INTERIM HIGH LEVEL RADIOACTIVE WASTE STORAGE AT THE IDAHO CHEMICAL PROCESSING PLANT

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ABSTRACT

Storage facilities, referred to as bin sets, are provided for the interim storage of the granular solid radioactive waste produced at the Idaho Chemical Processing Plant. Each bin set provides complete isolation of the waste from the environment by a double containment system. The primary containment barrier is comprised of stainless steel storage bins and the connecting piping systems, including retrieval lines, vent and relief system, and transport and fill system. The bins and piping systems are contained in a reinforced concrete vault, which is the second containment barrier. A cooling air system is provided to maintain the vault, bins and radioactive solids below their maximum safe temperatures. A double filtered vent and relief system protects the bins from excessive internal positive pressure or vacuum. Provisions are incorporated to allow retrieval of the solids for immobilization and placement in a permanent repository. Installed instrumentation, including radiation monitors, provides required information on the operating status of the facility.

INTRODUCTION

The Idaho Chemical Processing Plant (ICPP), located at the Idaho National Engineering Laboratory (INEL), is operated by Westinghouse Idaho Nuclear Company (WINCO) for the United States Department of Energy. At the ICPP government spent nuclear fuels are received and disposed of in a safe and cost effective manner.

The disposal method includes dissolution of the fuel elements by strong acid and recovery of the uranium by a solvent extraction process. This processing generates several hundred thousand gallons of radioactive waste annually, which is initially stored in 300,000 gallon stainless steel tanks. After a period of residence in the underground tank farm, the liquid waste is withdrawn and converted into granular solids (calcine) in a fluidized bed calciner located in the New Waste Calcining Facility (NWCF). The calcination process provides an approximate 6:1 waste volume reduction. After calcination the granular solids are transported to an interim storage facility by a closed loop pneumatic transport system.

Calcined Product Description

Two primary liquid waste types, zirconium fluoride and sodium, are calcined as a blend to produce the granular calcine product. Zirconium fluoride liquid wastes are generated during the dissolution of zirconium fuels with hydrofluoric acid. Aluminum nitrate is added subsequent to the dissolution step to complex the free fluoride to reduce the corrosiveness of the solution during solvent extraction and high level liquid waste storage. Prior to calcination at 500 degrees centigrade, calcium nitrate is added to the waste feed to suppress fluoride volatility to minimize corrosion in the off-gas system. Sodium wastes are the bottoms from the plant process evaporator and are blended with fluoride feeds at specified blend ratios. The blend ratios are set to yield a maximum of 5 mole percent sodium in the calcine to assure that the calcine remains free flowing and will not agglomerate at the expected storage temperatures. Agglomeration for sodium blend calcines occurs at storage temperatures above 600 degrees centigrade.

Typical chemical composition of the calcine in weight percent is: 60% calcium fluoride, oxide, and nitrate; 15% zirconium oxide; 12% miscellaneous oxides; 10% sodium compounds; and 3% aluminum oxide. The calcine stored in the interim storage facilities is approximately 20 weight percent fines (less than 150 microns) and 80 weight percent granules (mass mean particle diameter of 300 microns). Bulk density of the fines and granule mixture is about 1.4 g/cm^3.

Radioactive decay heat is generated at the rate of about 100 watts/cubic meter of calcine when initially calcined. Decay heat generation decreases to an average of 80 watts/cubic meter during the four years used to fill the storage facility. Thermal conductivity of the granular and fines mixture has been measured to be 0.19 watts per meter per degree centigrade.

Constraints

The bin set and transport system must provide highly reliable and safe containment of the calcine. They must withstand the Safe Shutdown Earthquake (SSE), Design Basis Tornado (DBT) and the ICPP Probable Maximum Flood. Table I lists the specific design requirements.

