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FINAL SAFETY ANALYSIS REPORT
FOR THE
FOURTH CALCINED SOLIDS STORAGE FACILITY

by

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SUMMARY AND CONCLUSIONS

Radioactive aqueous wastes generated by the solvent extraction of uranium from expended nuclear fuels at the Idaho Chemical Processing Plant (ICPP) are calcined to granular solids in the Waste Calcining Facility (WCF). The calcined solids are transferred from the WCF to stainless steel bins enclosed in a concrete vault for interim storage of up to 500 yrs (the facility design life).

The Fourth Calcined Solids Storage Facility provides an additional 17,000 ft^3 of storage volume for calcined solids. A New Waste Calcining Facility (NWCF) which will be connected to the Fourth Calcined Solids Storage Facility is scheduled to replace the WCF.

Granular solids stored in the Fourth Calcined Solids Storage Facility will be contained in three stainless steel bins which are enclosed in a partially buried concrete vault. Both the bins and the vault are designed to provide complete containment of solids in event of failure of the other containment. Retrieval access lines are provided in the event that calcine retrieval becomes necessary.

The calcined solids consist of mixed metal oxides and fluorides. Typical radionuclide concentrations are 1 to 4 Ci/lb each of Sr-90 and Cs-137 and 0.01 Ci/lb of transuranics (mostly Pu-238). Strontium and cesium are readily leached from calcined solids by water, but the transuranics leach out very slowly. The calcined solids to be stored in the Fourth Calcined Solids Storage Facility have heat generation rates in the range of 5 to 15 Btu/hr-ft^3. Most calcined solids can be stored at temperatures up to 1200°F without sintering, but some of the solids may sinter as low as 1000°F.

Decay heat generated by the stored solids will be removed by conduction through the vault walls; however, for the first few years of use, supplementary cooling will be provided by natural convection of air through the vault. Inlet air will be filtered and effluent cooling air will be monitored by a system that will close the inlet damper if radioactive particulates are detected. If cooling

air is interrupted, a standard type HEPA filter assembly and blower can be easily connected to existing ducting. Cooling air can then be restored (if necessary) before sintering of the stored solids occurs.

The double containment provided by the storage facility will prevent release of radionuclides to the environment if either a bin or the vault is breached. A sump with a liquid level monitor is provided in the vault to collect any in-leakage that occurs. Any water that accumulates in the sump can be removed by the sump jet.

Vault shielding assures that the general radiation level at the exterior vault surfaces will be limited to less than 0.5 mRem/hr (beams may reach 3.5 mRem/hr). Shielding calculations have been performed to verify that these design criteria limits have been met.

The safety analysis indicates that the facility will withstand an earthquake with a bedrock acceleration of 0.33 g and a tornado with a maximum wind speed of 175 mph, without releasing calcined material to the environment.

The storage of calcined material is essentially a passive operation and presents very little opportunity for radionuclide release. There is essentially no possibility of an accidental explosion in the facility.

There would be a slight chance of release of radioactive particulates into the atmosphere as a result of a bin leak. The Design Basis Accident (DBA), which has a very low probability of actually occurring, postulates the spill of solids from an eroded fill line into the vault coupled with a failure of the radiation monitor. The maximum calculated radiation dose at the nearest INEL boundary as a result of the postulated DBA is 80 mRem to the bone (this represents 0.053% of 10 CFR 100 criteria).

TABLE OF CONTENTS

TABLES

I. INTRODUCTION

This Safety Analysis Report describes the Fourth Calcined Solids Storage Facility and presents the results of a safety evaluation of the facility including a design basis accident.

The Idaho Chemical Processing Plant (ICPP) is a multi-purpose facility for recovering enriched U-235 from a wide variety of spent reactor fuels. Solvent extraction processes employed in recovery of fissile materials generate radioactive liquid wastes containing nuclear fission products. These liquid wastes are stored for several years in cooled, stainless steel tanks to allow decay of most short-lived radionuclides prior to calcination.[(1)]

In the Waste Calcining Facility (WCF), liquid wastes are atomized in a hot-air-fluidized-bed of granular solids. Water vapor and gaseous decomposition products are carried with the fluidizing air to an off-gas cleanup system prior to discharge to the environment. Chemical and fission product salts in the waste coat the bed particles and are converted to the corresponding metallic oxides or fluorides. Solids are removed continuously from near the bottom of the bed and are transported by air to the storage vault where they are separated from the air in a cyclone and fall into the stainless steel storage bins.

A New Waste Calcining Facility (NWCF) is being designed to replace the WCF. The Fourth Calcined Solids Storage Facility will receive solids from the NWCF. The safety analysis for the operation of the NWCF is in a separate document.

There are currently three calcined solids storage facilities in service at ICPP; two are full and the third is being filled. The Fourth Calcined Solids Storage Facility provides an additional 17,000 ft^3 of storage. The new facility is similar to the existing facilities and will not alter appreciably the low risk level associated with existing storage of calcined solids. Double containment of the calcined solids is provided in three 12-ft diameter, 50-ft high, stainless steel bins enclosed in a reinforced concrete vault as shown in Figure 1. The facility is designed to withstand effects of local natural catastrophies, viz. flood, tornado and earthquake. Decay heat will be removed from the vault by conduction

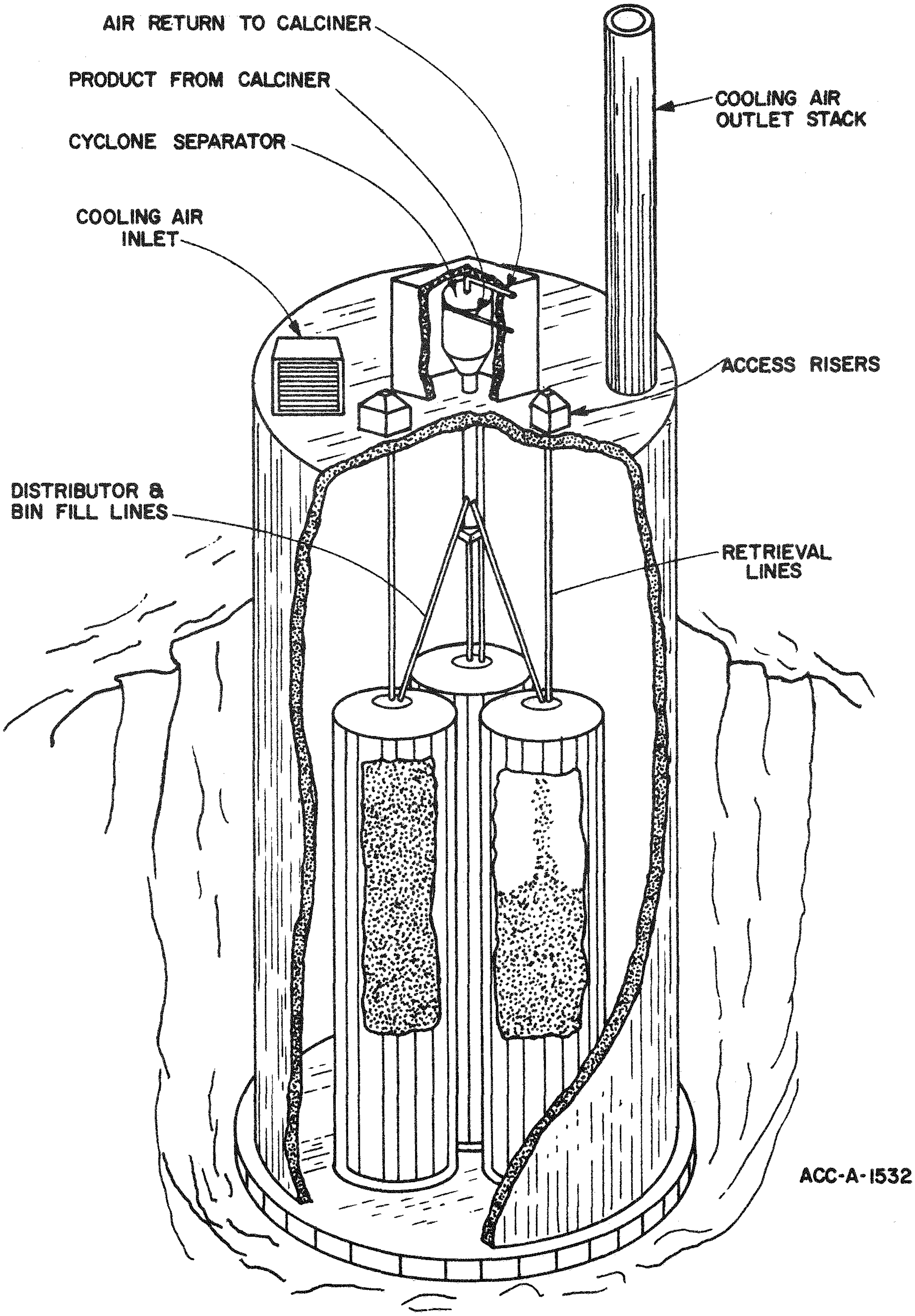

Fig. 1 Fourth Calcined Solids Storage Facility

through the vault walls to the surrounding air and soil. During the first few years of facility use, supplementary cooling will be provided by the natural convection of cooling air through the vault.

The new facility is similar to the existing calcined solids storage facilities[1]; however, the number of bins is reduced from seven to three.

II. FACILITY DESCRIPTION

1. SITE

The Idaho National Engineering Laboratory (INEL)--formerly the National Reactor Testing Station (NRTS)--was established in 1949 by the U.S. Atomic Energy Commission for testing various types of nuclear reactors, and associated equipment. The INEL is located along the western edge of the Upper Snake River Plain in southeastern Idaho. Lying at the foot of the Lost River, Lemhi and Beaverhead-Centennial Mountain Ranges, the INEL comprises an 894 square mile area with an average elevation of 5,000 ft above sea level. The Idaho Chemical Processing Plant (ICPP) is located in the south-central portion of the INEL, in Butte County, about 42 air miles west of Idaho Falls. Figure 2 shows the relative location of the ICPP, an enclosed area of approximately 100 acres, with respect to other facilities on the INEL. Figure 3 shows ICPP, the Test Reactor Facility in the background, and typical INEL landscape.

2. CLIMATE

The climate at INEL is arid, with an annual rainfall of approximately 8 in. per year.[2] Topographic features which affect the INEL weather patterns are the northeast-southwest orientation of the plain and the mountain ranges to the north and west. The INEL is relatively level with an average elevation of 5000 ft above sea level, but it is bounded by mountain ranges to the north and west that rise as high as 6000 ft above the plain. Surface winds are predominantly southwesterly and northeasterly. Air masses moving into the area are forced to cross mountain barriers and usually release their moisture over the mountains, entering the plain dry. The INEL climate is cool, with average maximum temperatures ranging from 28°F in mid-January to 89°F in mid-July. The average annual surface wind speed at the Central Facilities Area, about 3 miles south of the ICPP, is 7.5 mph. Severe thunderstorms with wind gusts over 50 mph and hail of 1/2-in. or greater diameter occur at a frequency of less than once per year. Since 1949, no confirmed tornadoes have occurred within the present boundaries of the INEL. Two small tornadoes have touched down just outside the INEL boundary but caused no damage. Ten confirmed funnel clouds and three unconfirmed funnel clouds have been recorded[3].

