Use of Multiple Remote Systems for Calcine Retrieval Operations at Idaho - 16592

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ABSTRACT

There are approximately 5000 m^3 of radioactive calcine material stored in six Calcine Solids Storage Facilities (CSSFs) at the DOE Idaho site. Each CSSF contains from three to twelve stainless steel tanks surrounded by a concrete vault. In accordance with the Idaho Settlement Agreement (ISA), this waste has to be retrieved and immobilized by December 31 2035 although no final decision has yet been made on how the calcine wastes are going to be retrieved from the CSSF's.

One of the primary issues with the retrieval is that, in accordance with the ISA, any existing risers into the tanks have to be used "to the maximum extent possible" in the retrieval process. Since these risers are only 6-8" in diameter, this limits the types of systems that can be used for the retrieval. In addition, each bin containing the calcine has a series of obstructions which need to be navigated around and so inflexible systems such as conventional hose-based vacuum type systems are not feasible. In addition, the retrieval system selected has to be able to manage multiple forms of calcine (powder, granular, agglomerated, chunks etc) and operate in a very highly radioactive environment.

This paper describes the progress made to date in developing an approach based on the use of multiple remote system platforms to gain entry into the binsets and to safely and cost-effectively retrieve the calcine wastes. Much of the work has focused on the application of the OC Robotic snake-arm robot system although significant effort has also been allocated to understanding the deployment mechanism of the snake-arm and to the ancillary supporting systems such as those for contamination control, cutting and welding new risers into the binsets and vacuum hose management within the binset. Future work will include the construction of a scaled mock up to demonstrate the field implementation of the system.

INTRODUCTION

Calcined high-level waste is stored in six of the Calcined Solid Storage Facilities (CSSFs) at the DOE Idaho site as depicted in Figure 1 below (CSSF 7 is currently empty). Under the Calcine Disposal Project (CDP) the calcined waste is scheduled for retrieval and alternative disposal. NuVision Engineering (NVE) has previously developed concepts for the pneumatic retrieval of calcine, and OC Robotics (OCR) has experience in developing and deploying remote manipulators in nuclear and industrial environments. This document presents NVE's and OCR's conceptual design for removal of calcine from CSSF 2. The same technology, with modifications, can be adapted to the other CSSFs.

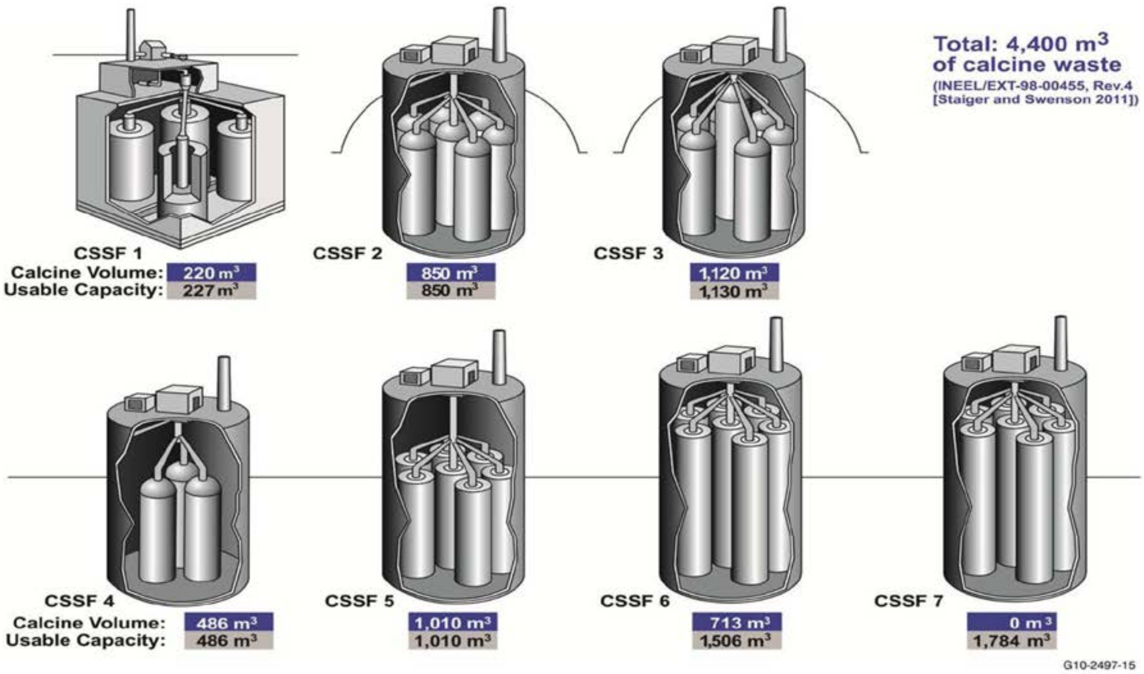

Figure 1: Overview of CSSFs

DESCRIPTION

This section gives a top level overview of the proposed approach. Subsequent sections present more detail. The retrieval system concept has been developed to suit the cylindrical bins in CSSF 2. The specification is presented in Figure 2.