TABLE I

Natural Phenomena Design Criteria

A. Safe Shutdown Earthquake

1. Maximum Bedrock Acceleration

a. Horizontal 0.24 g

b. Vertical 0.16 g

Work supported by the U.S. Department of Energy Assistant Secretary for Defense Programs, under DOE Contract No. DE-AC07-84ID12435.

2. Acceleration Response Spectrum per US NRC Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants."

B. Design Basis Tornado

1. Maximum Wind Speed - 282 Km/hr

2. Maximum Rotational Velocity - 233 Km/hr

3. Maximum Translational Velocity - 48 Km/hr

4. Total Pressure Drop - 4.5 kPa

5. Pressure Drop Rate - 1.7 kPa/sec

6. Missiles

a. 81.6 kg wood plank traveling at 166 km/hr

b. 907 kg automobile tumbling along the ground at 104 Km/hr

C. ICPP Probable Maximum Flood 1498.5 m above mean sea level.

The facility must also withstand the thermal loads resulting from the decay heat generated by the radioactive calcine, and must maintain the temperature of the calcine below the caking temperature (600° C) in order to facilitate retrieval at some future date. The facility must provide radiation protection for personnel operating the facility and occupying adjacent outside areas. The limit for internal areas is 1.25 mR/hr, and for outside adjacent areas 0.5 mR/hr. The facility must also provide two reliable arriers to prevent the release of radioactive contamination throughout the design life of the facility, which is 500 years.

DESIGN FEATURES

To date six interim storage facilities, referred to as bin sets, have been constructed. The Seventh Bin Set, now under construction, incorporates features developed from earlier bin sets and is described in this paper. It is a near copy of the Sixth Bin Set, and has a storage capacity of 1,784 cubic meters.

Storage Bins

The primary containment barrier is the stainless steel storage bins, together with all connecting transport piping, retrieval piping, and bin vent system piping and components. All components, piping and supports in these systems are stainless steel and are designed to withstand the applicable natural phenomena listed in Table I. Figure 1 is a schematic depiction of these systems.

There are seven storage bins, mounted vertically, with one in the center surrounded by the other six. Each bin is 20.7 meters high, with an outside diameter of 4.1 meters. These two bin dimensions, applicable to bin sets six and seven, were selected to provide the maximum size vessels that can be shipped by railroad from the off-site fabricator. Each bin is anchored to the facility base slab by a base ring that fits closely around the vessel skirt, and is attached to the skirt by 72 skirt bolts. The base ring mates to the anchor bolt assembly, which is embedded in the base slab by 36 anchor bolts. Figure 2 shows this mounting arrangement.

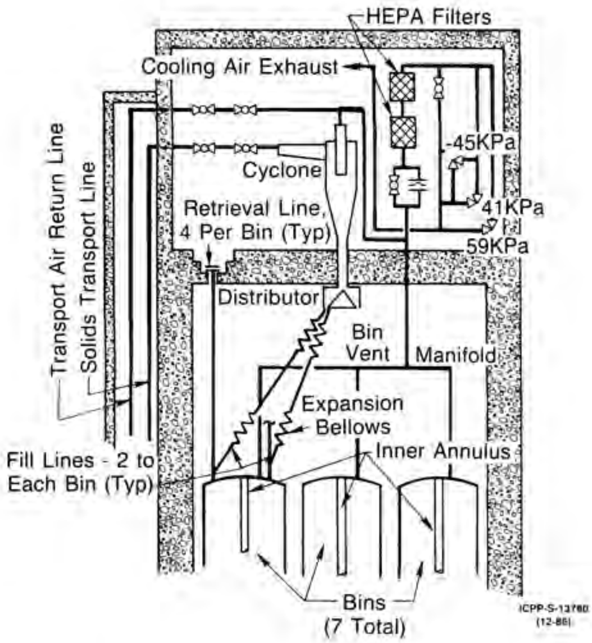

Fig. 1. Radioactive Solids Storage Schematic.

