Retrieval System for Calcined Waste for the Idaho Cleanup Project – 12104

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ABSTRACT

This paper describes the conceptual approach to retrieve radioactive calcine waste, hereafter called calcine, from stainless steel storage bins contained within concrete vaults. The retrieval system will allow evacuation of the granular solids (calcine) from the storage bins through the use of stationary vacuum nozzles. The nozzles will use air jets for calcine fluidization and will be able to rotate and direct the fluidization or displacement of the calcine within the bin. Each bin will have a single retrieval system installed prior to operation to prevent worker exposure to the high radiation fields. The addition of an articulated camera arm will allow for operations monitoring and will be equipped with contingency tools to aid in calcine removal. Possible challenges (calcine bridging and rat-holing) associated with calcine retrieval and transport, including potential solutions for bin pressurization, calcine fluidization and waste confinement, are also addressed.

INTRODUCTION

The Calcine Disposition Project (CDP), which is part of the Idaho Cleanup Project (ICP), has the responsibility to retrieve, treat by hot-isostatic pressing (HIP), and package for transport and final disposal of the calcine stored at the Idaho Nuclear Technology and Engineering Center (INTEC) located at the Idaho National Laboratory in southeast Idaho. Calcine is a granular solid that is the product of thermally treating liquid HLW produced during the reprocessing of spent nuclear fuel to recover uranium and sodium-bearing waste (SBW) from decontamination activities. Currently, the calcine is stored in six Calcine Solids Storage Facilities (CSSFs). Each CSSF contains from three to twelve stainless steel tanks surrounded by a concrete vault. The CSSFs are discussed in more detail in the Plant Facility and Support section of Report 12289 *The Hot-Isostatic Pressure Treatment Process for High-Level Waste Calcine for the Idaho Cleanup Project: An Overview of Project Planning*[1]. DOE selected HIP as the technology to treat calcine through the decision analysis process which evaluated several treatment technologies. In the *Amended Record of Decision: Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement*[2,3], the DOE documented the selection of HIP as the technology to treat calcine to provide a volume-reduced, monolithic, waste form that is suitable for transport outside of Idaho, with completion of treatment by a target date of December 31, 2035. This date is an Idaho Settlement Agreement milestone.[3] In addition, the Amended Record of Decision stated that "The Integrated Waste Treatment Unit (IWTU) facility, after completion of its SBW mission and suitable reconfiguration, will be used to support treatment of the calcine and other wastes and meet associated safety and seismic design basis requirements."

The design for the CDP complies with the requirements of the Amended Record of Decision and other requirements documents, including DOE Orders and Policies, CFRs, the ICP contract and state and local regulations. In the following sections, the systems engineering approach that was used by the CDP to comply with these requirements is discussed along with the Design for Quality (DFQ) tools that were used in the systematic approach. Following this discussion are sections on the process and facility at a conceptual level.

DESIGN REQUIREMENTS

The functional and interface requirements for the retrieval nozzle system are based on the Technical and Functional Requirements (T&FR) for the Calcine Disposition Project – Conceptual Design and system driven design decisions which include the following:

1. Complete retrieval, treatment, and packaging by 2035.

2. Provide for remote viewing and operation of the CDP retrieval, treatment, and packaging processes.

3. Protect equipment and personnel from extended exposure to extreme elements (e.g., snow, rain, wind, heat, and cold) expected during construction and operations.

4. Utilize existing access risers in the CSSFs, if possible, in lieu of designing a different means of access.

5. Remove calcine to the maximum extent practical in each bin such that the volume of the residue remaining in each CSSF meets acceptable risk criteria for the radioactive and hazardous constituents. (Risk Criteria being developed).

6. Provide video capabilities to observe and record the retrieval activities inside the bin. Functionality shall include ability to view any location within the bin and ability to zoom for close inspection, while accounting for dust conditions due to fluidization of the waste.