Bin Info:	CSSF 2
Bin Style:	Cylindrical
Bin Material:	304 SST
Number of Bins:	7
Bin Size:	42.3' Tall
	12' Diameter
Thickness of Bins:	0.25"
Risers per Bin:	1
Size of Riser:	6"

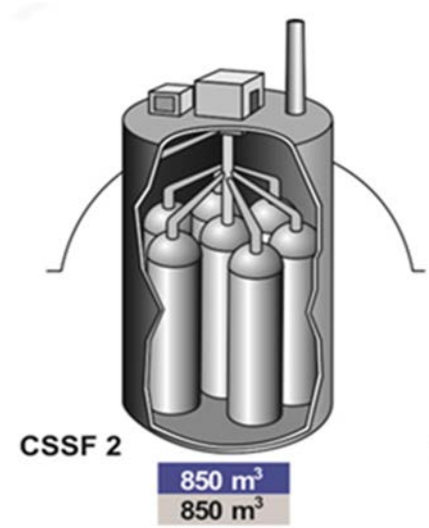

Figure 2: CSSF 2 specification and diagram (CSSF Summary, 2015)

It is understood that human access within the CSSF is prohibited in its current state due to the radiological environment. Remotely operated equipment is required to prepare the bin top area for retrieval. In this concept standard, commercially available, industrial robotic equipment will be used to prepare and clear this area.

To deploy equipment above the bins, it is assumed a grout floor can be put in place up to the dome level of the bins, Figure 3.

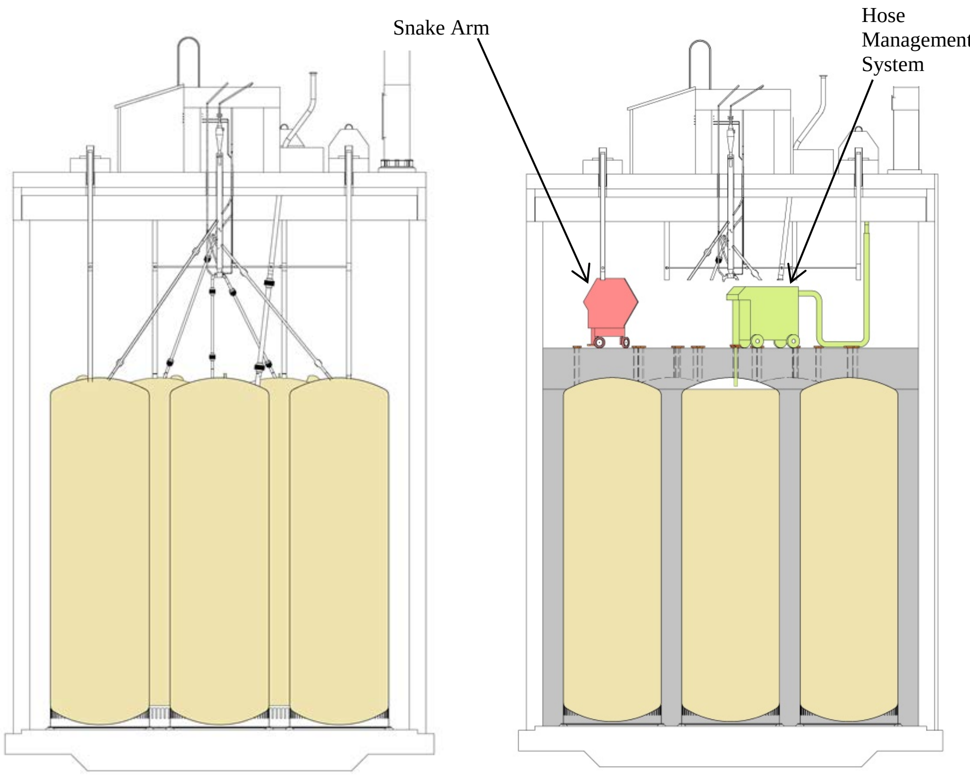

Figure 3: CSSF 2 current state (left), and with grout floor, shown in grey, for equipment to operate on (right)

With the floor in place, fill lines, existing risers, and other pipework and support structure can be emptied of calcine and removed.

Multiple new risers will be added to the bin tops allowing a vacuum hose, manipulator, and vision system to be positioned to allow full access to the bin diameter. Several methods exist to attach the risers, including welding or the use of epoxy to bond them to the bin dome. All of these operations will need to be carried out remotely.

Following the installation of additional risers, the level of the grouted floor will be raised to approximately 1.2m (4ft) above the bin tops to provide a continuous flat floor.

