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PRELIMINARY SAFETY ANALYSIS REPORT FOR THE FOURTH CALCINED SOLIDS STORAGE FACILITY

Allied Chemical
IDAHO CHEMICAL PROGRAMS

ENERGY SAFETY ENVIRONMENT

IDAHO NATIONAL ENGINEERING LABORATORY

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

IDAHO OPERATIONS OFFICE UNDER CONTRACT EY-76-C-07-1540

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PRELIMINARY SAFETY ANALYSIS REPORT
FOR
FOURTH CALCINED SOLIDS STORAGE FACILITY

by

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SUMMARY

Radioactive aqueous wastes generated by the solvent extraction of uranium from expended nuclear fuel elements at the Idaho Chemical Processing Plant (ICPP) are calcined to granular solids in the Waste Calcining Facility (WCF). A New Waste Calcining Facility (NWCF) will replace the WCF in the future. The granular solids are placed for interim storage in engineered, near-surface storage facilities at the ICPP. The Fourth Calcined Solids Storage Facility will provide 17,000 ft^3 of additional storage.

The ICPP is located on the 894 square mile Idaho National Engineering Laboratory (INEL) located on the sparsely-populated Snake River Plain of southeast Idaho. The nearest population center is Idaho Falls which is 42 miles from the ICPP. The INEL is arid; the nearest groundwater to the ICPP is the Snake River Aquifer whose surface lies 450 feet below the ICPP.

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. The strontium and cesium are readily leached from the calcined solids, but the transuranics leach out very slowly. Calcined solids can be stored without sintering at temperatures up to 1000°F and, most calcines will not sinter below 1300°F.

The basic facility design philosophy provides for double containment of the calcined solids with a set of stainless steel bins enclosed in a reinforced concrete vault. Both the bins and vault will be designed to provide complete containment in the event the other containment envelope should fail. Decay heat will be removed by conduction of the heat through the vault walls to the surrounding air and soil. Supplementary cooling will also be provided during the first few years of bin use by natural convection of cooling air through the vault. The cooling air discharging from the vault will be monitored by a system that will automatically shut-off the cooling air flow if radioactive particulates are detected in it. In this case, a filter could be added and the circulation of cooling air restored if necessary before sintering of the solids occurred; the solids temperature would increase at a slow rate upon vault isolation. The vault will be equipped with a sump to collect any water that might leak in, a liquid

detector, and a sump jet for water removal. The facility will be designed to resist an earthquake with a bedrock acceleration of 0.33 g and a tornado with a maximum wind speed of 175 mph. The general radiation field will be limited to less than 0.5 mrem/hr at the vault surface.

The double-containment design of the Fourth Calcined Solids Facility will prevent the release of radionuclides to the underlying groundwater if either a bin or the vault should fail. There would be a slight chance of the leakage 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. The operation is essentially passive and presents very little opportunity for radionuclide release. There is essentially no possibility of an accidental explosion.

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I. INTRODUCTION

The Idaho Chemical Processing Plant (ICPP) is a multiple-purpose facility for recovering highly-enriched uranium from a wide varity of spent nuclear reactor fuels. The solvent extraction techniques employed generate radioactive wastes containing nuclear fission products. These wastes are stored for an interim period of a few years in cooled, stainless steel tanks to allow decay of most of the short-lived radionuclides before being calcined to solids in the Waste Calcining Facility (WCF)[(1)]. There are currently three calcined-solids storage facilities at ICPP. Two are full and the third is being filled. The Fourth Calcined Solids Facility will provide additional storage for 17,000 ft^3 of calcined solids produced after the filling of the Third Calcined Solids Storage Facility. The new storage facility is basically similar to existing facilities; its construction and use will not alter appreciably the low risk level[(1)] associated with the storage of calcined solids in the existing calcined-solids storage facilities at ICPP.

In the WCF, wastes are pneumatically atomized in a hot-air-fluidized-bed of granular solids. Water vapor and gaseous decomposition products are carried with the fluidizing and atomizing air to an off-gas cleanup system for decontamination before they are discharged 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 with air to a solids storage area. There, they are separated from the air in a cyclone and fall by gravity into stainless steel storage bins.

A New Waste Calcining Facility (NWCF) is being designed to replace the WCF. The Fourth Calcined Solids Storage Facility will probably receive solids mostly or entirely from the new facility. The safety of the NWCF will be reviewed in a separate document.

The Fourth Calcined Solids Storage Facility will provide storage for 17,000 ft^3 of calcined solids. A double-containment principle will be followed by storing the solids in three 12-ft-diameter by 50-ft-high, stainless steel bins enclosed in a reinforced-concrete vault as shown in Figure 1. The facility will be designed to withstand natural catastrophies. Decay heat will be removed from the vault by conduction through the vault walls to the surrounding air and soil. During the first few years of facility use, supplementary cooling will also be provided by the natural convection of cooling air through the vault.

The design concept is similar to that used for existing calcined solids storage facilities[1]; however, the number of storage bins is reduced from 7 to 3.