7. Provide a means to clear and/or remove obstructions such as clogged calcine, thermowells and others.

8. Continuously maintain a primary confinement boundary between waste and workers/environment.

9. Retrieve calcine from any CSSF bin within CSSF-1 through CSSF-6 and allow calcine to be directed to any line of the downstream processes.

The design team also worked with the engineers associated with interfacing systems to establish the requirements imposed on the retrieval system by the upstream and downstream functions. These neighboring functions, which directly affect or are affected by the retrieval process, were discussed, and characteristics were included in the list of design requirements. These additional interface requirements include:

1. The ability to connect with the pneumatic transport system.

2. The ability to connect with the bin access riser.

3. Loads from the retrieval system must not be placed on the bin access riser.

4. Minimize loading on the CSSFs.

5. Minimize CSSF modifications.

6. Attenuate radiation to protect workers.

7. Provide a secondary confinement function.

8. Function in all weather conditions.

Using a DFQ and functional analysis methodology, these T&FR and system to system requirements were assembled into a House of Quality table and ranked by their importance, with the most important given a 5 and the least given a 1.

The House of Quality is a Lean Manufacturing and Six-Sigma design tool which provides a structured approach to satisfying design requirements with verifiable design technical characteristics, also known as design functions. The team then developed a set of technical characteristics which would directly satisfy each individual requirement. To help focus the design team's attention on the most critical areas, these characteristics were then scored on how well they satisfied all requirements and these scores were weighted against the requirement ranking. The highest scoring characteristics yield the greatest potential in the design and are developed first until all the requirements are satisfied. The technical characteristics for the retrieval nozzle system which satisfy all of the requirements, as identified in the functional analysis, are given in Table I.

Table I. Retrieval Nozzle Technical Characteristics Ranked by Relative Importance

	Technical Characteristic	Percent Importance
1	Ability to gain access to filled bin	11%
2	Ability to recover from off-normal conditions	11%
3	Capability to handle multiple forms of calcine	11%
4	Ability to meet target calcine retrieval rate of 500 lb/hr	11%
5	Ability to clear bin of calcine	8%
6	Reduce footprint on CSSF roof	8%
7	Reduce supported weight on roof	8%
8	Provide remote viewing	7%

DESIGN AND DESCRIPTION OF EQUIPMENT

The retrieval system will provide the means for removing calcine from the bins of the CSSF vaults. The system is designed to fluidize, vacuum, transport and direct the calcine from its current location to the CSSF roof-top transport lines. The retrieval system will be deployed into the stainless steel bins through bin access risers which span from the top of the bin to the roof of the concrete vault. The access risers are steel pipes ranging in diameter from 6-inch to 8-inch. The size and number of access risers available for retrieval operations varies by bin. An articulating camera arm, deployed through a separate access riser will work in conjunction with the retrieval nozzle to aid in calcine fluidization, remote viewing, clumped calcine breaking and recovery from off-normal conditions.

The system will remove calcine from the bin in a top-down approach as shown in Fig. 1. The nozzle tip will be lowered into a full bin to the top of the calcine and will vacuum calcine out of the bin in to the transport lines. A conveying velocity of approximately 60 ft/s is required to support calcine transport. A slewing system, located in the mechanical room above the bin will allow the nozzle to rotate 360 degrees in either direction, using a mechanical slewing drive, to help direct the fluidizing air to the calcine during the retrieval process.

