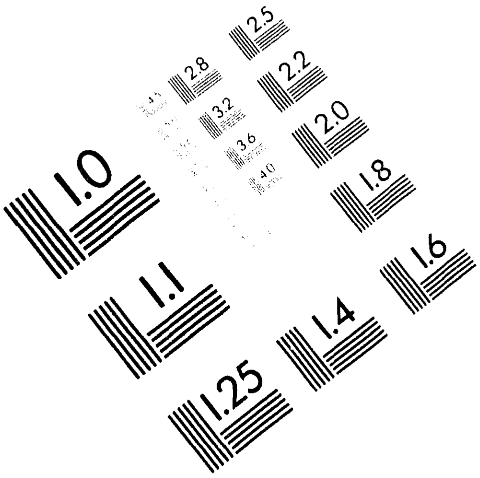

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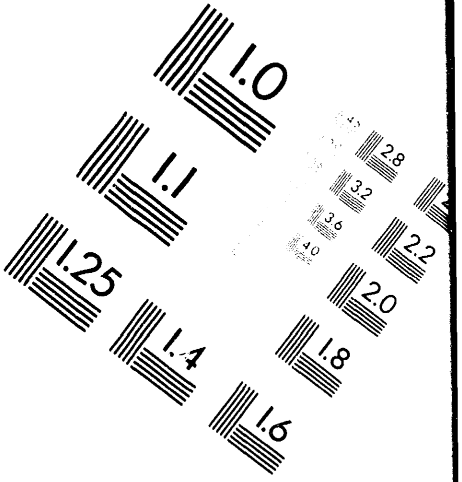

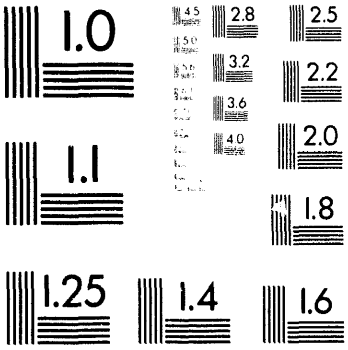

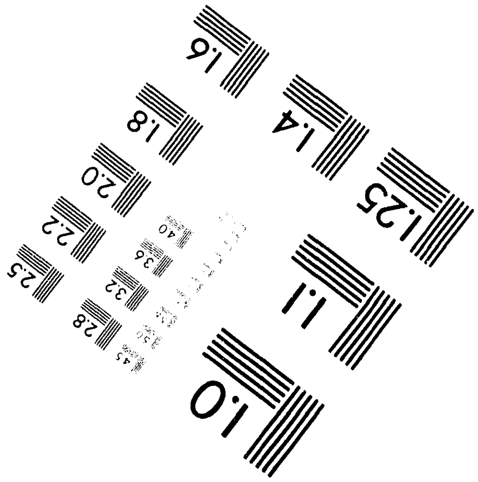

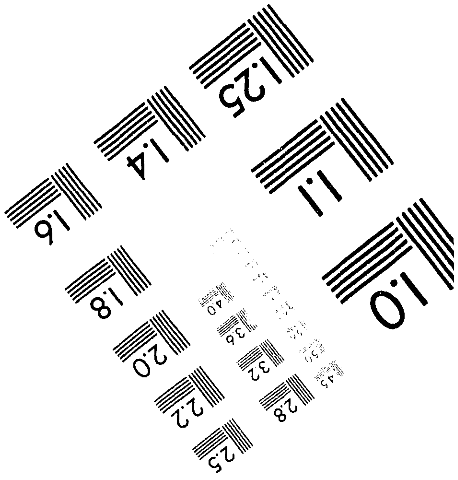

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CONCEPTUAL DESIGN FOR REMOTE HANDLING METHODS USING THE HIP PROCESS IN THE CALCINE IMMOBILIZATION PROGRAM

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ABSTRACT

This report recommends the remote conceptual design philosophy for calcine immobilization using the hot isostatic press (HIP) process. Areas of remote handling operations discussed in this report include: 1) introducing the process can into the front end of the HIP process, 2) filling and compacting the calcine/frit mixture into the process can, 3) evacuating and sealing the process can, 4) non-destructive testing of the seal on the process can, 5) decontamination of the process can, 6) HIP furnace loading and unloading the process can for the HIPing operation, 7) loading an overpack canister with processed HIP cans, 8) sealing the canister, with associated non-destructive examination (NDE) and decontamination, and 9) handling canisters for interim storage at the Idaho Chemical Processing Plant (ICPP) located on the Idaho National Engineering Laboratory (INEL) site.