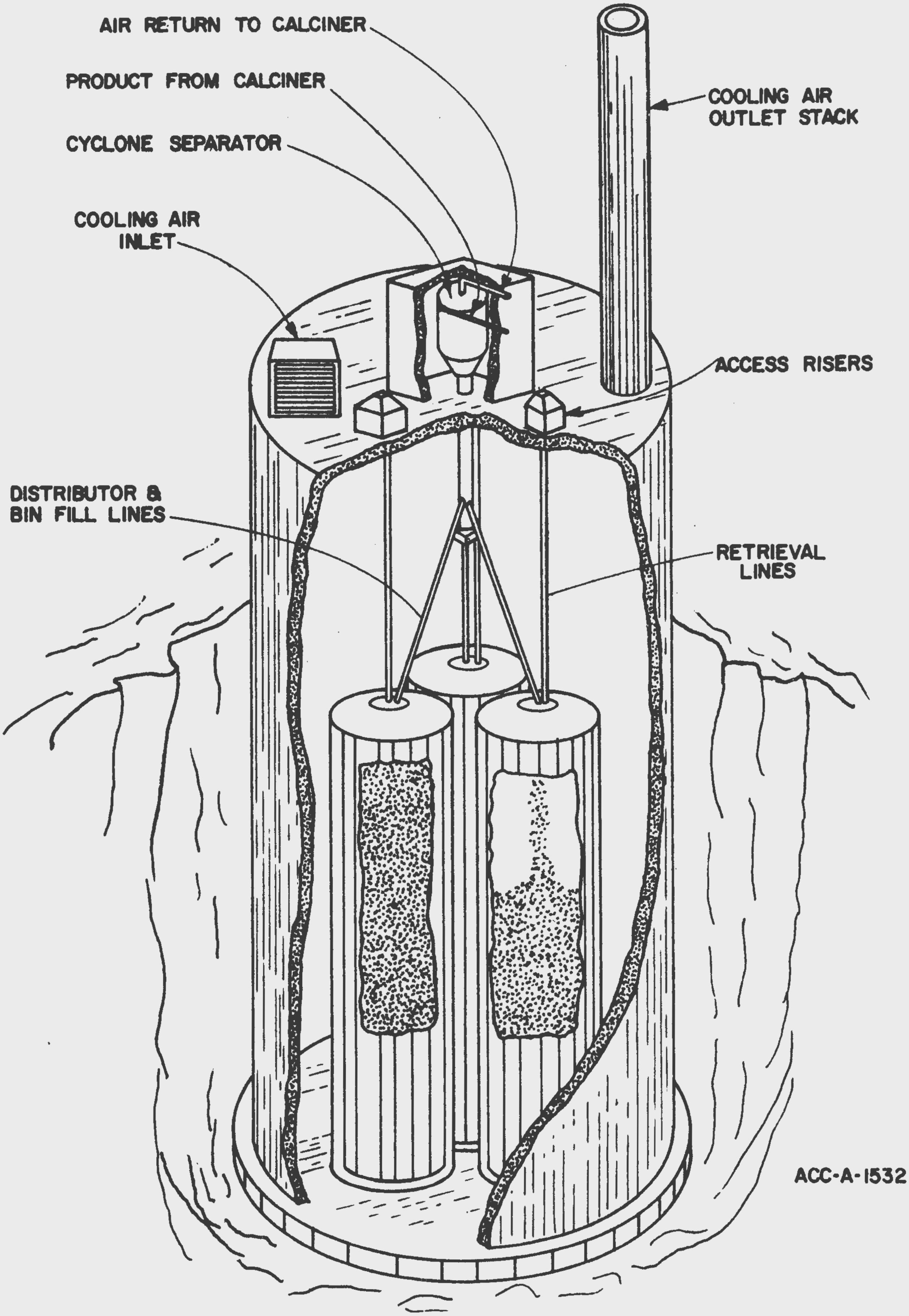

Fig. 1 Fourth Calcined Solids Storage Facility

II. CHARACTERISTICS OF CALCINED SOLIDS

The ICPP produces a variety of fuel reprocessing 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 those from the calcination of 1) zirconium-fluoride wastes, 2) a blend of zirconium-fluoride wastes with sodium-containing 2nd-cycle extraction wastes, and 3) a blend of aluminum and stainless steel nitrate wastes. Typical properties of the calcined solids are listed in Table I. Some calcine properties with safety implications are discussed below.

1. Leachability

Strontium and cesium, but not plutonium, are readily leached from fluoride calcine. In a 2000-hr leaching test[2] at 25°C, 60% of the Cs-137 and 40% of the Sr-90 were leached from a fluoride calcine sample. However, in the same test[2] only 0.1% of the plutonium was leached from the sample. The leachabilities of radionuclides from the fluoride-2nd cycle blend and the aluminum-stainless steel blend have not been determined. 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, solids retrieval becomes more difficult if the solids should sinter into a large clinker. Hence, calcine "sintering temperatures" are measured in laboratory tests 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 of a calcine varies with temperature from a slight sticking 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 sticking was observed in the lab tests and the calcine could be made free flowing by tapping the container.

TABLE I

TYPICAL PROPERTIES OF CALCINED SOLIDS

	Fluoride Calcine	Fluoride-2nd cycle 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 - 0.12	00.09 - 0.12	0.1 - 0.15
Sintering Temperature, ^oF	1300	1000-1300	unknown
Decay Heat, BTU/hr-ft^3	5-40	5-40	5-40
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

Hence the calcine should be free-flowing if stored at temperatures below the "sintering temperature". The measured "sintering temperature" of the solids from the calcination of a blend of fluoride and 2nd-cycle 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 decreased 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 not been determined but is expected to be roughly the same as that of the 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 and tritium--are driven off during the dissolution and calcination processes. In lab tests(3) 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 has been detected(4) at temperatures below 1475°F. In some 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 expected in storage when the Fourth Calcined Solids Storage Facility is filling will produce calcined solids with decay-heat generation rates from 5 to 40 Btu/hr-ft^3. The "cooler" (up to 10 or 15 Btu/hr-ft^3) wastes will be calcined and the solids stored in the Fourth Calcined Solids Storage Facility. The "hotter" wastes will be held for later storage facilities designed to store solids with higher decay-heat generation rates without reaching excessive temperatures.

III. CHARACTERIZATION OF EXISTING ENVIRONMENT

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. It is centered on a former Naval Proving Ground which served the Navy's Pocatello (Idaho) Ordnance Depot. 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 feet above sea level. The Idaho Chemical Processing Plant (ICPP) is located in the south-central portion of the INEL, in Butte County, Idaho 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.

The INEL is a government reservation with access limited for reasons of health, safety, and national security; there are no permanent residents on the site. The surrounding areas are sparsely populated, with the largest community near (42 miles to the east) the ICPP being Idaho Falls. Other communities (all small) are located at Mud Lake and Terreton (29 miles northeast), Arco (19 miles west), Howe (15 miles north), and Atomic City (12 miles southeast).

1. Topography and Climatology

The climate at the INEL is arid to the point of assuming a desert-like characteristic. The 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 5,000 feet above sea level. It is bounded to the north and west by mountain ranges with elevations as high as 6,000 feet above the plain. The predominant surface winds are either southwesterly or northeasterly. Nearly all air masses entering the plain are forced to cross mountain barriers; thus, the air masses usually release moisture over the mountains and enter the plain dry, giving the region its desert-like characteristics (annual precipitation of 8.5 inches[5]). The climate is cool, with average maximum temperatures

