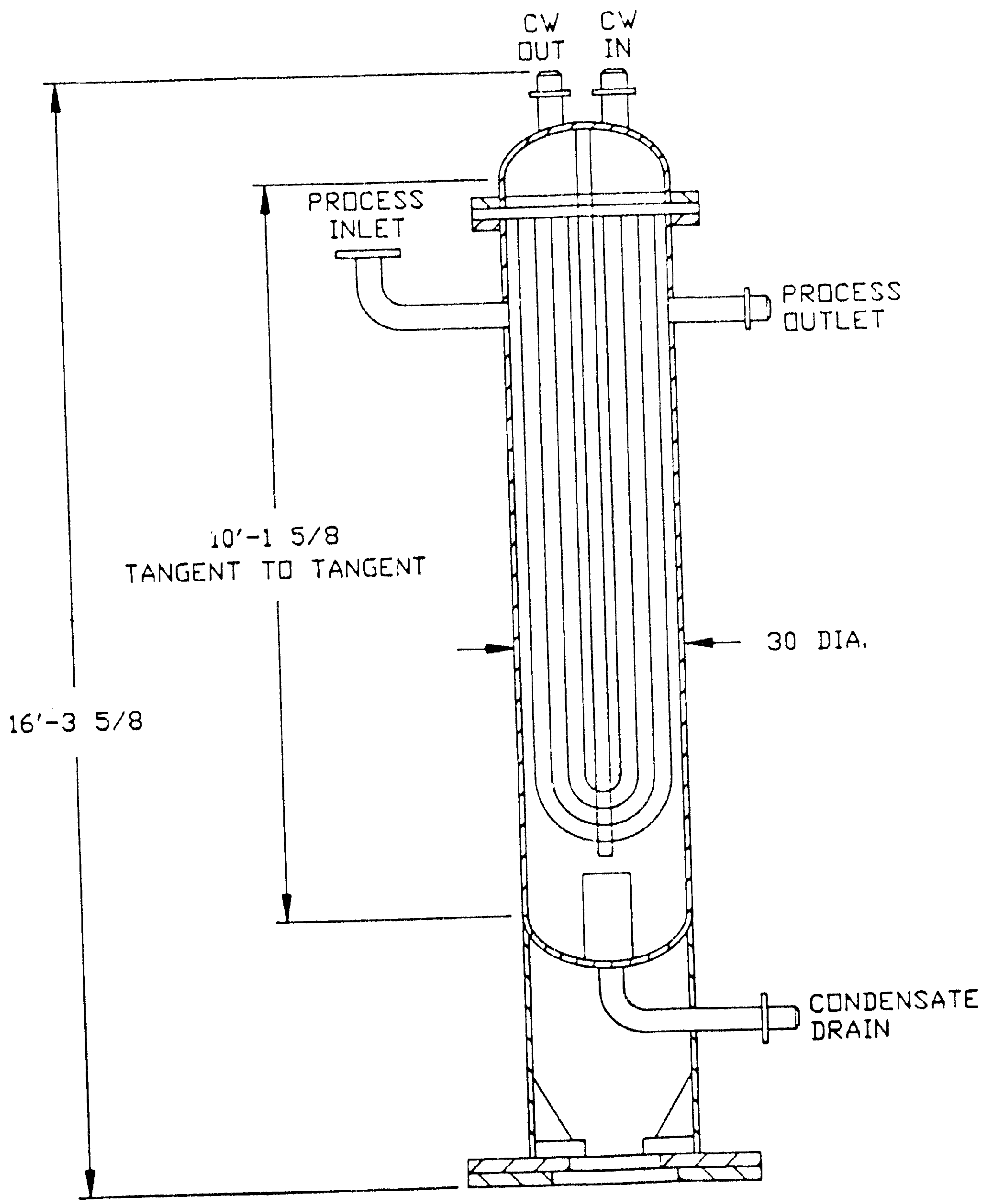


**Figure 8: Condenser**

### 4.1.2 Quenching/Scrubbing

Quenching and initial scrubbing is accomplished by the Submerged Bed Scrubber (SBS), shown in Figure 9. It is comprised of a scrubber vessel, and a receiver vessel which completely envelopes the scrubber vessel. It stands on four 610 mm by 610 mm (24 in x 24 in) rectangular support pads, made from Type 304L stainless steel plate, in the vitrification cell pit.

Jumpers provide solution transfer capabilities and access to instrumentation and utility services.

**1) The SBS Scrubber Vessel**

The scrubber consists of two concentric right cylindrical vessels made from 10 mm (3/8 in) Type 304L stainless steel with 0.41 mm (0.016 in) corrosion allowances. (The material selection is subject to re-evaluation prior to radioactive operations.)

The inner vessel contains the bed, is 1220 mm (4 ft) tall, 910 mm (3 ft) in diameter, and is constantly flooded with the water contained by the outer vessel. An Inconel 690 bed support/gas distributor plate forms the bottom. It houses a 0.5 $m^3$ (18 $ft^3$) bed of 10 mm (3/8 in) diameter ceramic sphere packing (Spheres are preferable to other packing shapes because they are least likely to plug.). A packing hold-down screen is located near the open top. Off-gases are introduced through a 250 mm (10 in) diameter Inconel 690 downcomer entering from the top and discharging at the bottom of the bed. The bed is remotely removable through the large flanged head in the receiver vessel.

The outer vessel is 1750 mm (69 in) tall and 1830 mm (6 ft) in diameter with a capacity of 2.3 $m^3$ (600 gal). The solid bottom is dished to facilitate complete evacuation by jet transfer. It is open at the top, and is kept filled with water.

The scrubber contains cooling coils in the annular space outside the bed with a design heat load of about 350 MJ/h (330,000 Btu/hr).

A sparger is installed in the scrubber to mobilize settled particulate, and a steam jet (not shown) is installed to evacuate liquid and suspended particulate to the SBS receiver. Instrumentation to measure temperature, vapor space pressure, liquid specific gravity and liquid depth are provided.

The design conditions for the scrubber are listed below.

| | | | |
|---|---|---|---|
| Temperature (Downcomer) | | 600 °C | (1100 °F) |
| (Other) | 300 °C | (570 °F) | |
| Pressure | (Coils) | 450 kPa | (65 psig) |
| (Other) | 13 kPa | (50 InWC) | |
| Vacuum | 23 kPa | (90 InWC) | |
| Flow (min.) | 6 $m^3$/min | (210 ACFM) | |
| (max.) | 22 $m^3$/min | (760 ACFM) | |
| DF (Particulate) | 10 | | |