Bulk retrieval of the calcine product will be conducted using a vacuuming system developed by NVE. The vacuum retrieval system comprises a flexible elastomer hose and a concentric nozzle. The hose feed into the bin will be controlled using a mechanism based on existing cable pusher technology.

The nozzle position will be controlled by the OC Robotics manipulator. The nozzle itself will incorporate a linear actuator, enabling fine control of nozzle feed independent of the snake-arm. The proposed in-bin manipulator is a planar snake-arm, (a snake-arm in which all joints can move in a single plane). It is characterized by its ability to coil onto a compact drum and its high slenderness ratio, enabling it to reach the full height of a bin (max 68') through an 8" riser. The in-bin manipulator will be used to position the vacuum nozzle and deploy cutting tools for obstruction removal. Containment concepts for the hose and snake-arm have been considered to allow repositioning movement between risers.

Due to the high levels of radiation inside the bins, it may not be appropriate to integrate a vision system into the snake-arm tool. An alternative has been devised that can be deployed down an empty riser to monitor the snake-arm and hose movement inside the bin, The final piece of in-bin equipment is a periscope and camera, enabling in-bin viewing without exposing the camera to the high radiation dose within the bin.

Methodology

The following sections give more detail on the systems proposed and the approach to be adopted at each stage of the process.

Vault / Riser Preparation

Starting Condition

With the exception of CSSF 6 it is currently assumed that the bins and all of their fill lines are all filled with calcine. CSSF 6 is currently assumed to be half full.

Grout Between Bins

A layer of new grout will be poured into the vault, raising the floor level to just below the top of the bins as shown in grey in Figure 4. This provides an initial surface from which to prepare the above bin area. This grouting concept is not a result of this retrieval concept design effort, but has been developed and proposed by the current managing contractor at Idaho (CH2M Washington Idaho LLC) and is currently under consideration by DOE-ID.

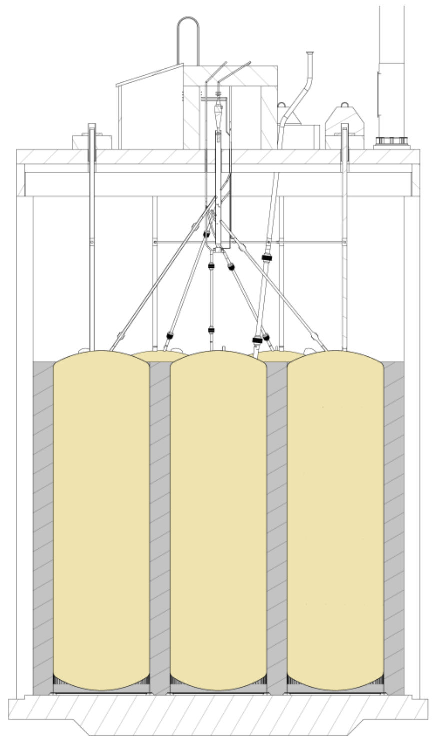

Figure 4: Initial Grouting Between Bins

Clear Existing Fill Lines

Due to the manner in which the bins were filled, it is assumed that some, if not all, of the fill lines will be backed up with calcine.

A vacuum/auger system as shown in Figure 5 will be deployed down the rodding lines into the fill lines to empty the lines above bin heads in preparation for cutting.

Clearing of the fill lines, and removal of a small amount of calcine from the top of the bins should be possible. In addition, vacumming some calcine through the existing risers has been considered.

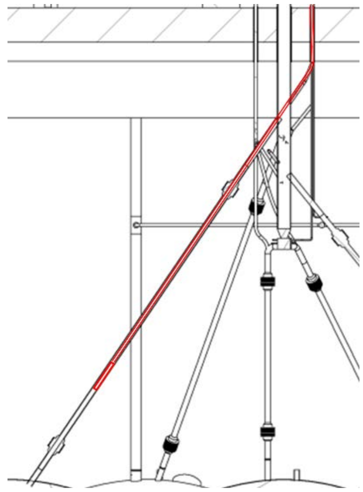

Figure 5: Clearing Existing Fill Lines

Initial Pipe Work

Removal

Installation of remote cutting and handling equipment will be done via the existing access hatches. These may require modification to fit the proposed equipment.

An industrial robot and tools will be used to cut the fill lines, rodding lines, and existing risers (Figure 6). Pipe ends of removed sections will be crimped in place and each section will be laid to the side in the vault for future dispostion.

