240
5/22/68

402

IN-1155
July 1968

MASTER

STORAGE FACILITIES FOR RADIOACTIVE CALCINED WASTE SOLIDS
AT THE IDAHO CHEMICAL PROCESSING PLANT

C. L. Bendixsen
G. E. Lohse

IDAHO NUCLEAR CORPORATION
NATIONAL REACTOR TESTING STATION
IDAHO FALLS, IDAHO

U. S. ATOMIC ENERGY COMMISSION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

IN-1155
Issued: July 1968
Waste Disposal and Processing 76
TID-4500

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

STORAGE FACILITIES FOR RADIOACTIVE CALCINED WASTE SOLIDS AT THE IDAHO CHEMICAL PROCESSING PLANT

by

C. L. Bendixsen
G. E. Lohse

IDAHO NUCLEAR CORPORATION

A JOINTLY OWNED SUBSIDIARY OF
AEROJET ALLIED
GENERAL CHEMICAL
CORPORATION CORPORATION

U. S. Atomic Energy Commission Research and Development Report
Issued Under Contract AT(10-1)-1230
Idaho Operations Office

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

STORAGE FACILITIES FOR RADIOACTIVE CALCINED WASTE SOLIDS
AT THE IDAHO CHEMICAL PROCESSING PLANT

By

C. L. Bendixsen
G. E. Lohse

A B S T R A C T

A detailed description of the second facility installed at ICPP for storage of radioactive calcined solids produced at the Waste Calcining Facility is presented. The major design criteria and special features such as a newly designed solids flow diverter valve, corrosion coupons of typical construction materials, a solids removal system, and thermocouples for measuring temperature gradients, are described. Costs of the two sets of storage facilities currently installed at ICPP are compared.

TABLE OF CONTENTS

	<u>Page</u>
I. SUMMARY	1
II. INTRODUCTION	3
III. DESCRIPTION OF THE FACILITY.	6
1.0 Design Criteria	6
1.1 Storage Volume	6
1.2 Maximum Allowable Temperature.	6
1.21 Heat Generation Rate	7
1.22 Cooling of the Bins.	8
1.23 Bin Diameter	9
1.3 Materials of Construction of Storage Bins.	10
1.4 Concrete Vault	11
1.5 Solids Removal	13
2.0 Design Details.	13
2.1 Storage Bins	13
2.2 Vault Size and Description	13
2.3 Solids Transport System.	16
2.31 Solids Storage Cyclone	19
3.0 Special Features.	19
3.1 Flow Diverter Valve.	20
3.2 Corrosion Samples.	21
3.3 Solids Removal	22
3.4 Temperature Gradient Measurements.	22
IV. COMPARISON WITH FIRST SOLIDS STORAGE FACILITY.	25
V. CONCLUSIONS.	27
VI. REFERENCES	28
Appendix A -- Itemized Actual Costs for the Second Solids Storage Facility.	30
Appendix B -- First Solids Storage Facility at the WCF.	31

LIST OF FIGURES

<u>No.</u>		<u>Page</u>
1.	Block Diagram of Waste Calcining Facility at ICPP.	4
2.	Heat Generation of Calcined Solids from Typical MTR-type Waste	8
3.	Corrosion Rate of Metal Alloys at High Temperature	11
4.	Second Facility for Permanent Storage of Granular Calcined Solids	12
5.	Plot Plan of ICPP.	14
6.	Elevation View of Typical Bin in the Second Solids Storage Facility	15
7.	Simplified Flow Diagram for Second Solids Storage Facility	17
8.	Solids Storage Cyclone	19
9.	Solids Flow-Diverter Valve in the Second Solids Storage Facility	20
10.	Solids Flow Rates Through Full Scale Model of Flow- Diverter Valve	21
11.	Thermowell Positions in Earth Fill Surrounding Solids Storage Vault.	23
12.	Simplified Diagram of Solids Storage Vault and Bins Showing Typical Locations of Thermocouples	24
13.	First Solids Storage Facility.	31

I. SUMMARY

The conversion to solids of high-level radioactive aqueous wastes was successfully demonstrated during the first campaign in the Waste Calcining Facility (WCF) at the Idaho Chemical Processing Plant (ICPP) that lasted from December 1963 to October 1964. This campaign was terminated when the first set of solids storage bins was filled with approximately 7500 cubic feet of solids generated from calcining over 500,000 gallons of aqueous waste. Using the experience gained during this campaign and additional development data, a second solids storage facility was designed and constructed to provide an additional 30,000 cubic feet of storage for WCF solids product. The new facility consists of seven stainless steel bins which are 12 feet in diameter and 42 feet high. The bins are contained in a buried, circular concrete vault and are in a circular arrangement, one in the center with the other six equally spaced around it. The design and construction of the vault and bins were based upon the following criteria:

1. A design limit on vessel-wall temperature of 290°C to preserve structural integrity.
2. A maximum solids temperature of 700°C to prevent any significant volatilization of fission-products.
3. Cooling of the bins (to remove the heat of fission product decay) by natural convection of atmospheric air over the bin surfaces.