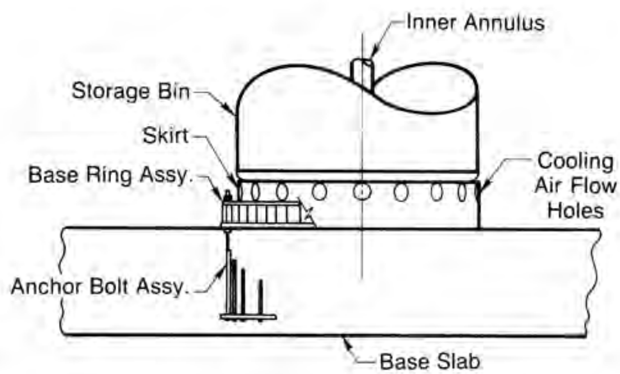

Fig. 2. Storage Bin Anchoring Arrangement.

Two specific features are built into the bins to enhance future retrievability of the calcine. Four 20.3 cm diameter nozzles are located in the head of each bin, concentric with the center of the bin and equidistant from each other. Each of these nozzles is welded to a pipe that extends up to the facility second floor and is terminated with a blind flange. When retrieval is desired a special articulating arm vacuum nozzle can be inserted through these risers into the bins for withdrawal of the calcine. The bins contain no internal bracing, and are designed to have no crevices, ledges or other places where the calcine may lodge, in order to facilitate access to all portions of the bins interior by the vacuum nozzles.

Since the bins can have no internal bracing, three stiffener rings are welded to the outside. Because installation of these rings by the fabricator would result in a bin O.D. of 4.37 m, thus exceeding railroad clearances in most parts of the United States, the external rings are shipped separately in segments and welded to the vessel at the ICPP. Three mounting pads are welded to the vessel exterior by the vessel fabricator at the stiffener rings attachment locations to avoid welding directly to the bin pressure boundary.

In order to monitor significant bin and calcine temperatures, thermowells are installed on or in the bins at strategic locations. Every bin has six thermowells on the exterior surfaces, plus two thermowells extending the full height of the bin, positioned on opposite sides of the inner annulus at the calcine maximum temperature zone. A multipoint thermocouple assembly is inserted into each of these latter two thermowells.

The storage bins are designed and fabricated to the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2. The Safe Shutdown Earthquake loading governs the design. The outer shell and heads are fabricated from type 304L stainless steel plate. The inner wall of the annular bin is fabricated from type 304L, 30.5 cm diameter, schedule 80S pipe. All plate and pipe includes a 0.5 mm corrosion allowance beyond the structurally required material thickness.

Annular bins were chosen over standard cylindrical bins to maximize radioactive decay heat rejection rates from the bins. For standard cylindrical bins, the outside diameter and volume would be limited to assure that calcine agglomeration temperatures were not exceeded at the centerline. Annular bins allow larger outside diameters and increased storage volumes since cooling air also circulates through what would normally be the maximum temperature zone of a cylindrical bin. A thermal analysis incorporating the calcine thermal properties was performed to size the inner wall diameter. A diameter of 30.5 cm will provide adequate cooling to prevent calcine agglomeration. Because the bins are annular, the maximum temperature zone is expected to be about 0.9 meters from the bin centerline.

Bins Vent and Relief System

The storage bins are provided with a bins vent and relief system to prevent pressurization to levels which would exceed the bins design collapse and rupture pressures. The vent and relief system vents to atmosphere through two High Efficiency Particulate Air (HEPA) filters in series. This system, which is an integral part of the primary containment, is shown schematically in Fig. 1. All pipe in this system is type 304L stainless steel, and all components are fabricated from 300 series stainless steel.

When the bins are not being filled, the facility is isolated from the calciner in NWCF by closing the valves in the calcine transport and transport air return lines. Opening the valve on the exhaust side of the dual HEPA filters will then allow the bins pressure to equilibrate with the atmosphere.