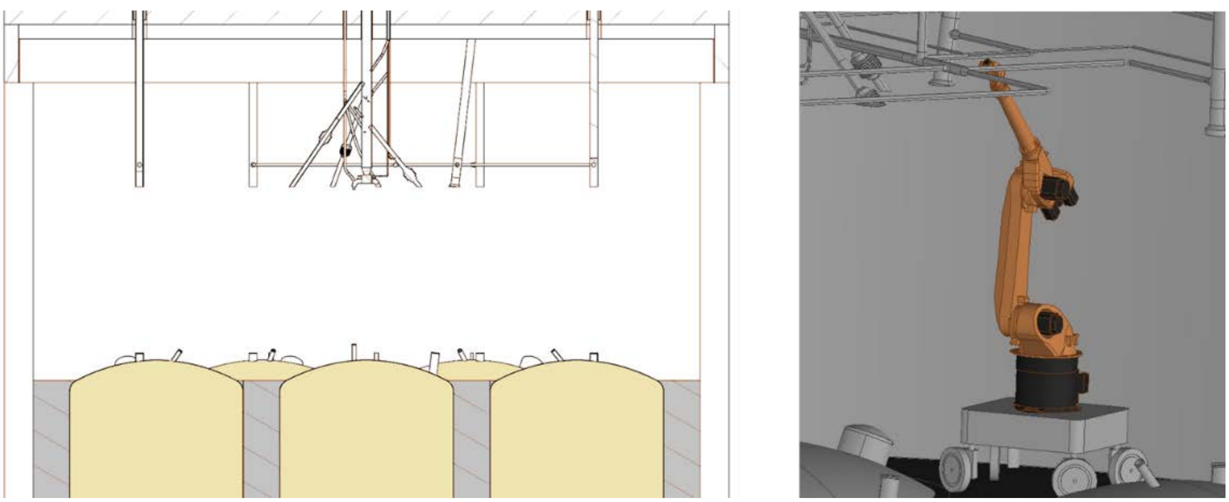

Figure 6: Fill Lines Cut Back

Installation

The industrial robot will be used to locate and profile the new riser positions on the top of each bin (Figure 7). If required, laser scanning can be used to produce an accurate surface model of the section of the dome where the new riser is to be positioned. This information can be used to CNC machine the new riser ends.

The new risers will be positioned and held in place by the industrial robot. They will then be remote welded securely in place. Each riser will be left long and will be cut down once the second layer of grout is added.

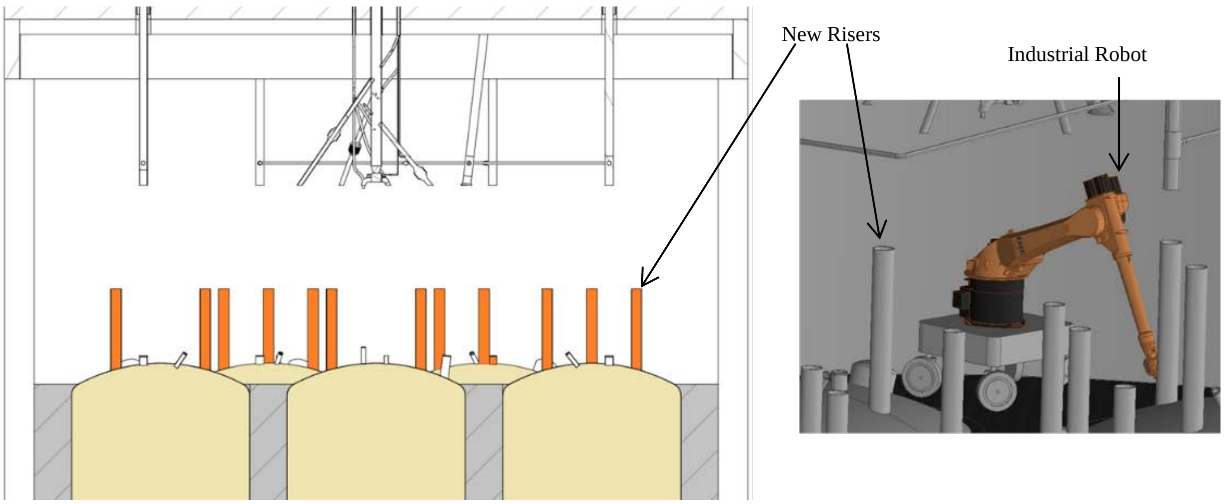

Figure 7: New Risers Installed

Figure 8 shows the conceptual arrangement of the new risers to be attached to each bin. Retrieval will be achieved using a snake arm robot which controls three independent vacuum hoses. The snake-arm robot riser is offset from the centreline of the bin so that the line of introduction of the snake-arm robot is not obstructed by the thermowell(s) or their support structure. The hose risers are offset slightly from each of the support structure arms. This enables tools such as cutters to be posted through the hose risers as close as possible to their location of use, when viewed in plan view. This minimises loading on the snake-arm robot.