SUMMARY

The objective of the Calcine Immobilization Program in using the hot isostatic press (HIP) process is to convert Idaho Chemical Processing Plant (ICPP) calcine into an acceptable glass-ceramic waste form suitable for terminal storage in a federal geologic repository. The highly radioactive nature of the calcine waste material requires that all movement from the storage bin vaults, pretreatment and blending, and final handling for the HIP process be accomplished using remote methods. This report specifically addresses conceptual design philosophy for remotely handling calcine/frit waste material from the time the HIP cans are introduced into the process until these cans have been overpacked into a canister for interim storage awaiting shipment to a federal geologic repository.

Calcine immobilization component and system tests are required to verify the remote handling concepts to achieve the glass-ceramic waste form using the HIP process.

This report establishes a basis for the conceptual design philosophy pertaining to remote handling methods for calcine immobilization using the HIP process. The report discusses the steps in the remote operations and handling of the process can from the time of introduction as an empty vessel to the time that it is overpacked in a canister for interim storage before being sent to a federal geologic repository.

The concepts put forth in this document for remote operations and handling scenarios are based on Fuel Process Restoration (FPR) project design criteria, technical expertise by the authors, literature search for background information, and discussions with various people in both nuclear and non-nuclear industries.

This report:

- traces the remote operations and handling steps identified in a flow diagram for the HIP process,
- discusses alternative approaches for each remote operation or handling step, with a recommendation on the preferred approaches,
- discusses areas of remote operation or handling that pose significant risks due to the nature of the particular operation being performed and/or equipment technology that is available,
- provides recommendations for areas needing further development to establish credibility for successful operation.

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CONCEPTUAL DESIGN PHILOSOPHY FOR REMOTE HANDLING METHODS USING THE HIP PROCESS IN THE CALCINE IMMOBILIZATION PROGRAM

1. INTRODUCTION

The ICPP High Level Waste (HLW) Calcine Disposal Program is an integral part of the DOE LDR Case-by-Case Extension Application for Radioactive Mixed Waste (September 1991). 40 CFR Part 268.5 requires, as stated in the Case-by-Case application, a "binding contractual commitment" to provide alternate treatment, recovery, or disposal capacity, specifically in this case to develop the glass-ceramic as a final waste form. The Idaho Waste Immobilization Facility (WIF) is listed in the application as being available to begin processing glass-ceramic logs in the year 2014.

Several technologies have been identified to date that could immobilize calcine; these include vitrification and glass-ceramic processing. Radioactive and nonradioactive laboratory tests have been carried out to develop glass waste forms for existing calcines. Some nonradioactive glass-ceramic forms, prepared using simulated calcine with high waste loadings of 50 to 70 weight percent, have shown leach rates similar to vitrified glass. Limited small-scale component and mock-up tests, which include calcine grinding, calcine transport, and vessel filling, have been performed for selected unit operations of the glass-ceramic process. Simplified, small-scale calcine retrieval mock-up tests have been run using calcium carbonate as a nonhazardous simulant. References 1 through 32 discuss some of these technologies and processes. While this work is not complete, it does provide significant background information demonstrating that an acceptable process can be developed in a reasonable time frame.

Nonradioactive and radioactive testing programs will be run to characterize the glass-ceramic materials and to verify the acceptable range of compositions for the most promising formulations. The results of these tests will be used to develop waste acceptance preliminary specifications and to establish criteria for pilot-scale tests. Nonradioactive and radioactive tests will be run to establish feasibility and criteria for developing the optimum glass-ceramic waste form.

The calcine immobilization program using the Hot Isostatic Press (HIP) process could start producing the glass-ceramic waste form in approximately the year 2010. The radioactive nature of this waste material requires that all handling and process operations be done remotely with operating personnel protected by thick shielding walls at the Waste Immobilization Facility (WIF). In order to operate and maintain this facility remotely, a design philosophy must be established early in the design process to assure that all facets of this approach are adequately addressed. A similar philosophy is described in reference 33, which describes remote equipment for waste package unloading, receiving inspection, transferring, electron beam welding, ultrasonic weld testing, storage handling, and related operations.

This report provides a discussion of the operation and handling steps requiring remote manipulation. By outlining all identified tasks on a flow diagram a logical sequence of operations was developed for the process cans for calcine immobilization using the HIP process. Figure 1, entitled "Calcine Immobilization Using the Hot Isostatic Press Process", shows this flow diagram. Each task requiring remote operation was analyzed and alternatives were evaluated. A recommendation is made and justified on the preferred approach. Follow-on work that should be pursued for verification of these proposed methods is also identified.

The proposed methods for remotely performing the handling and operational tasks demonstrate a "keep it simple" philosophy and reflect the best judgement at the time based on available information and/or assumptions for calcine immobilization using the HIP process. As the processes and methods are refined during the early phases of the program, changes may also be necessary to accommodate these refinements and/or take advantage of newer robotics/remote equipment and systems that become available.