The new structure contains the following four special features which will assist in providing data for the design of future solids storage facilities.

1. A specially designed solids flow diverter valve which can selectively divert special types of solid waste into either of two of the seven bins installed.
2. Corrosion coupons of four different construction materials inserted in the bins which are planned for removal and examination over an 80-year period.

3. Thermocouples strategically placed throughout the structure to provide data for determining important heat transfer characteristics.
4. Provisions for installing solids removal facilities.

The second solids storage facility provides more economical storage volume (because of differences in design criteria) than does the original facility which consisted of a square concrete vault and four nests of annular type bins. Unless continuing studies indicate that significant changes should be made in the present design criteria, future solids storage facilities are likely to be of the same basic design as the second solids storage facility.

II. INTRODUCTION

The increasing production rate of high-level radioactive wastes throughout the world during the past two decades places great emphasis upon improving the methods for safe and economical waste storage. At least 500 years are needed before normal fission product decay will reduce the radioactivity of high-level wastes to levels which are safe for environmental release. At the Idaho Chemical Processing Plant (ICPP), high-level radioactive liquid wastes are calcined to produce granular solids in the Waste Calcining Facility (WCF); these solids are safer and less costly to store than are the liquid wastes. The solids are stored in air-cooled, stainless steel bins which are enclosed in underground concrete vaults. Stainless steel tanks, holding up to 300,000 gallons each, were originally constructed for long-term storage of liquid radioactive waste; these are now used only for interim storage until the liquid waste is calcined in the WCF.

Using a method conceived at the Argonne National Laboratory⁽¹⁾, a fluidized bed calcination process was developed at the ICPP for converting liquid radioactive wastes to a solid form⁽²⁻⁷⁾. Utilizing these concepts, the Fluor Corporation designed and built the Waste Calcining Facility⁽⁸⁾ at the ICPP. The heart of the WCF is a fluidized bed calciner vessel, shown in Figure 1. Acidic liquid waste is fed directly into the heated bed of granular solids in the calciner vessel. In the high-temperature (400°C) fluidized bed, the liquid waste is converted to gaseous water vapor and nitrogen oxides plus solid metallic oxides. The water vapor and nitrogen oxides plus some small particulate matter leave the top of the calciner vessel and are processed through decontamination equipment before release of the off-gas to the atmosphere. The radioactive calcined solids containing the metallic oxides of the waste are slowly and continuously withdrawn from the bottom of the calciner vessel and are transported pneumatically to large underground bins for storage.

During a period of 10 months in 1963 and 1964, over 500,000 gallons of radioactive aluminum nitrate liquid waste were converted in the WCF⁽⁹⁾

Figure 1

BLOCK DIAGRAM OF WASTE CALCINING FACILITY AT ICFP

by the Phillips Petroleum Company to approximately 7500 cubic feet of solid calcined waste. Operation was suspended only when the first set of solids-storage bins⁽⁸⁾ were filled.

Using actual experience gained during the successful operation of the WCF⁽⁹⁾ and information from laboratory studies⁽¹⁰⁾, design and construction of a larger and more economical solids storage facility were completed in 1966. The purpose of this report is to summarize the design criteria, the details of construction, and the special features of this new installation. Operation of the WCF, now under the jurisdiction of the Idaho Nuclear Corporation, began again in March, 1966 and lasted through March, 1968. During this time 880,000 gallons of aluminum nitrate waste and 109,000 gallons of zirconium fluoride waste were converted to approximately 12,000 cubic feet of solid calcined waste and stored in the second set of solids storage bins.

III. DESCRIPTION OF THE FACILITY

The second solids storage facility, consisting of seven vertical, stainless steel bins surrounded by a cylindrical concrete vault, fulfills the requirements of an adequate storage volume, a safe solids temperature (which depends collectively upon the solid's generation rate, the mode of bin cooling, and the bin diameter), and dependable construction materials. The mode of construction of the new facility contains many features which provide for minimal surveillance plus low construction and operating costs. Other special equipment has been installed to collect data; ie, temperature, corrosion rates, etc., for use in the design of future solids storage facilities.