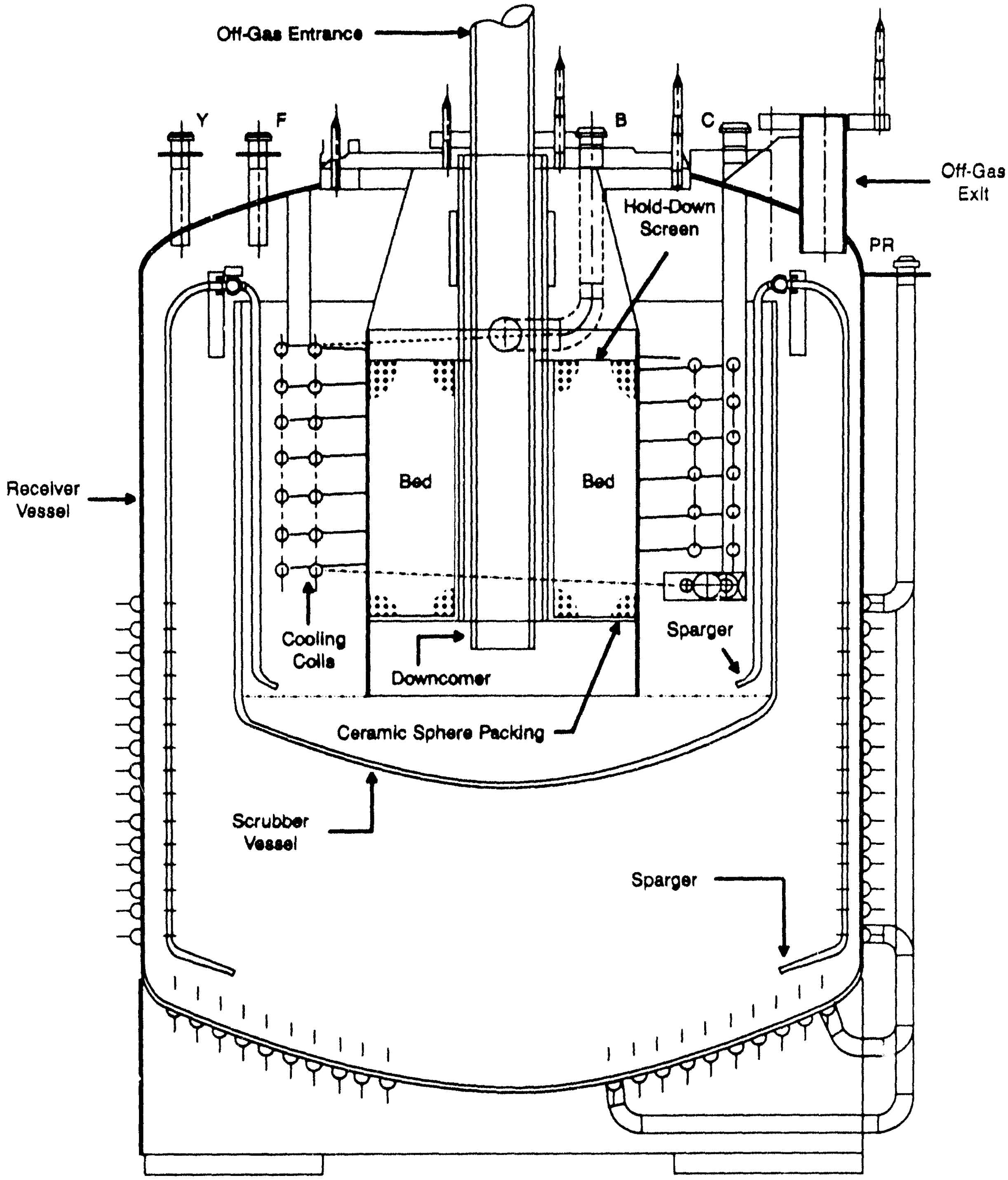


**Figure 9: Submerged Bed Scrubber**

## 2) The SBS Receiver Vessel

The maximum operating volume of the receiver is 5.5 $m^3$ (1450 gal). The SBS receiver vessel is a right cylindrical vessel, 2440 mm (8 ft) in diameter and 3350 mm (11 ft) tall, with a slanted bottom to allow complete evacuation by jet transfer. It is fabricated from Type 304L stainless steel, has a corrosion allowance of 0.41 mm (0.016 in), and has a total capacity of 11.5 $m^3$ (3,050 gal).

The vessel is equipped with half-pipe jacket to cool the fluid below 40 °C (104 °F) before jet transfer. The coils have a design duty of about 9.5 MJ/h (9000 Btu/hr).

A sparger is located at the bottom to mobilize settled particulate.

Steam jets (not shown) are provided to evacuate the contents to the waste header, or to the concentrator feed make-up tank.

Instrumentation is provided to measure temperature, vapor space pressure, liquid specific gravity, and liquid depth.

Design conditions for the receiver are as follows:

| | | |
|---|---|---|
| Temperature | 300 °C | (570 °F) |
| Pressure (Coils) | 450 kPa | (65 psig) |
| (Other) | 13 kPa | (50 InWC) |
| Vacuum | 23 kPa | (90 InWC) |

## 3) Mist Eliminator Housing and Element

The mist eliminator housing, shown in Figure 10, is made from Schedule 40, Type 304L stainless steel pipe which includes a corrosion allowance of 1.6 mm (1/16 in). The body is made from 460 mm (18 in) pipe, and the inlet and outlet ducting is from 150 mm (6 in) pipe.

The liquid return line is 25 mm (1 in) pipe that is sloped downward from the bottom of the housing into the SBS, and is equipped with a liquid seal at the end inside the SBS. Gases and vapors from the vessel ventilation condenser are accepted into the mist eliminator discharge through a 100 mm (4 in) Purex connector.

The pad is a 150 mm (6 in) thick, knitted mesh with a 360 mm (14 in) diameter exposed face. It is made from Type 304L stainless steel wire and structurals. The pad is designed to minimize fouling, and consists of four pads in series with each successive pad having a greater packing density. The packing densities are 53, 80, 140, and 173 kg/$m^3$ (3.3, 5.0, 9.0, and 10.8 $lb_m/ft^3$) respectively. The design face velocity is 2.4 m/s (8 ft/sec). The minimum and maximum acceptable face velocities are 1.5 m/s (5 ft/sec) and 3.44 m/s (11.3 ft/sec) respectively.

The spray nozzle is a wide angle, full cone spray nozzle.

The mist eliminator meets the requirements of ANSI/ASME N509-1980, bears an ASME "U" stamp, and is designed for the following conditions:

| | | | |
|---|---|---|---|
| Flow | (pad) | 13 $m^3$/min | (466 ACFM) |
| | (housing) | 28 $m^3$/min | (1000 ACFM) |
| Pressure | | 200 kPa | (30 psig) |
| Vacuum | | 30 kPa | (120 InWC) |
| Temperature | | 121 °C | (250 °F) |
| Density | (off-gas) | 1 kg/$m^3$ | (0.06 $lb_m/ft^3$) |
| Rel. Humidity | | 100 % | |
| Entrained Moisture | | 64 g/min | (0.14 $lb_m$/min) |
| Particulate | | 340 g/h | (0.74 $lb_m$/hr) |
| Efficiency | (5 μm) | 93+% | |
| Life Dose | | 26 kGy | (2.6 x $10^6$ Rads) |
| Dose Rate | | 1 Gy/h | (100 Rad/hr) |
| Pressure Diff. | | 250 Pa | (1 InWC) |
| | (dry, clean) | | |
| Housing Leak Rate | | 4 $m^3$/h-$m^2$ | (0.2 SCFM/$ft^2$) |
| | (Max. at 2.5 kPa (10 InWC)) | | |

### 4.1.3 High Efficiency Mist Elimination

**1) HEME Preheater**

The high efficiency mist eliminator (HEME) preheater includes a housing with heating element, a jumper to provide electrical energy, and a jumper to provide temperature measurement.

The HEME preheater housing is made from Type 304L stainless steel, and has a corrosion allowance of 1.6 mm (1/16 in).

The HEME preheater housing meets the requirements of ANSI/ASME N509-1980, bears an ASME "U" stamp, and is designed for the conditions below:

| | | |
|---|---|---|
| Flow | 37 $m^3$/min | (1300 ACFM) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 121 °C | (250 °F) |
| Density (off-gas) | 1 kg/$m^3$ | (0.06 $lb_m/ft^3$) |
| Rel. Humidity | 100 % | |
| Entrained moisture | 180 g/min | (0.39 $lb_m$/min) |
| Particulate | 18 g/h | (0.04 $lb_m$/hr) |
| Life Dose | 26 kGy | (2.6 x $10^6$ Rads) |
| Dose Rate | 1 Gy/h | (100 Rads/hr) |
| Pressure Diff. (max) | 250 Pa | (1 InWC) |
| Housing Leak Rate | 4 $m^3$/h-$m^2$ | (0.2 SCFM/$ft^2$) |
| (Max. at 2.5 kPa (10 InWC)) | | |

The HEME Preheater rests on its own steel structural support.