As shown in Figure 1, calcine pretreatment is identified in a dotted box to denote that remote handling tasks and operations will be required in that phase of the calcine immobilization program but are not addressed in this report. Interim canister storage and cooling after immobilization may require remote handling but are also not addressed.

2. BASIC REMOTE DESIGN REQUIREMENTS

2.1 General Requirements

The HIP process can/canister remote handling equipment design should include remote replacement of those items that experience has shown to be failure prone i.e, with a failure rate of less than 10 years per equipment item failure. Non-failure-prone equipment which can be adequately decontaminated or has a failure rate greater than 10 years per failure as noted in reference 34, (tanks, vessels, and columns) should be designed for hands-on maintenance.

In discussions of remote handling, the terms remote replacement and remote maintenance are frequently interchanged. In this report references to remote maintenance means that maintenance is performed hands-off by appropriate equipment such as master-slave manipulators, electro-mechanical manipulators, and cranes with special attachments. Remote replacement means that failed equipment is remotely removed/replaced for hands-on repair. For remote handling methods using the HIP process, remote capability means remote item replacement and not remote maintenance.

2.2 Equipment Items

Failure-prone equipment items typically include valves, instruments, motors, blowers/pumps, heat exchangers, motorized carts, and off-gas HEPA filters. These items must be grouped into common shielded areas and the areas provided with remote equipment handling devices, e.g. cranes, manipulators, and viewing windows as reviewed in references 34 through 37. The remote areas should also be adequately illuminated with remotely replaceable lights, remote maintenance service stations, tool-drop ports, work tables, and the necessary viewing systems.

Non-failure-prone equipment such as tanks, vessels, and HIP furnaces would also be located in shielded cells, but the cell handling equipment would not be equipped to permit remote replacement of these items. Rather, maintenance of these items would be hands-on after proper decontamination. Thus space should be provided for maintenance access and equipment removal without interference from adjacent equipment. Permanently installed working platforms with ladders for maintenance access should also be considered on a case-by-case basis.

Although certain equipment items are identified as hands-on maintenance items, remote features such as quick-disconnects, remote flanges, captive bolts, and lifting bales, may be incorporated into their design if such features are determined by remote mock-up and testing to be desirable. The purpose of these features is twofold:

1) to permit potential hands-on maintenance activities to proceed more rapidly, and
2) where possible to permit semi-remote (i.e., overhead crane and overhead handling system) activities to take place with these items.

In both cases, accessibility by overhead handling equipment shall be provided in the design. In addition, visibility, accessibility, and interferences should be considered early in the design of the WIF. Center-of-gravity lifting bails shall be provided on all remotely removable process equipment (e.g. valves) where practical. Remotely removable valves, blowers, etc., should be installed on pipe jumper (spool) assemblies to enhance remote removal and replacement. Remote piping connectors should be the remote maintenance kinematic-grafoil three-bolt flange system with graphite type gaskets, as described in reference 38, where practical.

Throughout the HIP process can/canister handling system, remote concepts and equipment should be proven items. Development items and unproven state-of-the-art items are unacceptable in a full-scale production facility unless the concepts and equipment are demonstrated by mock-up and use prior to incorporation. In addition, remote tooling and equipment provisions must be maintained as practical, straightforward, and simplc as possible. Standardization of sizes (especially of bolts and nuts), shapes, and arrangements should also be maximized.

2.3 Remote Handling Capabilities

To provide satisfactory remote handling capabilities in the WIF , the following considerations must be addressed:

1) The capability for remotely viewing and transferring radioactive items and materials is required to maintain personnel radiation exposures as-low-as-reasonably achievable (ALARA).

2) Process equipment should be accessible for ease of operation and maintenance.

3) Closed-circuit television (CCTV) should be provided for supplemental viewing with both fixed and movable in-cell support assemblies.

4) All in-cell mechanical and electrical equipment (windows, TV equipment, manipulators, electrical enclosures, etc.) should be sealed or otherwise protected from penetration by abrasive powders and corrosive gases or liquids as much as possible.

5) In-cell lights for remote cells should be designed for remote movement and replacement.

6) Provision should be made for tool storage and work tables as required.

7) Ladders, piping, and platforms should be designed to preclude interference during equipment replacement. They should be remotely removable if they would otherwise interfere.

8) Remote handling systems, including cranes where appropriate, and manipulators must be equipped with retrieval systems. Dedicated maintenance areas should be provided for repair of these items.