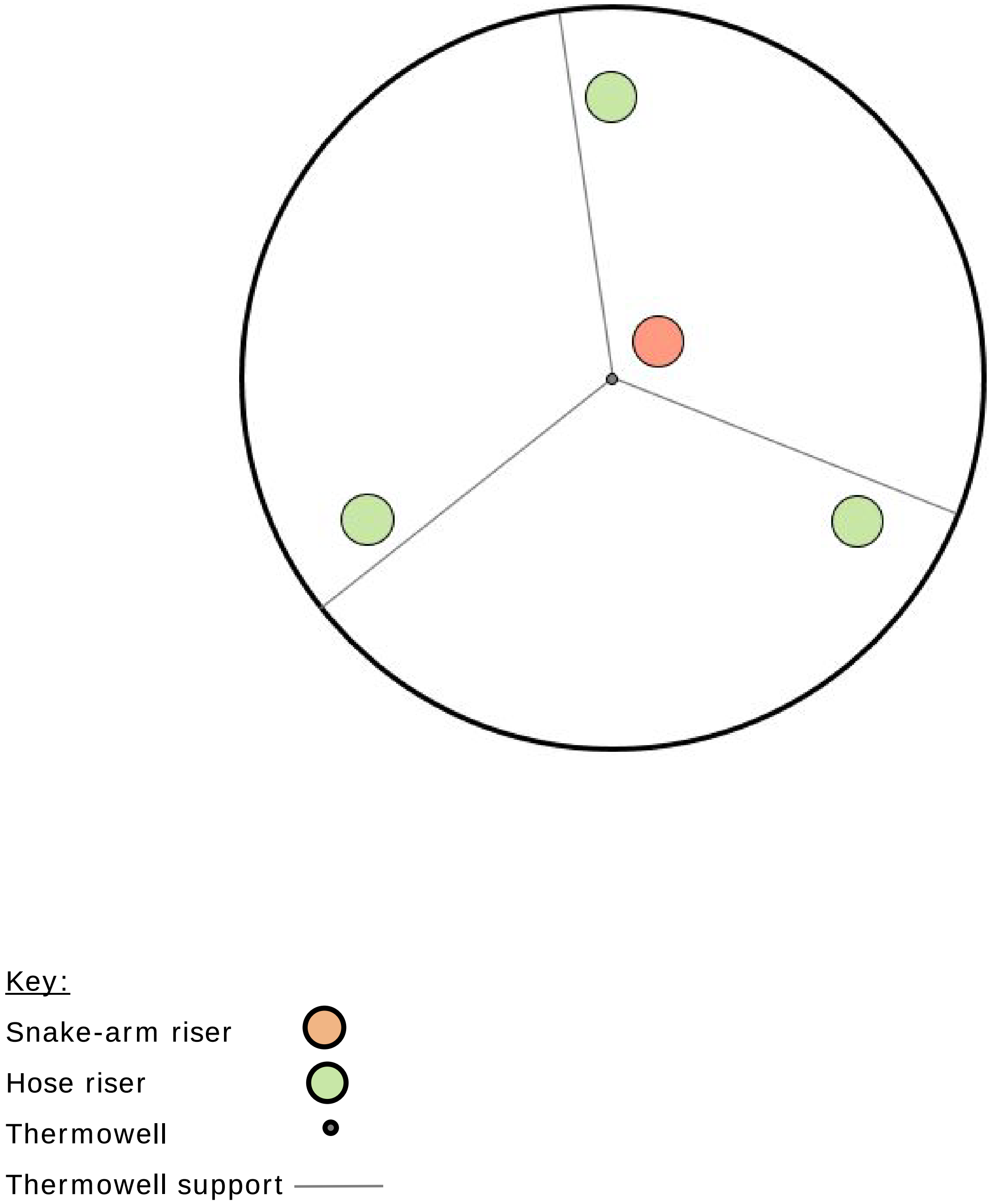

Figure 8: Bin top Riser Pattern

Placement of Grout Cap

The manipulator and platform will be removed from the vault and approximately 4’ of grout added, terminating just below the tops of the new risers as shown in Figure 9.

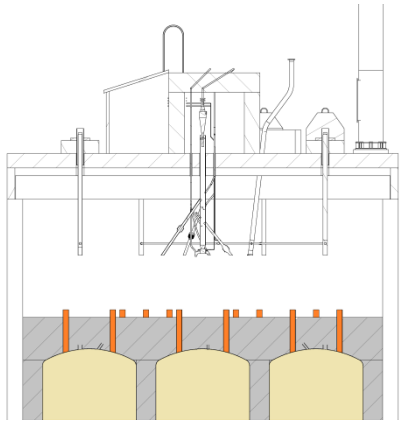

Figure 9: Grout Cap Added

Riser Completion & In-Bore Cutting of Bin Heads

The industrial robot will be lowered back into the vault. The risers will be cut, leaving a small amount of pipe available for the containment gate valve to be installed.