The interchangeable, 50 kW, electrical resistance heating element is operated with 480 V, 3 phase, electrical energy, and is sheathed in Incoloy. The element can be remotely removed from the housing and replaced.

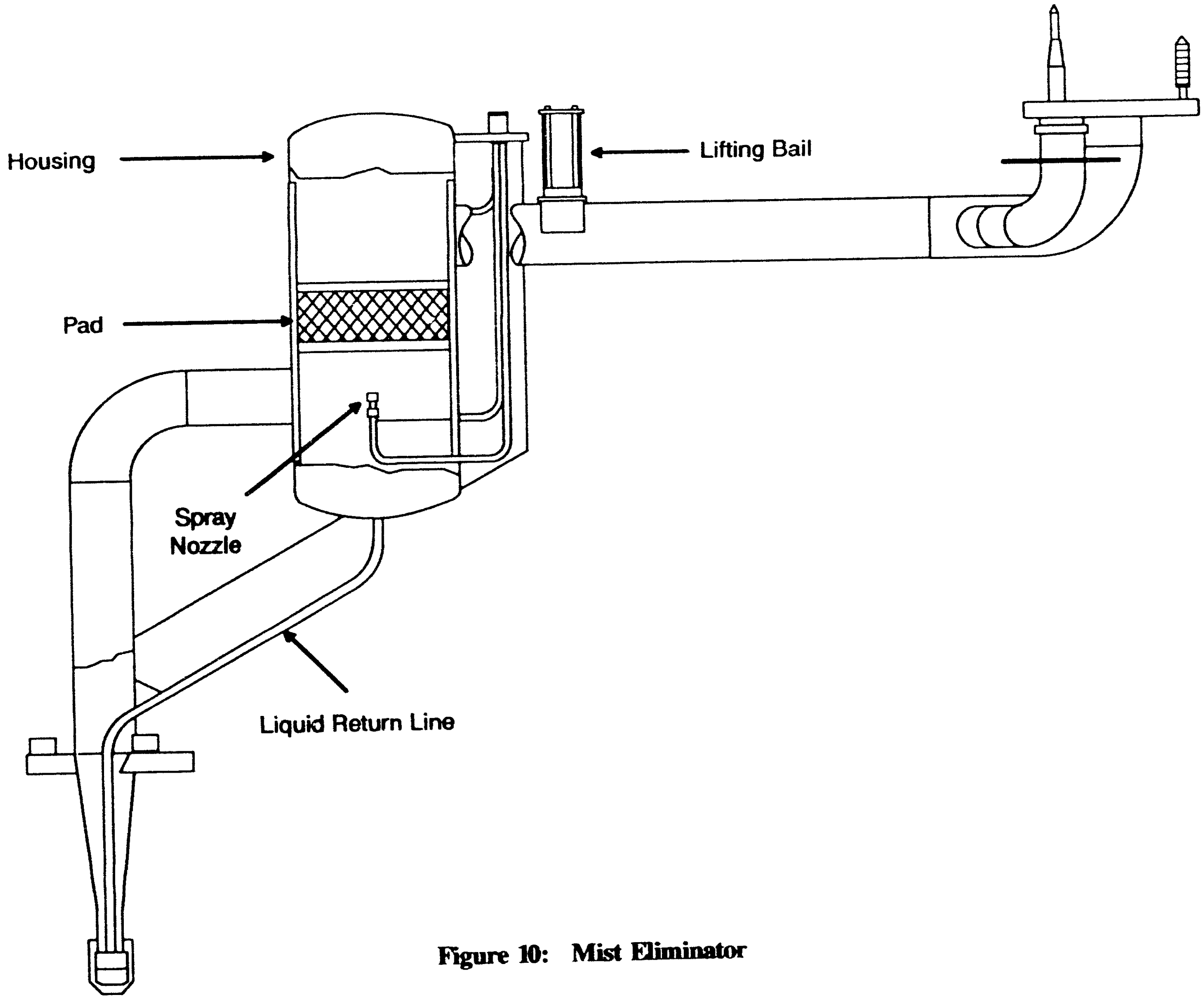


**Figure 10: Mist Eliminator**

### 2) Off-Gas Jumpers to the HEMEs

The off-gas jumpers from the HEME preheater to the HEMEs are made from seamless 150 mm ( 6 in), Schedule 40S, Type 304L stainless steel pipe, and 150 mm (6 in), 1 MPa (150 psi), full port ball valves. The valves are fabricated from Type 316L stainless steel, radiation resistant polyetheretherketone (PEEK) seats & bearings, and Grafoil packing. They were modified for operation from overhead by the impact wrench.

The jumpers are designed to the following conditions.

| | | |
|---|---|---|
| Temperature | 121 °C | (250 °F) |
| Pressure | 280 kPa | (40 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Flow | 37 $m^3$/min | (1300 ACFM) |

### 3) High Efficiency Mist Eliminators

The HEMEs are depicted schematically in Figure 11.

The HEME vessels are cylindrical, 1070 mm (42 in) diameter, 4060 mm (160 in) tall, with a base 610 mm (2 ft) high. They are made from Type 304L stainless steel with corrosion allowances of 1.6 mm (1/16 in).

The vessels are self-supporting, resting on circular, 1680 mm (66 in) diameter, lower base plates made from 50 mm (2 in) Type 304L stainless steel plate.

The HEME elements are 760 mm (30 in) in diameter, 3050 mm (10 ft) tall, with a wound glass fiber element. The element is enclosed by a woven wire screen of Type 316L stainless steel. The pad assembly can be remotely removed and replaced.

HEME element spray units are 3660 mm (12 ft) vertical lances made from 50 mm (2 in) Schedule 40S, Type 304L stainless steel pipe. Each unit holds 15 stainless steel, wide angle, full cone, spray nozzles positioned to deliver a spray of droplets to the inside surface of the corresponding HEME element.

The HEME vessels meet the requirements of ANSI/ASME 509-1980, bear ASME "U" stamps, and are designed for the following conditions.

| | | | |
|---|---|---|---|
| Flow | (vessel) | 37 $m^3$/min | (1300 ACFM) |
| | (element) | 23 $m^3$/min | (818 ACFM) |
| Pressure | | 280 kPa | (40 psig) |
| Vacuum | | 30 kPa | (120 InWC) |
| Temperature | | 121 °C | (250 °F) |
| Density (off-gas) | | 1 kg/$m^3$ | (0.06 $lb_m/ft^3$) |
| Rel. Humidity | | 100 % | |
| Entrained moisture | | 180 g/min | (0.39 $lb_m$/min) |
| Particulate | | 18 g/h | (0.04 $lb_m$/hr) |
| Life Dose | | 26 kGy | (2.6 x $10^6$ Rad) |
| Dose Rate | | 1 Gy/h | (100 Rad/hr) |
| Pressure Differential | (pad saturated) | 2.5 kPa | (10 InWC) |