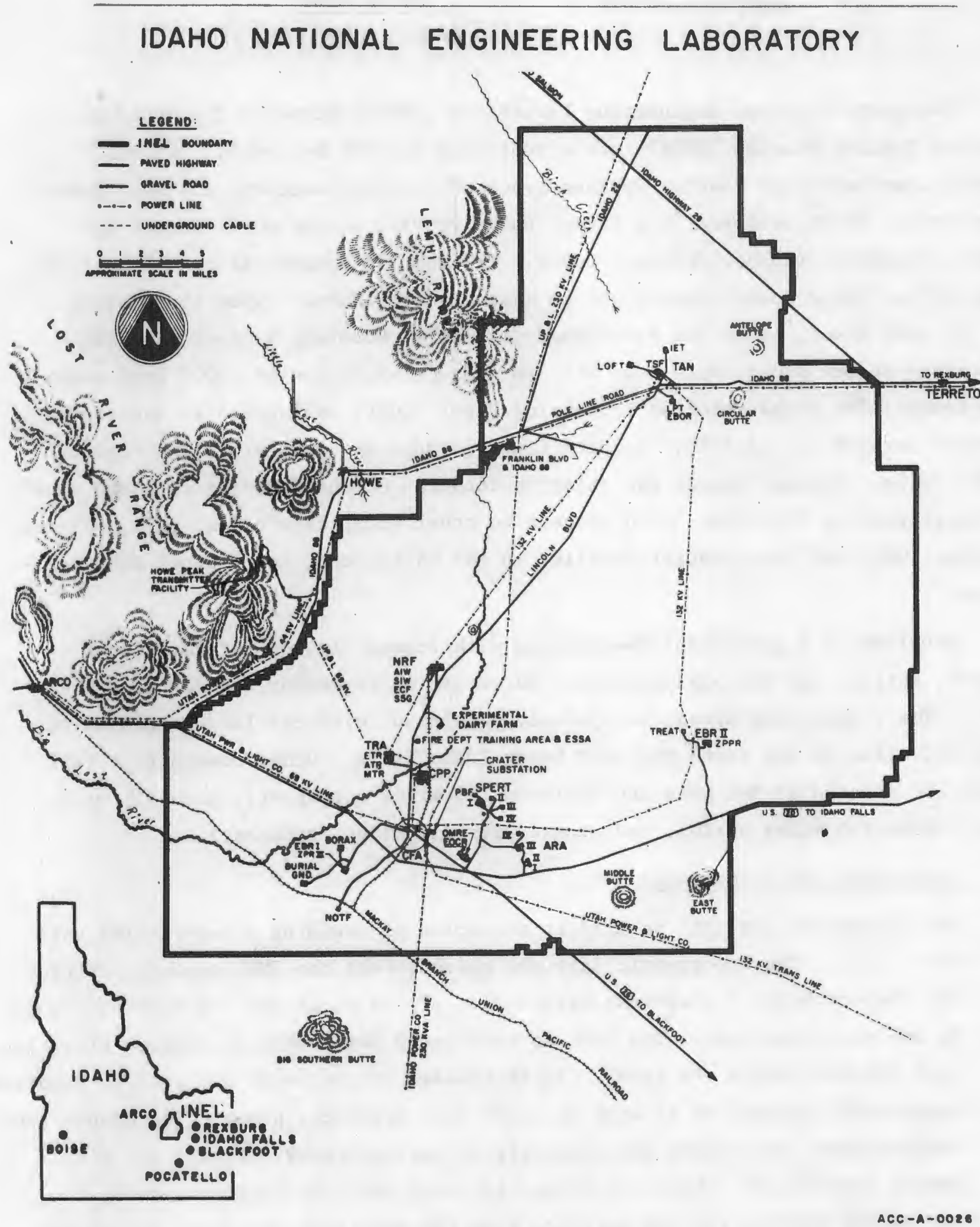

Figure 2. Detailed Map of the INEL

Figure 3. Aerial Photograph of ICPP and INEL Landscape

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 three miles south of the ICPP, is 7.5 miles per hour (mph). Severe thunderstorms with wind gusts over 50 mph and hail of 1/2-inch 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(6). Three confirmed funnel clouds have been recorded during the 24-year history of the INEL(6).

2. Hydrology

The Snake River Plain consists of composite layers of inter-bedded volcanic rock and sedimentary material. The INEL water table lies between 200 and 900 feet below ground level with the level at the ICPP about 450 feet below ground surface. The direction of subsurface water flow is from recharge areas to the north and east toward the main part of the Snake River Plain to the south. The INEL water supply is obtained from the twenty-four production wells at a combined rate of about 2 billion gallons per year. Of this, the two ICPP production wells withdraw approximately 400 million gallons per year of which 93% is recharged to the Snake River aquifer via a deep (598 feet) discharge well which injects the water 140 feet below the top of the regional water table.

The INEL lies in a basin which has no surface outlet for its streams. The largest source of surface water at the INEL, the Big Lost River, flows in a northerly direction and sinks into the desert floor at the northern end of the INEL. Two smaller streams (Birch Creek and the Little Lost River) flow onto the northern portion of the INEL and also sink into the desert. The only other surface water on the INEL results from snow melt during the spring.

3. Seismology

Until 1970, the region including the INEL was classified as Seismic Risk Zone 2 by the Pacific Coast Uniform Building Code(7). The New Uniform Building Code (UBC)(8) of the International Conference of Building Officials, issued in 1970, reclassified the INEL into Zone 3 which imposes more stringent design criteria on new facilities. A number of seismic instrument stations were installed in FY 1972 to monitor the fractional transmission of seismic energy from surrounding earthquake hepicenters to the INEL. In spite of its Zone 3 classification, no important earthquakes have originated in the eastern portion of the Snake River Plain during the period of recorded regional history (100 years).

The nearest geological faults are the Howe scarp located at the foot of the Lemhi mountains 15 miles to the north of ICPP and the Arco scarp located a few miles farther west. The Snake River Plain area around ICPP is considered aseismic because 1) an aerial study of the area revealed no evidence of faulting, and 2) there is no microseismic activity in the area. Both the Howe and Arco scarps were excavated to determine the displacement of existing fault slippages. Both scarps were assigned[9] a maximum credible earthquake with a (Richter) magnitude of 7.75 based on the maximum existing displacement at the scarp and on the historical record of earthquakes from similar faults in the "Basin-and Range Province" of the intermountain west. A calculation[9] of shock attenuation through 15 miles of basalt yields a bedrock acceleration at ICPP of 0.33 g (10.6 ft/sec^2).

4. Ecosystem

The ecosystem of the INEL is typical for a semi-desert region (see Figure 3). The ICPP area is also 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; the white-footed mouse and the jack-rabbit are found in all INEL areas. The only large mammals seen commonly on the INEL are the coyote, bobcat, the pronghorn antelope (the latter is migratory, wintering south and summering north of the INEL).

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.

Aquatic life is not significant at the INEL. The only major surface water flows are the Big Lost River, which is often dry much of the year, Birch Creek and the Little Lost River.

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. Sage grouse and pheasant are the only resident game birds; however, hunting is not permitted on the INEL.

5. Environmental Monitoring

Monitoring of the environment and plant effluents is conducted by the INEL contractors, the ERDA's Health Services Laboratory (HSL) 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 Lab 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 determining the integrated direct radiation exposures, composition of waste effluents (both air and water), water quality, noxious gas release, bioassay, airborne contaminants, soil radionuclides uptake. In addition special monitoring programs are conducted on a non-routine, as-needed basis.