During filling operations, interruption of the calcine transport system vacuum must be avoided. Therefore the valve on the exhaust side of the filters is closed to prevent suction of atmospheric air into the system. When this valve is closed the bins are protected by the vacuum and pressure relief valves, also shown in Fig. 1.

Transport and Fill System

The transport and fill system provides the remainder of the primary containment. This system consists of the calcine transport and transport air return lines, the cyclone separator, the distributor assembly, the expansion joint assemblies and connecting piping to the bins. Figure 1 includes a schematic depiction of this system.

Outside of the vault the transport line, a spare transport line, the transport air return line and the steam trace line run underground to the NWCF. All four of these lines are enclosed in a 45.7 cm diameter stainless steel encasement, which is encapsulated in reinforced concrete.

The cyclone separates the calcined solids from the transport air, drops them down into the distributor, and returns the transport air through the top of the cyclone to the NWCF. The limiting parameter for the 1.6 cm thick cyclone barrel is erosion; the barrel is fabricated from XM-29 stainless steel.

The distributor has a conical shaped flow splitter which diverts the calcine into the fourteen fill lines, two to each bin, located around the distributor periphery. The fill lines include expansion joint assemblies which are designed and tested to accommodate the thermal and seismic loads imposed on the piping. The distributor and the expansion joint assemblies are all fabricated from type 304L stainless steel.

Rodout lines, through which a flexible rod can be inserted to dislodge any calcine plug that may form, are provided at strategic locations. A rodout line is connected to each distributor fill line, and six locations in the transport and air return lines. Each rodout line extends through the cyclone cell roof into the metal building, is terminated with a blind flange and covered with a lead shielding cap.

Reinforced Concrete Vault

The second containment barrier consists of the heavily reinforced concrete structure (vault, second floor and roof) and transport line encasement. Figure 3 shows the significant features and dimensions of the vault. Figure 4 depicts typical reinforcing. The leveling slab is keyed into bedrock, approximately 15.3 meters below grade. The vault structure provides both the secondary containment and the required radiation protection, as discussed previously. The only penetration through the vault wall is the sump discharge line which penetrates the vault wall 0.7 meters above the ICPP Probable Maximum Flood Level elevation of 1498.5 meters. All vault wall joints below the elevation of 1499.2 meters incorporate a water stop.

The penetrations through the facility second floor (vault roof) include electrical conduit for temperature instrumentation, the bins vent manifold, fill system, sump monitoring and steam jet lines, vault cooling air inlet and exhaust ducts, and the retrieval pipes from the bins. The cooling air inlet and exhaust ducts can be isolated from the outside air by closing steel dampers. The retrieval pipes are covered by lead shielding plugs. Crane access to these plugs is through aligned hatches in the facility roof. The various fill, vent system, conduit, and sump lines are sealed penetrations.

The entire concrete structure was analyzed for conditions of dead weight, live, thermal, wind, tornado and seismic loading. The design thickness of the vault shell below the second floor is controlled by shielding requirements. Seismic loading governs the thickness of the walls above the second floor.

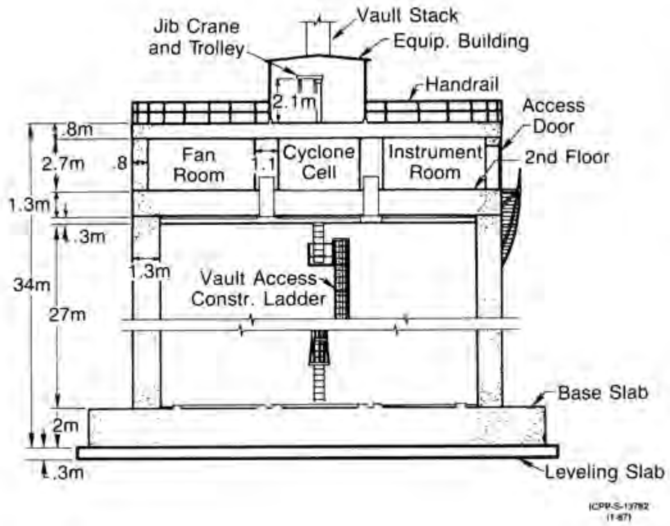

Fig. 3. Vault Cross Section.