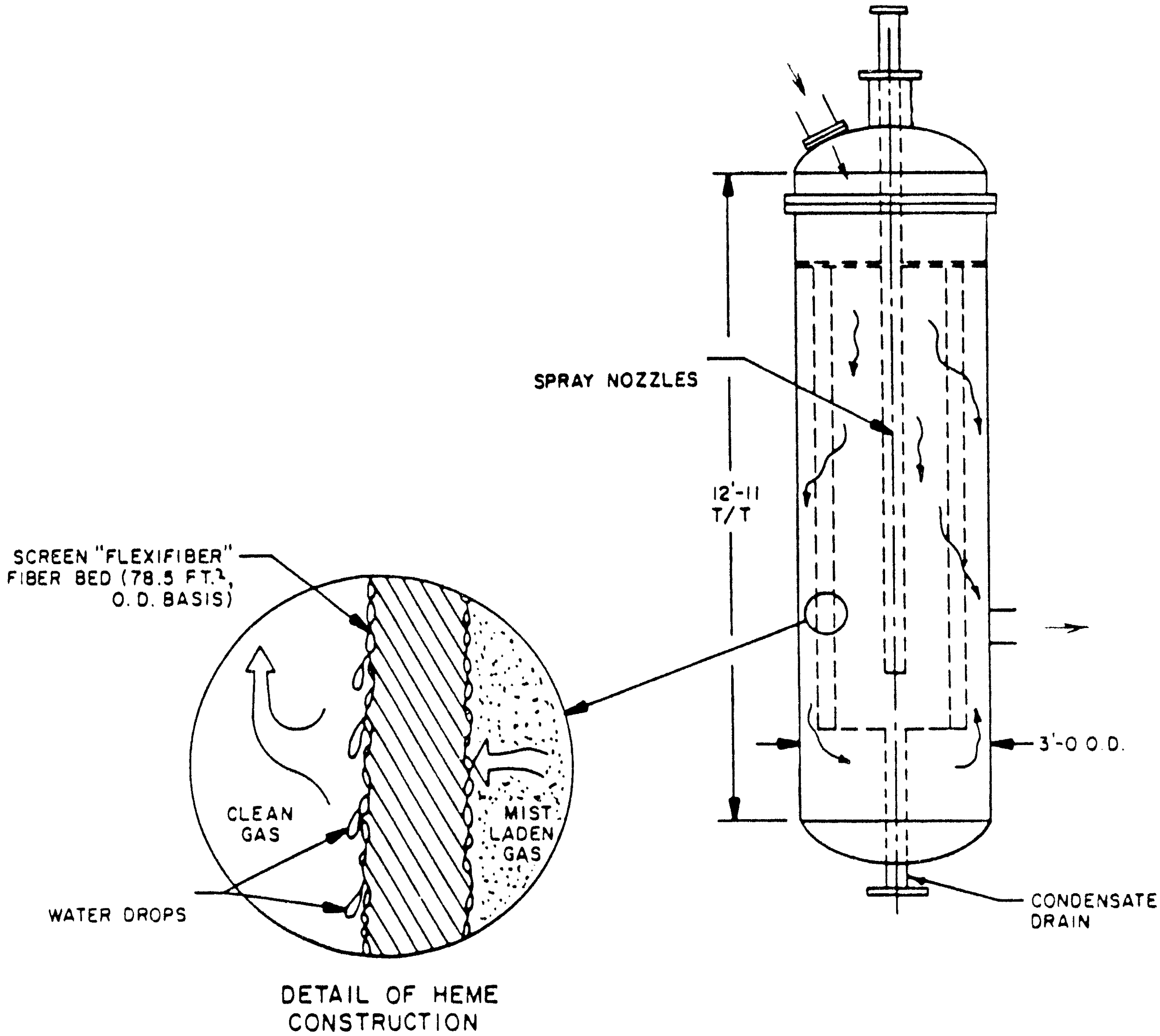


Figure 11: High Efficiency Mist Eliminator

### 4.1.4 Prefiltration

#### 1) Filter Preheaters

Each filter preheater consists of a housing and an element, a jumper providing electrical energy to the element, a jumper to monitor the pressure upstream from the prefilter, and a jumper with temperature instrumentation.

The filter preheaters are shown schematically in Figure 12.

The housings, made from Type 304L stainless steel, have a corrosion allowances of 1.6 mm (1/16 in). They meet the requirements of ANSI/ASME N509-1980, bear ASME "U" stamps, and are designed for the conditions below.

| | | |
|---|---|---|
| Flow | 42 $m^3$/min | (1500 ACFM) |
| Pressure | 280 kPa | (40 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 121 °C | (250 °F) |
| Density (off-gas) | 1 kg/$m^3$ | (0.06 $lb_m/ft^3$) |
| Rel. Humidity | 100 % | |
| Entrained Moisture | 36 g/min | (0.08 $lb_m$/min) |
| Particulate | | 680 mg/h (1.5 x $10^{-3}$ $lb_m$/hr) |
| Life Dose | 26 kGy | (2.6 x $10^6$ Rad) |
| Dose Rate | 1 Gy/h | (100 Rad/hr) |
| Pressure Diff (max) | 250 Pa | (1 InWC) |
| Housing Leak Rate (Max. at 2.5 kPa (10 InWC)) | 4 $m^3$/h-$m^2$ | (0.2 SCFM/$ft^2$) |

The heating elements are the same as, and interchangeable with, those of the HEME preheater and the postheater.

#### 2) Prefilters

Each prefilter assembly consists of a housing made from Type 304L stainless steel with no corrosion allowance, a perforated flow straightening baffle, and two HEPA filter elements in series. The baffle is rectangular sheet of 3.6 mm (10 Gage) Type 304L stainless steel with about 390 uniformly spaced 19 mm (3/4 in) diameter holes. The elements are sealed with a silicone sealer.

For traceability, the housings are marked on both sides with black serial numbers 32 mm (1-1/4 in) tall.

Provision is made in adjacent equipment to measure the differential pressure across the filter elements to measure filter plugging. This provision allows prefilter assembly replacement without requiring removal of the jumpers used to monitor the pressure differential.

Replacement prefilter assemblies are DOP tested prior to introduction into the vitrification cell, to assure that there are no perforations in the filter media and that there are no breaks in the seal between the filter elements and the housing. Anti-tampering seals are installed on the housings following the successful DOP tests to assure that the filter seals have remained untouched.

The prefilter assemblies meet ANSI/ASME N509 requirements, bear ASME "U" stamps, and are designed for the conditions below.

| | | |
|---|---|---|
| Flow | 42 $m^3$/min | (1500 ACFM) |
| Pressure | 280 kPa | (40 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 121 °C | (250 °F) |
| Density (off-gas) | 1 kg/$m^3$ | (0.06 $lb_m/ft^3$) |
| Rel. Humidity | 10 % | |
| Entrained Moisture | 0 | |
| Particulate | 680 mg/h | (1.5 x $10^{-3}$ $lb_m$/hr) |
| DF (0.3 μm) | 3333 | |
| Life Dose | 26 kGy | (2.6 x $10^6$ Rads) |
| Dose Rate | 1 Gy/h | (100 Rads/hr) |
| Press. Diff (max.) (clean, dry) | 500 Pa | (2 InWC) |
| Housing Leak Rate (Max. at 2.5 kPa (10 InWC)) | 4 $m^3$/h-$m^2$ (0.2 SCFM/$ft^2$) | |

The prefilter assembly is shown schematically in Figure 12.