IV. FACILITY DESCRIPTION

A. Design Criteria

The safety-related features of the design criteria[10] are discussed below:

1. Earthquake Resistance

The bins, vault and all connecting piping, ducting, and valves needed for primary and secondary containment will be designed to resist a design-basis earthquake with a bedrock acceleration of 10.6 ft/sec^2 (0.33 g) and the energy spectrum reported[11] for the May, 1940 El Centro earthquake.

2. Tornado Resistance

All components needed for primary and secondary containment will be designed to resist a design-basis tornado with a total wind velocity of 175 mph, a pressure drop of 0.75 psi, and two tornado borne missiles: a 2-in. by 12-in. by 12 ft long plank going 155 mph and a Volkswagen automobile tumbling along the ground at 65 mph.

3. Flooding Resistance

Flood resistance will be provided by constructing the vault roof at least 5 ft above the original ground (standard datum 4917 ft above MSL) level and by not allowing near or below grade wall penetrations through which water might penetrate. The roof hatches will be designed to keep rainwater out of the vault. The backfill will be compacted and contoured to prevent the formation of voids allowing the pocketing of groundwater around the walls.

4. Radiation Shielding

The vault roof, walls, hatches, transport lines, and vent lines will be designed with sufficient shielding to limit the radiation fields with fresh calcine in the bins to a general field of 0.5 mRem/hr and vertical beams of 3.5 mRem/hr.

5. Bin Design

The three calcine bins will be constructed of SS type 304 and anchored to the vault floor. They will be designed to the requirements of Section VIII, Div. II and Section IX of the ASME Boiler and Pressure Vessel Code for a pressure range of 3.75 psig vacuum to 3.75 psig pressure plus the static head of the solids combined with the design-basis earthquake. The bin wall design temperature is 250°F.

6. Retrievability

Each calcine bin will have a pair of 6-in-diameter retrieval-access lines through which a retrieval line could be introduced into the bin.

7. Calcine Temperature Monitoring

Each bin will have a column of thermocouples on the centerline spaced every 5 ft and a set of 3 thermocouples on the bin wall.

8. Venting

Each bin will have a 3-in-diameter vent line connecting to a common vent system on the vault roof which vents to the vault stack as shown in Figure 4. The vent system will provide vacuum and pressure protection with a vacuum-relief valve set at 3 psig and pressure-relief valves set at 2 psig and 3 psig.

9. Vault Cooling Air Monitor

The airborne particulate concentration in the cooling air leaving the vault shall be monitored continuously and recorded by a monitor capable of detecting and measuring particulate gross beta or gross beta-gamma concentrations of 1×10^{-9} µCi/ml or less in a 10 minute counting interval. The air activity monitor shall be coupled to an alarm and control system that will automatically alarm and shut off the cooling air flow if airborne activity exceeding the set point is detected. The monitor shall automatically shut off the cooling air flow if it loses power or otherwise goes out of operation.

10. Vault Isolation Valves

The vault cooling air inlet will have an automatic, fail-closed,

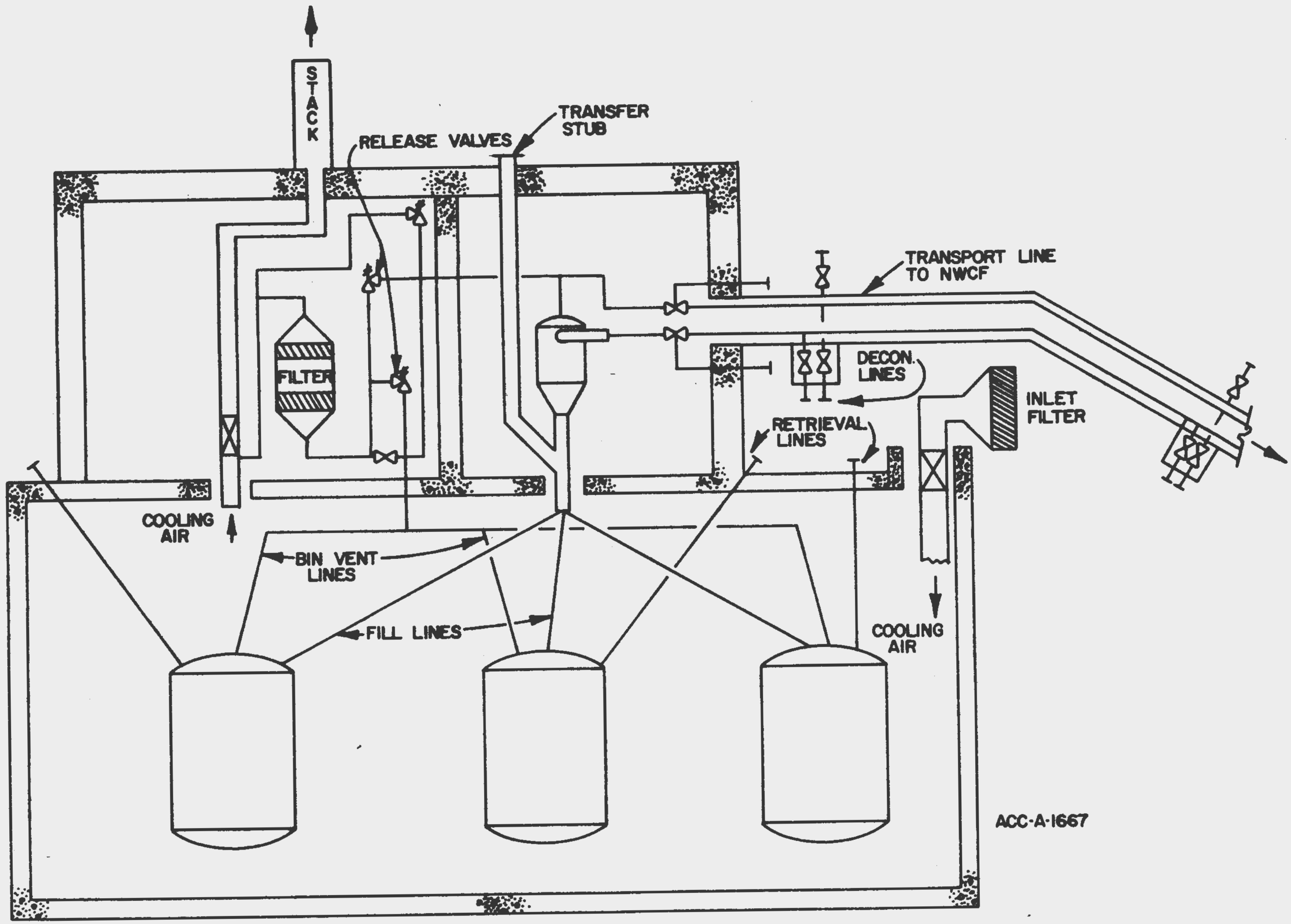

Figure 4. Solids and Air Flowsheet for 4th Calcined Solids Storage Facility

isolation valve will automatically shut-off the cooling air flow if radioactivity is detected in the cooling air discharge. The cooling air outlet will have a manual isolation valve.