9) Provide clearances for standard operation and removal of master-slave type manipulators. Use of a dedicated cart-mounted handling system is advantageous in removal and replacement of manipulators.

10) Decontamination capability should use non-wetting technologies (such as CO_2 and light ablation) as much as possible. This will reduce secondary liquid waste generation and the difficulties associated with wetting a dry solids processing system. The use of remotely controlled sprays and wash-down technologies should be included as backup capability.

11) Remote connectors, bolts, flanges, wrenches, sockets, extensions, etc. should be standardized to the extent possible to reduce the need for wrench changes and varied operating envelopes during equipment replacement.

12) Equipment should be movable, maintainable, and replaceable without disturbing adjacent equipment whenever possible.

13) Design of in-cell equipment supports and concrete embedments should consider possible retrofit of alternate process equipment.

14) Equipment components and subsystems should be of modular design where possible to make replacement easier.

15) Commonality of equipment, such as transfer carts, should be incorporated into design of the facility.

2.4 Facility Requirements

To accommodate remote requirements the facility should include certain features:

1) Embedments for viewing windows and master-slave manipulators, remote arms, cranes, and overhead handling equipment must be incorporated early in construction.

2) All cells should have complete ceiling hatch access.

3) Cells should have labyrinth entryways with utility maintenance service stations where required.

4) Both oil-filled and solid viewing windows should be installed for in-cell viewing to permit unrestricted remote operation. Viewing angles from adjacent windows should overlap. Remote operating and maintenance tasks should be planned for location within the normal viewing angles of the windows. Protective, remotely removable alpha shields should be provided for the viewing windows if the process design dictates.

5) Operating corridors should have crane, overhead handling system, and electro-mechanical manipulator control station outlets adjacent to viewing windows in sufficient numbers to permit unrestricted remote operation (this includes being able to operate from multiple levels if required to maintain operation integrity).

6) All master-slave manipulators, including counterweights, must have sufficient clearance surrounding both ends to permit unrestricted movement and easy removal and replacement from the operating corridor.

7) Dedicated maintenance areas should be provided that can be isolated from any radioactive material and equipment and into which cranes and/or overhead handling systems could be withdrawn for maintenance.

2.5 Remote Equipment

To the greatest extent possible, standard remote handling techniques and equipment should be used in the WIF:

1) Racks, such as described in reference 39, should be used throughout the facility for the HIP process cans.

2) Remote overhead handling systems, electro-mechanical manipulators, and master-slave manipulators should be used for routine operations.

3) Extensive use of remotely operated transfer carts for lateral or translational movements would optimize HIP process can handling.

4) All in-cell remote handling equipment should be provided with redundant features and retrieval systems where feasible to minimize the effects of a failure during operations for processing calcine waste for immobilization.

5) If viewing windows cannot be provided, remote CCTV camera equipment could be installed at reasonable cost if provisions were made in the design of the facility.

2.6 Mock-Ups

All remote HIP process can handling equipment should be mocked up and thoroughly tested for design validation prior to design completion and procurement. Mock-ups should include mechanical equipment, remote handling equipment, viewing provisions, and cell sizes and arrangements where appropriate. Items being checked should include accessibility, interferences, visibility, maintainability, operability, transfer routes, lifting mechanisms, and grappling devices.

3. DISCUSSION OF REMOTE HANDLING AND OPERATIONS PROCESS STEPS

3.1 General

The flow diagram shown in Figure 1 represents the anticipated remote operational and handling steps required from the time of introduction of the empty HIP process can through filling, evacuation, sealing, inspection, HIPing, survey/decon, and loading into overpack canisters.

3.2 Process Can Handling Considerations

In the following sequences consideration was given to handling the process cans by the bottom surface, the girth, or from a top flange structure. Choices for can handling considered simplicity, functional capability, and previous or follow-on operations. The can lid top flange structure was chosen as the best candidate for handling the can since it satisfies key functional requirements such as:

1) It provides a solid lifting point.

2) It provides a relatively stable alignment surface for filling and sealing operations.

3) Sealing during filling and evacuation is more easily accomplished on this feature.

4) A locking restraint for can sealing (friction welding) can be easily designed in this area.

5) The top surface is the most flexible, durable, and accessible area to locate can identification or tagging. Barcoding similar to that described in reference 41 could be incorporated for permanent, easy recordkeeping purposes.

Therefore, the handling sytem recommended and described in this report is the overhead type for the HIP process can. Reference 40 describes a pneumatically operated grapple for handling nuclear waste packages; reference 42 describes a pintle arrangement that could be used with a grapple for nuclear waste containers; reference 43 describes canister handling briefly. All of these devices could be reviewed for possible inclusion in the handling system.