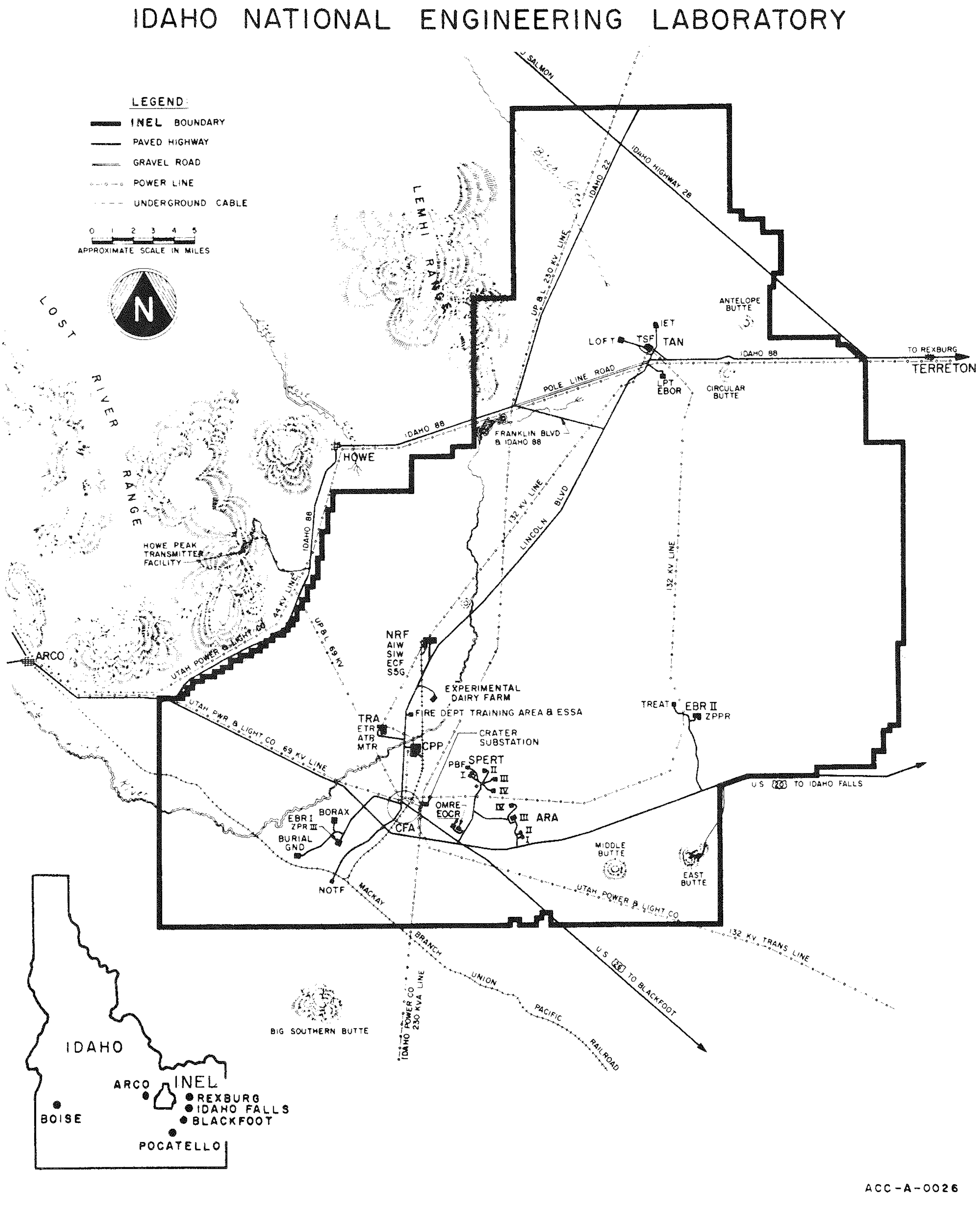

Figure 2. Detailed Map of the INEL

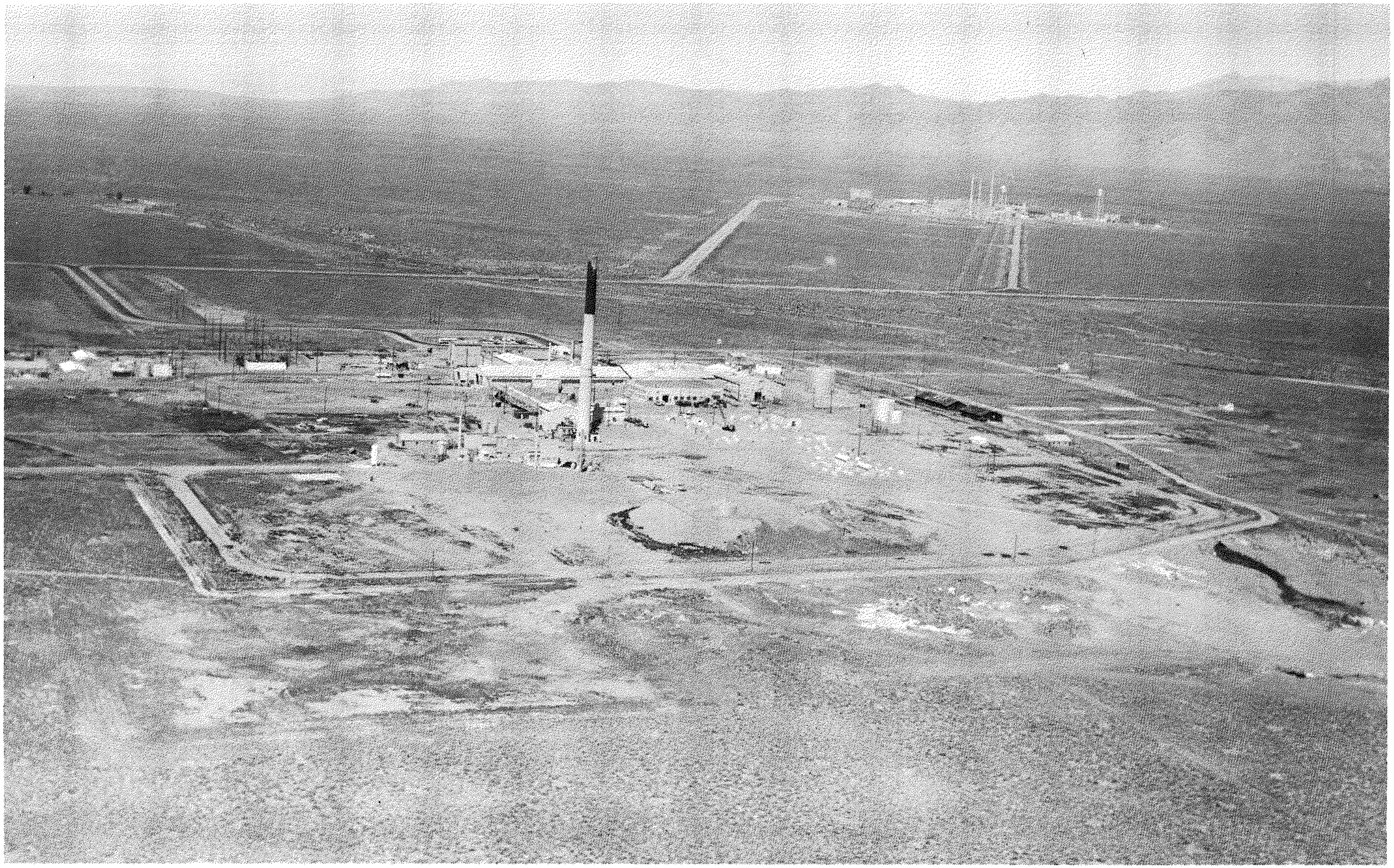

Figure 3. Aerial Photograph of ICPP and INEL Landscape

3. SEISMOLOGY

The seismic record of the Snake River Plain is short; the first recorded earthquake occurred in 1884. Since then, there have been 67 quakes of sufficient intensity to be classed as Modified Mercalli intensity of V or greater, i.e., strong enough to be noticed by nearly everyone in the area. These quakes originated at least 80 miles away from ICPP. The nearest active faults to ICPP are the Howe scarp located about 15 miles north and west of ICPP and the Arco scarp located several miles west of the Howe scarp.

The Snake River Plain in the vicinity of INEL is considered to be aseismic. This conclusion is based on the absence of microseismic activity in the area and on an aerial survey which revealed no evidence of faulting.

Both the Howe and Arco Scarps were excavated to determine displacement on existing faults. A maximum credible earthquake potential with a Richter magnitude of 7.75 was assigned to both faults[(4)] based on measured displacements and on historical records of earthquakes from similar faults in the Basin and Range Province. The strongest recorded earthquake (7.1 on the Richter scale) for the area occurred in August 1959 with an epicenter near the northwest corner of Yellowstone Park, approximately 100 miles northeast of INEL.

A calculation[(4)] of shock attenuation through 15 miles of basalt yields a bedrock acceleration at ICPP of 0.33g (10.6 ft/sec^2). The INEL is classified within Seismic Risk Zone 3 of the Uniform Building Code, 1970 edition[(5)].

4. HYDROLOGY

The INEL is adjacent to the foothills of the Lost River and Lemhi mountain ranges. INEL has no well-defined surface water drainage system and is not crossed by perennial streams. However, the INEL overlies the Snake River Plain aquifer whose thickness has been estimated at between 1,000 and 2,500 ft and which has an estimated lateral flow of at least 2,000 cfs.

Very little water enters the INEL by surface inflow and no water leaves by surface outflow except for minor local runoff. The streams flowing into the INEL are the Big Lost River, the Little Lost River and Birch Creek. Most of the water in these streams is diverted for irrigation purposes. Only the Big Lost River flows onto the INEL, and this flow disappears into a number of sinks within the INEL area. Flooding hazard from the Big Lost River has been largely eliminated by construction of a diversion channel to a holding basin in the southwest section of INEL. The ICPP is located about 1/2 mile south of the Big Lost River and is about 10 ft higher than the river bed.

5. ECOSYSTEM

The ecosystem of the INEL is typical for a semi-desert region and the ICPP area is typical of the INEL, except that large mammals are excluded from the area by a chain-link fence. The types of vegetation are limited, with the most prominent ground cover being a mixture of sagebrush, lanceleaf rabbitbrush, and a variety of grasses. This vegetation covers practically all of the INEL.

The vegetation supports a variety of desert rodents. Chipmunks and ground squirrels inhabit the shrub areas; the mixed grasslands are inhabited mainly by mice; the herb dry-lands are preferred by kangaroo rats, and, the white-footed mouse and the rabbits are found in all INEL areas. The only large mammals seen commonly on the INEL are the coyote, bobcat, and pronghorn antelope. Some migratory birds (doves, larks and hawks) inhabit the INEL during the summer. Other migrants such as eagles (golden and very rarely, bald) and waterfowl pass through the INEL in the spring and fall. Sage grouse and pheasant are the only resident game birds; however, hunting is not permitted on the INEL.

Aquatic life is not significant at the INEL.

Of special ecological interest are the flats (playas) that are subjected infrequently to flooding by the Big Lost River. These flats support a distinctive vegetation mixture composed almost solely of dense bluestem wheatgrass, and a small perennial herb, Iva Axillaris. These provide the most unique biota on the site.

6. ENVIRONMENTAL MONITORING

Monitoring of the environment and plant effluents is conducted by the INEL contractors, the Radiological and Environmental Sciences Laboratory (RESL) and the United States Geological Survey (USGS) in cooperation with the National Oceanic and Atmospheric Administration (NOAA). The monitoring programs have been in effect since the inception of the Idaho National Engineering Laboratory and have been updated and improved as new instruments and techniques became available.

The comprehensive program includes monitoring within the INEL boundaries, and monitoring of the off-site areas surrounding the INEL. Routine monitoring programs include determination of integrated direct radiation exposures, composition of waste effluents (both air and water), water quality, noxious gas release, bioassay, airborne contaminants, and soil radionuclides uptake. In addition special monitoring programs are conducted on an as-needed basis.

7. FACILITY

The Fourth Calcined Solids Storage Facility is located in the ICPP area approximately 350 ft east of the Waste Calcining Facility. The storage facility consists of three stainless steel storage bins enclosed in a reinforced concrete vault, and provides 17,000 ft^3 of storage for calcined solids. Other equipment included in the facility are a cyclone separator, vault cooling air system, bin vent system, fill system, vault sump system and various instrumentation. The bins, vault and all connecting piping, ducting, and valves used for primary or secondary containment are designed to resist the design basis tornado and the design basis earthquake.

7.1 Vault

The vault is a reinforced concrete structure approximately 65-ft high with an inside diameter of 36 ft. The vault floor is a slab 4.5-ft thick, 42-ft in diameter, set on and anchored to bedrock. Vault walls are 2.0-ft thick from the base slab to an elevation of approximately 40-ft and 3.5-ft thick from the 40-ft elevation to the top of the vault. The vault roof is supported by six precast, reinforced concrete beams.

Approximately two-thirds of the vault is below ground. The vault is of watertight construction and the excavation for the vault has been backfilled to prevent water from entering the vault. There are no vault penetrations at an elevation low enough to allow water infiltration even during the maximum credible flood. A 2-ft diameter by 3-ft deep sump in the southeast vault floor will accumulate any in-leakage that occurs. The sump level indicator will actuate an alarm and the water can be removed with the sump jet.

A hatch in the northeast quadrant of the roof allows access to the vault interior. (A steel construction ladder is attached to the vault wall directly below the hatch.) Other roof penetrations include inspection ports, rod-out lines, retrieval access lines, distributor pipe access, and cooling air ductway. Roof penetrations are sealed to prevent water in-flow or air out-flow. Roof penetrations exposed to the weather are curbed to prevent entry of rainwater.

An Equipment Vault and an Instrument Building are located on the vault roof. The shielded, heated cyclone cell is situated in the Equipment Vault centrally above the three storage bins. A stairway on the south exterior vault wall provides access to the roof, Instrument Building and Equipment Vault.

7.2 Bins

The storage bins are the primary containment for the radioactive calcined solids, and are designed to the requirements of Section VIII, Division II and Section IX of the ASME Boiler and Pressure Vessel Code. Bins are designed for storage of calcined solids with decay heat generation rates of up to 15 Btu/hr-ft^3 with low probability of sintering. Each of the three 12-ft diameter by 50-ft high stainless steel bins is anchored to the vault floor by twenty-four 2-1/4-in. diameter stainless steel bolts.

To provide retrieval capability, each bin is equipped with a pair of 6-in. diameter retrieval access lines. Retrieval access lines are routed from the tops of the bins in a straight line to access risers on the vault roof. The pair of

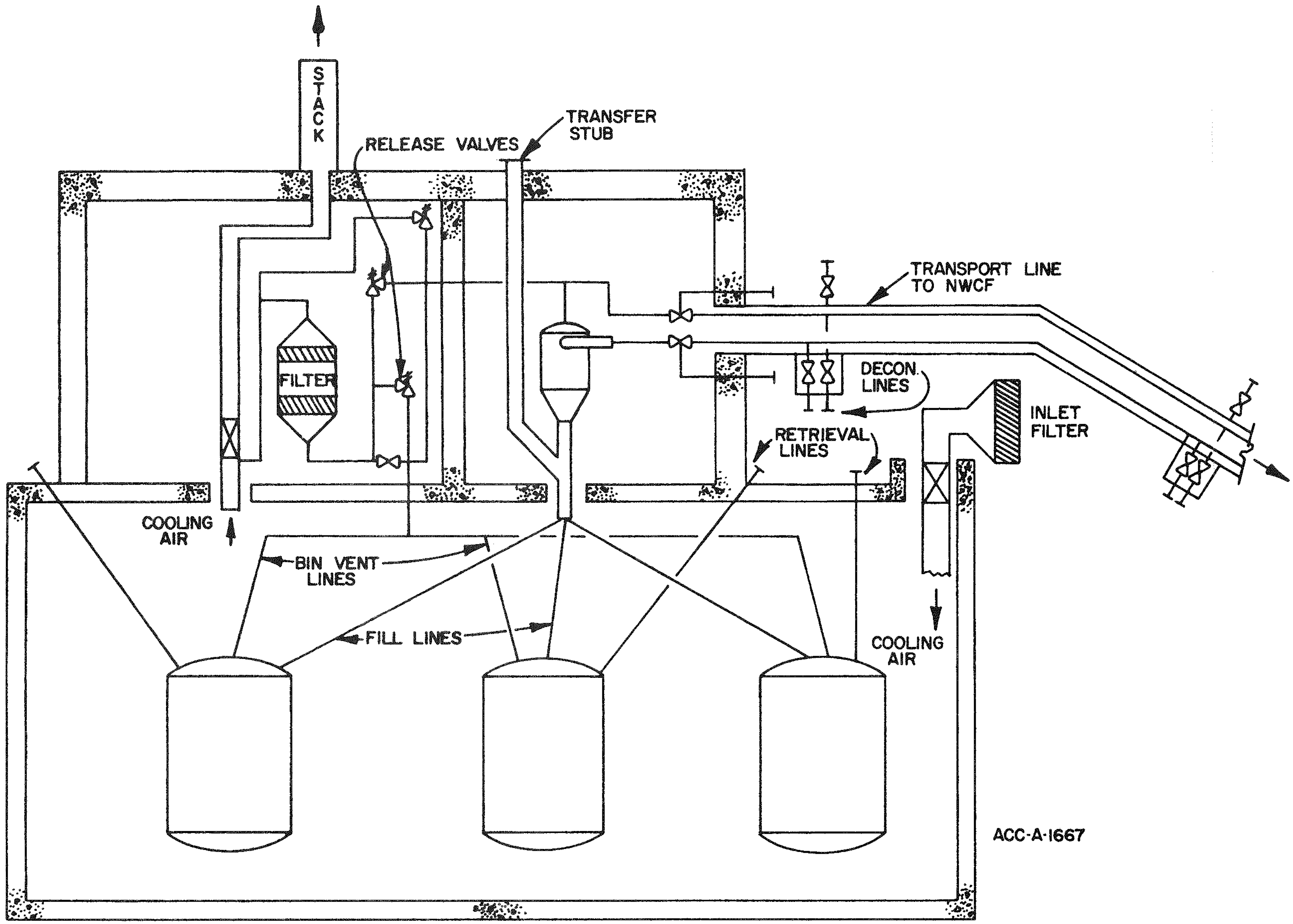

Figure 4. Solids and Air Flowsheet for 4th Calcined Solids Storage Facility

lines for each bin terminate in a common access riser. A retrieval system can be inserted through one of the access lines and the other access line can be used to observe the retrieval operation.