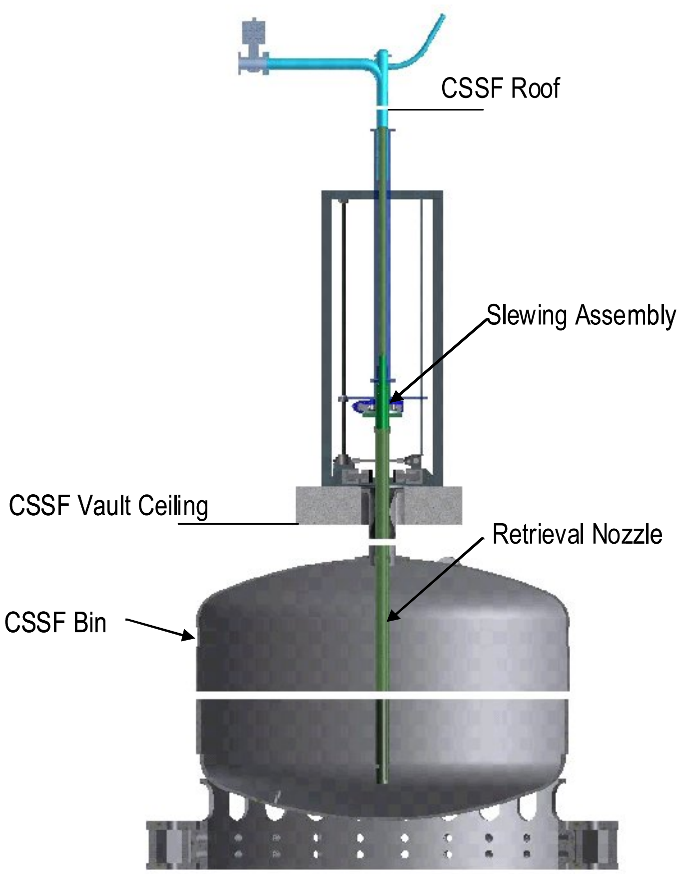

Fig. 1 Retrieval system incremental approach

The vacuum tip (Fig. 2) and associated pipe sections will be constructed in an annulus configuration using 4-inch stainless steel pipe surrounding 2-inch stainless steel pipe. The center pipe will serve as the transport area for the calcine and the annulus will serve as the fluidizing air chamber. An air jet located on the side of the retrieval nozzle vacuum tip will provide makeup air for the retrieval process and a means to fluidize the calcine. The end of the vacuum portion of the nozzle tip will employ a pair of cross-hatch rods across the opening to prevent large agglomerated chunks of calcine from entering into and clogging the retrieval and transport systems. The nozzle tip's annular ring will extend beyond the vacuum opening to prevent the vacuum tip from being plunged directly into the calcine.