1. DESIGN CRITERIA

Important design criteria such as storage volume, storage bin centerline temperature, materials of construction, etc., are each discussed in the following paragraphs.

1.1 Storage Volume

Based upon an expected calcining production rate^{*} averaging about 6400 cubic feet of solids per year, the 30,000-cubic-foot storage volume of the new facility will be adequate until 1971. Recent operation of the WCF indicates that an average net feed rate of 70 gallons per hour of zirconium type waste can be maintained.

1.2 Maximum Allowable Temperature

To eliminate any possible environmental release of fission products, a maximum bin centerline temperature of 700°C was chosen--well below the

*The projected yearly production of calcined solids is based upon an average liquid to solids volume reduction ratio of nine fold. In estimating the required solids storage volume, a total of ten percent of the bin volume was allowed for the storage of spent silica-gel from the ruthenium absorbers, of calciner startup beds, and of solids produced from calcining non-radioactive feed during startup.

temperature at which the fission products would volatilize from the solids storage bin. The centerline temperature of a bin for storing heat generating solids is affected by the interrelations of the solids heat generation rate, the mode of cooling the bins, and the bin diameter. Since these items are equally important in determining the temperature levels in a specific facility, each is discussed in turn in sections 1.21, 1.22, and 1.23 below.

The selection of a bin centerline temperature is important since the energy released from radioactive decay produces heat as the energy is absorbed by the surrounding materials. In the storage of radioactive calcined solids, this heat must be removed at a rate to keep the temperature low enough to prevent the volatilization of radioactive fission products from the stored solids. Little was known of the volatility of fission product oxides at high temperatures when the first solids storage bins were built. Therefore the solids temperature in those bins was selected during design to be below the calcining temperature, 400°C . Studies have since shown that value to be unnecessarily conservative.

Alumina solids produced from high-level radioactive wastes at Argonne⁽¹¹⁾ showed no loss of gross gamma activity when heated to 700°C . Tests being conducted at the ICPP when the final design was completed, also showed no measurable release of fission products from actual WCF solid samples when heated to 800°C ⁽¹⁰⁾. Studies completed since then indicate that at a temperature of about 700°C and above, measurable amounts of ruthenium will volatilize slowly and migrate to cooler zones of the solids. However, this migration and condensation will cause no adverse effects to the second solids storage facility. To date no release of fission products from the nearly 20,000 ft³ of stored solids at the ICPP has occurred.

1.21 Heat Generation Rate. The heat generation rate of fission products contained in the solids is an important factor in determining the centerline temperature in a particular storage bin. The second set of solids storage bins was designed to cope with a heat generation rate of at least 0.3 Btu/hr per pound of solids since it represented the minimum activity level which could be easily achieved through proper aging and/or blending of various liquid wastes produced at the ICPP. However, operating

experience has indicated that the bins can safely store solids having a heat generation rate of approximately 0.6 Btu/hr per pound. This higher acceptable heat generation rate is desirable because of the increased flexibility for blending various ages and types of waste prior to calcination. Figure 2 shows a plot of typical heat generation rates for MTR-type fuel waste versus time since discharge from the reactor.

Figure 2

HEAT GENERATION OF CALCINED SOLIDS FROM TYPICAL MTR-TYPE WASTE

1.22 Cooling of the Bins. Natural convection of air over the bin surfaces was selected as a practical and economical method of cooling the vault and storage bins. Natural convection has the advantages of simplicity, low corrosion potential, low unit cost, and need for minimal surveillance.

All heat produced in the solids eventually must be released to the atmosphere or to the ground near the WCF, and each of the following cooling modes was considered as a possible means to dissipate radiolytic decay heat.

1. No coolant (buried bins)
2. Direct cooling
 - a. Air passed through the solids
 - b. Slurry (water plus calcine)
3. Indirect cooling
 - a. Water
 - b. Air (once-through or closed-circulation systems)
 1. Forced convection
 2. Natural convection

Underground burial is the most economical method for shielding radioactivity, and the storage of solids in directly buried vessels would be a simple and cheap method, but its feasibility depends upon the value of the soil thermal conductivity and upon the maximum solids temperature allowable in the vessel⁽¹²⁾. An evaluation indicated that the thermal conductivity of soil that would surround a vessel would be too low for adequate heat conduction away from the vessel walls and for keeping the solids temperature below 700°C for large diameter vessels; consequently, this scheme was discarded. All the other modes of cooling except once-through natural convective air cooling were discarded because of high material costs or because of the probability for breakdown of the system through corrosion or mechanical failure with the resultant release of radioactive contamination.