A cutting tool will then be inserted inside the riser to remove a disk from the bin top. The cutting tool will be removed and the gate valve closed to prevent potential spread of contamination.

Figure 10 shows two views of the top of the second layer of the grout depicting the installed gate valves and the industrial robot performing bin top cutting through the installed riser and open gate valve.

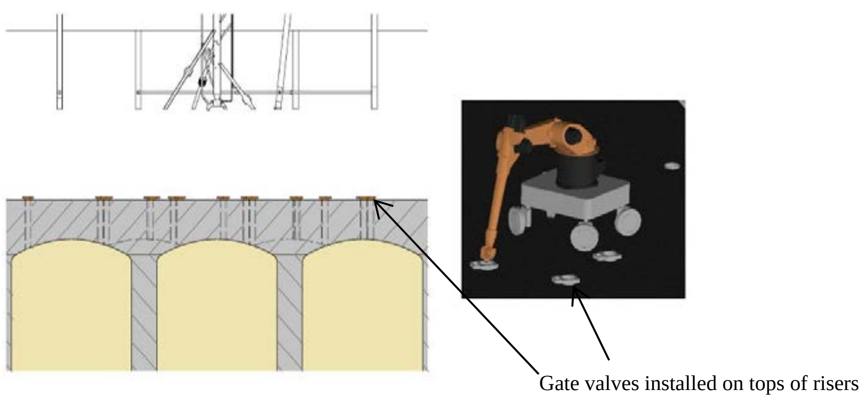

Figure 10: Riser Completion and In-Bore Cutting of Bin Heads

Calcine Retrieval Equipment Installation

The planar snake-arm, hose handling system and camera/periscope system will be lowered into the vault and coupled to their respective risers on the first bin.

Initial Bin Entry

Initially, it will not be possible for the planar snake-arm or periscope to enter the bin due to the presence of calcine. The vacuum nozzle will therefore be deployed into each riser in turn using a hose management system but no snake-arm to clear the immediate vicinity of the riser (Figure 11). This operation will continue until a single void connects the risers.

If the calcine at the top of the bin does not flow well enough to facilitate removal with the vacuum hose alone, an air driven mini flail can be provided at the nozzle tip to break-up the calcine.

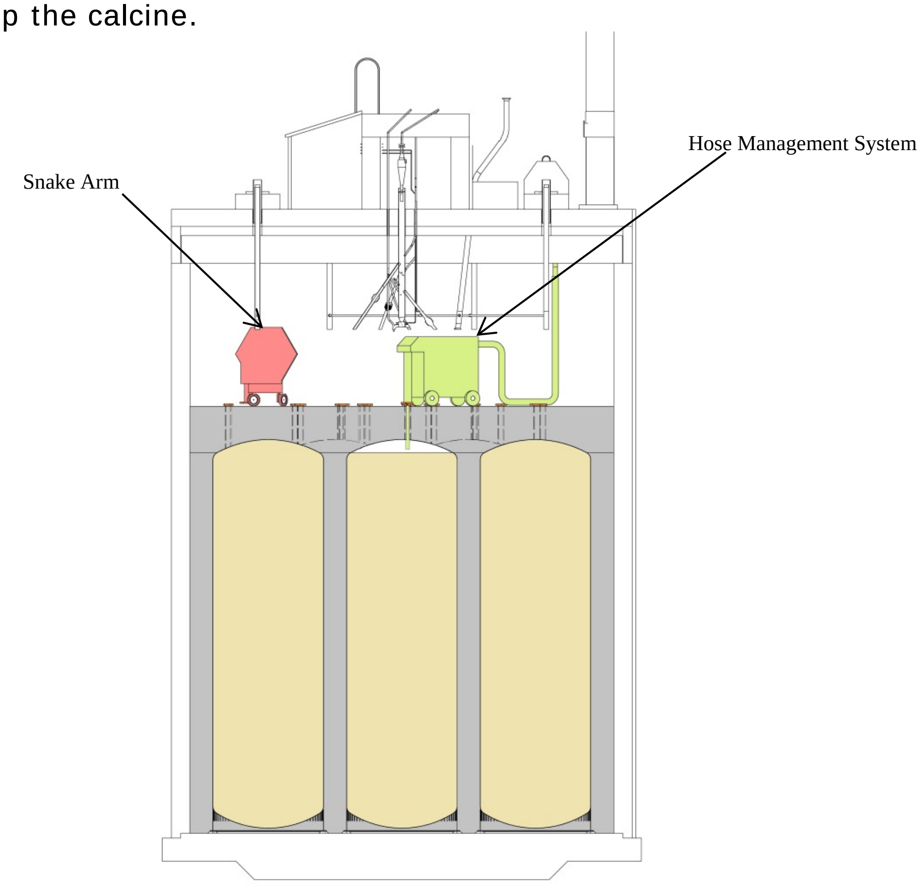

Figure 11: Initial Bin Entry Using Nozzle Only

Calcine Retrieval

Once the initial void is created, the planar snake-arm will be deployed through the riser near the centerline of the bin. The vacuum nozzle and periscope will be deployed through two of the peripheral risers. The snake-arm will reach across to grip the nozzle and maneuver it as calcine is removed. At each location, the short vertical feed of the nozzle will be provided by the nozzle actuator. Based on lessons learned from testing in 2006, this short vertical control is the best method to manage the local nozzle motion required to manage the removal of the calcine material.