The bins are vented to a common line which is connected to a filter system, two pressure relief valves, and one vacuum relief valve. This common vent line discharges to the vault cooling air outlet duct downstream of the vault outlet damper. The vent system is isolated when the bins are filling and are connected to NWCF by the transport air lines.

Since temperature of the stored solids is critical, the following thermocouples are provided on the bins: (1) twelve thermocouples are installed on the centerline of each bin at 5-ft intervals from top to bottom; (2) three thermocouples are installed on each bin wall at mid-elevation at 120° intervals, and; (3) in addition to the above thermocouples, one bin has a pair of thermocouples, on opposite walls at elevations of 1/4 and 3/4 bin height.

One bin contains five cables of corrosion coupons. Each cable holds four coupons and each coupon consists of four materials typical of bin construction material. The coupons will be retrieved at different times to monitor bin wall corrosion rates under actual storage conditions.

7.3 Vault Cooling Air System

Heat generated by the stored solids is removed by conduction through the vault walls, but during the first few years of use supplemental cooling is provided by the vault cooling air system. The cooling air system utilizes natural convection to draw outside air through filters into the vault. Incoming air enters the vault near the floor, is heated, then rises and is discharged through the 3-ft diameter, 50-ft high stack on the vault roof.

Effluent cooling air is monitored by a radioactivity detection system capable of detecting gross beta or gross beta-gamma concentrations of 1×10^{-9} μCi/ml. If the radioactivity level reaches the detection system setpoint, an alarm is actuated and the inlet air damper is automatically closed. The inlet air damper is also closed if power is interrupted to the radioactivity detection system.

If particulate material responsible for actuating closure of the inlet damper originated in the vault, the outlet cooling air damper would be manually closed to isolate the vault. Vault cooling could be restored, if necessary, by moving an auxiliary blower and filter to the vault roof and connecting them to the cooling air ducting. Flanges are provided on the ducting to facilitate the auxiliary installation. It is estimated that the vault could be isolated for up to one month without sintering the stored solids[1].

7.4 Transport Air System

Calcined solids will be pneumatically transferred from the NWCF to the cyclone separator above the storage bins via 3-in. diameter piping. The transport and return air lines for this system are both enclosed in a 14-in. diameter, schedule 10 stainless steel pipe. Steam tracing inside the encasement pipe will be used to maintain the temperature of the transport lines above 175°F to preclude condensation which would cause plugging. The encasement pipe is sealed at both ends and is provided with a 1-in. diameter air sampling line at either end.

The transport lines are routed out the north wall of the cyclone cell, across the vault roof, down the outside of the north vault wall to an elevation approximately 10-ft below ground level then underground to NWCF. Because piping bends are exposed to concentrated erosion by calcined solids during transport, the number of bends in the pipe routing has been minimized. Where elbows are required, long radius bends are employed, hard alloy steels are used, and the outside of the bends are reinforced with wear plates. The cyclone separator is also made of hard alloys to resist erosion.

The 14-in. encasement pipe and the transport air lines are supported to resist effects of the design basis earthquake and to prevent sagging which could cause accumulation of moisture and/or solids.

Transport and return air lines are 3-in. diameter, schedule 40 pipe; different sections of pipe are fabricated of different materials as follows:

Elbows	Nitronic 50
Piping from NWCF to yard connection	Nitronic 50
Remaining transport air lines	304 L Stainless Steel

The 14 in. diameter encasement pipe is enclosed in a concrete duct for support and shielding. Lines are shielded to reduce radiation fields to less than 0.5 mRem/hr with the transport line half filled with solids.

7.5 Fill System

The fill system consists of the cyclone separator, distributor pipe and fill lines to each storage bin. Calcined solids enter the cyclone from the transport air line, separate from the air, fall through the 8-in. diameter distributor pipe, through the fill lines and into the bins.

The cyclone separator is located in a shielded cell in the Equipment Vault and is centered over the three storage bins. An electrical heater is provided to maintain the cyclone cell temperature at 175°F during operation.

The high efficiency cyclone is designed for a collection efficiency of 85% for 2μ particles, 95% for 5μ particles, and 99% for 10μ particles for a solid with a specific gravity of 2.3.

The fill lines for bins VES-WCS-142 and -144 are connected to the distributor pipe at the same elevation and these two bins will fill simultaneously. The third bin fill line connects to the distributor pipe at a lower elevation and also connects to the diverter valve at the bottom of the distributor pipe. Sequence of filling for the third bin (VES-WCS-143) is controlled by the diverter valve. Each 3-in. diameter fill line is fitted with an expansion joint to accommodate bin expansion due to a temperature increase from 20 to 250°F.

Blind-flanged cleanout lines accessible at the vault roof can be used to rod-out fill lines, distributor pipe and cyclone.

A pneumatic vibrator is installed on the cyclone to dislodge calcined material that adheres to cyclone surfaces. The vibrator is operated from the Instrument Building adjacent to the cyclone cell.

7.6 Instrumentation

The Fourth Calcined Solids Storage Facility includes instrumentation for monitoring various facility parameters, i.e., temperatures, pressure, flows, level, and radiation. Indicators are panel mounted and locally mounted in the Instrument Building on top of the vault. Refer to the Instrument Summary in Table I for individual instrument functions.

Temperatures of the storage bins are indicated on TI-WCS-1. Twelve thermocouples are installed on the centerline of each bin at 5-ft intervals from top to bottom; three thermocouples are installed on each bin wall at mid-elevation and at 120° intervals, and; bin VES-WCS-142 has a pair of thermocouples on opposite walls at elevations of 1/4 and 3/4 bin height. Temperatures of vault walls, cyclone, transport air inlet, transport air outlet and cyclone cell are also monitored.

Pressure indication is provided for the following: each storage bin, cyclone outlet, inlet and outlet vault cooling air, each of the purge air lines, and the steam line. Differential pressure is indicated across the cyclone, across the off-gas prefilter and across the off-gas HEPA filter.

Flow of purge air to transport air valves and decontamination valves is also indicated for each valve.

The vault sump liquid level is sensed by a differential pressure cell which inputs to a level indicator and a high level alarm.

A radiation detection system monitors the effluent vault cooling air for radioactive particulate material. In event of radioactivity levels high enough to trip the detector, an alarm is actuated and the inlet cooling air damper is closed automatically.

Prior to beginning filling of the Fourth Calcined Solids Storage Facility, the following instruments will be connected to the NWCF operating panel:

a. Pressure of transport air leaving cyclone

b. Outlet vault cooling air radiation monitor

c. Pressure drop across the cyclone

d. Cyclone surface temperature

e. Temperature of the transport air and transport air return lines in the cyclone cell

f. Liquid level detector-alarm for the vault sump

g. Vault cooling air radiation monitor

TABLE I

INSTRUMENT SUMMARY

Safety Related Instruments

RM-WCS-1

Function	--	RM-WCS-1 monitors the effuent vault cooling air for radioactive particulate material. If radioactivity reaches a preset level, this system will actuate an alarm in the NWCF control room office and automatically close the inlet vault cooling air damper.
Type	--	Constant Air Monitor, capable of detecting gross beta or gross beta-gamma concentrations of 1×10^{-9} μCi/ml
Range	--	0 - 50,000 CPM
Alarm	--	Adjustable
Location	--	Instrument Building

Process Instruments

TI-WCS-1

Function	--	TI-WCS-1 monitors bin, vault and transport air system temperatures
Type	--	Digital display indicator, Leeds and Northrup 923-3121-1 or equal, for chromel-alumel thermocouples, 110 Vac-60 Hz power
Range	--	0 to 2500^{o}F
Alarm	--	Alarm is actuated on Instrument Building panel on "High Temperature Transport Air Return Line".
Location	--	Instrument Building Panel

TABLE I

INSTRUMENT SUMMARY (Continued)

The outputs of the following thermocouples are indicated on TI-WCS-1:

TE-WCS-1-1 through -12	VES-WCS-143 centerline temperatures
TE-WCS-1-13 through -24	VES-WCS-144 centerline temperatures
TE-WCS-1-25 through -36	VES-WCS-142 centerline temperatures
TE-WCS-37, -38 and -39	VES-WCS-143 wall temperatures
TE-WCS-40,-41 and -42	VES-WCS-144 wall temperatures
TE-WCS-43 through -49	VES-WCS-142 wall temperatures
TE-WCS-50 through -57	Vault wall temperatures
TE-WCS-58	Vault outlet air temperature
TE-WCS-59	Transport air inlet temperature
TE-WCS-60	Transport air outlet temperature

TI-WCS-2

Function -- TI-WCS-2 monitors the transport outlet air from the cyclone via TE-WCS-2-2/3-1

Type -- Remote meter for type K thermocouple

Range -- 100 to 600^{O}F

Location -- Instrument Building Panel

TI-WCS-3

Function -- TI-WCS-3 monitors the cyclone surface temperature via TE-WCS-2-3

Type -- Remote meter for type K thermocouple

Range -- 100 to 600^{O}F

Location -- Instrument Building Panel

TI-WCS-4

Function -- Monitors Equipment Vault temperature via type J TE-WCS-4-1. Input to temperature controller TC-WCS-1

Type -- Remote meter for type J thermocouple

Range -- 0 to 250°F

Location -- Instrument Building Panel

TABLE I

INSTRUMENT SUMMARY (Continued)

PI-WCS-142,
-143 and -144

Function -- PI-WCS-142, -143 and -144 provide pressure indication for bins VES-WCS-142, -143, and -144 respectively

Type -- Pressure indicator, Dwyer Magnehelic No. 2300 or equal

Range -- -15 to + 15 in. of H_2O

Location -- Instrument Building Panel

PR-WCS-1/PdR-WCS-1

Function -- Monitors transport air return pressure and cyclone differential pressure.

Type -- Two point recorder -- left side is -50 in. to + 50 in. of H_2O and right side is 0 to 10 in. -- 4 to 20 mA input, 1 in./hr chart speed

Location -- Instrument Building Panel

Purge Air Pressure Indicators

Function -- These unnumbered indicators monitor the air purge pressure to transport air and decontamination valves

Type -- Ashcraft No. 1010 or equal, 6 in.

Range -- 0 to 60 psi

Location -- Instrument Building, locally mounted

Steam Pressure Indicator

Function -- Monitor pressure of steam line

Type -- Ashcraft No. 1010 or equal, 6 in., for steam service

Range -- 0 to 150 psi

Location -- Instrument Building, locally mounted

TABLE I

INSTRUMENT SUMMARY (Continued)

PPI-WCS-VG-1 and -2

Function -- Monitor vault inlet and outlet cooling air pressure respectively

Type -- Dwyer Magnehelic 2000-0 or equal

Range -- 0 to 0.5 in. of H_2O

Location -- Instrument Building Panel

Off-Gas Prefilter and Filter Pressure Differential

Function -- Monitor the pressure drop across the filters on the bin off-gas vent system

Type -- Dwyer Magnehelic 2010 or equal

Range -- 0 to 10 in. of H_2O

Location -- Equipment Vault, locally mounted

LI-WCS-1

Function -- Monitor vault sump level and actuate a high level alarm if water enters the sump

Type -- Foxboro 65 HV-OJT indicator or equal, 4 to 20 mA input

Range -- 0 to 50 scale

Location -- Instrument Building Panel

FI-WCS-TA-1, -2, -3 and -4

Function -- Measure purge flow rates to transport air line valves and the decontamination station

Type -- Purge meter, Fisher-Porter 10A3135N-53R-2110 or equal

Range -- 5 to 45 scfh

Location -- Instrument Building, locally mounted

FI-WCS-145

Function -- Flow meter for the diverter valve

Type -- Flow meter, Fisher-Porter 10A-3535A or equal

Range -- 0 to 25 scfm

Location -- Instrument Building, locally mounted

TABLE I

INSTRUMENT SUMMARY (Continued)

FI-WCS-VG-1

Function	--	Measures purge air to signal lines
Type	--	Purge meter, Fisher-Porter 10A3135N-53R-2110 or equal
Range	--	0.2 to 2 scfh
Location	--	Instrument Building, locally mounted

7.7 Equipment Summary

Table II summarizes major equipment items associated with the Fourth Calcined Solids Storage Facility.

TABLE II

EQUIPMENT SUMMARY

1. Bins	
Dimensions	12-ft O.D. by 50-ft high, wall thickness varies from 0.609 to 0.359 in.
Design Parameters:	
Temperature	250°F
Pressure Range	-3.75 to + 3.75 psig
Life	500 yrs
Material of Construction	304L stainless steel
2. Vault Cooling System	
Filters	Replaceable, 85% efficient - NBS spot test
Dampers	The inlet damper is a motor operated unit with spring-to-close, power-to-open operation. Sized for installation in a 24 X 24-in. duct, this damper is connected to the radiation monitor system and will close automatically on high particulate radiation or on power failure. The cooling air outlet motorized damper is similar to the inlet damper except it is not wired for automatic operation and is sized for a 46- by 24-in. duct. The manual outlet damper is the same as the motorized damper except for manual operation.
Ducting	All ducting in the vault (except transitions) is 26-in. diameter, 10 gauge stainless steel designed for 250°F and a pressure of 6-in. of H_2O. Ducting above the vault is carbon steel. The inlet filter-to-vault ducting is 24 by 24-in. and the vault-to-stack ducting is 46 by 24-in.
Stack	The stack is a 36-in. I.D., 7/16-in. wall, carbon steel pipe 50-ft high, anchored to the vault roof.