The use of individual shrouds to surround each bin was considered because there was a possibility that this would direct the cooling air more closely to the bin surfaces and thereby improve the convective heat transfer rate. However, an investigation of the first set of storage bins at ICPP showed that a significant heat transfer mechanism was radiation of heat to surrounding walls and, then, conduction of the heat through those walls to the soil⁽⁹⁾. Experimental investigation of the shroud concept in a laboratory⁽¹³⁾ proved that shrouds seriously hindered the radiative heat transfer rate and did not significantly improve heat transfer rates to air using only natural convection. Therefore, the concept of employing shrouds was discarded.

1.23 Bin Diameter. The diameter of the storage bins was an important part of the overall design limitation, and its selection depended upon a simultaneous analyses of:

1. Engineering factors such as the solids heat generation rate, thermal conductivity of the solids, heat transfer mechanism, and selection of the maximum allowable system-temperature and cooling mode of the bins.
2. Economic factors such as field fabrication of the bins as compared with shop fabrication and problems of transportation of large diameter bins.

It was concluded that a bin with a diameter of 12 feet could be economically shop-fabricated and transported to the ICPP and that it would also satisfy the engineering criteria. The engineering factors were evaluated mainly from a simplified mathematical model of the seven-bin arrangement. Since the mathematical model for radiative heat transfer was complex and included many factors which were difficult to determine accurately, the heat transfer model was based primarily on natural convective heat transfer to air.

1.3 Materials of Construction of Storage Bins

The primary bases for selection of materials for bin construction were lifetime requirements and overall cost. Due to the large volume of calcined waste together with the great amount of long-lived fission products (particularly strontium-90 and cesium-137), at least 500 years will be needed before release of the solids from storage to the open environment may be considered. Economical non-metallic materials, such as concrete, were eliminated from consideration because of their susceptibility to failure through cracking, thus making it impossible to insure their integrity over long lifetimes. The use of buried single-walled vessels for radioactive storage was considered; however, it was deemed advisable to have the additional safety factor possible with double containment. A double containment system such as metal bins in a concrete vault could temporarily, or permanently if conditions allowed, contain any solids coming from a breached metal bin.

Corrosion data from field experience on metallic materials over the long lifetime expected of the bins are almost non-existent. However, an analysis of the available data indicated that the corrosion of the metallic bins by the cooling air to be more significant than that by the calcined solids. Based on these data, austenitic stainless steel was selected over carbon steel in order to extend the bin life to at least 500 years

(see Figure 3)⁽¹⁸⁾. Stainless steel Type 304 was used because it was the least expensive of the austenitic stainless steels.

Figure 3
CORROSION RATE OF METAL ALLOYS AT HIGH TEMPERATURE

1.4 Concrete Vault

A circular concrete vault (see Figure 4) containing seven vertical bins--six equally spaced bins encircling a center bin--represents the best configuration to optimize cooling characteristics and unit costs of a 30,000 cubic-foot storage facility. Reinforced concrete as the vault construction material best satisfies the requirements of storage; shielding of radioactivity, bin protection against changing weather conditions, secondary containment of the solids in the event of bin failure, and construction material cost. The circular vault arrangement also makes effective use of the high compressive strength of concrete through a pressure ring effect and thereby reduces the volume and cost of construction material.

WCF SOLIDS STORAGE BINS

Figure 4
SECOND FACILITY FOR PERMANENT STORAGE
OF GRANULAR CALCINED SOLIDS

1.5 Solids Removal

Due to (1) the possibility of future development of an improved technology for storing radioactive wastes, (2) the possible future desirability of recovery of specific isotopes from the solidified waste, or (3) the possibility, however remote, of bin rupture, it may be desirable to remove the radioactive solids from the bins at some time during the 500-year life of the solids storage facility. Because of the uncertainty of any such need, only minimal parts of a solids removal system were installed in the facility; these are described in Section 3.3.

2. DESIGN DETAILS

The second solids storage facility, which is located 150 feet southeast of the WCF, (see Figure 5) contains three major parts: The storage bins, the storage vault, and the solids transport system. A brief discussion of design details of each part, together with their associated piping and instrumentation follows:

2.1 Storage Bins

The second solids storage facility consists of a circular concrete vault holding seven vertically-arranged cylindrical metal bins. Each bin has dished heads at both ends and is 12 feet in diameter and 42 feet high as shown in Figure 6. All junctions are welded, and each weld has been 100 percent radiographed. The bins, which are constructed of ASTM-SA-240-61T Type 304 stainless steel, have $\frac{1}{4}$ -inch thick walls, including a $\frac{1}{8}$ -inch allowance for corrosion protection. The design pressure range is ± 3.75 psig at a maximum design temperature of 500°F . Each bin has a 4580-cubic foot capacity for a total capacity of 32,400 cubic feet. This capacity is roughly equivalent to 2,000,000 gallons of liquid waste, assuming a volume reduction factor of 9 to 1 and a 10 percent void space at the top of the bins.