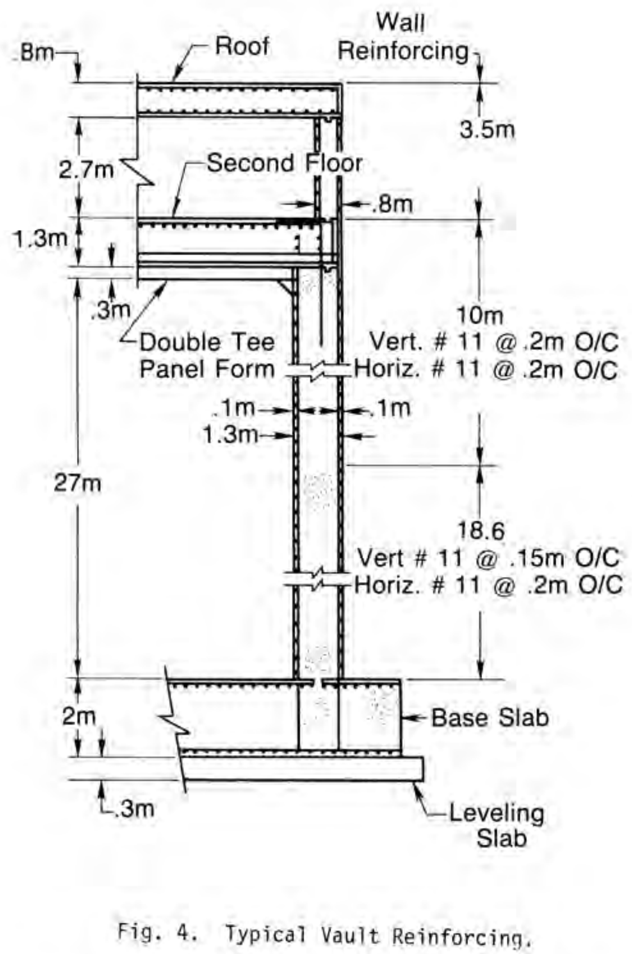

Fig. 4. Typical Vault Reinforcing.

The secondary containment for the transport lines to NWCF is the 1.9 meter by 2.2 meter reinforced concrete encasement, supported by pipe piles driven down to bedrock. The design of this encasement and supports is governed by the Safe Shutdown Earthquake.

Cooling Air System

To maintain the calcine below the caking temperature, and the facility structure below limiting temperatures, the facility is provided with a combined natural and forced convection cooling system. This system is shown schematically in Figure 5. Natural convection will provide 7,700 kg/hour cooling airflow; optionally, the in-line blower can be used to provide 45,000 kg/hour. A Constant Air Monitor (CAM) continuously samples the air leaving the exhaust plenum, and in the event of detection of radioactive contamination, the powered in-line air exhaust damper is signaled closed. One of the two centrifugal blowers is automatically turned on to exhaust the cooling air from the vault through HEPA filters. The second centrifugal blower is a standby.

Natural convection will provide adequate cooling to maintain calcine temperatures below the caking temperature for the expected calcine heat generation rate (100 w/m^3). The forced convection system is provided as a safety margin and will allow storage of calcine of up to 170 w/m^3. With natural convection, approximately 15 percent of the cooling air passes through the center of the bins; with forced convection, approximately 7 percent passes through the center.

Radiation/Contamination Control

In addition to the CAM which monitors exhaust plenum discharge airflow, a second CAM monitors the cyclone cell. In the event that radioactive calcine should be spilled into the cell this CAM will provide early detection. Thus corrective action can be initiated at on-set of failure and radiation exposure can be minimized. Both CAMs provide local (bin set) alarms and alarm signals to the NWCF Control Room.