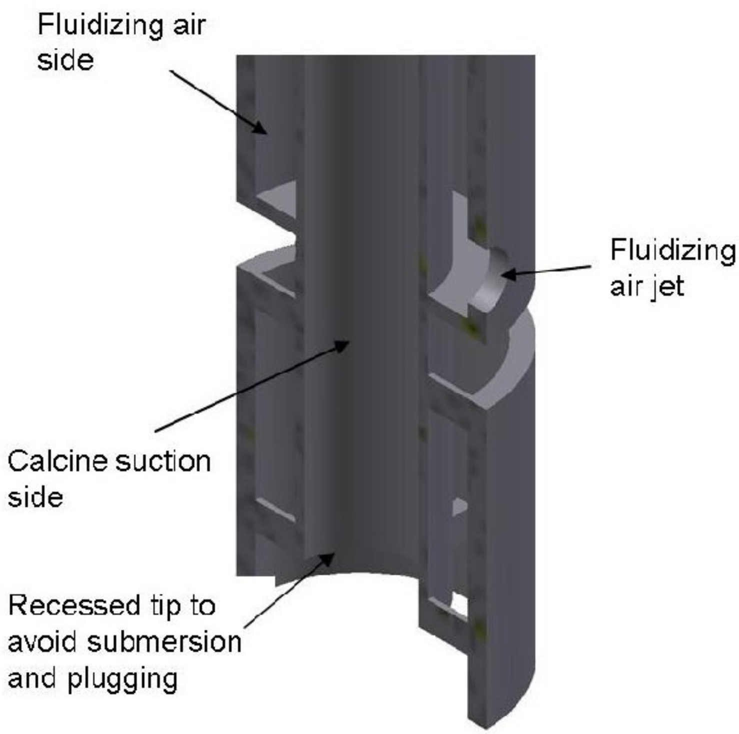

Fig. 2 Retrieval nozzle vacuum tip

Initially, only one portion of the retrieval piping will be installed; the nozzle tip. This pipe section will be installed in conjunction with the slewing assembly. Once retrieval begins, additional pipe sections will be installed using the Nozzle Advancement Subsystem, an automated process contained within a glove box. The retrieval vacuum tip will be lowered as calcine is vacuumed from the bin. After the vacuum tip has been lowered the full length of one annulus-pipe section, the deployed pipe section(s) will be secured in place by the slewing jaws. The slewing head will be uncoupled from the lower section and lifted up to the home position and a new 5-foot pipe section will be installed. Fig. 3 shows the retrieval slewing system in the retracted position, ready for installation of a new pipe nozzle. Once a new pipe section is successfully installed, the retrieval process will resume and the nozzle will continue to vacuum calcine as it moves down the bin.