2.2 Vault Size and Description

The solids storage vault was designed to house and protect the solids storage bins and to provide a radiation shield for any persons in the area near the facility. The vault is also constructed to act as

Figure 5
PLOT PLAN OF ICPP

Figure 6
ELEVATION VIEW OF TYPICAL BIN IN THE SECOND SOLIDS
STORAGE FACILITY

a secondary containment vessel should one or more of the bins ever crack or rupture. The vault has a 46-foot inner diameter, two-foot thick reinforced concrete walls, and stands 68 feet high. The vault rests on bedrock, 45 feet below ground level. The vault walls above ground level have been covered with an earth fill for additional radiation shielding. The roof of the vault is constructed of prestressed concrete beams and covered with a poured concrete roof. The vault has been equipped with a steam jet to remove any water in case a crack ever develops in the concrete followed by a heavy rainfall or a flood in the area. The water table is about 500 feet below the vault; consequently no problem from underground water is ever expected.

The vault has been provided with a cooling air inlet filter and duct work to transport the natural convective cooling air to the bottom of the vault (see Figure 7). A stack has been installed on top of the vault to discharge off-gas cooling air to the atmosphere. An automatic shutoff valve in the cooling air inlet and a provision for insertion of high efficiency filters in the exhaust air have been included in the cooling system. In case of bin failure and discharge of solids to the vault floor, the cooling air could carry radioactive particles toward the cooling air stack. If this occurs, the automatic shutoff valve will close if an unsafe level of radioactivity is detected in the cooling gas. Off-gas filters can then be installed in the cooling system, after which cooling air again could be allowed to circulate.

Atop the solids storage vault are an instrument building and an equipment vault. The instrument building contains instruments for recording pressures, off-gas flows, temperatures, radioactivity in the cooling air, and the sump liquid level of the vault. The equipment vault contains the solids storage cyclone with its associated valves and piping.

2.3 Solids Transport System

The solids transport system is designed to move safely up to 1000 lb/hr of granular solids from the WCF to the storage area where the solids can be diverted into the bins. The calcined solids are pneumatically conveyed in a concrete-encased, three-inch, stainless steel transport

Figure 7
SIMPLIFIED FLOW DIAGRAM FOR SECOND SOLIDS STORAGE FACILITY

line. The solids transport line enters a cyclone separator located in the equipment vault which is atop the storage vault and the solids drop from the cyclone to a six-inch distributor pipe inside the storage vault as shown schematically in Figure 7. The bins are attached to the distributor pipe at different elevations by gravity flow lines. These lines are inclined downward at a minimum of 45 degrees to insure solids flow into the bins; the measured static angle of repose of the solids is 33 degrees. The order of filling five of the bins is determined by the height that their gravity flow lines are attached to the distributor pipe. Bins WC-136-1 and WC-136-2, on the other hand, are filled selectively by use of a specially designed flow diverter valve located at the base of the distributor pipe. This valve is discussed further in Section 3.1.

During WCF operation, the solids-transport air is returned to the calciner from the cyclone through a three-inch, concrete-encased stainless steel pipe. Each bin has a separate vent line which is also attached to the returning transport air line. When the calciner is not operating, the solids transport line from the WCF is valved off, and the bin off-gas is vented to the first solids storage facility; there, any off-gas is cooled and filtered before being discharged through the ICPP stack to the atmosphere. By making use of the bin off-gas system in the first solids storage facility, considerable savings were effected. This technique required only a three-inch concrete-encased line for connecting the two systems, and thus eliminated construction of a filter, condenser, and transfer lines to the stack from the new facility.

Although no plugging of the solids gravity flow lines is expected, eight cleanout stubs are provided to unplug the bin fill lines, the cyclone, and the distributor pipe. Seven stubs enter the distributor pipe, one placed opposite each of the gravity flow lines to the bins. The eighth stub enters the top of the cyclone. The cleanout lines extend outside the equipment vault where they are each equipped with a flanged neoprene diaphragm and a blind flange. If cleanout becomes necessary, the blind flange can be removed, the neoprene diaphragm can be punctured, and a probe can be inserted for unplugging. During normal operation, the flexible diaphragm seals the probe surface and prevents discharge of contaminated air in case the bins are ever slightly pressurized.