HIP can lid development is being conducted at the INEL to determine an appropriate lid configuration that would allow sealing of the lid to the can remotely, while maintaining contamination control and allowing the can to be moved by an overhead lifting mechanism. See Figure 2 for a cross-sectional view of the proposed HIP can lid. The grapple mechanism would attach to the upper flange of the lid. Design of the lid is such than it can withstand the lifting loads imposed by a filled can as well as the forces generated during the sealing (friction welding) operation. A safety factor of five is used in the lid design for can handling purposes. The lid is designed for a compliant HIP can structure i.e., a type of can that deforms axially during the HIPing process. This lid design may require modification if a straight wall can design is chosen for calcine immobilization.

This lid design has been evaluated for machinability, structural strength,and compatibility with sealing operations. Limited thermal testing has been performed to determine resistance to deformation. Future testing of the HIP process with reduced scale cans will be conducted to determine:

1) verification of the process with the proposed lid design

2) amount of lid distortion on reduced scale cans

The overhead handling system could be similar to the XR 100 Gantry Robotic System currently being produced by PaR Systems, and described in Figure 6. The overhead handling system would have the basic X (left/right), Y (in/out), and Z (up/down) motions plus additional degrees of movement incorporated into add-on end effectors. For can handling purposes, it is assumed that the grapple mechanism would be attached directly to the bottom end of the mast (telescoping tube assembly) of the overhead handling system rather than as an end effector. The system could be teleoperated under direct control of an operator or automated by use of a supplementary controller such as PaR's CIMROC 4000X. Reference 44 provides additional information on this system.

3.3 Introduction of HIP Process Can

The process cans will be supplied by an off-site vendor and would be shipped to a warehouse receiving location on-site before the cans are transferred to the WIF. It is assumed that the process cans will be transferred to the WIF using standard transportation methods, most likely by truck. The cans may arrive at the WIF in individual cartons or on pallets. In either case, using conventional handling methods such as overhead crane or forklift, these cans would be unloaded in preparation for processing calcined waste material.

As shown in Figure 2, the process cans would enter the WIF through an air lock system. Several methods have been identified for moving the process cans through the air lock. These include a cart, forklift, portable crane, or a permanently installed small telescoping jib boom crane.

In order to minimize spread of possible contamination from the process can handling corridor, it is recommended that a method which allows the can to be picked up and transported into the corridor with a minimum amount of contact between the potentially contaminated can handling corridor and adjacent clean areas be used. A motorized, telescoping (extending) jib boom crane in the air lock area is recommended to transfer the process can into the adjacent handling corridor area. A similar system was to have been used in the Fuel Processing Restoration facility to transport uncontaminated pipe jumper assemblies into the pump and valve corridor of the plant.

The method for introduction of process cans into the WIF process can handling corridor is as follows:

1) Empty process cans would be transported approximately halfway into the airlock using standard methods such as forklift or cart. During this operation the inner shielding air lock doors remain closed to preclude exposing personnel transporting process cans in the air lock area.

2) After the cans are placed in the air lock, the associated handling equipment/personnel would exit the area. The outer air lock doors would be closed. The inner air lock doors would be opened. The jib boom crane would be remotely controlled via a station outside the air lock by an operator observing through a shielded viewing window. Additional viewing capability could be provided by CCTV. The hook on the jib boom crane hoist would interface with a grapple device that could engage/disengage from the can top for handling purposes or alternatively a grapple could be designed to directly fasten to the jib boom crane rigging in place of the hook.

3) The operator, via a remote control station, would bring the jib boom over the can and, with the grapple, engage the handling ring on the can lid, and hoist the unit clear of the floor in the air lock.

4) The inner shielding air lock doors would be opened and the empty process can would be placed into the handling corridor a distance sufficient for the overhead handling system to access the can. This task is accomplished by the telescoping feature of the jib boom that allows sufficient extension into the can handling corridor without touching anything that could potentially contaminate the crane.

5) The jib boom crane hoist would lower the can down to the floor, disengage the grapple, and retract back into the air lock area.

6) The inner air lock doors would then be closed. The process can would be moved to the next station by the overhead handling system with a corresponding grapple mechanism attached.

3.4 Handling of the HIP Process Can in the Main Process Corridor

Several methods were considered for handling the HIP process can in the main handling corridor between the airlock and the evacuation/weld station. The method shown in Figure 3 indicates an overhead handling system with associated translational transfer carts for the initial work stations. The major advantage of this approach is that it is a low technological risk, since this is established technology and generally accepted for remote operations. British Nuclear Fuels Limited is using a cabling and reel management system for power and control at Sellafield in the United Kingdom for similar purposes, as described in reference 45.