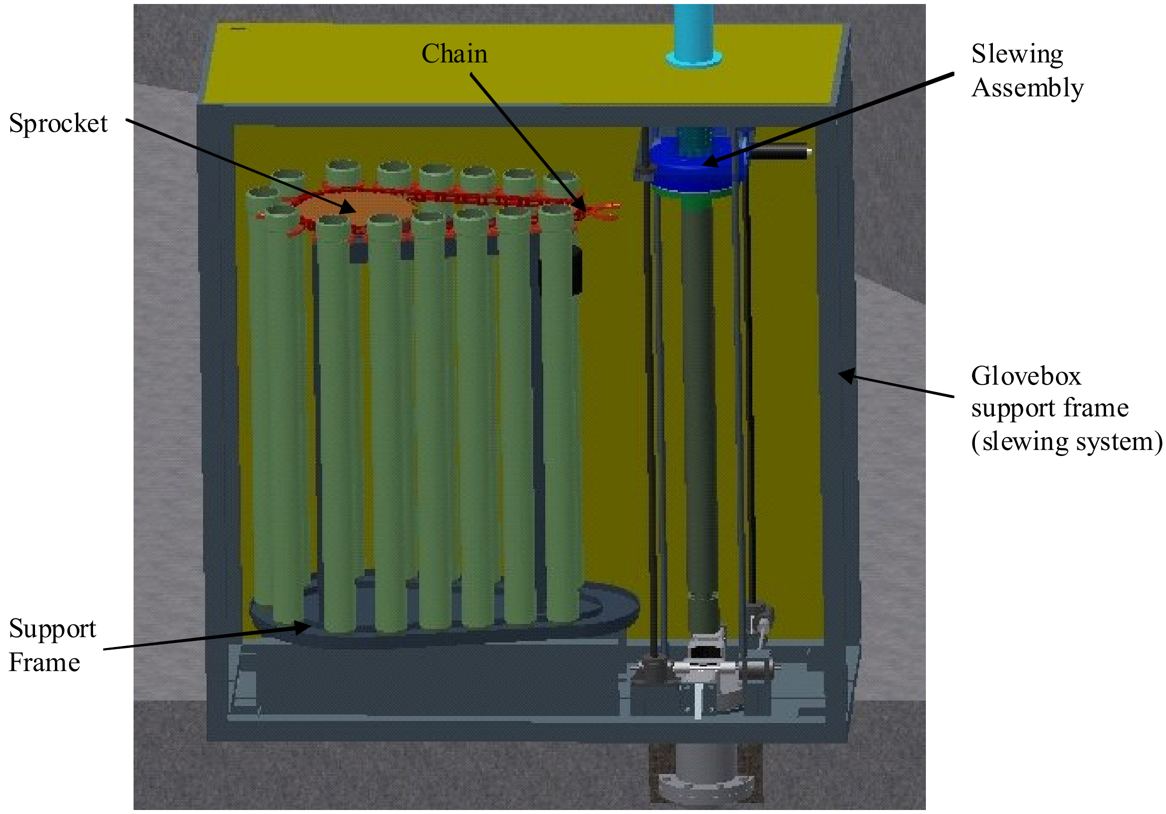

Fig. 3 Retrieval system slewing and advancement assemblies

The vertical retrieval nozzle design must allow the calcine retrieval stream to transition to the horizontal transport lines. This 90 degree change in the flow path requires a specialized elbow. Standard, long-radius piping elbows are susceptible to erosion when transferring abrasive materials (such as calcine) due to the low angle of impact of the particle on the elbow wall. To reduce the potential for erosion at the transition and to ensure the retrieval system maintains contamination confinement, the retrieval design will employ a specialized low erosion elbow (Fig.4). This specialized elbow will reduce erosion by capturing a small initial amount of conveyed particles in a vortex at the bend. These particles will then subjected to the impact of subsequent particles, reducing the impact with the elbow wall. The design employs features and attributes similar to the pneumatic conveying elbow designed by HammerTek, known as the Smart Elbow®[4].

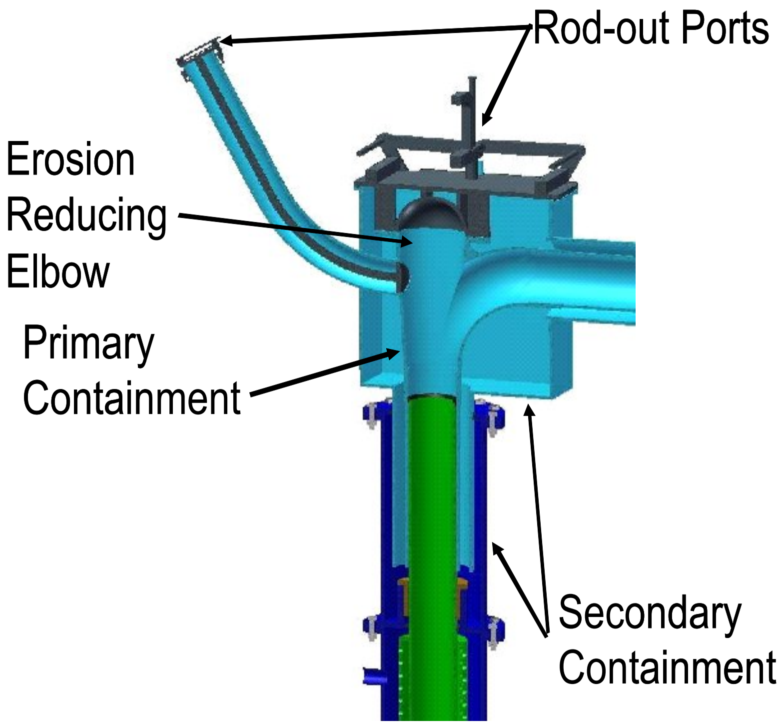

Fig. 4 Retrieval system erosion reducing elbow

The elbow also utilizes double-wall construction to decrease the potential for contamination release. Pressure indicators and radiation monitors will be placed in the vacant region of the elbow box to detect a leak in the transport line, allowing for elbow repair or replacement prior to an outer wall contamination breach.

Rod-out ports have been included in the elbow design to allow for recovery from off-normal conditions. The first rod-out port is located on the left wall of the elbow containment box for use when clearing the Transport Manifold. The second rod-out port is in the form of a removable cap for use when clearing the nozzle. In the event that the nozzle piping or transport line becomes plugged, the rod-out port or removable cap can be opened and a long reach tool used to break up the plug.

The removable cap also allows for quick repairs in the event that excessive calcine erosion is experienced. If the special elbow does erode, the elbow cap can be easily replaced and retrieval operations can resume.