2.31 Solids Storage Cyclone. The solids storage cyclone (see Figure 8) is used to separate the calcined solids from the WCF transport air. The cyclone is constructed of 3/16-inch Type 304 stainless steel plate and was designed for full vacuum and 30 psig at 500°C, for a pressure drop of four inches of water at 100 scfm, and for a maximum solids loading of 1000 lbs/hr. The cyclone was designed for a minimum removal efficiency of 98 percent for solids having a size distribution 99.8 percent greater than the 100 Tyler mesh screen. The root pass of all butt welds and the finished surface of all welds were dye penetrant inspected. All butt welds were 100 percent radiographed, and fillet welds were spot radiographed at a minimum of two places per seam.

3. SPECIAL FEATURES

Special features for the new solids storage facility include a solids flow diverter valve, corrosion coupons of various construction

Figure 8
SOLIDS STORAGE CYCLONE

materials, a solids removal system, and a series of thermocouples to provide temperature data on the entire facility. A discussion of these features follows:

3.1 Flow Diverter Valve

A flow diverter valve, as shown in Figures 4 and 9, was specially designed⁽¹⁴⁾ and installed in the second solids storage facility to divert the solids into either bin number WC-136-1 or WC-136-2; this valve can be used if desired to keep special types of solids separated from other stored solids. The valve contains no moving parts and is located at the base of the distributor pipe in the solids storage vault. The calcined solids drop through the distributor pipe into a square box which has separate, three-inch, horizontal outlets to the two bins. Two air purge lines enter the box, one opposite each of the outlet lines, and terminate at the junction of the box and outlet lines. The angle of repose of the solids in the box is such as to prevent solids flow through the horizontal

Figure 9

SOLIDS FLOW-DIVERTER VALVE IN THE SECOND
SOLIDS STORAGE FACILITY

outlets under normal conditions. When desired, air purging into one of the outlet lines overcomes this angle of repose, and allows the solids to flow into one of the two bins. Before installation, a full-scale model was constructed and tested⁽¹⁵⁾, and the results confirmed the applicability of the valve and established its operating parameters (see Figure 10). The tests showed that many types of solids could be diverted with this type of valve and also indicated that a flow diverter valve could be designed to handle multiple outlets.

3.2 Corrosion Samples

A long-term corrosion testing program has been instigated for the new storage bins. Existing corrosion information on metal alloys suitable as possible construction material for calcined-solids storage bins has been obtained from tests lasting only 10 years or less. Although corrosion of bin walls by the solids is not expected to be a problem, little is known about the corrosive effects of the solids on metal alloys for long periods of time. Therefore, 160 sample coupons were hung on ten cables in two of the storage bins; one bin is expected to contain zirconium type solids with aluminum type solids in the other. Each cable has 16 sample coupons, four each of four different alloys--ASTM Types 405, 304, and 304L stainless steels, and AISI Type 1025 carbon steel. It is planned that one cable from each bin be withdrawn on the 5th, 10th, 20th, 40th, and 80th year of solids storage and that the samples will be examined and measured for corrosion effects. The test results will be used for more accurate determination of the expected lifetime of the bins and for the design of future solids storage bins.

Figure 10

SOLIDS FLOW RATES THROUGH FULL SCALE MODEL OF FLOW-DIVERTER VALVE

3.3 Solids Removal

Partial installation of a solids removal system has been made since it is possible that advancing technology or integral failure of the facility may make it desirable or necessary to remove the calcined solids from the present bins. Any prediction of the time when removal may be necessary would be based on arbitrary assumptions; therefore, since the installation of a complete solids removal system would have been costly, only a minimal part was installed in the new facility. A six-inch Schedule-40 pipe extends from the top of each bin upward through the vault roof into a concrete cap where the pipe is flanged and capped. If the need does arise, the concrete cap may be lifted, the flange and welded cap removed, and a solids removal system inserted.

3.4 Temperature Gradient Measurements

A series of 187 thermocouples have been installed throughout the new solids storage facility to obtain temperature data (see Figures 11 and 12). The thermocouples fall into two groups, those inside the bins and those outside the bins in the surrounding vault and soil. The thermocouples inside the bins will be used to monitor the bin centerline temperature (hence the solids depth in the bins) and to determine the temperature gradient within the solids.

The thermocouples inside the vault and in the surrounding soil will provide data for analyzing the mechanisms of heat transfer from the facility. The thermal conductivity of the surrounding earth fill also may be determined. All the collected information eventually will be used to improve the design of future storage facilities.