TABLE II

EQUIPMENT SUMMARY (Continued)

3. Fill System

Cyclone Separator

Design Parameters:	
Temperature	500°F
Pressure Range	-15 in. of Hg to 30 psig
Pressure Drop	4-in. W.G. with a gas flow of 175 scfm at 175°F and 12 psia
Gas Flow	150 to 200 scfm at 210°F and 12 psia
Solids Load	1000 lb/hr (during bed unloading only, average anticipated load is 180 lb/hr)
Corrosion and Erosion Allowance	0.125 in.
Materials of Construction	Nitronic 33 -- connecting stubs are Nitronic 32

Distributor Pipe

Dimensions	8-in. diameter schedule 40 by 8-ft 8-7/8-in. long
Design parameters:	
Temperature	250°F
Pressure Range	15-in. of Hg vacuum to 30 psig
Materials of Construction	304 stainless steel with 17-4 PH tips

Fill Piping

Dimensions	3-in. diameter schedule 40, run from distributor pipe to applicable bins. Each fill line contains an 11-ft long expansion joint assembly fitted with bellows at each end to accommodate thermal expansion of bins
Design Parameters:	
Temperature	250°F
Pressure Range	± 3.75 psig
Material of Construction	304 stainless steel

TABLE II

EQUIPMENT SUMMARY (Continued)

4. Transport Air System

Transport Piping	
Dimensions	3-in. diameter schedule 40, elbows are long bend radii with 0.460-in. wall and with an extra 1/4-in. of metal on the outside of the bend.
Design Parameters:	
Temperature	250°F
Pressure	150 psi internal and 3.75 psi external
Materials of Construction	Long radius bend elbows are Nitronic 50, piping from NWCF to yard connection is Nitronic 50 and remainder of piping is 304L stainless steel
Encasement Piping	14-in. diameter, schedule 10 stainless steel
Valves	3-in. ball, stainless steel

5. Off-Gas Vent system

Pre-filter and filter	Both filters are HEPA filters with a flow rate of 175 scfm at 1-in. W. G. and capable of 500 scfm and a static pressure peak of ± 3 psi
Pressure Relief Valves	
Design Parameters:	
Temperature	500°F
Pressure	150 psi internal and 3.75 psi external
Material of Construction	316 stainless steel
Low Pressure Relief Valve	3-in. for + 2 psig/@ 2.75 psig, minimum flow to be 9000 scfh
High Pressure Relief Valve	4-in. for + 3 psig/@ 3.75 psig minimum flow to be 21,000 scfh
Vacuum Relief Valve	4-in. for - 3 psig/@ 3.75 psig minimum flow to be 30,000 scfh

TABLE II

EQUIPMENT SUMMARY (Continued)

6. Vault Sump Jet

Steam operating pressure	110 to 125 psig
Maximum operating temperature	350°F
Liquid pumped	Water @100 ± 5°F
Specific gravity	0.904
Flow rate	10 gpm @100°F ± 5
Discharge head	100-ft
Suction lift	3-ft
Material of Construction	300 series stainless steel

III. PROCESS DESCRIPTION

Operation of the Calcined Solids Storage Facility is relatively simple because it is essentially a passive operation.

During filling, the calcined solids are carried from the calciner by transport air to the storage facility cyclone where solids are separated from the air and fall into the bins. Transport air returns to the calciner.

The transport system and bins operate at a slight vacuum (20 to 30 in. W. G.) produced by and dependent primarily on the calciner vacuum. The temperature of the calcined solids at the bin centerline is currently read once a week.

One potentially hazardous operation performed occasionally is the rod-out of a plugged line. Cyclone, distributor pipe, and fill lines are equipped with rod-out lines accessible from the vault roof. A long tool can be inserted into the rod-out line (after removal of the blind flange) and can be used to unplug the applicable line. The contaminated rod-out tool is then removed and placed in a plastic bag for disposal. This operation is performed with care and is monitored by a Health Physics Technician to minimize contamination spread and radiation exposure of personnel. Some radiation exposure will be incurred in any event, during the removal and bagging of the contaminated tool.

After filling, the bins will be isolated from the calciner and vented through the off-gas vent system. The bins are then at atmospheric pressure and will "breathe" as ambient pressure fluctuates. During the first few years of bin use, cooling air will be circulated through the vault by natural convection. Later the vault will be isolated. The bin temperatures will continue to be monitored at a reduced frequency (currently monthly) after the bins begin to cool.

IV. CHARACTERISTICS OF CALCINED SOLIDS

The ICPP produces a variety of wastes from the reprocessing of reactor fuels composed of or clad with aluminum, Zircaloy or stainless steel. The principal calcined solids anticipated in the storage facility are from the calcination of: (1) zirconium-fluoride wastes, (2) a blend of zirconium-fluoride wastes with sodium-bearing wastes, and (3) a blend of aluminum and stainless steel nitrate wastes. Typical properties of the calcined solids are listed in Table III. Safety implications resulting from certain calcine properties are discussed below.

1. LEACHABILITY

Strontium and cesium, but not plutonium, are readily leached from fluoride calcine. In a 2000-hr leaching test[6] with distilled water at 77°F, 60% of the Cs-137 and 40% of the Sr-90 were leached from a fluoride calcine sample. However, in the same test only 0.1% of the plutonium was leached from the sample. The leachabilities of these blended calcines are expected to be roughly similar to those of the fluoride calcine because of the similar structure of the calcines.

2. SINTERING TEMPERATURES

Calcined solids can be readily retrieved from storage as long as they are in a free-flowing form. However, retrieval will become more difficult if the solids sinter into a large mass. Calcine "sintering temperatures" were measured in laboratory tests[19] with simulated, non-radioactive calcines to provide a basis for calcine storage temperature limits. A "sintering temperature" is not a precise number. The degree of sintering varies with temperature from a slight cohesiveness at lower temperatures to extensive melting and agglomeration at higher temperatures. The "sintering temperature" values used herein are the temperatures at which only a slight cohesiveness was observed in the laboratory tests and in which the calcine could be made free flowing by tapping the container.

TABLE III

TYPICAL PROPERTIES OF CALCINED SOLIDS

	Fluoride Calcine	Fluoride-Na waste blend	Aluminum-SS blend (estimated)
Composition, wt %			
Al_2O_3	15	15	65
ZrO_2	23	19	-
CaF_2	55	44	-
$Ca(NO_3)_2$	6	5	-
$NaNO_3$	-	16	1
Stainless steel oxides	-	-	32
Miscellaneous	1	1	2
Bulk Density, lb/ft^3	95	110	75
Thermal Conductivity, Btu/hr-ft-^oF	0.09-0.13	0.09-0.13	0.1-0.15
Sintering Temperature, ^oF	1200-1300	1000-1300	1300-1500
Decay Heat, Btu/hr-ft^3	5-40	5-40	5-40[a]
Sr-90, Ci/lb	1-4	1-4	1-4
Cs-137, Ci/lb	1-4	1-4	1-4
Total Transuranic, Ci/lb	1×10^{-2}	1×10^{-2}	1×10^{-3}
Pu-239, Ci/lb	2×10^{-4}	2×10^{-4}	5×10^{-4}
Other Fission Products, Ci/lb	0.3 - 30	0.3 - 30	0.3 - 30

(a) Calcines stored in the 4th CSSF should not have heat generation rates in excess of 11 Btu/hr-ft^3.

This temperature at which the calcine begins to cake is considered the temperature that cannot be exceeded without affecting calcine retrieval. The calcine should be free-flowing if stored at temperatures below the "sintering temperature". The measured "sintering temperature" of the calcined solids from a blend of fluoride and sodium-bearing wastes varies with the fraction of calcium added. The "sintering temperature" of the calcine formed when a stoichiometric fraction of calcium is added is about 1300°F. The addition of excess calcium decreases the "sintering temperature" in some cases to as low as 1000°F. The "sintering temperature" of solids from the calcination of blends of aluminum and stainless steel wastes has been determined to be slightly higher than other calcines.

3. FISSION PRODUCT MIGRATION

Ruthenium is the only fission product in the calcined solids that is sufficiently volatile to migrate in storage if the centerline temperature does not exceed 1300°F. The highly volatile fission products krypton, iodine, and tritium are driven off during the dissolution and calcination processes. In laboratory tests(7) in which a temperature gradient was placed across calcine samples, some ruthenium migrated from calcine at 1300°F and deposited in cooler zones where the temperature was about 1000°F. No migration of any other fission product was detected(8) at temperatures below 1475°F. In storage bins where the surface temperatures will be about 150°F, no release of volatile ruthenium is expected; no ruthenium release has been observed from existing facilities.

4. DECAY HEAT GENERATION RATE

The liquid wastes in storage when the Fourth Calcined Solids Storage Facility is filling are expected to produce solids with decay-heat generation rates of from 5 to possibly 40 Btu/hr-ft^3. The "cooler" (up to 10 or 15 Btu/hr-ft^3) wastes will be calcined first and the "hotter" waste (>15 Btu/hr-ft^3) will be held for later calcination and storage in facilities designed to store solids with higher decay-heat generation rates.

V. SAFETY EVALUATION

The Fourth Calcined Solids Storage Facility uses a double-containment principle to isolate the calcined solids from the environment. The solids will be stored in stainless-steel bins that are enclosed in a reinforced-concrete vault. Both the bins and vault are designed to contain the solids in the event the other containment is breached. Release of calcined solids into the atmosphere would require breaching of a bin or a fill line with subsequent leakage from the vault. The release of fission products into the Snake River aquifer underlying the ICPP would require breaching of both the bins and vault plus the leaching of the calcined solids by ground water not now present at ICPP. Consequently, the release of radionuclides from the Fourth Calcined Solids Storage Facility to the aquifer is extremely unlikely.

The Design Basis Accident (DBA) postulated for the Fourth Calcined Solids Storage Facility is a spill of calcined solids into the vault from a hole eroded in a fill line. When coupled with a failure of the cooling air radiation monitor (allowing the unhindered release of all small particles) for 16 hrs, the DBA results in a maximum total integrated dose to the bone, (the critical organ) of only 80 mRem at the INEL boundary.

The response of the Fourth Calcined Solids Storage Facility to a number of postulated conditions and incidents is discussed below. The discussion of a postulated incident here does not imply that the incident will or is expected to occur. Postulated abnormal occurrences are summarized in Table VI. There is no potential for criticality involved in the storage of calcined solids.

1. EXTERNAL CATASTROPHE

The following are potential events originating outside of the facility:

1.1 Earthquake

The bins, their anchors, and all connecting components needed for containment are designed according to the criteria of the ASME Boiler and Pressure Vessel Code (Section VIII) for resistance to the 0.33 g Design Basis Earthquake (DBE) coupled with the design pressure (or vacuum) and load. The general requirements of this code limit primary stresses to values less than the yield strength of the metal. However, the main design problem for the bins is to prevent buckling by an earthquake or the bin vacuum. To prevent buckling, the compressive wall stresses as a result of a DBE will be limited by code requirements that are much more restrictive than the general limits on tensile stress. Consequently, a DBE or any lesser earthquake should not result in any bin damage, breakage, or loss of fission products (refer to Appendix C for calculations of bin stress analysis). The loss of solids from piping broken in an earthquake should be slight because all piping attaches at the top of the bins.

The small possibility of a bin failure during an earthquake due to a defective bin weld cannot be ruled out. This possibility is considered under "Bin Failure" in this section of this document.

1.2 Tornado

The bins, vaults, and all connecting components required for double containment are designed to resist the design basis (175 mph) tornado and accompanying missiles. The maximum damage from a tornado would be the loss of the exhaust stack and the instrument station. The consequence of the loss of the exhaust stack during the period when natural-convection cooling is being used, would be a loss of vault cooling leading to a slight chance of calcine sintering but not to fission product release. The loss of the instrument station would eliminate the passive monitoring instruments which measure temperatures and pressures, but there would be no radioactivity release. The instruments could be repaired.

The tornado suction (0.75 psig) could rupture the filter on the bin vent system and release some of the bin air to the atmosphere. The volume of bin air removed will be restricted by the small piping--3-in. diameter or less--and the short duration--3 sec--of the tornado. The radioactive dust concentration in the bin atmosphere usually will be low because particles are introduced into the bin only during filling when the bins are isolated from the vent systems. After filling, the larger particles will settle out rapidly leaving only the sub-micron particles airborne. The quantity of sub-micron particles will be small because the cyclone is unable to collect them; the only sub-micron particles would be those formed by attrition during filling. Sub-micron particles formed during filling would be removed by agglomeration into larger particles and by settling. Hence, the quantity of radioactivity carried by the small volume of bin air removed by a tornado would be minor--certainly much less than released in the DBA.

1.3. Flood

The ICPP lies in a 3-mile-wide flood plain with a slope of 0.2 to 0.3%; consequently, any floods would be very broad and shallow. The maximum postulated flood (i.e., design-basis flood)[1,15] at ICPP would reach an elevation of 4916.6 ft. The Fourth Calcined Solids Storage Facility whose top will be 15 to 25 ft above the ground level will be unaffected by any flood.

1.4. Airplane Crash

An airplane crash into the vault roof or wall could in one extremely low-probability event penetrate the vault, demolish one or more bins, and disperse calcined solids into the atmosphere. The potential consequences include gross contamination of the INEL and possibly off-site areas of the upper Snake River Valley. The penetration of a jet airplane through the vault roof could result in demolition of one or more bins and an explosion (fuel) and fire leading to dispersal of large quantities of calcined solids through the hole in the vault into the atmosphere.

The airplane crash is not considered the DBA because of the extremely low probability of occurrence. Wall[10] has estimated crash incidences for an average plant location and penetration incidences for reinforced concrete. Penetration of the reinforced concrete wall or roof would require a direct hit by a large, high-velocity airplane striking the roof at a steep angle or the wall at a low angle. The airplane crash probability at the INEL is much lower than the national average[10] because of the low volume of air traffic over the INEL and is considered sufficiently low to eliminate the crash as a design consideration or DBA.

2. POTENTIAL INCIDENTS OF INTERNAL ORIGIN

The following sections consider potential facility breaches and other processes or incidents originating within the facility which might conceivably release radionuclides.

2.1 Explosion

An accidental explosion in a calcined solids storage bin is extremely unlikely because of the lack of a combustible or explosive material in the bins. Although the potential consequence of a bin explosion is severe (ruptured bins), the explosion in the bins is not selected as the DBA because of the extremely low probability of accumulating an explosive mixture in the bins. The introduction of explosive concentrations of combustible gases or vapors into the storage bins from the in-bed combustion process in the calciner vessel is extremely unlikely because: (1) the calciner effluent is not combustible under normal or expected abnormal conditions[11]; and (2) the storage bins are separated from the calciner and connected only by a length of transport line in which the calciner effluent will be diluted with (fresh) transport air. This is shown in Figure 5.