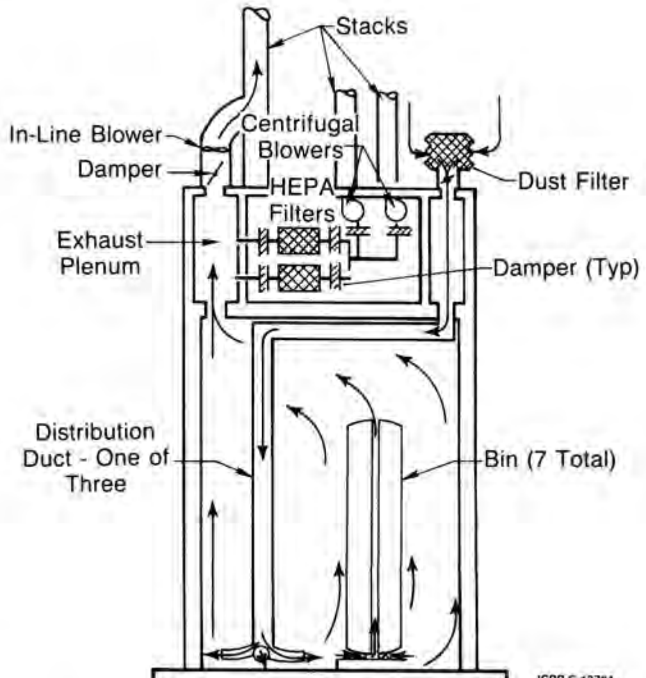

Fig. 5. General Arrangment of Vault Cooling Air System.

Two Remote Area Monitors (RAMs) are installed in the Bin Vent Filter Room. One RAM, mounted on the wall, will warn personnel of high radiation levels before they enter the room, thus allowing implementation of appropriate protective measures. The second RAM is mounted inside the shielding around the upstream HEPA filter. The purpose of this RAM is to advise of radioactive levels on the filter, and thus determine when the filter must be changed out. Both RAMs provide local alarms and alarm signals to the NWCF Control Room.

The bin sets also incorporate passive radiation and contamination control features. Special decontaminable epoxy paints are used in the Cyclone Cell, Cyclone Cell Access, and Bin Vent Filter Room. As described previously, the facility concrete walls are of sufficient thickness to provide the required radiation protection. Lead shielding plugs are used at retrieval pipe hatches, and lead bricks are used to shield around the upstream bin vent filter.

Instrumentation/Monitoring Systems

Instrumentation is provided to monitor the condition and operation of the bin set systems. This instrumentation is tabulated in Tables II and III. As listed in the tables, the readouts are either local in the bin set (instrument room, bin vent filter room, or fan room) or remote in the NWCF Control Room. The instrumentation is intended to provide information on:

a. Function of cooling air system and components;

b. Function of transport and cyclone separator system;

c. Condition and status of HEPA filters;

d. Radiation and contamination conditions;

e. Fill level of the bins.

TABLE II

7th Bin Set Temperature Instrumentation

Identification	Quantity	Readout
Bins Multipoint	196	Instrument Room
Bins Surfaces	42	Instrument Room
Vault Surfaces	18	Instrument Room
Distributor	1	Instrument Room
Cyclone and Cell Wall	2	Instrument Room
	1	NWCF
Transport and Air Return Lines	8	Instrument Room
	2	NWCF
Cooling Air System	2	Instrument Room

Temperature information used to determine fill level of the bins is provided by the multipoint thermocouple assemblies in each bin. The thermocouples are located at 1.5 meter intervals on each assembly, with the two assemblies in each bin offset by 0.75 meters, thus providing a temperature readout each 0.75 meters up the full height of the bins. The temperatures are monitored to determine the fill level of calcine in each bin, and to verify that calcine agglomeration temperatures are not exceeded.