11. Vault Sump

The vault will have a sump to collect any water that might leak into the vault and a transfer jet designed to remove the water. The sump shall have a level detector and alarm system to detect liquid in the sump and an alarm at the NWCF control panel if liquid is detected. The destiny of any water removed from the sump would depend on its radioactivity content. Contaminated water would be transferred to the evaporator (for contaminated liquid wastes) feed tanks. Temporary lines would be used.

B. Quality Assurance Program

The final design will contain a quality assurance program designed to assure that the bins, bin supports, bin anchors, retrieval access lines, vault, and sump level detector are capable of remaining intact and functional for the 500 year design life. The quality assurance program will also be designed to assure that the solids transport and distribution system, and the bin thermocouples are capable of remaining functional and intact as they are needed.

C. Operation

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

1. During Filling

During filling the calcined solids will be carried from the calciner by the transport air to the bin cyclone where they will drop out and be distributed into the three bins. The transport air will return to the calciner. The transport system and bins will operate at a slight vacuum--20 to 30 in. W. G.--produced by and dependent mostly on the calciner vacuum. The temperature of the calcine at the bin centerline will be read periodically (The current practice is weekly).

One operation (performed occasionally now) of potential safety hazard is the rod-out of a fill line that has become plugged. The bin filling system is equipped with rod-out lines through which an operator standing on the roof can insert a long tool and clear a plugged fill line. The contaminated rod-out tool is then pulled from the line and placed in a plastic bag for disposal. This operation is done carefully and monitored by health physics technicians to minimize contamination of the environment and radiation exposure to personnel. Nevertheless, the operator is exposed to some radiation from the retracted contamination during the removal and bagging.

2. <u>After Filling</u>

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

V. SAFETY ANALYSIS

The Fourth Calcined Solids Storage Facility will use a double-containment principle to isolate the calcined solids from the environment. The solids will be stored in stainless-steel bins which will be enclosed in a reinforced-concrete vault. Both the bins and vault will be designed to contain the solids in the event the other is breached. Release of calcined solids into the atmosphere would require breach of a bin or line and leakage from the vault. The release of fission products into the Snake River Aquifer underlying the ICPP would require the breach of both the bins and vault plus the leaching of the calcine 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 8 hours, the DBA results in a maximum dose (Total Integrated Dose) at the INEL boundary to the bone (the critical organ) of only 80 mrem.

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.

A. External Catastrophe

The following considers potential events whose origin is outside of the facility.

1. Earthquake

The bins, their anchors, and all connecting components needed for containment will be 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 preventing buckling by an earthquake and 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. The piping attached to the vault -- fill and vent lines -- could be damaged or broken; their earthquake resistance cannot be evaluated until after detailed design. The loss of solids from piping broken in an earthquake should be small because the piping all 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 in Section B5 "Bin Failure".

The design of the Fourth Calcined Solids Storage Facility for earthquake resistance depends on the good--or at least conservative--judgement in selecting the parameters--particularly the 0.33 g bedrock acceleration--of the DBE which is a maximum credible earthquake. The earthquake evaluation included a number of judgement factors which the evaluator believed[9] were conservative. Hence, the chances of a non-conservative error in the earthquake evaluation should be very small. The design procedures, which limit primary stresses to yield stress or less, allow some margin for error before reaching the ultimate or breaking strength of the materials. The consequence of an unexpected worse-than-design earthquake would be buckling of the bins and cracking of the vault.

2. Tornado and Wind Damage

The bins, vaults, and all connecting components needed for two containment envelopes will be designed to resist the design basis (175 mph) tornado and its 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 capability leading to a small chance of sintering the calcine but not to fission product release. Sintering and cooling air loss are discussed in Sections 6 and 7. The loss of the instrument station would result in the loss of passive monitoring instruments which measure temperatures and pressures; no radioactivity release would result from their loss. The instruments could be repaired later.

The tornado suction (0.75 psig) could rupture the filter on the bin vent system and suck some of the bin air out into the atmosphere. The volume of bin air sucked out 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 air will usually be relatively low because particles will be introduced into the bin atmosphere only during filling operations during which the bins will be isolated from the vent systems. After filling, the larger particles will settle out rapidly leaving only the sub-micron particles airborne. The quantity of submicron particles will be relatively small because the cyclone will be unable to collect submicron particles; the only submicron particles would be those formed by attrition during filling. The submicron particles formed during filling would be removed by agglomeration (into larger particles) and settling. Hence, the quantity of radioactivity carried by the small volume of bin air sucked out by a tornado would be minor--certainly much less than released in the DBA discussed in Section C.

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 with relatively little depth. Estimates[1,16] of maximum flood (i.e. design-basis flood) depths at ICPP range from 1/2 to 2 ft of water depth. The Fourth Calcined Solids Storage

Facility whose top will be 15 to 25 ft above the ground level will be unaffected by any flood.

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 also off-site areas of the upper Snake River Valley. The penetration of a jet airplane through the vault roof could readily be followed by demolition of one or more bins and a (fuel) explosion 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 design basis accident because of its extremely small probability of occurring. Wall[12] 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 considerably less than the national average[12] because of the low air traffic over the INEL. Hence, the airplane crash probability is considered sufficiently low to eliminate the crash as a design consideration or design basis accident.

B. 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.

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 design basis accident 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(13), and 2) the storage bins will be 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(13); none of the upsets tested produced a combustible or explosive effluent.

It is conceivable to postulate a potentially explosive mixture of kerosene vapor and air in the calciner effluent as a result of start-up incident. The mixing without combustion of flowsheet quantities of kerosene and air (plus oxygen) would produce a (explosive) mixture containing 1.8% kerosene. Kerosene ignites 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 of the operators 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 of the operators (and supervisor) to recognize that ignition was not occurring.