The calciner effluent normally contains less than 3% carbon monoxide, less than 1% hydrogen, and traces (0.01 to 0.06%) of hydrocarbons. These concentrations are well below the flammability limits of carbon monoxide (11%) and hydrogen (4%) in air.

Anticipated process upsets and abnormalities likewise do not produce a flammable effluent primarily because combustion continues to occur in the calciner vessel above the fluidized bed. Potential process upsets were simulated in pilot-plant tests[11]; none of the upsets tested produced a combustible or explosive effluent.

A potentially explosive mixture of kerosene vapor and air in the calciner effluent is conceivable as a result of a startup incident. The mixing without combustion of flowsheet quantities of kerosene and air (plus oxygen) would produce an explosive mixture containing 1.8% kerosene. Kerosene ignites

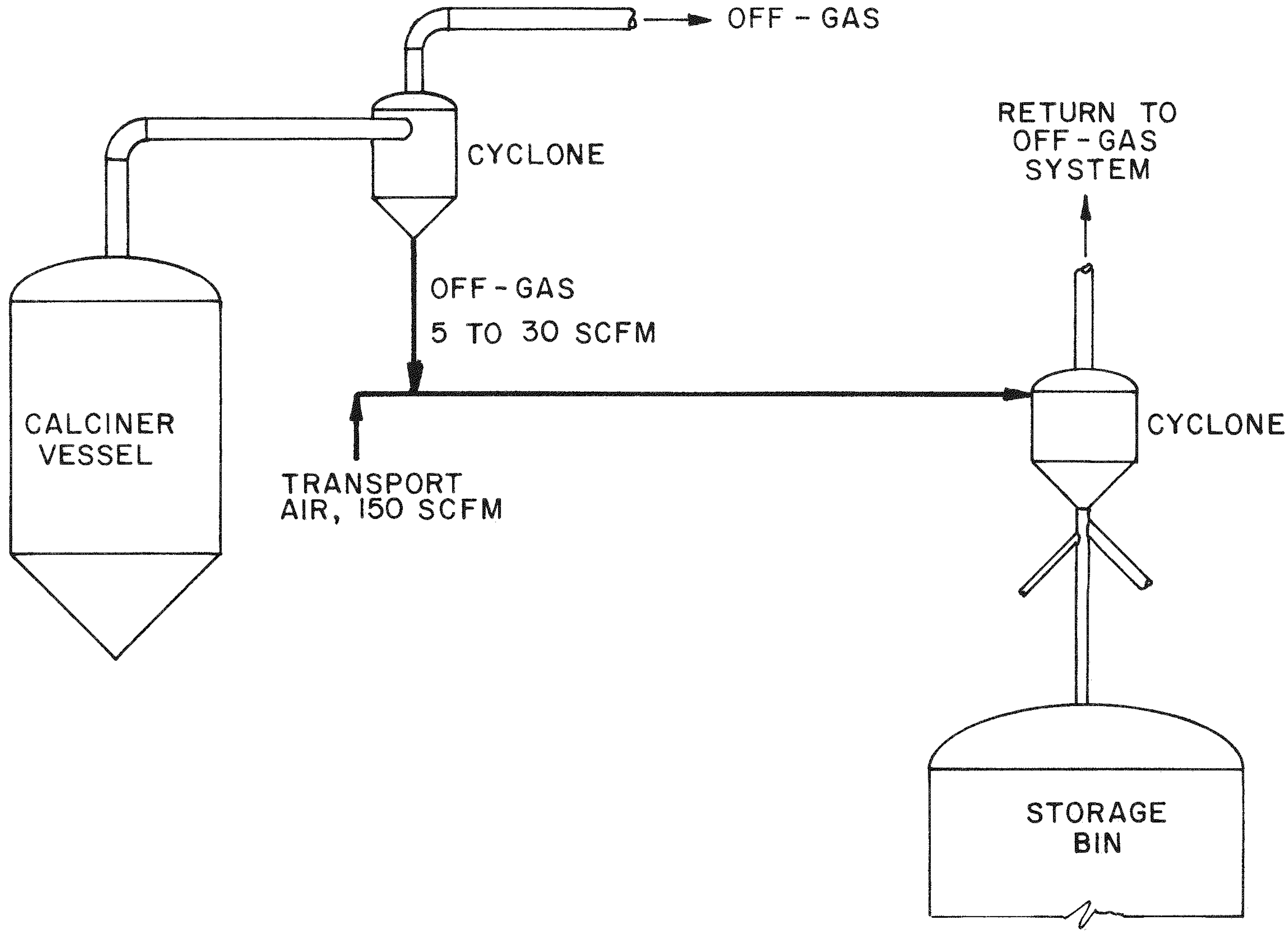

Figure 5. Simplified Transport System Flowsheet

spontaneously at temperatures above the auto-ignition temperature; hence, the formation of an explosive kerosene-air mixture in the calciner would require kerosene injection during start-up (or re-start) at a temperature below the auto-ignition temperature. This postulated incident would require two operating errors and an equipment failure: (1) the decision to open the fuel block and control valves and introduce kerosene at too low a temperature, (2) the failure of the automatic temperature interlock designed to valve off fuel injection at temperatures below the auto-ignition temperature; and, (3) failure to recognize that ignition was not occurring. The probability of all three errors or failures occurring in sequence is very low.

Combustible vapors can reach the storage bins from the calciner only through the solids transport line (see Figure 5) in which 5 to 30 scfm of calciner effluent will be diluted by a factor of 6 to 30 with 150 scfm of transport air. This dilution would reduce the kerosene vapor concentration from 1.8% in the calciner effluent to 0.06 to 0.3% which is below the 0.7% combustion limit for kerosene vapors. Hence, the postulated incident could not lead to an explosion in the bins.

It can also be postulated that kerosene vapors are forced into the bins by an overpressure of the calciner vessel at the same time as the previously-described fuel-injection incident. In this case, the hot calcined solids could ignite the gases; however, the probability of this occurring approaches zero. A calciner pressurization might occur if the off-gas system were plugged (e.g., at a mist collector) and the fluidizing air input continued. This would require: (1) that the off-gas system plug occur (none have occurred in 10 yrs of operation); (2) Operator failure to respond to a low-vacuum alarm on the calciner vessel; and (3) Operator failure to respond to an excessive vacuum alarm on the off-gas blowers followed by blower shut-down or failure. In order to cause a bin explosion hazard, the above three failures or oversights would have to occur at the same time as (or in rapid sequence with) the three errors or failures needed to inject fuel without ignition. That is, six distinct failures, errors, or oversights would be required. The probability approaches zero.

Radiolytic decomposition of the small quantity of moisture in the bins produces only trace concentrations of hydrogen in the bin atmosphere. There is sufficient circulation (primarily breathing) in the bins to prevent a long term buildup of oxygen. The observed hydrogen concentration in the existing bins is less than 0.01%.

In summary, the chances of accumulating an explosive atmosphere in the bins is sufficiently small to obviate the detailed evaluation of an accidental explosion.

2.2 Sintering

For the purposes of this analysis, sintering is defined as the point at which the calcined solids just begin to cake since caking could interfere with calcine retrieval. Laboratory tests(19) have shown that the lowest sintering temperature evidenced in a variety of ICPP calcine samples was in a calcine produced from three volumes of simulated first cycle zirconium-fluoride waste blended with one volume of simulated sodium-bearing waste. The calcine neither caked nor stuck to the side of the vessel containing it when heated for one month in an open ceramic container at 1100°F. When heated at 1200 and 1300°F for one week, the calcine caked slightly and stuck to the sides of the container. The cake could be broken and calcine freed from the sides by rotating the container. Calcine heated at 1380°F for three days caked but the cake could be broken by rotating the ceramic container. Within three days, calcine heated at 1470°F caked and the cake could not be broken even by tapping the container on a hard surface. Calcines from electrolytic wastes appear to have the highest sintering temperatures. A calcine of primarily electrolytic waste neither caked nor stuck to the sides of the container when heated in an open ceramic container at 1300°F for one month.

A maximum allowable storage bin centerline temperature of 1100°F has been selected to assure that stored calcine will not sinter. This temperature is obviously very conservative and should preclude calcine sintering even if the vault were isolated for up to two weeks during filling.

The maximum allowable decay-heat generation, Q_{max}, in a calcine bin depends on the calcine thermal conductivity, k, the bin radius, R, the temperature limit, T_{max}, and the wall temperature, T_W:

$$Q_{max} = \frac{4k\,(T_{max} - T_W)}{R^2}$$

Thermal conductivity values used in determining the maximum allowable decay heat generation rate are based on testing at Battelle Pacific Northwest Laboratories[20] on samples of fines and granules of simulated zirconium and zirconium-sodium blend calcines. Recommended thermal conductivities resulting from this testing are 0.13 Btu/hr-ft°F for zirconium calcines and 0.11 Btu/hr-ft-°F for calcines from a blend of zirconium-sodium waste.

The maintenance of the calcined solids in free flowing form depends on administrative controls used in selecting wastes for calcination and storage in the Fourth Calcined Solids Storage Facility whose decay heat will not result in bin centerline temperatures in excess of 1100°F.

Solids expected from calcination of long-cooled fluoride (zirconium) wastes have calculated decay heat generation rates of 5 to 10 Btu/hr-ft^3 and should cause no sintering problems as long as they are segregated from the hotter (up to 50 Btu/hr-ft^3) co-processing wastes. There will thus be ample volume of "cooler" wastes --mostly older fluoride wastes--in storage whose calcined solids can be readily stored in 12-ft diameter bins at temperatures well below the sintering temperatures of the calcined solids. Sintering will be prevented by either calculating from the age of the wastes that the decay heat generation rate for a particular liquid waste is less than Q_{max} or by sampling the liquid waste and calculating the decay heat generation rate from radiochemical analysis.

An operational indication to avoid calcine sintering will be provided by monitoring of the bin centerline thermocouples and bin filling would be stopped if any of these thermocouples approached the 1100°F limit. Calcine liquid waste feed could then be changed to a waste with lower decay heat.

If the vault cooling were interrupted, bin temperatures would gradually increase, but based on temperature increases when bin sets 1 and 2 were isolated[8] approximately two weeks would be available to restore cooling without sintering the calcine. The consequence of calcine sintering would be increased difficulty in retrieval. There is no near term danger of release of radioactivity. The facility is expected to have a life of about 500 years which will allow decay of gamma emitters to a level where direct-contact methods could be used to retrieve the solids.

2.3 Loss of Vault Cooling

During the first few years of bin use, cooling air will be circulated by natural convection through the vault to supplement cooling by the conduction of heat through the vault walls. Cooling air could be lost in several ways. The radioactivity monitor on the cooling air discharge will automatically shutoff the cooling air flow if radioactivity is detected or if electrical power is interrupted. Radioactive particles could enter the vault cooling air through: (1) contamination of the outside air, (2) leakage of particulate material from the roof following a rod-out operation, or (3) leakage from a bin or fill line. Cooling air flow could also be lost if the inlet filters plugged or if the outlet stack were destroyed.

The consequence of interrupting vault cooling air flow would be an increase in the vault, bin, and calcine temperatures. During the first 1 to 5 yrs of bin use, there is a slight chance that the loss of vault cooling air might lead to calcine sintering if the bins were filled with calcine of the maximum allowable heat generation rate. The consequences of sintering were discussed in Section 2; no fission product release would occur. Emergency cooling can be provided if needed by connecting an auxiliary filter and blower section to the vault ventilation ducting and by venting cooling air through the auxiliary filter.

Operating experience[8] with the first and second bin sets has shown that natural air convection is completely adequate for cooling without forced convection. Both the first and second bin sets were deliberately isolated (cooling air shut off) when they contained calcine with approximately the same total heat generation rate as projected for the Fourth Calcined Solids Storage Facility (~200,000 Btu/hr).

The first bin set was isolated after being filled with hot alumina calcine. After the bins had been isolated, the temperature peaked two months later with the calcine temperature increasing 80°F. During the first month after isolation, the calcine temperature had increased approximately 70°F.

Similarly, the second bin set was isolated in March 1969, during the third WCF campaign while calcine was being added. In June 1969, calcine addition was stopped and in September 1969, peak temperatures were reached. At that time the bins contained hot alumina calcine and cooler zirconium calcine. The peak temperature increases due to vault isolation, calcine addition and seasonal temperature increases were 270°F in the alumina calcine and 180°F in the zirconium calcine. The maximum bin wall temperature was 180°F.

The operating experience with these two bin sets shows that only moderate temperature increases will occur due to vault isolation, and about two weeks would be available to install an auxiliary blower in the existing duct. A few years after filling, the calcine decay heat generation rate will have decreased sufficiently to allow isolation without sintering. In no case will vault isolation cause the bin design temperature to be exceeded.

2.4 Fission Product Volatilization or Migration

There will be no release of volatile fission products from the Fourth Calcined Solids Storage Facility. All the highly volatile fission products--krypton, iodine and tritium--are driven off during fuel dissolution and calcination. At the anticipated storage temperatures, some migration of ruthenium (only) could occur. The ruthenium will migrate from the high-temperature zones and condense in low-temperature zones. No ruthenium release occurs because the temperatures at the surface of the calcine are low--150 to 200°F. If the calcined solids were inadvertently allowed to overheat, some cesium could migrate from the high-temperature zones to cooler zones. Again, no release would occur because of the low temperatures at the calcine surface[8, 16].

2.5. Bin Failure

The bins will be welded according to the stringent fabrication and inspection requirements of the ASME Boiler and Pressure Vessel Code, Sections VIII and IX and also Idaho Chemical Programs Quality Assurance Procedures Manual. Nevertheless, there will remain a small possibility of a low-energy fracture path provided by a precipitated, embrittled, or otherwise defective weld as a result of a welding error or oversight, improper heat treatment, improper weld-rod selection, or weld contamination by an impurity. Late in the bin life there would also be a possibility of stress-corrosion cracking of a sensitized weld.

A (severely) defective weld is likely to fail if stressed by an earthquake. The bin contents would then be released to the vault floor. The radioactivity monitor on the vault cooling air discharge would automatically isolate the vault when airborne radioactivity was detected to prevent a large-scale release of the solids. The airborne solids release would be less than the DBA case discussed below and in Section 3. The presence of the spilled solids on the vault floor would not present a near-term hazard to the environment; the vault would still isolate the solids from the environment. Much of the spilled solids could probably be vacuumed from the vault floor. If any water leaked into the vault (from a crack in the roof), it would be collected in the vault-sump and removed. Final vault clean-up would require many decades of radionuclide decay to lower radiation to a level that would allow entry into the vault.