Figure 11
THERMOWELL POSITIONS IN EARTH FILL SURROUNDING
SOLIDS STORAGE VAULT

Figure 12
SIMPLIFIED DIAGRAM OF SOLIDS STORAGE VAULT AND BINS
SHOWING TYPICAL LOCATIONS OF THERMOCOUPLES

IV. COMPARISON WITH THE FIRST SOLIDS STORAGE FACILITY

A comparison of the second solids storage facility at the ICPP with the first one shows that several significant cost reducing features were incorporated in the second facility which will result in lower unit storage costs of the solids. A direct cost comparison is shown in Table I, and construction costs for the second solids storage facility are itemized in Table II of Appendix A. Appendix B contains a brief description of the first solids storage facility. The largest cost reduction feature results from designing for a bin centerline temperature of 700°C instead of $<400^{\circ}\text{C}$ and for storage of solids having a heat generation rate per pound of solids of 0.3 Btu/hr instead of 2.5 Btu/hr. These criteria allowed the use of less costly cylindrical bins instead of the annular bin configuration used for the first set of bins⁽¹⁶⁾. The second set of bins are also much taller than the first set of annular bins.

Another economical feature of the new facility is the vault and bin configuration. The circular arrangement of the bins allowed a reduction in the overall size of the vault as compared to a rectangular-shaped vault housing bins in the same configuration. The circular vault also has superior compression strength in a pressure ring effect; hence, thinner walls and less reinforcement were required than for the straight walls of a rectangular vault.

In addition, a less expensive cooling system was installed in the new facility. Natural convective cooling eliminated the need of air blowers, and only a minimal amount of ductwork had to be installed with the second solids storage facility. Any need for an off-gas cleanup system was eliminated by attaching vent piping to the off-gas system of the first solids storage facility. This also was significant cost reduction feature.

Table I

UNIT COST COMPARISON OF THE TWO WCF SOLIDS STORAGE FACILITIES

	First Set of Solids Storage* Bins (Two Foot Thick Annular Bins)	Second Set of Solids Storage Bins (12-foot Diameter Cylindrical Bins)
Number of Bins	4	7
Total Volume of Bins, ft ³	8,200	32,400
Cost of Bins, \$	121,900	311,000
Cost of Vault, \$	159,500	580,000
Cost of Cooling Equipment, \$	<u>50,600</u>	<u>32,000</u>
Total Direct Cost, \$	332,000	923,000
Construction Overhead, \$	132,800 (40%)	131,000 (14%)
Engineering and Inspection, \$	49,800 (15%)	196,000 (21%)
Other Indirect, \$	<u>66,400 (20%)</u>	<u>109,000 (12%)</u>
Total Investment, \$	581,000	1,359,000
Cost per ft ³ of available bin volume, \$	70.8	45.3

*The costs cited for the first solids storage facility⁽¹⁷⁾ were normalized to those of the second storage facility by increasing the costs by a factor of 1.10--a ratio based on the Engineering News-Record Construction and Building Cost Indexes for 1965 and 1961.

V. CONCLUSIONS

Waste calcination and solids storage at the WCF are expected to continue along the same general trend as at present although no final plans have yet been made on the design of future solids storage facilities. Future designs will be based upon the results of further experimental studies and continued evaluation of the present storage facility. The type, size, and cost of future storage facilities will depend primarily upon the maximum allowable bin temperature, the fuel processing schedules, and the heat generation rate of the solids⁽¹⁵⁾. Since the ICPP has a large volume of interim storage tankage available for liquid wastes, fresh wastes can be allowed to age or can be used as blending stock with older wastes such that the heat generation rate of the solids will be in a desirable range for greatest bin economy.

If the maximum allowable solids temperature can be increased significantly above 700°C, it may be possible to increase the diameter of the bins and thus decrease the unit storage cost. It may also be possible to calcine higher-activity level waste solutions, and thus create solids having higher heat generation than the solids now being produced in our overall waste management scheme. This decision awaits further study, but indications are that bin centerline temperatures significantly above the present 700°C limit would not create any hazards.