TABLE III

7th Bin Set Pressure Instrumentation

Identification	Quantity	Readout
A. Transmitters		
Inlet Air Filter Pressure Drop	1	Instrument Room
Vault Sump Liquid Level	1	Instrument Room Alarm in NWCF
Cyclone Pressure Drop	1	NWCF
Calcine Transport Line	1	NWCF
Transport Air Return Line	1	NWCF
B. Gages		
Bins Vent Manifold	3	Instrument Room
Steam Supply Pressure	1	Instrument Room
Regulated Air Pressure	1	Instrument Room
HEPA Filters Pressure Drop		
Cooling Air	2	Fan Room
Bin Vent	2	Filter Room

In addition to the instrumentation listed in Tables II and III, material coupons from the various material heats used in the fabrication of the bins, welded by the same processes and welders at the same time as the bins are welded, are suspended in the vault and bins. One assembly of coupons is suspended in the vault air space, and five assemblies are suspended in each of two bins through separate nozzles and connecting pipes terminating in the facility second floor in the same manner as a solids retrieval pipe. These coupons can be retrieved at intervals throughout the life of the facility to assess the physical condition of the bins.

Utilities and Maintenance Features

The facility is provided with utilities necessary for operation and maintenance. Plant steam is provided for steam tracing of the solids transport line back to the NWCF, and to operate the vault sump jet. Plant air is provided and regulated for instrument air purge systems and for purging into the solids transport line if required. Electrical power is provided to the facility for heating, lighting, operation of blower motors, and instrumentation and controls. Two 480 volt, 60 amp, welding receptacles are provided. The facility also has an intercom system between the instrument and fan rooms and a telephone.

Various special maintenance features are designed into the facility. Two jib cranes are installed on the roof. One crane will remove the cyclone cell roof hatch; both the hatch and crane are located inside a metal building. The second crane can both raise loads to the facility roof and remove the hatch of the cyclone access cell. These two hatches provide two different routes for access into the cyclone cell. Six inspection ports are provided in the facility second floor (vault roof) that may be used to visually examine the vault interior with remote viewing devices.

All pressure transmitters and gages are accessible for calibration. HEPA filters are located with adequate clear space for filter changeout operations. The filter housings and ducting have all ports required for in-place Dioctyl Pthalate (DOP) testing. All blowers and motors are accessible for maintenance. The bins vent relief valve system has built-in test ports and isolation valves to allow in-place calibration.

BIN SET OPERATION

Chemical and radiochemical analyses are performed on the liquid wastes fed to the calciner as the storage facility is filled. Calculations are performed using these analyses to determine the heat generation rates at the time of calcination for the specific calcines being generated. The calculated heat generation rates, together with measured stored calcine temperatures, are used to determine if operation of the vault cooling air blower is required.

Bin thermocouple readings are used to establish when a storage facility is filled with calcine. As each storage facility is filled, the calcine transport system from the NWCF is switched to the next bin set. Valve line-up to accomplish the switch is performed at each bin set. Following the switch, the filled storage facility is isolated from the NWCF by closing the redundant valves in the supply and return lines adjacent to the cyclone. The bins are then vented to the atmosphere through double HEPA filters. Isolated storage facilities are routinely monitored to assure continued containment of the radioactive calcine at safe storage temperatures.

CONCLUSIONS

Calcination of high level radioactive liquid wastes, resulting from government nuclear fuel disposal, is performed at the Idaho Chemical Processing Plant to produce a dry, noncorrosive granular waste. Safe, on-site interim storage of the solidified waste is provided by the solids storage facilities. The facilities are designed to reliably contain the calcine for a minimum of 500 years, and to assure that the calcine remains free flowing for pneumatic retrieval. Access is provided for retrieval of the calcine for eventual waste immobilization and final disposal. The design features and the carefully documented and inspected fabrication and construction of the storage facilities assure the required containment and eventual retrieval.