Retrieval will proceed in the sector of the bin closest to the hose riser until the calcine level is approximately 2’ below that in the adjacent sectors. At this point the hose will be retracted by the hose management system, the slide valve closed, and the hose management system disconnected from the bin riser. The equipment (periscope or ventilation hose) attached to the next riser for retrieval will be disconnected and installed at the riser vacated by the hose management system. Finally the hose management system will be connected to the new riser and the hose lowered into the bin and the calcine retrieval process will continue in the new sector of the bin. This process will be repeated in stages until the bin is empty. Based on previous proof-of-concept testing, this process has been found to be the best way to prevent material cave-ins that have the potential to trap equipment.

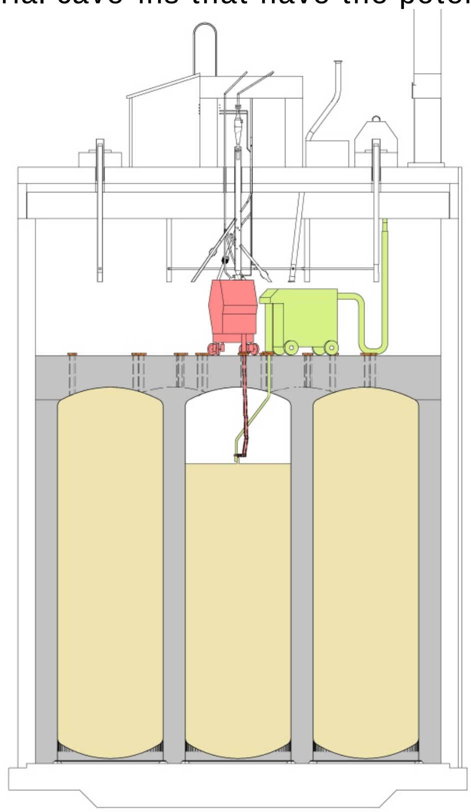

Figure 12: Calcine Retrieval – Elevation View

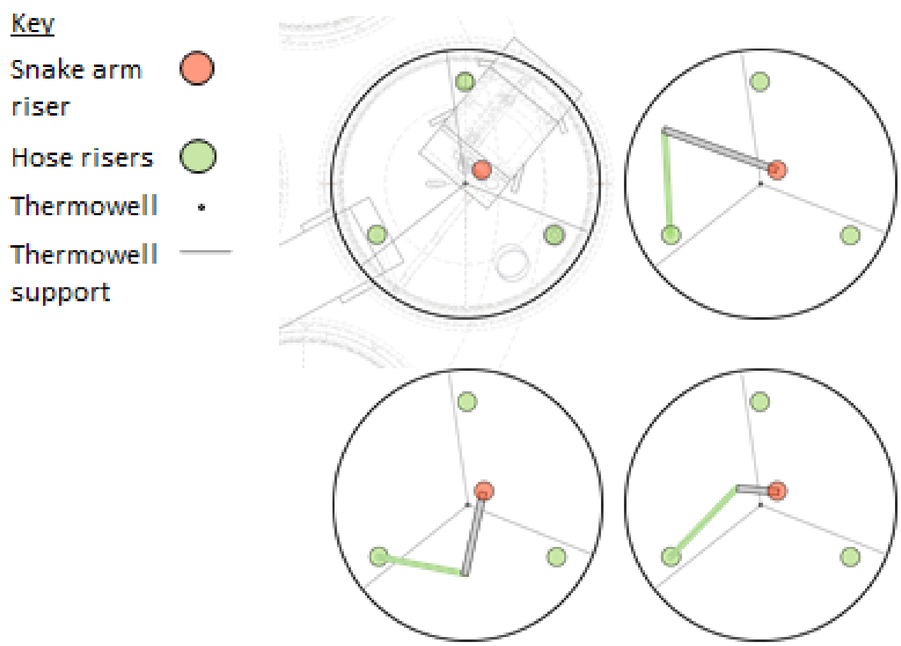

Figure 13: Calcine Retrieval – Plan View

As shown in Figure 13 above, the arm will move the hose through one third of the bin area for each hose location. If required automated paths can be programmed by the operator to facilitate fast removal and reduce operator workload

In-Bin Obstruction Removal

Each bin contains a 38.1mm (1.5" Schedule 120) thermowell and three support struts regularly placed along the height of the bin. Additionally, bins 1 and 4 in CSSF 2 have an array of supplementary thermowells.