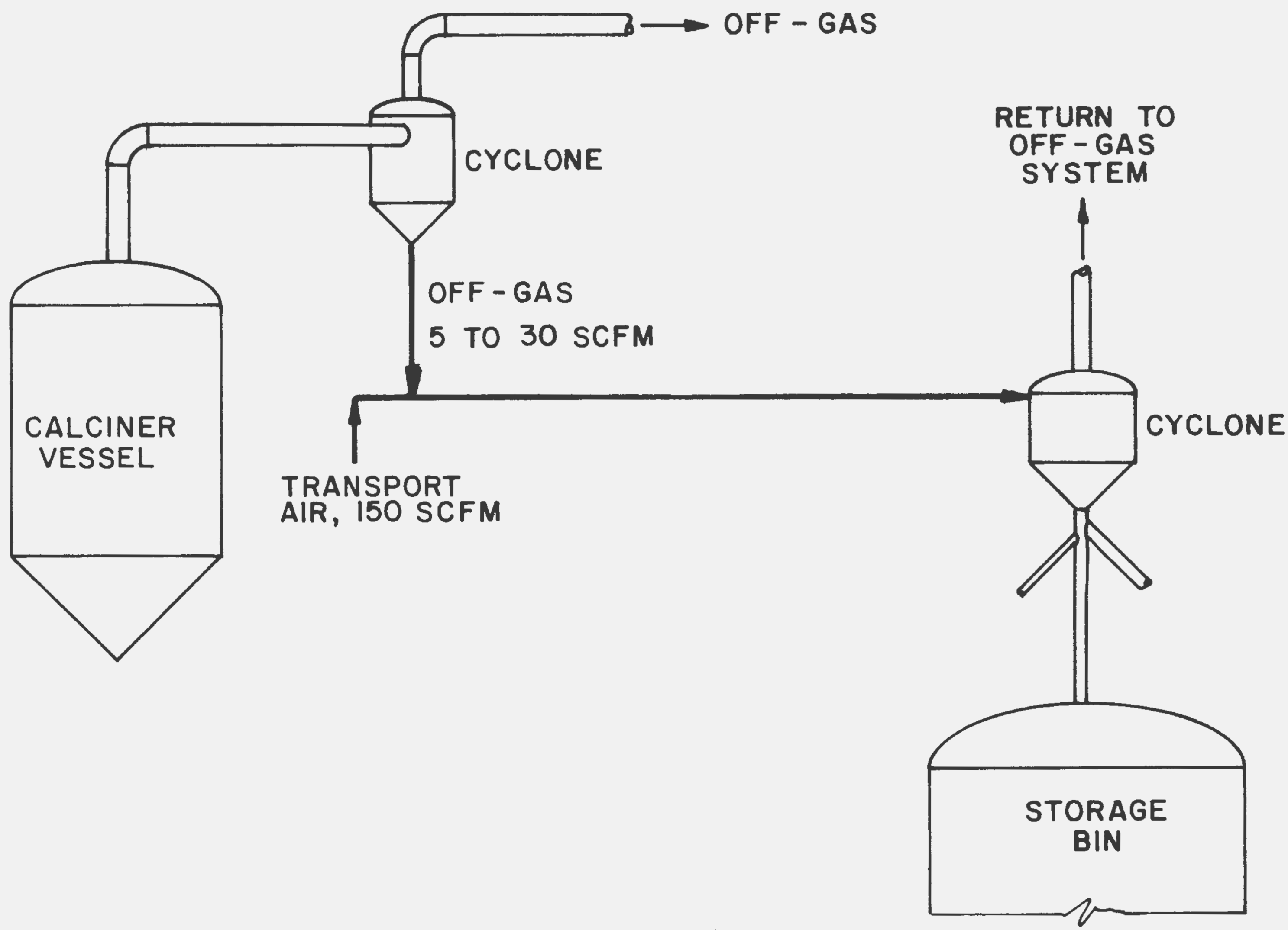

Figure 5. Simplified Transport System Flowsheet

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 - 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.

Another case one might postulate is 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 -- eg, at a mist collector -- and the fluidizing air input continued. This would require that: 1) the off-gas system plug occur (none have occurred in 10 years of operation) 2) the operator not respond to a low-vacuum alarm on the calciner vessel, and 3) the operator not 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 to 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 build-up of hydrogen. 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. <u>Sintering</u>

The maintenance of the calcined solids in readily-retrievable, free-flowing form depends on administrative controls and judgement in selecting wastes for calcination whose decay-heat generation rates are not excessive. If allowed to heat to temperatures in excess of the sintering temperature, the calcined solids would sinter into an agglomerate that would be difficult to retrieve. At the time the Fourth Calcined Solids Storage Facility is being filled, the ICPP will have liquid wastes in storage with a wide range of decay-heat generation rates. There will be an 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 1000-to-1300°F sintering temperatures of the calcined solids. There will also be fresh coprocessing wastes in storage which would produce calcined solids that would reach temperatures far above the sintering temperatures if stored in a 12-ft diameter bin. Consequently, the avoidance of sintering by maintaining acceptably-low storage temperatures will require selective calcination of the "cooler" wastes and holding the "hotter" wastes for later storage facilities.

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:

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

The thermal conductivity of fluoride calcines and the blended calcines are in the range from 0.09 to 0.12 Btu/hr-ft-°F. The maximum allowable calcine temperature will be somewhat lower than the (1000-to-1300°F) sintering temperatures. Using these values and a 200°F bin-wall temperature, one obtains a maximum decay heat generation rate range of 8 to 15 Btu/hr-ft^3. The solids expected from the calcination of long-cooled fluoride wastes have calculated decay-heat generation rates of 5 to 10 Btu/hr-ft^3 and should provide no sintering problems as long as they are segregated from the hotter (up to 50 Btu/hr-ft^3) coprocessing wastes.

Because of the variety of calcines that are scheduled[18] to be placed in the fourth bin set and because of the uncertainties in the calcine thermal conductivity data and inaccuracies in sintering temperature data, it cannot be proven in advance that sintering will not occur for all calcines. Flowsheets for calcination of some wastes (2nd cycle blends) are still being developed. For these reasons only a range of acceptable heat generation rates can be stated, i.e. 8 - 15 Btu/hr-ft^3. However, sintering can be prevented by: (1) Determination of decay heat generation limits for each type of calcine prior to calcination based on measured sintering temperatures and thermal conductivities, and (2) either calculating from the age of the wastes that the decay heat generation rate for a particular liquid waste is less than the above limit, or sampling each tank prior to calcination and calculating the decay heat generation rate from radiochemical analysis.

The operational safeguard against calcine sintering is the column of thermocouples spaced every 5 ft on the centerline of each bin. A regular monitoring of the bin temperature will warn of temperatures approaching excessive values and allow remedial action--e.g. stop filling or change waste--before excessive temperatures are reached. However, sufficient margin must be provided to allow for continued heating after filling has ceased. The bins do not come to a steady state temperature until a month or more after solids addition is stopped.