There is also a slight chance of a small leak as a result of undetected shipping or construction damage to the bins or of erosion of a hole in a fill line. The spill of calcined solids into the vault from an erosion hole in a fill line and subsequent leakage to the atmosphere is designated as the Design Basis Accident (DBA) and is discussed in detail in Section 3. The radiation monitor for the effluent vault air is sufficiently sensitive to prevent the undetected release of hazardous quantities of radionuclides. The maximum undetected release (with 1000 CFM of cooling air) would be about 15 mCi/yr. The INEL-boundary dose from this release would be less than 0.001 mRem/yr, a larger leak would rapidly activate the automatic system to shut off the cooling air flow.

2.6 Vault Leakage

The leakage of precipitation into the vault would not result in a release of radionuclides. The bins would isolate the calcined solids from water in the vault. Any water that did leak into the vault would collect in the sump and be jetted out after sampling for radioactivity (contaminated liquids would be transferred to the PEW evaporators). It should also be noted that the soil at the ICPP is sub-saturated; moisture does not drain from the soil into voids. Water can enter the vault only by channelling of rainwater or snowmelt through voids in the ground to a crack in the vault.

2.7 Transport Line Leak

Erosion of a hole in the transport air line through which the calcined solids are transferred to the storage facility is a possiblity. No release of radionuclides to the environment would result because the transport and air-return lines are encased in a stainless steel pipe. Leakage through a hole in the transport air line would be small because the lines usually operate under vacuum. Some solids leakage into the encasement could occur if the transport air line were pressurized to clear a plug or were decontaminated. The solids that leaked from the transport air line would still be contained by the encasement.

It is possible to sample the air in the transport line encasement and to decontaminate the encasement. The encasement has connections through which decontamination solutions can be introduced. The encasement can be drained to the NWCF hot sump if required.

During filling of the Third Calcined Solids Storage Facility, holes were eroded through the transport air line and through the cyclone inlet section. Solids were spilled in the cyclone cubicle from both holes. The spilled solids were removed by normal clean-up procedures, and there was no release of material to the environment (other than contamination on tools and workers clothing).

Piping for the Fourth Calcined Solids Storage Facility has been routed to minimize the use of elbows. Where required, elbows have 5-ft bend radii with a buildup of 1/4-in. on the outside of the curve.

3. DESIGN BASIS ACCIDENT

The Design Basis Accident (DBA) selected for this safety analysis is the leakage of solids into the vault, during filling, through a hole eroded in a bin fill line. The bin fill line leak is considered with and without two complications: (Case A) a reduction in the transport system operating vacuum and the radiation monitor functional, and (Case B) the same as Case A except with a failure of the radiation monitor on the vault cooling air discharge. The fill line breach is selected as the DBA because it is possible (but not very likely) and has consequences similar to or worse than other potential bin breaches. Some erosion holes have occurred in the transport lines of the existing WCF but not in the bins or their fill lines. However, not enough is know about erosion rates to say with certainty that a hole will not be eroded in filling the somewhat larger (than the second bin set) bins in the Fourth Calcined Solids Storage Facility. The spill from an erosion hole in the fill line is probably greater than from a breach due to construction damage. A massive breach of the bins is not considered credible because the bins are designed to resist the design basis earthquake. The aircraft crash discussed above is not considered because ot its low probability.

Case A -- Radiation Monitor Functional

The assumptions of Case A are:

1. The bin is 75% full when the hole in the fill line occurs.

2. The cooling air radioactivity monitor detects the spill, automatically closes the vault inlet damper, and activates the alarm. The vault outlet damper is closed manually.

3. Operations continue until the bin is full.

4. The fraction of the solids added after the line is first breached that would be spilled to the vault varies with bin vacuum from 1% under normal vacuum to 20% under reduced vacuum.

   The bins are normally filled under an operating vacuum of about 20-in. W.G. This operating vacuum would strongly inhibit solids leakage by producing an air in-leakage (opposing solids leakage) with a velocity of several hundred ft/min. Only a small fraction of the largest particles would be released; 1% is assumed for this analysis.

   The operating vacuum in the bins could be reduced (possibly to zero) by a flow restriction in the transport air return. A maximum release fraction of 20% is assumed for this case. The solids spill would be restricted by the hole size (small) even with a (unlikely) total loss of vacuum.

5. Ten percent of the solids spilled are in the "dust" size range and remain airborne.

   "Fines" would not be spilled because of the in-leakage of air. Some dust would be produced by attrition as the particles impact the bins and the vault floor. Also fines agglomerated on the large particles could be separated by collisions. The fraction of fines formed by these mechanisms should be well below 10%.

6. The leakage of vault air is 2% per day. Although the vault inlet and outlet valves will be closed, some leakage will occur through the valves and the vault hatches as a result of thermal expansion of the vault air and barometric pressure fluctuations. The vault temperature will increase when the vault is isolated. Due to the large heat capacity of the concrete vault and the surrounding soil, the bin temperature will increase very uniformly when the vault is isolated. Daily ambient temperature fluctuations will have a negligible effect on the bin temperatures. A thermal expansion of 1%/day is assumed as a result of a temperature increase of 5°F/day. Barometric pressure fluctuations amount to at most 1-in. Hg out of a total pressure of 25-in. Hg, i.e., 4%. When the barometric pressure falls, air will leak out of the vault; when the barometric pressure increases, air will leak back into the vault. The 2%/day leakage value is derived by assuming two barometric cycles per week and adding the contribution for thermal expansion.

7. The sizes of the airborne particles are initially evenly distributed over the range from 0μ to 20μ.

8. The leakage and release extend over a sufficiently long period that annual-average atmospheric dispersion factors are applicable.

9. Particle settling and deposition deplete the particle sizes larger than 5μ (deposition losses were not considered for the smaller particles).

10. The particles are released from the stack at a height of 75-ft (a ground-level release would result in a slightly lower radiation dose at the INEL boundary because of increased deposition losses on the ground).

Case B -- Radiation Monitor Failure

Case B adds to the assumptions of Case A, the short-term failure of the radiation monitor.

1. The start of the spill is undetected for 16 hrs because of monitor failure (e.g., failure of the blower that draws the air sample to the monitor). The failure is detected on the next monitor check 1 to 16 hrs later (Monitor checks are once a shift) and the vault is isolated. Cooling air circulation might continue for 16 hrs after the start of the leak.

2. The fraction of the (added) solids spilled is 0.5% with a normal vacuum and 10% with the reduced vacuum.

   A lower spill fraction and a smaller hole size is assumed than in Case A, because the radioactivity monitor failure is assumed to be detected within a maximum of 16 hrs after the start of the spill and before bin filling is stopped. The erosion-caused hole is assumed to increase in size as bin filling continues. Since it is assumed for Case A that the bins continue to be filled-after the hole is detected and the vault is isolated, the hole will continue to expand for several months.

3. Ten percent of the spilled solids are small airborne particles.

4. All of the small airborne particles are carried out of the vault (for the 16 hours) by the cooling air.

5. The sizes of the airborne particles are evenly distributed over the size range from 0 to 20μ.

6. Inversion (Class F) atmospheric conditions prevail.

7. The particles larger than 5μ are partially depleted by deposition on the ground.

8. The release height is 75 ft.

The calculated atmospheric release of radioactive solids (in lbs) is shown in Table IV. The calculation models are detailed in Appendix B. With the assumption (see Table III) of a radionuclide content of 4 Ci/lb of Sr-90, 4 Ci/lb of Cs-137, and 0.01 Ci/lb of Pu-238, the inhalation radiation doses were calculated for a person at the INEL boundary using the ICRP Lung Clearance Model. The maximum calculated doses (at the INEL boundary) are listed in Table V for each of the four subcases.

TABLE IV

CALCULATED CALCINE RELEASE TO THE ATMOSPHERE, LB.

	Case A	Case B
	Monitor Functions	Monitor Fails
Vacuum Normal	1	4
Vacuum Reduced	20	90

TABLE V

CALCULATED INHALATION DOSES*

AT THE NEAREST INEL BOUNDARY, mRem

	Monitor Functions	Monitor Fails
Vacuum Normal	0.4	80
Vacuum Reduced	7	1600**

* TID to the bone which is the critical organ

** This case is not designated the DBA because of the extremely low probability of all three failures occurring simultaneously.

The case with both the reduced vacuum and the radiation monitor failure is not considered credible because it would require three coincident failures. The radioactivity monitor failure and the reduced transport system vacuum would have to occur at nearly the same time as the hole eroded through the line. The most severe of the remaining cases is the normal vacuum leak coupled with the radiation monitor failure; the calculated maximum dose is 80 mRem. This case is designated the Design Basis Accident.

The presence of the spilled calcine--up to 280 ft^3 -- on the floor of the vault would not be a near-term concern. The vault would still isolate the calcine and most of the spilled solids could probably be vacuumed from the floor. If any groundwater leaked into the vault it would be collected in the sump and removed. If solids on the floor were wetted, they would probably cake and be difficult to remove.

There are means which could and probably would be used to mitigate the consequences of a sustained slow spill once the situation were recognized. The vault exhaust ducting is equipped with a blind-flanged tee to which a filter could be added to vent the vault. The speed at which a vent filter is attached would depend on how quickly the situation were recognized, the availability of materials (ducting, filter housings etc), and the procedural reviews required before opening the ducting and attaching the filter. The solids spill might also be controlled by shutting down or increasing the transport system vacuum. There would be no way of mitigating the consequences of a leak undetected because of a radiation monitor failure.

In summary, there is a low-probability of the leakage of calcined solids from an erosion hole in a fill line or from another small leak. Some fine solids would leak from the isolated vault; the maximum calculated radiation dose at the INEL boundary would be 0.4 mRem (TID to the bone). There is a very low probability that the calcine leak would coincide with either a radiation monitor failure or a reduction in system vacuum. The largest calculated radiation dose (at the INEL boundary) is 80 mRem (bone) for the case of the radiation monitor failure; this case is designated the Design Basis Accident. The probability of all three failures -- fill line leak, loss of vacuum, and radiation monitor -- is extremely low and does not give serious consideration.

TABLE VI

POSTULATED ABNORMAL OCCURRENCES FOR THE FOURTH CALCINED SOLIDS STORAGE FACILITY

Normal Operation	Postulated Abnormal Occurrences	Cause	NORMAL PREVENTION: Primary Safeguard	NORMAL PREVENTION: Secondary Safeguard	Detection	Correction and/or Control	POSSIBLE CONSEQUENCE OF ABNORMAL OCCURRENCE: This System	POSSIBLE CONSEQUENCE OF ABNORMAL OCCURRENCE: Other System
Storage	Activity Release	Design basis earthquake (0.33/g horizontal acceleration)	Bins are designed to withstand effects of the DBE	Vault is designed to withstand effects of the DBE		None	Possible damage to piping at top of bins with little or no release of activity	None
Storage	Activity Release	Design basis tornado (175 mph winds)	Vault is designed to withstand the effects of design basis tornado	Bins are designed to withstand the effects of design basis tornado		Repair and replace damaged or destroyed equipment. Restore vault cooling if necessary	Destruction of vault cooling stack and Instrument Building, loss of electrical power, possible slight release of radioactivity	None
Storage	Activity Release to aquifer	Design basis (10,000 yr) flood	Vault is water tight with no penetrations below level of 10,000 year flood	Bins isolate calcined solids from any water that might enter vault	If water does enter the vault, the sump level will alarm	If water does enter the vault, sample water and remove it with sump jet	None	None
Storage	Activity Release	Airplane crash into storage vault	Vault construction	Bin construction	Probability of this accident occurring is almost incredible		Vault pentration, demolition of one or more bins and dispersal of radioactive calcined solids	None
Filling	Activity Release	Explosion in a storage bin	Absence of combustible material in the calcined solids storage facility	Controls on NWCF operation and distance combustibles would have to travel (from NWCF) to bins	Probability of this accident occurring are too low to warrant analysis, (six errors or failures would have to occur simultaneously or in rapid sequence)		Release of radioactive material to atmosphere	None

TABLE VI (Continued)

POSTULATED ABNORMAL OCCURRENCES FOR THE FOURTH CALCINED SOLIDS STORAGE FACILITY

			NORMAL PREVENTION				POSSIBLE CONSEQUENCE OF ABNORMAL OCCURRENCE	
Normal Operation	Postulated Abnormal Occurrences	Cause	Primary Safeguard	Secondary Safeguard	Detection	Correction and/or Control	This System	Other System
Storage	Sintering	Storage of solids that generate more than 11 Btu/hr-ft^3	Bin and Vault design provide necessary cooling	Administrative controls on liquid wastes calcined	Bin high temperature alarm	Restore Vault cooling if shut off	There is no safety hazard, but retrieval would be more difficult	None
Storage	Sintering	Loss of vault cooling	Heat will be removed by conduction through vault walls	An auxiliary cooling system can be connected to blind flanges in cooling air ducting	Bin and vault high temperature alarm	Restore vault cooling	Sintering of stored calcined solids (no safety hazards involved)	None
Storage	Fission Product Volatilization or Migration	Storage of solids that generate more than 11 Btu/hr-ft^3	Bin and Vault design provide necessary cooling	Controls on liquid wastes calcined to avoid sintering		None	Ruthenium could migrate to lower temperature zones within the stored solids, but there would be no release	None
Storage	Activity Release	Bin Failure	Bin design	Vault design	High radiation effluent cooling air alarm	Vacuum any spilled solids from vault floor and restore vault cooling if necessary	Some solids could be spilled to vault floor but they would be contained by vault	None
Storage	Vault Leak	Earthquake	Vault design	Bin design	High vault sump level alarm	Sample vault sump and pump out water with sump jet	Solids are isolated in bins and no hazard involved	None
Filling	Activity Release	Transport Line Leak	Transport Pipe (material and design)	Containment pipe and concrete enclosure (vault and pipe enclosure).	High radiation effluent cooling air alarm	Vacuum any spilled solids from vault floor and repair failed line	If the radiation detection system failed in conjunction with this occurrence radioactive material would be released	Radiation exposure to personnel. Refer to DBA discussion.