Figure 14 shows a cutting tool, in this instance a conceptual design of a hydraulically operated two-jaw cutter, being guided by the end of the snake-arm robot to enable a vertical pipe or thermowell to be cut.

The cutting tool would be inserted through one of the hose risers (shown in Figure 8 and Figure 13) as close as possible to the object to be cut. The tool weight would be supported by a cable (the thin vertical line in Figure 14). The cable would also support the hydraulic lines (in this case) or other tool services. The interface to the tool is the same gripper used by the snake-arm robot to manipulate the hose.

Cut sections of thermowell and support struts should be small enough to rest on the calcine and be moveable during the remaining retrieval.

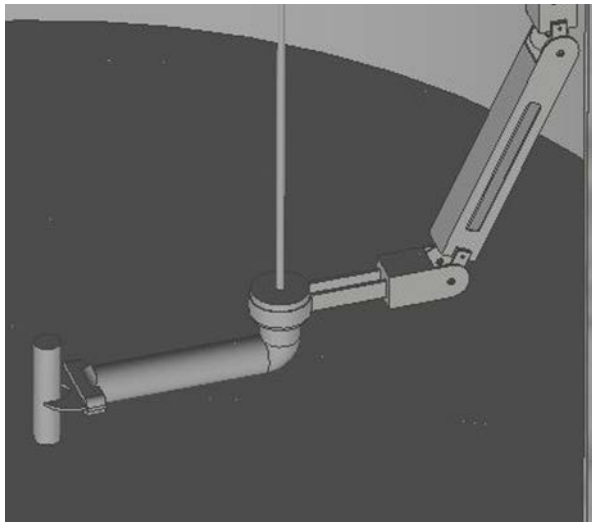

Figure 14: Cutting Tool Held by Manipulator

Demobilization From Bin

At the end of retrieval operations in each bin the retrieval hose will be decoupled from the vacuum transfer line and nozzle and fed into the bin where it will be abandoned in place. All internal obstructions will also be abandoned in place. The periscope and planar snake-arm will be retracted from the bin. The planar snake-arm, periscope and hose management system will then be decoupled from their respective risers and the risers capped.

Demobilization from Vault

The planar snake-arm, hose management system, periscope and in-vault robot will be bagged or sleeved for contamination control and removed through the roof hatch at the end of operations.

Key Challenges

Contamination Control

Contamination control is essential to allowing human access into the vault. The snake-arm, hose and periscope will all enter the contaminated interior of the bins.

The hose management system containment housing will be sealed to the bin riser but additionally the hose passing through the system will also need to be contained. As described above, this will be achieved by means of a flexible sleeve.

The snake arm will need to be housed in its own containment housing as well. Since the snake arm coils onto a spool (unlike the hose) it is anticipated that this containment housing will allow for the avoidance of the use of a bag for the snake arm itself for normal operations.

In a similar manner, the periscope should be able to extend form and retract into its own containment housing.

Obstacle Removal or Avoidance

Working around obstacles in the bins presents has three impacts:

- Productivity is reduced during the required additional maneuvers
- Contamination control is needed during the additional maneuvers required to remove or avoid obstacles.
- There is a risk of equipment becoming snagged on obstacles

Bulk Properties of Calcine

The bulk properties of calcine and in particular its drain angle of repose will affect the degree to which the hose will need to be maneuvered to all parts of the bin and, potentially, the quantity of internal obstacles that require removal.

Radiation Dose from Calcine in Hose

Some residual calcine will remain in the hose after retrieval operations. It is not known whether the quantity is sufficient to prevent contact handling of the hose. In the event of an unplanned shutdown of the retrieval system the quantity of calcine in the hose could be larger.

Conclusions

The technology offered by NVE and OCR is capable of retrieving the calcine in CSSF 2 and, with modifications, the other bin sets at Idaho. The retrieval methodology presented here is robust and is based on conservative assumptions about the capabilities of the retrieval equipment and the bulk properties of the calcine.

The design presented in this paper is at the early concept stage. It is anticipated that additional funding will be made available in FY16 to complete sufficient preliminary design and allow for the fabrication of equipment prototypes and a facility mock-up to begin design demonstration and testing. This mock-up could be designed and built at the NVE, Mooresville, NC facility and it would closely approximate the shape of a single bin if not its full height. Some capabilities that could be demonstrated include:

- Long reach nozzle positioning
- Material removal
- Obstruction removal and handling
- Remote metal cutting and welding
- Flowable vs agglomerated calcine
- Remote monitoring and control
- Hose management
- Contamination control
- Failed manipulator removal