Vitrified high level waste canisters will also be handled in an overhead mode at Savannah River Laboratory, Westinghouse Hanford, and West Valley Nuclear Services. In addition, the overhead approach offers good flexibility because the handling system is free while process cans are located at work stations, thus offering better availability to perform other functions.

The translational stations could be designed as show in Figures 3 and 4, as cart systems that move the cans into position under the process fill and evacuation/seal stations from the main corridor. The carts would be self-contained units with the necessary elevation mechanisms to raise and lower and mate the process cans to the work stations. Cart raising and lowering could be accomplished hydraulically as described in reference 46, or electrically. The latter is preferred because it avoids hydraulic fluid seepage in a potential contamination/radiation zone.

Cart maintenance could be facilitated by the overhead handling system that could remove units to a decontamination/hands-on maintenance area at the end of the main handling corridor. This location could also serve as a maintenance area for the overhead handling system. This maintenance approach is commonly used at nuclear processing facilities and would have been extensively used at the Fuel Processing Restoration facility at ICPP. This method could also allow integration into a fully automated system similar to the fuel handling bridge systems currently used nationwide at many of the commercial nuclear facilities and similar to a system recently furnished to a Japanese facility by PaR Systems, as described in reference 44.

3.5 Filling of Process Can

The first step in the immobilization process is to fill and compact the process can with the calcine/frit material.

1) An operator at a remote control station outside of the handling corridor, viewing through a shielding window, and augmented if necessary by CCTV, would engage the process can flange assembly. With this approach, the overhead handling system with grapple device would hoist the process can and place it in the work station cart which has a vibratory compactor unit mounted on it.

2) The cart would move or translate to a position under the fill port work station.

3) The elevating mechanism on the cart would be energized and the can raised to interface with a double door fill port system. The purpose of the double door port system is to keep contamination on the outside of the can to an absolute minimum (preferably none) and maintain tight contamination control in the process can handling corridor area of the WIF for maintenance and decontamination purposes. The design of the fill port could be similar, although simplified in design, to the existing Central Research Laboratory double door transfer systems currently in use at ICPP. The top flange of the process can would seal in the fill port area. As the lid of the fill port is opened into the process can fill cell, the weld plug assembly, acting as a temporary cap that has been placed on the can prior to introduction, would be attached to the lid thus opening the can and allowing the calcine/frit material to be introduced.

4) The fill port door would open into the fill cell at the same time that the weld plug assembly, acting as a temporary cap, would be attached to the open door unit.

5) A mass flow hopper, containing sufficient calcine/frit material to fill a can, along with an associated nozzle extension system, would be lowered to mate directly with the can top opening. An example of filling is shown in reference 47.

6) The valve on the bottom of the mass flow hopper would be opened and the can filled while the vibratory unit on the cart shakes the can to ensure adequate green density.

3.6 Testing and Evaluation of Can Filling

Some limited small-scale laboratory testing of can filling and compaction at ICPP has been conducted. No compaction or powder flow data is available at this time, however initial tests appear promising. Two methods for filling the process can are currently being evaluated by the WINCO Applied Technology Department. These are:

1) a mass flow batch hopper with nozzle extension, and

2) a fluidized bed system where the can interfaces directly with the mixing/blending vessel of calcine/frit material.

Figure 3 shows the mass flow batch hopper approach, although at this time there is insufficient data to indicate that this is the preferred method. In either case, the process can could interface with a double door fill port system that seals the can top flange to a mating surface and removes the temporary cap (inertial weld plug) to allow the calcine/frit material to be introduced. While the double door port system appears at present to be a preferred approach, additional development would be required to provide an effective filling interface for the HIP process can. Other types of interface/filling systems could be considered if test data supports a different approach from that propose in this report. However, the double door port system does offer a very good approach to controlling the spread of contamination.

3.7 Considerations for Sealing of Process Can

Several methods were considered for performing evacuation and sealing of the process cans. Among them were:

1) An external screw thread would be formed on the lid and an internal screw thread on the can top. The lid would be screwed down against a seal.

2) The lid would be bolted against a seal onto the can top.

3) The lid would be brazed or soldered onto the can top.

4) The lid would be seal welded in place.

References 46, 48, 49, 50, and 51 describe several methods of conventional welding processes while references 52 and 53 provide some background for friction (inertial) welding. Preliminary research, as described in reference 52, points to friction welding as the recommended method because a better seal is accomplished without the attendant heat and distortion from conventional welding. In addition, the friction weld method can be performed in a vacuum which is required for can evacuation.