VI. REFERENCES

- (1) A. A. Jonke, et al, "The Use of Fluidized Beds for the Continuous Drying and Calcination of Dissolved Nitrate Salts," Nuclear Science and Engineering, 2, pp. 303-319 (May 1957).
- (2) E. S. Grimmett, Calcination of Aluminum-Type Reactor Fuel Wastes in a Fluidized Bed, IDO-14416, (August 1957).
- (3) D. R. Evans, Pilot Plant Studies with a Six-Inch Diameter Fluidized Bed Calciner, IDO-14539 (April 1961).
- (4) B. P. Brown, et al, Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot-Square Pilot Plant Calciner. Part I: Equipment and Initial Process Studies, IDO-14586 (June 1962).
- (5) B. R. Wheeler, et al, Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot-Square Pilot Plant Calciner. Part II: Factors Affecting the Intra-Particle Porosity of Alumina, IDO-14587 (July 1962).
- (6) B. P. Brown, et al, Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot-Square Pilot Plant Calciner. Part III: Intermediate Process Studies - Runs 11 through 22, IDO-14618 (February 1964).
- (7) B. P. Brown, et al, Development of a Fluidized Bed Calcination Process for Aluminum Nitrate Wastes in a Two-Foot-Square Pilot Plant Calciner. Part IV: Final Process Studies - Runs 23 through 37, IDO-14627 (June 1964).
- (8) L. T. Lakey, et al, ICPP Waste Calcining Facility Safety Analysis Report, IDO-14620 (December 1963).
- (9) R. E. Commander, et al, Operation of the Waste Calcining Facility With Highly Radioactive Aqueous Waste, IDO-14662 (June 1966).
- (10) M. W. Wilding and D. W. Rhodes, Stability Studies of Highly Radioactive Alumina Calcine during High Temperature Storage, IDO-14670 (January 1966).
- (11) J. W. Loeding, et al, The Fluid-Bed Calcination of Radioactive Waste, ANL-6322, (May 1961).
- (12) D. E. Black and B. R. Dickey, Mathematical and Experimental Analysis of Heat Dissipation from Cylindrical Sources Buried in Soil, IN-1032 (December 1966).

- (13) J. C. Petrie, et al, Radiative and Convective Heat Transfer Within Vertical Annular Spaces Open at the Ends, TN-1110 (December 1967).
- (14) J. W. Gerhart, Development of a Valve for the Control of Streams Composed of Powdered or Granular Solids, HW-54330 (November 1957)
- (15) J. C. Petrie, E. D. Cooper, A Flow Diverter Valve for Granular Solids, IDO-14666 (March 1966).
- (16) J. L. Lockard, J. W. Garner, Solidification and Long-Term Storage of Highly Radioactive Wastes, CONF-660208 (November 1966).
- (17) J. I. Stevens, An Economic Evaluation of Ultimate Disposal of Liquid Radioactive Wastes by the Fluidized Bed Calcination Process, IDO-14595 (October 1962).
- (18) T. Lyman, Metals Handbook, American Society for Metals, Metals Park, Ohio, 1961, 8th Ed., p. 598.

APPENDIX A

Table II

ITEMIZED ACTUAL COSTS FOR THE SECOND SOLIDS STORAGE FACILITY

A.	Site Preparation, Grading and Landscaping	\$ 15,279
B.	Buildings and Structures	
	Solids Storage Building	354,193
	Equipment Vault Building	7,877
	Instrument Building	17,277
	Cooling Air Stack	<u>5,332</u>
	SUBTOTAL	\$384,679
C.	Utilities	27,843
D.	Process Equipment	
	Solids Storage Bins	310,814
	Expansion Joint Assemblies	27,254
	Steam Syphon Jet	996
	Solids Storage Cyclone	14,725
	Gate Valves	7,688
	Air Cooling Equipment	20,532
	Off-Gas System	<u>37,381</u>
	SUBTOTAL	\$419,390
E.	Instrumentation	
	Thermocouple Assemblies	56,930
	Temperature Indicators	10,648
	Pneumatic Transmitters	2,488
	Pressure Recorders	1,220
	Sump level Recorder	500
	Radiation Monitor System	<u>3,722</u>
	SUBTOTAL	\$75,468
	TOTAL DIRECT COSTS	\$922,659
	TOTAL INDIRECT COSTS	\$436,000
	TOTAL COSTS	\$1,358,659

APPENDIX B

FIRST SOLIDS STORAGE FACILITY AT THE WCF

As shown in Figure 13, the original storage facility consists of four assemblies of bins housed in a single concrete vault. Each assembly contains a central 36-inch diameter cylindrical bin surrounded by two 24-inch thick annular bins all fabricated of Type 405 stainless steel. The annular bins are 20 feet high and the central bins are 24 feet high. Each of the bins was filled sequentially through the series of pipes radiating at different elevations away from the cyclone outlet above the central bin. Two-inch wide, annular, cooling air channels separate the storage bins to permit passage of cooling air. This storage facility was equipped with over 200 thermocouples to determine the level of solids in the bins during filling and to monitor heat generation rates and radio-nuclide decay.

Figure 13

FIRST SOLIDS STORAGE FACILITY