The consequences of calcine sintering would be increased difficulty in retrieval. There would be no near-term danger of radionuclide release. However, eventually--after hundreds of years beyond facility life--the storage facility would probably deteriorate and allow exposure of the remaining (transuranic) radionuclides to ground moisture if the facility were not repaired or the solids retrieved. The facility is expected to have a sufficient life--around 500 yr--to allow decay of gamma emitters. The bins could then be entered and direct-contact methods used to retrieve the solids. Hence, there is little chance of any accidental calcine sintering leading to the eventual release of radionuclides from the storage.

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. However, cooling air could be lost in several ways. The radioactivity monitor on the cooling air discharge will automatically shut-off the cooling air flow if radioactivity is detected in the cooling air. Radioactive particles might get into the vault cooling air as a result of (1) intrusion from outside in the cooling air, (2) leakage in 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 were plugged or if the outlet stack were destroyed by an earthquake or tornado.

The consequence of loss of vault cooling air would be an increase in the vault, bin, and calcine temperature. During the first one to five years of bin use, the loss of vault cooling air might lead to calcine sintering if the calcine temperature with natural convection cooling were close to the sintering temperature. The consequences of sintering were discussed in Section 2; no fission product release would occur. Emergency cooling can be provided if needed by attaching an improvised filter and blower section to the vault ventilation ducting and venting cooling air through the filter.

Operating experience[4] with the first and second bin sets has shown that natural air convection is completely adequate for cooling without forced convection. Heat is removed from the bin vault by both natural convection and conduction through the concrete walls and surrounding soil. Both the first and second bin sets were deliberately isolated when they contained calcine with approximately the same total heat generation rate as projected for the fourth bin set ($\sim$ 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 45^{o}C. During the first month after isolation, the calcine temperature had increased approximately 40^{o}C.

Similarly, the second bin set was isolated in March 1969, during the 3rd 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 150°C in the alumina calcine and 100°C in the zirconium calcine. The maximum bin wall temperature was 82°C.

The operating experience with these two bin sets shows that only moderate temperature increases will occur due to vault isolation, and about one month would be available to install an improvised blower in the existing duct, if desired. These temperature increases can only potentially cause sintering if the calcine temperatures are high enough before isolation, (i.e. Centerline temperatures are already close to sintering temperatures), and if the vault is isolated shortly after filling. 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.

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 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[4, 17].

5. Bin Failure

There is a small possibility of a bin failure as a result of a welding defect coupled with an earthquake. 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. 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--e.g., 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 (see Section VI-1). A (severely) defective weld is likely to fail if stressed by an earthquake. The bin contents would then be dumped on the vault floor. The radioactivity detector on the vault cooling air discharge would automatically isolate the vault upon detecting airborne radioactivity and prevent large-scale release of the solids. The airborne solids release would be less than the DBA case discussed below and in Section C. 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. However, final vault clean-up would require waiting many decades for sufficient radionuclide decay to allow entry into the vault.

There is also a small chance of a small leak as a result of undetected shipping or construction damage, 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 discussed in detail in Section C.

The sensitivity of the radiation monitor on the vault air is sufficient 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 diversion system which would shut off the cooling air flow.

6. <u>Vault Leakage</u>

The leakage of groundwater into the vault would not result in a release of radionuclides. The calcine 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 checking for radioactivity (contaminated liquids would be transferred to the ICPP waste evaporators).

One should also note that the soil at the ICPP is sub-saturated; moisture does not drain from the soil into voids. Water can get into vaults only from the channelling of rainwater or snowmelt through voids in the ground to a crack.

7. Transport Line Leak

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

It will be possible to sample the air in the transport line encasement and to decontaminate the encasement. The encasement will have lines through which decontamination solutions could be introduced and drained (to the NWCF hot sump) if needed.

C. Design Basis Accident

The Design Basis Accident (DBA) selected for this PSAR is the leakage of solids into the vault during filling through a hole eroded in a fill line. The bin leak is considered with and without two complications: a) a reduction in the transport system operating vacuum, and b) 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 known about erosion rates to say with certainty that a hole will not be eroded in filling the somewhat larger (than the 2nd bin set) bins in the Fourth Calcined Solids Storage Facility. The spill 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 considered in Section IV-4 is not considered because of its low probability.

Case A -- Radiation Monitor Functional

The assumptions of case A are:

1. The bin is 75% full when the hole occurs.
2. The cooling air radioactivity monitor detects the spill, closes the vault inlet, and alarms. The vault outlet is closed manually.
3. Operations continue until the bin is full.
4. The fraction of the solids added after the start of the hole that are spilled 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/sec. Only a small fraction of the largest particles would be released; one percent 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 hit the bins and the vault floor. Also fines agglomerated on the large particles could be knocked loose 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 particle sizes of the airborne particles are initially distributed evenly over the range from 0 to 20 microns diameter.

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 5 microns (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. Radioactivity 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 hours because of a monitor failure (eg, failure of the blower that draws the air sample to the monitor). The failure is detected on the next monitor check 1 to 16 hours later (Monitor checks are once a shift) and the vault is isolated. Cooling air circulating thus might continue for 16 hours 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 is assumed and a smaller hole size is assumed than in Case A, because the radioactivity monitor failure is assumed to be detected within a maximum 16 hours after the start of the spill and the filling of the bins is stopped. The erosion-caused hole is assumed to start small and grow as the bins continue to be filled. Since it is assumed for Case A that the bins continue to be filled-after the hole is detected and the vault isolated-the hole will continue to grow in size for several months.

3. Ten percent of the spilled solids are airborne small particles.
4. All of the small airborne particles are carried out of the vault (for the 8 hours) by the cooling air.
5. The particle sizes of the airborne particles are distributed evenly over the size range from 0 to 20 microns diameter.
6. Inversion (class F) atmospheric conditions prevail.
7. The particles larger than 5 microns diameter 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 tabulated in Table II. The calculation models are detailed in Appendix B. With the assumption (see Table I) of a radionuclide content of 4 Ci/lb

TABLE II

CALCULATED CALCINE RELEASE TO THE ATMOSPHERE, LB.

	Monitor Functions	Monitor Fails
Vacuum Normal	1	4
Vacuum Reduced	20	90

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 III for each of the four subcases.

TABLE III

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 together.

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 from the ground. 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 will be 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--at the time, 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 chance 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 closed-off 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.