VI. LONG TERM CONSIDERATIONS

The Fourth Calcined Solids Storage Facility is designed to provide both long-term interim storage and calcine retrievability capabilities. The calcined solids can be either retrieved and transferred, or stored for a long interim period. A nominal design life of 500 yrs has been chosen for the facility to provide a factor of 100,000 decay of Cs-137 and Sr-90. After 500 yrs of storage, only small concentrations of gamma emitters (0.01 to 0.04 mCi/lb of Cs-137 and 0.5 mCi/lb of Sm-151) will remain; the potential hazard of the calcined solids will then be almost entirely from the transuranic alpha emitters. The calcined solids could then be handled without the requirement for extensive gamma shielding.

Calcined solids could conceivably remain in storage in the Fourth Calcined Solids Storage Facility long after the ICPP has been shutdown. Some aspects of long-term interim storage are discussed below:

1. BIN LIFE

The life of the stainless steel bins is uncertain because of uncertainty of the actual weld conditions, surface contaminations, and environmental conditions. There appears to be no problem for the first 200 yrs of bin life during which the decay heat will keep the bins warm and dry. The total corrosion allowance of 0.016 in. is sufficient for 500 yrs under dry conditions. A corrosion allowance of 0.006 in. for the bin interior was obtained by extrapolating the observed corrosion of coupons exposed inside existing calcine bins for 2 yrs. A corrosion allowance of 0.010 in. for the bin exterior was obtained from data in the literature[12,13].

When the facility is over 200 yrs old, the bin walls could become moistened by condensation or by leakage through cracks in the roof. Sensitized welds would then be subject to corrosion and to stress-corrosion cracking by residual contamination of chlorides (and other corrosives). If corrosion cracking became extensive (in any weld), the bin would be vulnerable to failure in an earthquake.

The bin condition is monitored by corrosion coupons located both inside and outside the bins. The corrosion coupons are as representative as feasible of the bin materials: i.e., from the same material heats, welded in the same manner, and with the same surface treatments. The coupons will be retrieved periodically for inspection. It is also possible to remotely inspect the bin exterior through the vault inspection ports.

In conclusion, the bins should last at least 200 yrs. They may last several hundred years longer providing surface contamination by chlorides or other corrosive materials is low or if they remain dry.

2. VAULT LIFE

There is likewise some uncertainty about the long-term durability of the reinforced concrete vault. The concrete could deteriorate and the reinforcing steel could corrode but the vault exterior is accessible by removal of some dirt for inspection and possible repair. It will be possible to visually inspect (remotely) the interior of the vault. If necessary, it would be possible to construct a new vault around the vault.

3. SURVEILLANCE

The continued storage of calcined solids will require a modest surveillance effort to assure facility integrity and safety of the population of the surrounding area. The safety-related instrumentation consists of the radiation monitor on the vault cooling air, the thermocouples in the calcine, and the liquid detector in the vault sump. The greatest service effort will be required by the cooling-air radiation monitor which will require once-a-shift chart checks, weekly filter changes, and some servicing. After an initial decay period of 5 to 10 yrs, the vault cooling air system will probably be isolated. The radiation monitor could then be replaced by periodic (once a year) "grab" samples. The calcine and bin temperature measurements are required to guide bin fill operations and during changes in cooling conditions, e.g., vault isolation.

As a consequence of continuing radionuclide decay, the calcine temperatures will slowly decrease after reaching a peak value following bin filling or vault isolation. The measurement of bin and calcine temperatures could be discontinued after monitoring the temperature peak following vault isolation. Only the sump liquid detector monitoring requirement would remain after vault isolation. This instrument could be monitored remotely from another location but vault servicing would be required on an annual basis.

A periodic vault inspection (once every few years) would be required to verify facility integrity. The vault is equipped with an air sampler for sampling for radioactive particulates in the vault air, and a set of inspection ports through which a portable inspection device (TV camera, camera, or periscope) can be inserted for visual inspection of the floor, bin walls and vault walls. This inspection could be performed by personnel from another site if ICPP was not in operation. There would also be a long-term need to maintain a security fence and warning signs around the facility.

4. DECOMMISSIONING

It should be feasible to decommission the Fourth Calcined Solids Storage Facility when required. A postulated decontamination procedure assuming the solids are not sintered is outlined below.

The bulk of calcined solids could be retrieved from the bins by inserting a retrieval system through the retrieval access lines. Most of the residual radioactive solids clinging to the bins walls would then be removed by inserting decontamination nozzles through the retrieval access line, and spraying the walls with a decontamination solution such as nitric acid. The solution would be removed with a jet introduced through the retrieval access line. The facility should then be sufficiently decontaminated to allow personnel entry for final clean-up by direct contact methods. However, if the unexpected leakage of solids from a bin or fill line should occur, there would be surface contamination of the concrete surfaces inside the vault that would be difficult to remove. The facility could be razed after decontamination, but this probably would not be done because of the tremendous effort required to demolish and remove the reinforced concrete vault.

Decommissioning would be complicated if the calcined solids sintered. In this case it would be necessary to either wait about 500 yrs until the bins could be entered to remove the solids or until more sophisticated removal systems than are now available were developed.

VII. REFERENCES

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17. H. G. Spencer, et.al., ICPP Multiple Fuels Processing Programs FY 1967 Supplement Document, ACI-201, May 1977.

18. Private communication, dated July 17, 1978.

19. Private Communication, dated May 15, 1978.

20. Private communication, dated October 16, 1978.

APPENDIX A

SAFETY ANALYSIS REVIEW ASSUMPTIONS

TECHNICAL STANDARDS

Technical Standard (Operating Concern)

APPLICABILITY:

This standard applies to the 4th Calcined Solids Storage Facility (CSSF).

OBJECTIVE:

This standard is intended to prevent sintering (caking) of calcined solids stored in the 4th CSSF.

SPECIFICATION:

To prevent sintering, the heat generation rate of stored calcine must not exceed the value calculated in accordance with the following:

1. The decay heat generation rate of the calcine will be determined either by calculation based on the age and type of liquid waste or by radiochemical analysis of samples of the liquid waste.

2. The maximum allowable decay heat generation rate (Q_{max}) for the calcine to be stored in the Fourth Calcined Solids storage Facility shall be calculated as follows:

$$Q_{max} = \frac{4K\ (T_{max} - T_{wall})}{R^2}$$

$$Q_{max} = \frac{4K\ (1100°F - 200°F)}{36}$$

The values used for K (thermal conductivity) and T_{max} (maximum allowable storage temperature) may vary as more information becomes available. The most conservative, verified values in calculating Q_{max} shall be used.

Use 1100°F for T_{max} and for K use 0.11 Btu/hr-ft-°F for Zr-Na bearing calcine or 0.13 Btu/hr-ft-°F for Zr calcine, unless more recent verified values become available.

3. It will be verified that the heat generation rate of the calcine to be stored will not exceed Q_{max}.

BASIS:

The 4th CSSF is intended for interim storage of calcined solids; therefore, the solids must remain in a retrievable condition. Heat generation rates of calcined solids must be low enough so that temperatures never reach caking temperatures as defined in reference (1). Although not a safety factor, caking of the solids would drastically increase the cost of retrieval.

REFERENCES:

1. B. J. Newby letter to J. T. Nichols, Nby-7-78, "Caking Tests on Calcine from a Simulated Zirconium--Sodium Bearing Wastes Blend," dated May 15, 1978.

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SURVEILLANCE REQUIREMENTS:

PRIOR TO VAULT ISOLATION

1. Activity monitors shall be checked once a shift.

2. Calcine temperatures (bin centerline temperatures) shall be checked once a week while the bins are filling.

FOLLOWING VAULT ISOLATION

1. Yearly "grab" samples of vault air shall be taken once per year and analyzed for radioactive particulate.

2. The sump liquid level shall be monitored remotely on a daily basis.

APPENDIX B

CALCULATIONS

I. RELEASE WITH MONITOR FAILURE

Fill rate is 3600 gpd X 2 lb/gal = 7200 lb/d.

The release fraction through the small (initial) hole against the full vacuum is 0.5%

7200 lb/d X 0.005 = 36 lb/d.

The monitor failure is discovered after 16 hr.

36 lb/d X 2/3d = 24 lb.

The fraction of the spill in the "dust" size range is 10%. All of the small dust particles are released. The weight released is

0.1 X 24 lb = 2.4 lb

The (dust) particle sizes are assumed to be evenly distributed over the range 0 to 20μ.

0.3μ	5%
1.5μ	5%
3μ	10%
5μ	10%
7μ	10%
10μ	20%
15μ	30%
20μ	10%

The maximum radionuclide content is:

Cs-137	4 Ci/lb
Sr-90	4 Ci/lb
alpha (Pu-238)	0.01 Ci/lb

II. LEAKAGE FROM AN ISOLATED VAULT

The solids leaking into an isolated vault will settle out on the floor or other surfaces and thus be removed from the air. The deposition rate (in lb/d) is:

$$(86{,}400 \text{ s/d})\ V_s CA$$

where V_s is settling velocity, ft/sec

C is solids concentration, lb/ft^3

and A is the floor area, ft^2

With a steady input (I lb/d), the input and deposition rate will reach equilibrium;

$$I = 86{,}400\ V_s CA.$$

Solving for C gives

$$C = I/86{,}400\ V_s A$$

with a 2%/day leakage from the vault, the solids release rate is

$$R = 0.02\ AHC = \frac{0.02\ HI}{86{,}400\ V_s}$$

Where R is release, lb/day

and H is the vault height, ft.

The release fraction is $R/I = \dfrac{0.02H}{86{,}400\ V_s}$

The maximum spill rate (reduced vacuum) is assumed to be 20% while the last 1/4 of a bin is being filled:

0.2 X 7200 lb/day = 1440 lb/day,

0.2 X 1/4 X 567,000 lb = 28,000 lb. total

with 10% in the "dust" size range, the airborne input terms are

$$I = \begin{cases} 144 \text{ lb/d} \\ 2800 \text{ lb total} \end{cases}$$

The preliminary release calculation is summarized (for H = 70 ft) in Table B-1 below:

TABLE B-1

SOLIDS LEAKAGE CALCULATION

Part. Size μ	% of input	I lb	$V_s^{(1)}$ (ρ=2) ft/s	R/I	R lb
0.3	5	140	2×10^{-5}	0.8	112
1.5	5	140	5×10^{-4}	0.03	4.5
3	10	280	0.002	0.008	2.3
5	10	280	0.005	0.003	0.9
7	10	280	0.01	0.016	0.45
10	20	560	0.02	8×10^{-4}	0.45
15	30	840	0.05	3×10^{-4}	0.3
20	10	280	0.08	2×10^{-4}	-

The calculated release of sub-micron particles can be reduced by consideration of their agglomeration into larger particles which settle more rapidly. The agglomeration rate of particles is[2]

$$\frac{dn}{dt} = kn^2$$

where n is particle concentration, cm^{-3}, t is time

and k is a constant for which a conservative (low) value is[2] $3\times10^{-10} cm^3/sec$

A steady source will reach steady-state in which $\frac{dn}{dt} = 0 = \text{Source} - Kn^2$

or $n = \sqrt{\text{source}/k}$

The input of sub-micron particles (assumed 0.3μ) is 0.05(144 lb/d) = 7.2 lb/d.

The mass of a 0.3μ particle is

$$\frac{\pi}{6}\,(0.3\times10^{-4}\text{cm})^3\,\frac{2.5\text{g/cm}^3}{454\text{g/lb}} = 7.8\times10^{-17}\text{ lb}$$

The source/cm^3 is then

$$\frac{7.2\text{ lb/d}}{(86{,}400\text{ s/d})\,(7.8\times10^{-17}\text{lb})\,(50{,}000\text{ft}^3)\,(28{,}300\frac{\text{cm}^3}{\text{ft}^3})} = 755\text{ sec}^{-1}\text{cm}^{-3}$$

The steady state (0.3μ) particle concentration is then

$$\left(\frac{755\ \text{sec}^{-1}\text{cm}^{-3}}{3\text{x}10^{-10}\text{cm}^{3}/\text{sec}}\right)^{1/2} = 1.6 \times 10^{6}\text{cm}^{-3}$$

The mass concentration is

$$(1.6\text{x}10^{6}\text{cm}^{-3})\ (28{,}300\ \text{cm}^{3}/\text{ft}^{3})\ (7.8\text{x}10^{-17}\text{lb}) = 3.5 \times 10^{-6}\text{lb/ft}^{3}$$

The release with 2%/day leakage is

$$(0.02\text{d}^{-1})\ (20\text{d})\ (50{,}000\ \text{ft}^{3})\ (3.5\text{x}10^{-6}\frac{\text{lb}}{\text{ft}^{3}}) = 0.07\ \text{lb}.$$

The fine particles will agglomerate mostly with the larger particles which settle out but some agglomerates will still be in the sub-micron size range. The calculation of the full size distribution would require much more sophisticated calculation than performed here. To account for larger sub-micron particles, the "sub-micron" release quantity is increased to 1 lb. The remaining 139 lb of this size fraction are assumed to agglomerate into the 1 to 2μ size fraction for which the release fraction is 0.03. The revised leakage calculation is summarized in Table B-2. The total release is 14 lb of solids.

TABLE B-2

REVISED SOLIDS LEAKAGE CALCULATION

Particle Size μ		Release lb
0.3		1
1.5		9
3		2.3
5		0.9
7		0.45
10		0.45
15		0.3
	Sum	14.4

Radiation Dose Calculations

The radiation doses calculated for this report are total integrated doses (TID) over a 50-yrs lifetime calculated using the ICRP Lung Clearance Model. The atmospheric dispersion factors used were an annual-average X/Q of $2X10^{-17}$ sec/M^3 and a Class F fumigation X/Q of $6.2 X 10^{-6}$ sec/M^3.

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APPENDIX C
SEISMIC STRESS ANALYSIS CALCULATIONS FOR CALCINED STORAGE BINS

I. SHELLS ANALYSIS

1. Thermal Gradients

The 15 psi internal pressure and 3.75 psi external pressure local cases included a 100° thermal gradient in the skirt. The following analysis separates the pressure and thermal stresses in the skirt area and shows that the stresses due to pressure alone are smaller than the worst combined case.

2. Effect of Seismic Motion on Waste Pressure

The following analysis shows the effect of waste pressure. These loads were analyzed as required, and the factor of safety for each stress category is summarized below. The safety factor represents the margin of safety available, i.e., if the maximum stress applied by the DBE were 20,000 psi and the structure would withstand a 40,000 psi force, then the SF would be 2.0.

a)	P_m without seismic	S.F. = 2.42
	P_m with seismic	S.F. = 1.69
b)	$P_L + P_b$ w/o seismic	S.F. = 1.78
	$P_L + P_b$ with seismic	S.F. = 1.47
c)	$P_L + P_b + Q$ w/o seismic	S.F. = 3.06
	$P_L + P_b + Q$ with seismic	S.F. = 2.40

Where Pm is primary membrane stress intensity and $P_L + P_b$ is primary bending stress intensity.