3.8 Process Can Evacuation and Sealing

After the process cans are filled and vibratory compacted to the proper level at the fill port work station, these units are ready for the next step in the HIP process. This step consists of evacuating the process can to a vacuum in the 5-50 torr range and then sealing the fill hole area of the can. This vacuum range is based on preliminary test data and may require further evaluation. To perform this operation remotely, a continuation of the work station principle used for can filling would be applied.

Figure 3 shows views of the work station areas depicting the recommended approach for can sealing.

1) At the completion of can filling, the double door fill port lid would close and place the weld plug assembly (acting as a temporary cap) back onto the can.

2) The filled can would be lowered by the cart elevation mechanism and moved back to a position in the main corridor accessible by the overhead handling system.

3) The overhead handling system with grapple device would be brought over the can and lowered. The grapple device would engage the handling flange on the can, and the can would be raised for transport to the sealing work station transfer cart.

4) At the sealing work station the can would be lowered to the cart and the grapple device would be disengaged, freeing the overhead handling system to perform other functions.

5) The cart would translate under the weld station work port and raise the can into position so that the handling flange would engage and lock into the work port.

6) The weld port door would be opened remotely to expose the can lid containing the weld plug assembly.

7) The spindle of the inertial welding machine would lower so that the nose piece would engage the respective mating surface of the can plug, then raise back up to a standoff position with respect to the opening in the can lid.

8) At this point, a vacuum chamber (somewhat akin to a bell jar) surrounding the spindle assembly would be lowered to seal to the top surface of the can handling flange.

9) The vacuum system would be activated and the pressure gradually lowered in the vacuum chamber, and consequently in the process can, to the required level before the sealing (welding) occurs. The rate of evacuation would have to be slow enough to not fluidize calcine/frit material near the opening in the can lid.

10) The final step in the sealing process would be to permanently install the weld plug assembly using the friction welding method. The welder drive unit would rotate the spindle and associated flywheel weight system up to speed where a clutch mechanism would then disengage the driver from the flywheel.

11) A ram mechanism, which is part of the friction welding equipment, would force the plug into the opening of the can lid while still rotating at high speed, generating sufficient frictional heat that the two surfaces join together to produce a sound, high integrity weld closure.

This welding method lends itself to locating all the equipment, except the spindle and vacuum chamber, outside the weld hot cell thus providing a means for hands-on maintenance and repair. This closure method has already been successfully demonstrated in a vacuum with slightly tapered weld plugs 2 inches in diameter by approximately one half inch thick as described in reference 52. A similar application is described in reference 54.

3.9 Non_Destructive Examination of Process Can Seal

Non-destructive examination (NDE) of the process can seal is considered mandatory since assurance is required that the cans will maintain integrity during calcine immobilization using the HIP process. The friction welding approach is an easy-to-automate process that consistently produces high quality, mechanically sound welds that can be readily inspected by remote NDE methods.

Any of several NDE methods may be feasible, but the preferred method at present for examination of this type of weld would be ultrasonic (UT) inspection because it is simpler to set up and is more reliable in a hot cell type of environment. UT is subject to further testing to validate it for verification of weld sealing in a vacuum. The fine metallurgical grain patterns produced by friction welding can best be inspected by UT with a high assurance of weld joint integrity for the HIP process. However,weld voids not detectable by UT could present problems, so another method such as helium leak detection should be also considered.

Before the NDE inspection of the weld area would be conducted, it is recommended that an initial decon of the can top in the area of the weld be completed. This decon could be accomplished by the same remotely controlled arm mechanism that would carry and locate the NDE probe. The decon could be accomplished by the use of a small vacuum system that is maneuvered by the remote arm mechanism or by CO_2 and light ablation.

The present HIP can lid design is such that the plug sealing the can is recessed in the center area as required for spindle engagement to accommodate torque during welding. This recess also provides a location to contain a coupling fluid for the UT head on the NDE equipment. This fluid would be a fast evaporating type to eliminate cleanup. The NDE inspection would be conducted remotely by a probe located in the weld cell on a remotely controlled arm mechanism so that the entire weld zone area can be completely examined. All electronics, except for the UT probe, would be located outside the weld hot cell to afford easy hands-on maintenance and repair.

If the NDE inspection of the weld indicated a defect or problem area that could cause the process can to become re-pressurized or lose vacuum, then this hot cell could also become a repair station by using the inertial welding equipment to cut out the old plug and install a new one. This task could be achieved by configuring the spindle nose with the appropriate cutting tool (such as a hole saw or trepanning cutter) and rotating the spindle much slower to achieve the desired cut to remove the defective weld and associated plug. To accomplish this task, the remote handling mechanism for the NDE probe could also function as a remotely controlled arm to attach the cutting tool mechanism. This arm would also remove the cutting tool, retrieve the defective plug, and place a new plug on the end of the spindle for repeating the inertial welding process. The current HIP can lid design shown in Figure 2 is configured to allow this repair approach to be achieved.