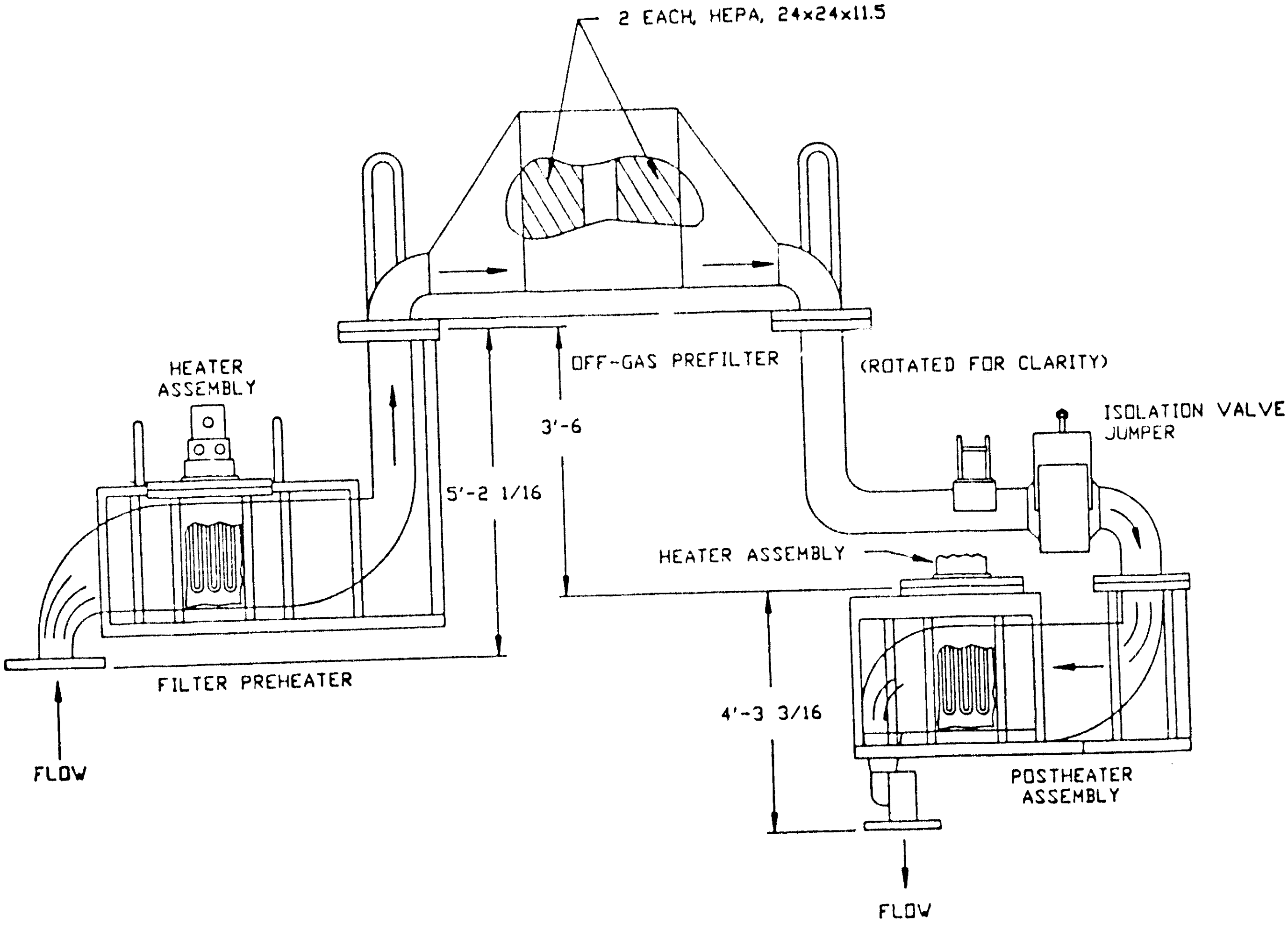


**Figure 12: Filter Preheater, Prefilter, Off-Gas Jumper to Postheater, and Postheater**

3) **Off-Gas Jumpers from the Prefilters to the Postheater**

Each off-gas jumper assembly consists of an off-gas jumper and a pressure tap jumper. An off-gas jumper to the postheater is depicted schematically in Figure 12.

The off-gas jumpers are made from seamless 150 mm (6 in), Schedule 40, Type 304 stainless steel pipe and hold valves. They are supported by brackets on the structural supports.

The valves are 150 mm (6 in), 1 MPa (150 psi), full port ball valves made from Type 316L stainless steel, radiation resistant PEEK seat & bearings, and Grafoil packing. They were modified for operation from overhead by the impact wrench.

The jumpers were designed for the following conditions.

| | | |
|---|---|---|
| Flow | 42 $m^3$/min | (1500 ACFM) |
| Pressure | 280 kPa | (40 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 121 °C | (250 °F) |

### 4.1.5 Heating

1) **Postheater**

The postheater assembly consists of a housing and element, plus a support assembly, an electrical energy jumper and a temperature instrumentation jumper.

The postheater is depicted schematically in Figure 12.

The postheater housing is made from Type 304L stainless steel with a corrosion allowance of 1.6 mm (1/16 in). It rests on its own structural steel supports, meets the requirements of ANSI/ASME N509-1980, bears an ASME "U" stamp, and is designed for the conditions below.

| | | |
|---|---|---|
| Flow | 42 $m^3$/min | (1500 ACFM) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 185 °C | (365 °F) |
| Density (off-gas) | 800 g/$m^3$ | (0.05 $lb_m/ft^3$) |
| Rel. Humidity | Negligible | |
| Entrained Moisture | 0 | |
| Particulate | Trivial | |
| Life Dose | 26 kGy | (2.6 x $10^6$ Rads) |
| Dose Rate | 1 Gy/h | (100 Rads/hr) |
| Pressure Diff (max) | 250 Pa | (1 InWC) |
| Housing Leak Rate | 4 $m^3$/h-$m^2$ | ( 0.2 SCFM/$ft^2$) |
| (Max. at 2.5 kPa (10 InWC)) | | |

The heating element is the same as, and is interchangeable with, those of the HEME preheater and both filter preheaters. A blind flange is available to seal the housing for operation without having the heating element installed.

2) **Discharge Header**

The discharge header consists of a duct with an installed mass flowmeter, and an instrumentation jumper that services the flowmeter. The header is made from seamless 200 mm (8 in), Schedule 40, Type 304L stainless steel pipe. The flowmeter is made from Type 316 stainless steel. The assembly is designed for the following conditions.

| | | |
|---|---|---|
| Flow | 42 $m^3$/min | (1500 ACFM) |
| Pressure | 210 kPa | (30 psig) |
| Vacuum | 30 kPa | (120 InWC) |
| Temperature | 185 °C | (365 °F) |

## 4.2 Atmospheric Protection Equipment

Equipment located inside the 01-Cell of the 01-14 Building was designed for remote manual switchover. These items include the off-gas reheater, HEPA filters, filter housings, reactor preheaters, and catalytic reactors.

### 4.2.1 HEPA Filtration

1) **Duct to 01-14 Building**

The duct from the vitrification cell to the 01-14 Building is an insulated, 250 mm (10 in), Schedule 40, Type 304L stainless steel pipe. The trench through which the duct runs is steam heated to help maintain the temperature of the off-gas above its dew point.

2) **Entrainment Separator**

An entrainment separator, intended to minimize the heating load requirement of the off-gas reheater, is located at the low point between the vitrification cell and the 01-14 Building to collect any condensation that might occur in the duct. Accumulated condensation is delivered to a condensate collection tank.

3) **Condensate Collection Tank**

The condensate collection tank accepts and accumulates liquid from the entrainment separator drain. From the condensate collection tank the liquid is delivered to the Liquid Waste Treatment System.

4) **Reheaters**

Dual, redundant, electrical resistance reheaters are provided. Either heater operating alone can assure the off-gases approaching the HEPA filters are well above their dew point.