II. SEISMIC RESPONSE

Seismic response analysis was performed using MRI's STARDYNE computer program. The storage bin was modeled as a cantilever beam as shown in Figure 3.1. A seismic load of .33g as defined by the average acceleration spectrum of the 1940 El Centro earthquake was applied in the horizontal direction. Vertical seismic loading was applied simultaneously with the horizontal loading and was 2/3 of the values for the horizontal loads; 5% of critical damping was used.

1. Vertical Distribution of Mass

In the vertical direction, as well as the horizontal, the waste mass was distributed to nodes 3 through 8. Since the vertical seismic acceleration never reaches 1g, the mass is effectively at node 3 only. For members above node 3, the analysis is conservative because they are now being loaded by the acceleration of some of the waste mass. Below node 3 the analysis is correct because the members are loaded by the acceleration of all of the waste mass in either case.

2. Vertical Seismic Spectra

The vertical seismic load should be 2/3 times the design spectra, but a larger value, .75 times, was used; so the analysis is conservative.

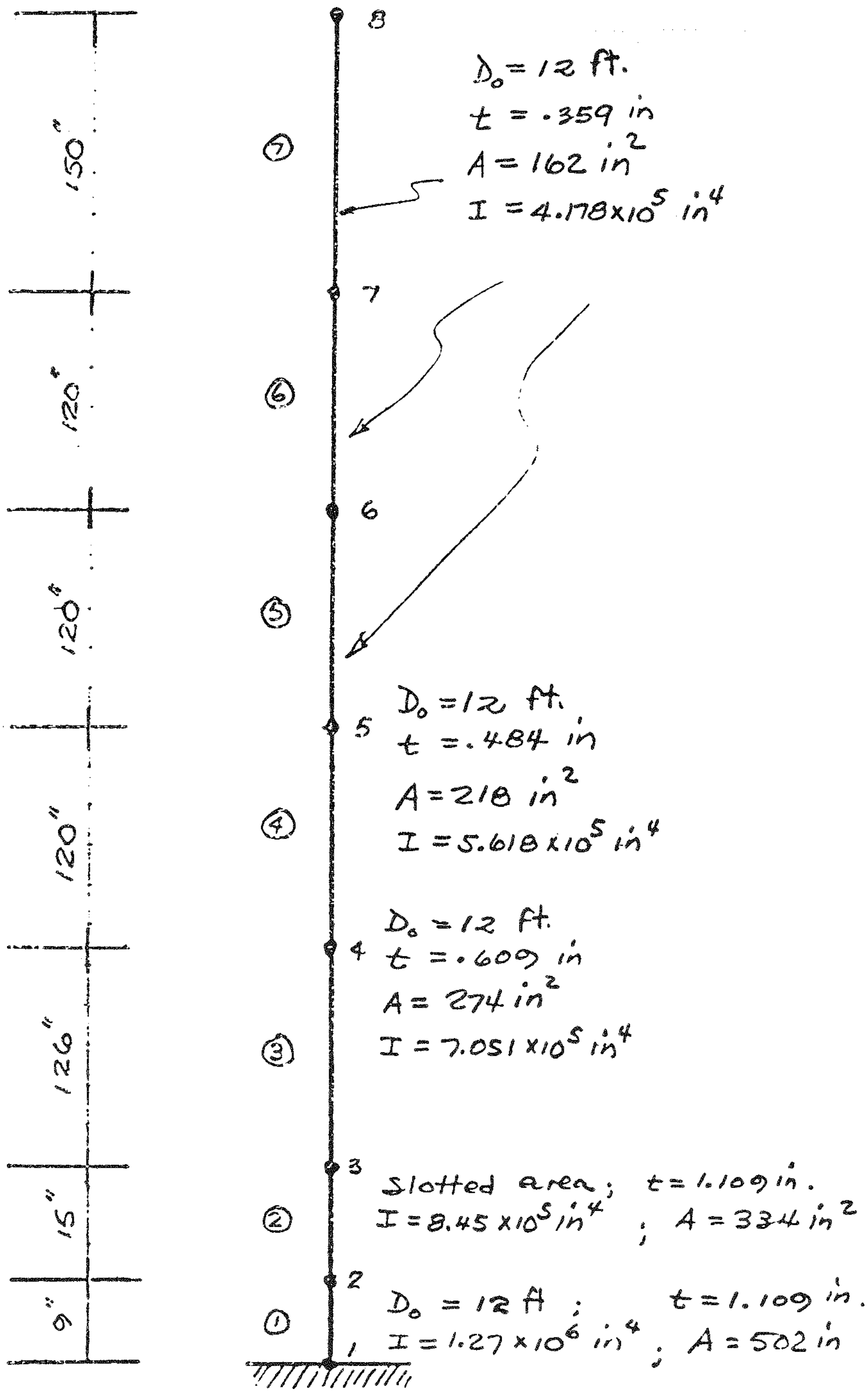

Figure 3.1 Beam Model (STARDYNE Dynamic Analysis)

III. NOZZLES

Three analyses were performed for the nozzles.

1. Reinforcement around the opening
2. Stresses in the nozzles
3. Stress at the nozzle-shell interface.

In order to perform the first analysis it was necessary to also determine minimum nozzle and vessel wall thicknesses per the Code.

The results of the following analyses are:

1. All nozzle and vessel wall thicknesses exceed the minimums required by the Code.

2. The reinforcement area around the openings exceeds the Code requirement.

3. The minimum safety factor for nozzle stress is 9.67 ($P_L + P_B$ class stress in 3 inch nozzles).

4. Nozzle-shell interface stresses were determined and can be combined with shell stresses to determine total stress at each interface.

IV. COMBINED LOADS

The applied loads were combined to give the worst case stresses. The resulting stress intensities were compared with the proper stress intensity limit as described in Article 4-130, ASME Section VIII, Division II. The factor of safety for each stress category is summarized below:

A) P_m without seismic S.F. = 2.42

P_m with seismic S.F. = 2.1

B) $P_L + P_b$ without seismic S.F. = 1.78

$P_L + P_b$ with seismic S.F. = 1.52

C) $P_L + P_b + Q$ without seismic S.F. = 3.06

$P_L + P_b + Q$ with seismic S.F. = 2.34

V. BUCKLING

The critical buckling stress for the cylinder under axial compression was computed in accordance with the procedures described in AD-340. Buckling for the cylinder under bending was evaluated using the procedures given by the NASA AP-8007, dated August 1968.

The equation for the critical stress is

$$\sigma_{cr} = \frac{\gamma E}{\sqrt{3(1-\nu^2)}} \cdot \frac{t}{R} \qquad (1)$$

where factor γ is used to correct the disparity between theory and experiment. On the basis of various experimental data the recommended value of factor γ is

$$\gamma = 1 - .731(1 - e^{-\phi}) \qquad (2)$$

where

$$\phi = \frac{1}{16}\sqrt{\frac{R}{t}} \quad \text{for } \frac{R}{t} < 1500 \qquad (3)$$

Equation (2) is presented graphically in Figure C.1. Table AHA-1 of the Code shows allowables based on safety factors of 1.5 on yield or 3.0 on ultimate, whichever is less. A conservative safety factor of 4 is used for this buckling analysis. Therefore, the bending stress (for $\nu = .3$) is

$$\sigma_{cr} = (.15)\, E\, \gamma \frac{t}{R} \qquad (4)$$

The interaction equation for combined compressive and bending stresses is

$$R_c + R_b = 1 \qquad (5)$$

The quantities R_c and R_b are, respectively, the compressive and bending stress ratios. The denominators of the ratios are the allowable critical stresses given by the Figure AHA-28.1 for a cylinder in axial compression and by equation (4) for a cylinder in bending.

For the slot region in the skirt support, the critical stress was obtained from the curved sheet panels in axial compression. The formula for the maximum allowable critical stress is (p. 487, Timoshenko and Gere, Theory of Elastic Stability, 2nd Edition).

$$\sigma_{cr} = \frac{\pi^2 E t^2}{3(1 - \nu^2)(R\beta)^2} + \frac{E\beta^2}{4\pi^2} \tag{6}$$

Using the correction factor for a cylinder in axial compression as shown in Figure C.2, Equation (6) with a safety factor of 4 can be written as

$$\sigma_{cr} = (.9038)\ E \frac{t^2}{(R\beta)^2} + (.0063) E\ \beta^{2\gamma} \tag{7}$$

The following analysis shows the minimum safety factor to be 1.19 (in the 3/8" wall cylinder).

VI. REFERENCES

1) A.M. Haire, and Tso, F., Stress Analysis of CPP Calcined Solids Storage Facility Fourth Edition Storage Bins, MRI-2881-TR-1, March 1, 1976.

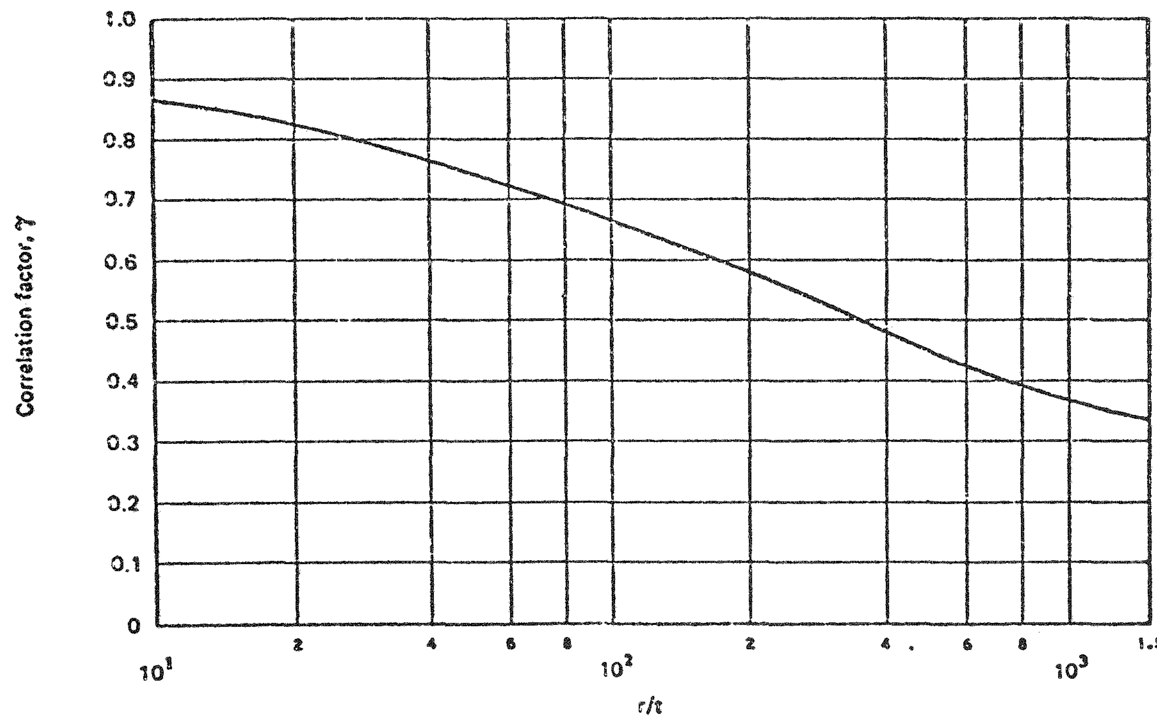

Figure C-1 Correlation factors for isotropic circular cylinders subjected to bending

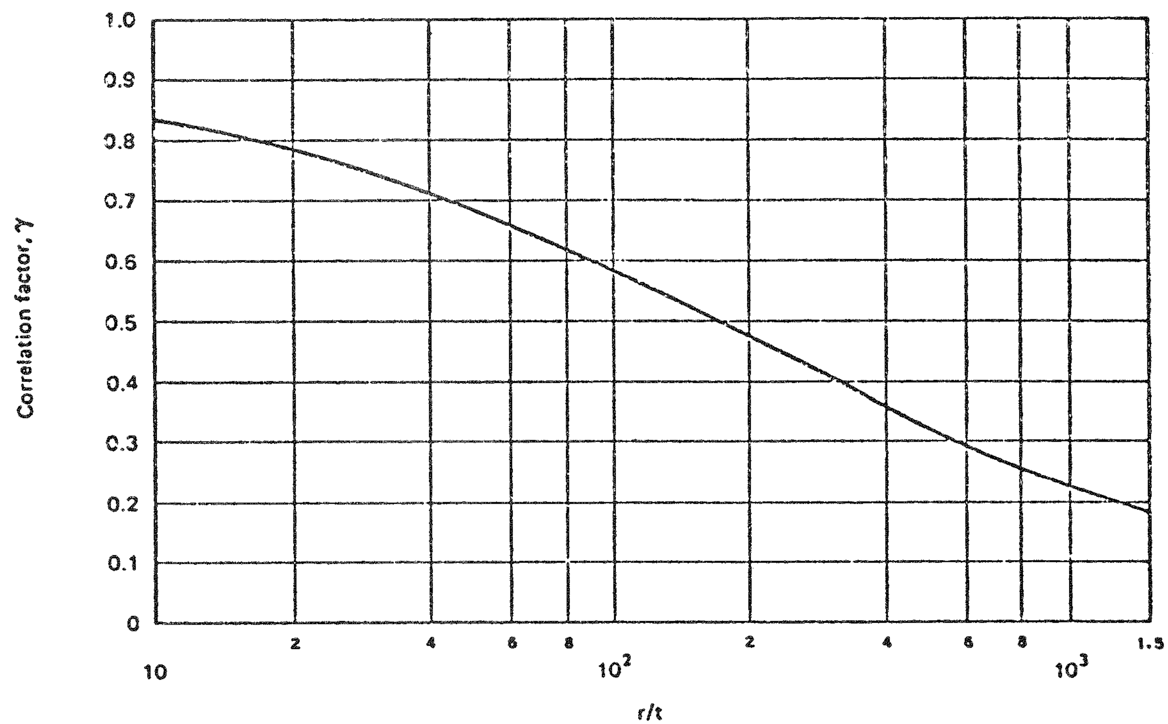

Figure C-2 Correlation factors for isotropic circular cylinders subjected to axial compression