PRINCIPLES OF OPERATION

Operation of the retrieval system will take place from the bin set retrieval control room. From the control room the operator will have the ability to raise and lower the retrieval nozzle through use of the slewing system structural support and control the rotational direction and speed of the slewing drive mechanism, directing the flow of the nozzle fluidizing air. Since the controls of the retrieval nozzle are so embedded within the components and functions of the slewing system, controls for the two systems will be heavily coupled. Retrieval nozzle functions, which include slewing and linear actuation, will be accomplished using a human/machine interface. Digital displays will be used to monitor rotational speed of the stationary nozzle, location of the nozzle tip within the bin and Smart Elbow® leak detection. An automated control system may be employed.

The entire retrieval process will be able to be viewed from an overhead camera, or by using the camera on the articulating camera arm. The operator will be able to use this visual aid to detect in-bin obstructions, uneven calcine levels, and cavities in the calcine caused by the process (rat-holing). As the calcine level becomes uneven, the operator can use the air jet on the articulating camera arm to blow calcine to the nozzle, reducing the hills of calcine which may form. By maintaining an even calcine level in the bin, the operator will be able to significantly reduce the risk of calcine sloughing. Calcine fluidization at the nozzle tip will help to avoid rat-holing during the retrieval process.

One retrieval nozzle system will be required per bin. Each retrieval nozzle system will be accompanied by an articulating camera arm. Two articulating camera arms will be used in each annular-style bin to ensure that all calcine can be adequately reached by the camera arm air jet.

Pressure in the bin will be monitored during the retrieval process to ensure that levels are being maintained at a slight vacuum. This is to ensure that contamination remains in the bin while ensuring that vacuum levels do not exceed the structural capability of the bin. As air is removed from the bin during the vacuum process, make-up air will be added to prevent excessive vacuum which might cause a bin collapse.

FUTURE WORK

Conceptual design of the retrieval system is scheduled to be completed in late 2014 and move in to preliminary design through 2018. Preliminary design will focus on detailed design of the retrieval system and subsystems and include proof-of-concept testing of the retrieval nozzle system. Validation of the retrieval system design will begin in early 2016 with full-scale mock-up testing in an Integrated Test Facility.

SUMMARY

The Calcine Disposition Project has the responsibility to retrieve, treat, and package HLW calcine. The calcine retrieval system has been designed to incorporate the functions and technical characteristics as established by the retrieval system functional analysis. By adequately implementing the highest ranking technical characteristics into the design of the retrieval system, the system will be able to satisfy the functional requirements.

The retrieval system conceptual design provides the means for removing bulk calcine from the bins of the CSSF vaults. Top-down vacuum retrieval coupled with an articulating camera arm will allow for a robust, contained process capable of evacuating bulk calcine from bins and transporting it to the processing facility. The system is designed to fluidize, vacuum, transport and direct the calcine from its current location to the CSSF roof-top transport lines. An articulating camera arm, deployed through an adjacent access riser, will work in conjunction with the retrieval nozzle to aid in calcine fluidization, remote viewing, clumped calcine breaking and recovery from off-normal conditions. As the design of the retrieval system progresses from conceptual to preliminary, increasing attention will be directed toward detailed design and proof-of-concept testing.

REFERENCES

1. Report 12289 ,"The Hot-Isostatic Pressure Treatment Process for High-Level Waste Calcine for the Idaho Cleanup Project: An Overview of Project Planning" Waste Management Symposia, 2012

2. 75 FR 7, 2010, "Amended Record of Decision: Idaho High-Level Waste and Facilities Disposition Final Environmental Impact Statement; Correction," *Federal Register*, U.S. Department of Energy, January 12, 2010.

3. Idaho, 1995, *Idaho Settlement Agreement between the State of Idaho, the Department of Energy, and the Department of the Navy, to resolve all issues in the actions Public Service Co. of Colorado v. Batt, No CV-91-0035-S-EJL (D. Id.) and United States v. Batt, No. CV-91-0065-S-EJL (D. Id.)*, dated October 16, 1995.

4. HammerTek Corporation, Smart Elbow®, Landisville, PA, http://www.hammertek.com/index.asp