Each reheater consists of a 1570 mm (62 in) tall, 250 mm (10 in) diameter, Type 304L stainless steel housing with a removable, 60 kW, 480 V, 3 phase, immersion heating bundle of Incoloy 800 sheathed elements. The housings are ASME code stamped for the following conditions.

| | | |
|---|---|---|
| Pressure | 620 kPa | (90 psi) |
| Temperature | 400 °C | (750 °F) |

Thermocouples located in the outlets of the housings serve as process control sensors. The housings are insulated with 50-75 mm (2-3 in) of high temperature ceramic wool to limit the temperature of exposed surfaces to 60 °C (140 °F).

### 5) HEPA Filters

To provide remote manual switchover, automatic operators were added to the previously existing butterfly valves at the entrances to, and exits from, the previously existing HEPA filter housing.

Both parallel HEPA filter trains, consisting of two HEPA filter elements in series, are contained in a common housing made from 6 mm (1/4 in) Type 304L stainless steel plate. The housing, depicted in Figure 13, accommodates filter elements 610 mm by 610 mm by 290 mm deep (2 ft X 2 ft X 11-1/2 in). The filter elements are held in place by air piston actuated, remotely operated, clamping devices. Off-gases enter from the bottom of the housing, pass horizontally through two filter elements, then exit from the top of the housing.

Each filter element position is provided with a bag-out port.

Additional, previously existing, filter housings are located directly downstream from the HEPA filter housings. These housings were made from 3 mm (1/8 in), Type 304L stainless steel and were designed to hold filter elements 610mm by 610 mm by 290 mm deep (2 ft X 2 ft X 11-1/2 in). Their change-out ports were designed for element "bag-in" and "bag-out."

## 4.2.2 Motivation

### 1) Duct to Blowers

The duct to the blowers includes an air in-bleed valve for use in controlling the pressure (vacuum) at the blower suction. Air is drawn from out-of-doors through filters. Outside air is used so fluctuations in the in-bleed rate will not affect the building ventilation. The air is filtered to protect the blowers from abrasive particules.

### 2) Blowers

The primary off-gas blower is a new, positive displacement rotary blower slightly oversized for 42 $m^3$/min (1500 ACFM) flow at the blower inlet to accommodate melter start-up operations. It is driven by an electric motor, typically at a speed to motivate only 37 $m^3$/min (1300 ACFM). This assures that no process upset would occur should the primary blower fail and the first backup blower, which will move 37 $m^3$/min (1300 ACFM), is automatically started.

The first backup off-gas blower was previously existing and is depicted schematically in Figure 14. It is a positive displacement, lobe type blower manufactured from Type 304 stainless steel (headplates, cylinder, impellers and shafts.). An electric motor is directly coupled to the first backup blower.

The second backup off-gas blower was previously existing equipment and is physically identical to the first backup off-gas blower. The second backup blower is driven by a diesel motor rated at 32 kJ/s (43 brake hp) when operated at 1200 r/min. Auxilliary equipment to the diesel motor includes an auto start cabinet, a day tank for fuel, and 12 V wet cell batteries.

The blower suction is equipped with a vacuum relief valve.