VI. LONG-TERM CONSIDERATIONS

The Fourth Calcined Solids Storage Facility will be designed to provide both long-term interim storage and calcine retrievability capabilities. The calcined solids can thus be either retrieved and transferred, or stored for a long interim period, depending on ERDA policy. A nominal design life of 500 years has been chosen for the facility to provide a factor of 100,000 decay of Cs-137 and Sr-90. After 500 years 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 derive nearly 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 shut-down. Some aspects of long-term interim storage are discussed below:

1. Bin Life

   The actual life of the stainless steel bins is not completely certain because of uncertainties about the actual weld conditions, surface contaminations, and environmental conditions. There appears to be no problem for the first 200 years 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 years under dry conditions. A corrosion allowance of 0.006 in. for the bin interior was obtained by extrapolating the observed corrosion of corrosion coupons exposed inside existing calcine bins for 2 years. A corrosion allowance of 0.010 in. for the bin exterior was obtained from data in the literature[14,15].

   After the facility is 200 years 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 will be monitored with corrosion coupons placed both inside and outside the bins. The corrosion coupons will be as representative as feasible of the bin materials: made from the same material heats, welded in the same manner, and undergoing the same surface treatments. The coupons will be retrieved periodically for inspection. It will also be possible to (remotely) inspect the bin exterior.

In conclusion, the bins should last at least 200 years. 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 uncertainity about the long-term durability of the reinforced concrete vault. The concrete could deteriorate and the reinforcing steel could corrode. However, the vault exterior will be accessible by digging away 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 the facility integrity and the safety of the population of the surrounding area. The safety-oriented instrumentation consists of the activity 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 activity monitor which will require once-a-shift chart checks, weekly filter changes, and some servicing. After an initial decay period of 5 to 10 years, the cooling air will probably be closed off. The cooling-air activity monitor could then be replaced by periodic --e.g. once a year--pulling of "grab" samples. The calcine and bin temperature measurements will be needed to guide filling operations and during changes in cooling conditions--e.g., closing off the vault. 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 thus be abandoned after monitoring the temperature peak following vault isolation. Hence, the only monitoring requirement remaining after vault isolation would be the sump liquid detector. This instrument could be monitored remotely from another location. Servicing would be required on an annual basis.

A periodic vault inspection—once every few years—will also be required to verify the facility integrity. The vault will be 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--could be inserted for visual inspection of the floor, bin walls and vault walls. This could be done by someone from another site if ICPP was not in operation. There would also be a long-term need to maintain a 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 decontamination nozzles through the retrieval access line, spraying the walls with a decontamination solution—e.g., nitric acid—, and removing the solution with a jet introduced through the retrieval access line. The facility should then be sufficiently decontaminated to allow 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 removed after decontamination; however, 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 years) before removing the solids until the bins could be entered or develop more sophisticated removal systems than are now available.

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APPENDIX A

SAFETY ANALYSIS REPORT ASSUMPTIONS

Safety Limits and Requirements

None

Standard Operating Procedures

1. Activity monitors are checked once a shift.

2. Calcine temperatures are checked once a week while the bins are filling.

3. Procedure to avoid sintering:

   (1) Determine decay heat generation limits for each type of calcine prior to calcination based on measured sintering temperatures and thermal conductivities, and

   (2) Calculate from the age of the wastes that the decay heat generation rate for a particular liquid waste is less than the above limit, or sample each tank prior to calcination and calculate the decay heat generation rate from radiochemical analysis.

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 from 0 to 20μ.

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

The maximum radionuclide content is:

Cs-137	4 Ci/lb
Sr-90	4 Ci/lb
alpha	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 is (in lb/d.)

$$(86{,}400\ s/d)V_sCA$$

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), and input and deposition rate will reach equilibrium;

$$I - 86{,}400\ V_sCA.$$

Solving for C gives

$$C = I/86{,}400\ V_sA$$

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 $R/I = \dfrac{0.02H}{86{,}400V_s}$

The maximum spill rate (reduced vacuum) is assumed to be 20% while the last ¼ of a bin is being filled:

$$0.2 \times 7200\ \text{lb/day} = 1440\ \text{lb/day},$$

$$0.2 \times \tfrac{1}{4} \times 567{,}000\ \text{lb} = 28{,}000\ \text{lb. total}$$

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	$2x10^{-5}$	0.8	112
1.5	5	140	$5x10^{-4}$	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	$8x10^{-4}$	0.45
15	30	840	0.05	$3x10^{-4}$	0.3
20	10	280	0.08	$2x10^{-4}$	-

The calculated release of submicron 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)] $3x10^{-10} cm^3/sec$

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 submicron particles (assumed 0.3μ) is 0.05(144 lb/d) = 7.2 lb/d.

The mass of a 0.3μ particle is

$$\frac{\pi}{6} (0.3x10^{-4} cm)^3 \frac{2.5 g/cm^3}{454 g/lb} = 7.2x10^{-17} lb$$

The source/cm^3 is then

$$\frac{7.2 \text{ lb/d}}{(86,000 \text{ s/d})(7.8x10^{-17} \text{lb})(50,000 ft^3)(28,300 \frac{cm^3}{ft^3})} = 755 \text{ sec}^{-1} cm^{-3}$$

The steady state (0.3μ) particle concentration is then

$$\left(\frac{755\ sec^{-3}cm^{-3}}{3x10^{-10}\ cm^{3}.sec}\right)^{1/2} = 1.6 \times 10^{-6} cm^{-3}$$

The mass concentration is

$$(1.6x10^{-6}\ cm^{-3})(28,300\ cm^{3}/ft^{3})(7.8x10^{-17} lb) = 2.5 \times 10^{-6} lb/ft^{3}$$

The release with 2%/day leakage is

$$(0.02d^{-1})(20d)(50,000\ ft^{3})(3.5x10^{-6}\frac{lb}{ft^{3}}) = 0.07\ lb.$$

The fine particles will agglomerate mostly with the larger particles which settle out. However, some agglomerates will still be in the submicron size range. The calculation of the full size distribution would require much more sophisticated calculation than performed here. To account for larger submicron particles, the "submicron" release quantity is increased to 1 lb. The remaining 139 lb of this size fraction are assumed to agglomerate into the 1-2μm 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-year lifetime calculated using the ICRP Lung Clearance Model. The atmospheric dispersion factors used were an annual-average χ/Q of $2x10^{-17}$ S/M^3 and a Class F fumigation χ/Q of 6.2×10^{-6} S/M^3.

REFERENCES

1) R. H. Perry, and Chilton, C. H. Ed., Chemical Engineers Handbook, 5th Ed. McGraw-Hill, 1973, Fig. 5-82.

2) Gussman, et.al., Proc 7th AEC Air Cleaning Conference "Factors in Condensation Nuclei Counters for Measurement of Aerosol Agglomeration," 1961.