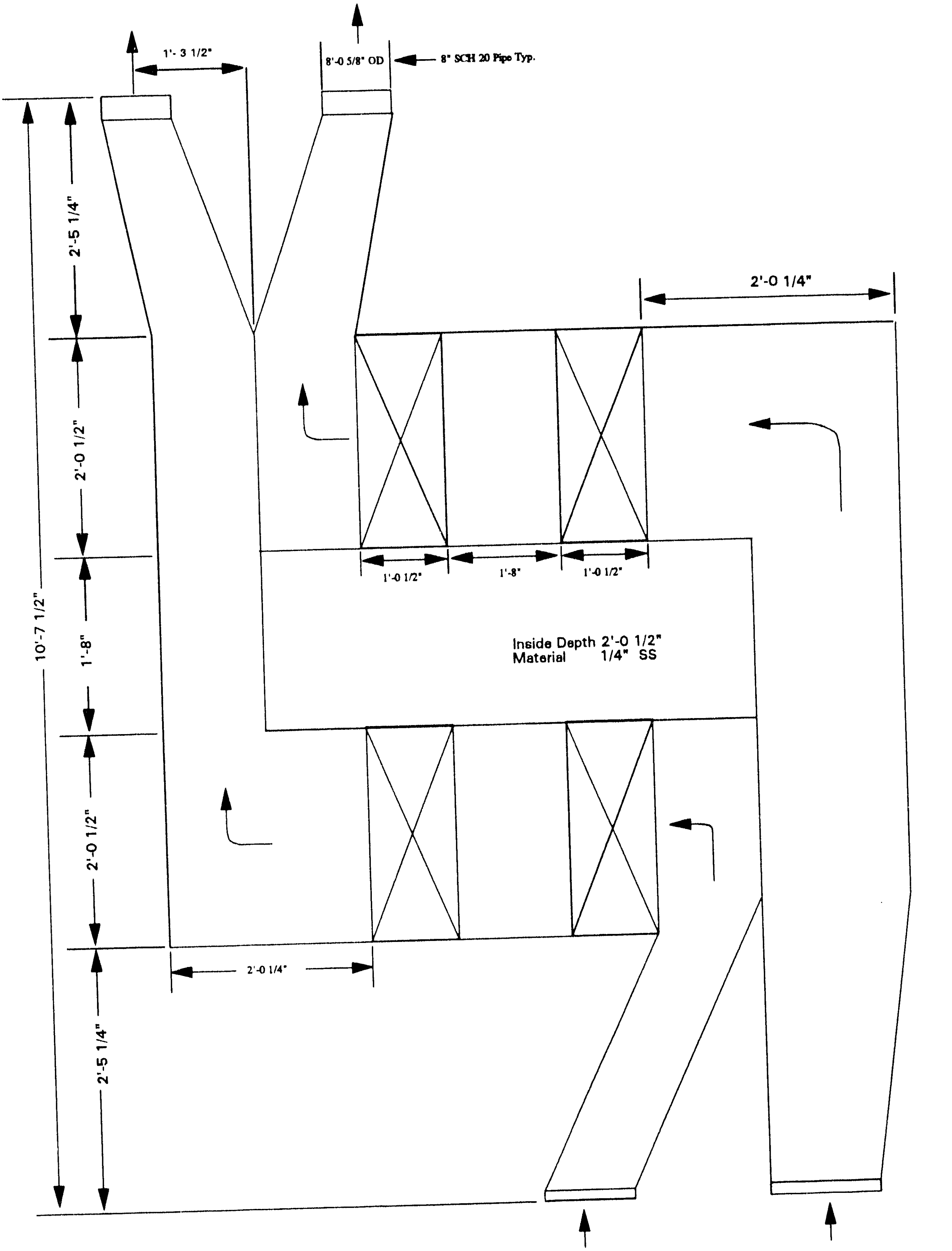


Figure 13: HEPA Filters

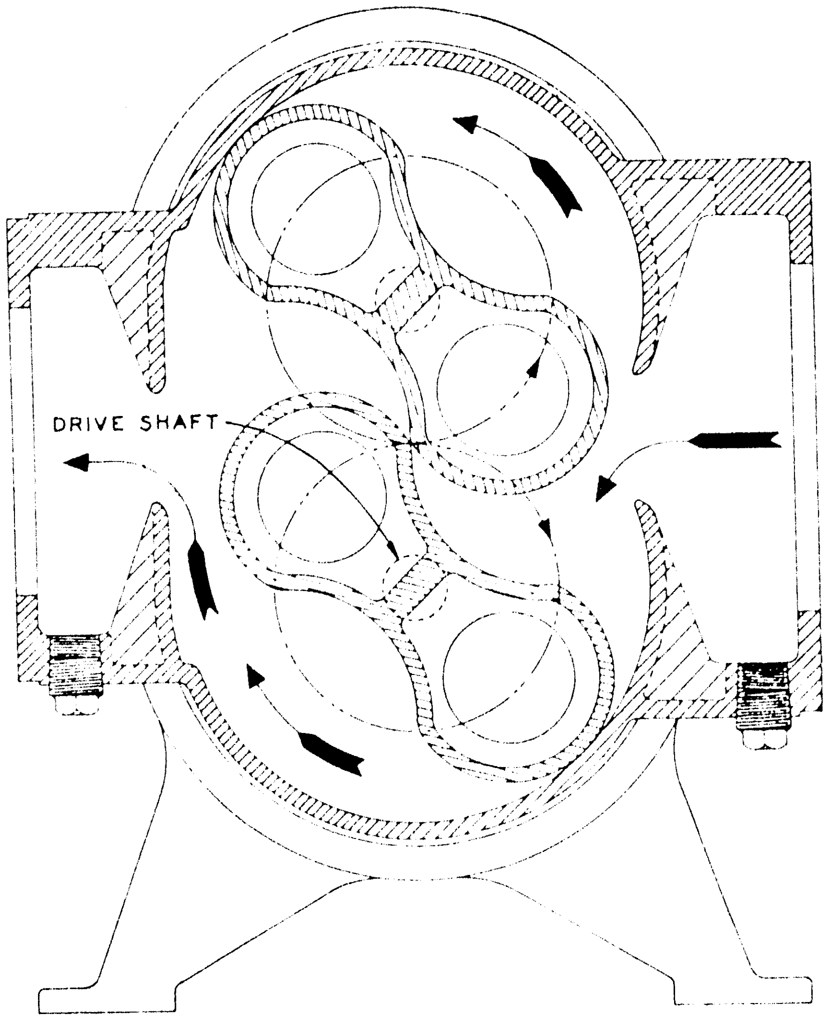


**Figure 14: Blower**

### 4.2.3 $NO_x$ Destruction

The $NO_x$ destruction system is designed to limit $NO_x$ emissions during any 1-hour period to no more than 1.9 kg (4.2 $lb_m$).

The system is designed to preclude formation of ammonium nitrate in the $NO_x$ reactors, discharge ducting, and main plant stack.

The $NO_x$ destruction reactors are designed to allow no more than 50 ppm ammonia in the outlet during normal operation and no more than 100 ppm during startup operation.

#### 1) Analyzers

Four analyzers are used. Three are identical $NO_x$ analyzers, and the fourth is a $NO/NO_2/NH_3$ analyzer. Two of the $NO_x$ analyzers monitor the reactor inlet concentrations and are non-dispersive infrared. The $NO/NO_2/NH_3$ analyzer monitors the reactor outlet and is a process diode array spectrophotometer using an UV visible detector. The fourth analyzer is a spare and can monitor the $NO_x$ concentrations in either the inlet or the outlet.

#### 2) Ammonia Supply

The ammonia supply system was designed for anhydrous ammonia to minimize the equipment complexity and aqueous waste streams associated with use of aqueous ammonia.

The ammonia storage tank is a carbon steel right cylinder, 5180 mm (17 ft) tall, 1070 mm (42 in) in diameter, with elliptical dished heads and a corrosion allowance of 3 mm (1/8 in). It is designed for a maximum inventory of 3.8 $m^3$ (1000 gal), an 18 day supply. The tank is designed to, and ASME stamped for, the following conditions.

| | | |
|---|---|---|
| Pressure | 1.7 MPa | (250 psig) |
| Temperature | 43 °C | (110 °F) |

The tank is equipped with level floats, pressure relief, and a fill line routed west to the road, allowing remote direct transfer from a tank truck.

The tank is equipped with two, redundant, 18 kW, 480 V, 3 phase, electric immersion vaporizers. The heating elements are sheathed in Incoloy 800. The housings are :anufactured from 200 mm (8 in) carbon steel pipe and are insulated with 38 mm (1.5 in) of calcium silicate jacketed with Type 304 stainless steel.

The hardware is designed to maintain the temperature above 4 °C (40 °F) to prevent ammonia condensation when the ambient temperature is as low as -34 °C (-30 °F), and when the wind is as great as 130 km/h (80 mph).

The vaporized ammonia is drawn from the vapor space at the top of the tank, and is routed to the redundant, pressure reducing, mass flow control train. Either flow control train can deliver ammonia to either $NO_x$ reactor. The ammonia is delivered to the off-gases downstream from the preheaters and upstream from static mixers at the reactor inlets.

### 3) Preheaters

Dual, redundant, preheaters are provided. Each consists of two electric, explosion resistant, heater elements arranged in series. Each heater element is rated at 480 V, 3 phase, and 100 kW. Each preheater assembly includes a 3100 mm (122 in) tall, 300 mm (12 in) diameter, Type 304L stainless steel housing and a removal immersion heating element bundle. The housings are ASME code stamped for the conditions below, and are fully insulated with 150 to 200 mm (6-8 in) of high temperature ceramic wool insulation to maintain the temperature of exposed surfaces below 60 °C (140 °F).

| | | |
|---|---|---|
| Pressure | 170 kPa | (25 psi) |
| Temperature | 400 °C | (750 °F) |

The heater elements are sheathed in Incoloy 800. A thermocouple located in the housing outlet serves as the process control sensor.

### 4) Reactors

Two identical reactors, as shown in Figure 15, are installed in parallel.

The reactor vessels were sized to fit through the previously existing 1370 mm (54 in) diameter overhead hatch. The vessels are right cylinders, made from Type 321 stainless steel, standing on four legs, with the inlet at the top and the outlet at the bottom. The walls are 6 mm (1/4 in) thick. The overall height of each reactor is 3480 mm (11 ft - 5 in), with the cylindrical bed section being 1650 mm (5 ft - 5 in) high. The cylindrical sections have inside diameters of 1000 mm (39-1/2 in). Each reactor is equipped with a manway at the top for catalyst installation and removal. The reactors are insulated with 200 mm (8 in) of calcium silicate insulation to maintain the surface temperature below 60 °C (140 °F). The insulation is jacketed by Type 304 stainless steel.

The reactor vessels are ASME code stamped for the following conditions.

| | | |
|---|---|---|
| Pressure | 170 kPa | (25 psig) |
| Temperature | 482 °C | (900 °F) |

The 1120 mm (44 in) deep catalyst bed is zeolite based. The primary catalyst bed consists of 890 mm (35 in) of 6 mm (1/4-in) Raschig rings. The polishing bed is located beneath the primary bed, and consists of 230 mm (9 in) of 1.6 mm (1/16 in) catalyst extrudate. The catalytic bed is supported on 3 mm (1/8 in), non-catalytic balls, which are supported on 30 mm (1.2 in) diameter non-catalytic balls. This combination is designed to provide an efficiency of 93% while producing a pressure differential of no more than 7.5 kPa (30 InWC) at a flow rate of 46 m$^3$/min (1620 ACFM).

### 5) Discharge Duct

The duct leading toward the base of the stack is an insulated 200 mm (8 in) pipe. The insulation is specified to maintain the off-gas above its dew point.

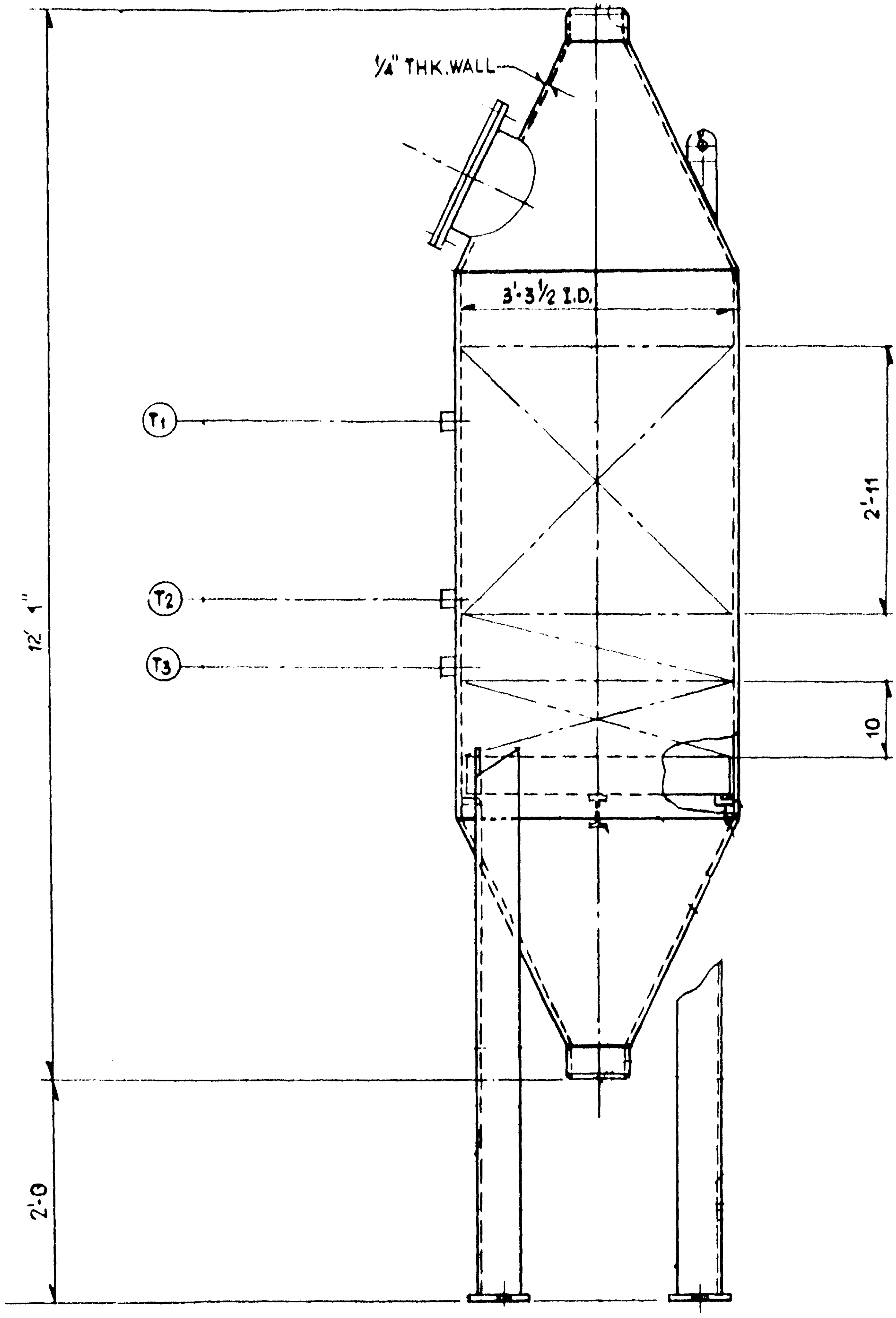


Figure 15: $NO_x$ Reactor

# 5.0 SYSTEMS CONTROL

## 5.1 ALARA Control

The system is generally passive, with only one in-cell assembly that is subject to periodic automatic motion, the vessel ventilation pressure control valve and its associated actuator.

The motive forces for establishing a vacuum are provided by the blowers located downstream in the out-of-cell melter off-gas treatment system. The control valve located in the jumper that directs vessel ventilation gases and vapors to the melter off-gas treatment system, is automatically modulated to maintain the vessel ventilation header at a predesignated vacuum. This is done to maintain a slight negative pressure on the primary process systems, relative to the vitrification cell atmosphere, for purposes of contamination control.

**NOTE**

Should the vacuum in the melter become less than prescribed, a valve in the jumper between the melter and the vessel ventilation header automatically opens to direct gases and vapors from the melter to the vessel vent header. Because this valve is used to control conditions within the melter, it is functionally part of the melter rather than of the off-gas system.

The vessel ventilation equipment is also used to control the steam that is evolved from the concentrator feed makeup tank. This steam is condensed and cycled back to the tank farm for subsequent processing by the integrated radwaste treatment systems.

The amount of water that is discharged from the system, in the form of water vapor directed to the stack, is established by controlling the operating temperatures of the condenser and submerged bed scrubber. Temperature increases result in increased water vapor expulsion rates. The temperature in the submerged bed scrubber must be kept low enough, however, to prevent loss of solution from the scrubber. Temperature control is provided by modulation of the amount of closed loop cooling water sent to the cooling coils in the condenser and the scrubber vessel.

The temperature of the off-gases approaching the prefilter is maintained above the dew point by modulation of the power supplied to the filter preheater elements, based upon off-gas temperatures readings immediately downstream from the preheater.

## 5.2 Atmospheric Protection Control

The atmospheric protection system equipment is operable from the vitrification facility control room.

Two $NO_x$ analyzers with sample probes located at the inlet of the $NO_x$ abatement equipment monitor NO and $NO_x$. The probe from a third analyzer is located at the outlet to monitor $NO_x$. These are used to control the addition of the ammonia reactant, and to monitor the $NO_x$ destruction efficiency. A fourth analyzer serves as a backup to any of the other three during calibration operations.

# 6.0 EQUIPMENT MAINTENANCE

## 6.1 ALARA Equipment

To allow for equipment maintenance without having to suspend melter feed operation, a redundant train of off-gas treatment equipment was installed.

Normally, one of the installed redundant off-gas trains (high efficiency mist eliminator, filter preheater, prefilter) is operated while the other train is valved out-of-service. While out-of-service, maintenance operations can be performed. A train is placed into service by opening the isolation valves in the jumpers upstream from the high efficiency mist eliminator and downstream from the prefilter. A train is removed from service by closing the same two isolation valves.

The vessel ventilation header is a non-maintenance item.

## 6.2 Atmospheric Protection Equipment

The system is designed for hands-on maintenance.

Installed redundant equipment was required for all equipment which would require removal from service for periodic maintenance, and whose removal from service ould require suspension of melter feed operation. These items included the off-gas reheaters, HEPA filter trains, blowers, reactor preheaters, $NO_x$ destruction reactors, ammonia vaporizers, and ammonia flow controllers. Therefore, items of major equipment can be removed from service prior to performing maintenance.

The design for maintenance was based upon the philosophy that opening of a boundary, when pressurized $NO_x$ is isolated by valving alone, would be an undue risk to personnel. Therefore, double isolation valves with bleed lines between the isolation valves leading to the blower suction, were provided to positively isolate process gases from equipment requiring maintenance.

The design for maintenance is also based upon the philosophy that routine access to a room or space in which pressurized $NO_x$ exists in equipment would also be an unacceptable risk to personnel. Therefore, items of equipment on the discharge side of the blowers were located inside the 01-Cell of the 01-14 Building, and an off-gas by-pass line was provided for use when any of those items of equipment requires maintenance.

To allow for purging of $NO_x$, purge ports are provided for all major components exposed to off-gases.

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