The remotely controlled arm could also serve to raise the vacuum chamber up onto the spindle and lock it in place so that the plug removal process can be observed by an operator viewing through a shielding window. Additional viewing capability could be supplied by CCTV. The repair process would be completed by lowering the vacuum chamber back down onto the flange assembly of the can top, re-establishing the desired vacuum level, and performing the inertial weld with the new plug in place. Once again, the weld would be examined by NDE methods. When the weld is verified as acceptable, the process can would be ready for the next step in the HIP process as shown on the flow diagram (Figure 1).

The next step would be to close the weld port door and lower the work station cart and process can clear of the weld port. The cart would translate back into the main corridor so that the overhead handling system with the attached grapple mechanism could engage and lift the can clear of the cart. At this point, the process can is a sealed unit that is ready for survey/decon and then loading into the HIP furnace.

3.10 Process Can Survey/Decontamination

Following welding, it will be necessary to perform a complete examination for surface contamination on the exterior of the can and to decon it if necessary before the can is placed into the HIP furnace for densification. It is recommended that the survey/decon station be located along the main corridor and that once again the cart type work station approach be used. The decon station would have containment doors to isolate the survey/decon area from the main corridor.

The overhead handling system in the main corridor would transport the process can down the corridor to the survey/decon station cart as shown in Figure 4.
The handling system would lower the can onto the cart and disengage the grapple. A small jib boom crane located in this area would be used to off-load the can from the transfer cart, the cart moved back into the corridor area, and the can lowered onto a turntable mechanism for the start of the survey/decon process.

The decon station could be equipped with a pair of master-slave manipulators that could perform the swipe function for contamination determination and other decon and maintenance functions within this area. As an alternative, a programmable robot (robotic arm) could fulfill this function. A testing and evaluation program on a Schilling Titan II electro-hydraulic slave arm with bilateral control is currently in progress at WINCO. Data from this evaluation would be considered pertinent as a possible robotic arm application for can examination and decon work. The decon station would be designed for multifunctional decon capability and for general purpose maintenance on the work station carts.

3.11 Minimized Waste Decontamination

The decontamination operation on the process cans and routine servicing on other equipment should use non-wetting technologies as much as possible, such as the CO_2 pellet blasting system which leaves only the contaminated particulate behind for disposal after lightly ablating the surface. Results from the current testing program of this technique at ICPP should be considered, so that if this proves to be a viable approach it could be incorporated into the WIF. Remotely controlled spray and wash-down techniques could be included as backup capability.

In order to enhance the maintenance capabilities of the jib boom crane in the decon station, the unit could be designed to fit into a master-slave type penetration that could be serviced from outside the decon cell. A system would be devised to allow the trolley-hoist mechanism to be easily removed from the jib boom so that the unit could be removed through the shielding wall. Removal of the trolley-hoist mechanism could be accomplished by using the overhead handling system, located above the decon station area, that also serves to load/unload the HIP furnace and load the densified cans into the overpack canister as shown in Figure 4.

3.12 Transporting Filled, Decontaminated Process Can Into HIP Furnace Area

To aid in contamination control, the HIP furnace area and stations for subsequent steps should be separated by closable doors or hatches from the main handling corridor. Recommendations for this approach would require a hatch to be located above the decon station to allow the HIP furnace overhead handling system to retrieve the decontaminated process cans into the HIP furnace cell area. Subsequent steps would take place in the upper corridor area. The upper handling corridor, which encompasses the HIP furnace area, HIPped process can survey/decon area, canister overpack area, and loadout facilities would be served by an overhead handling system similar to the configuration in the lower process can handling corridor. This handling system should have the capacity to accommodate not only single process cans but a canister overpack with multiple cans inside.

3.13 Process Can Densification Into Glass-Ceramic Waste Form

The process can must be remotely loaded into the HIP furnace due to the high radiation fields from the calcine waste. The upper overhead handling system grapple would be lowered through a hatchway into the decon cell area so that just the grapple mechanism contacted and engaged the can. It would then be used to raise the process can up into the furnace area. At this point, the hatch between the two areas would be closed and the process can would be positioned for placement in the HIP furnace isolation shield for immediate HIPing or set aside in a temporary storage area for later HIPing.

There are two basic types of HIP furnaces, top loading and bottom loading, either of which could theoretically be used to perform the densification process remotely. These furnaces and the HIP process are described in detail in references 24 and 55 through 61. The process can top flange assembly, as described earlier in this document, should be the least affected part of the can after HIPing and thus would be the easiest part to interface with for subsequent handling (reference Figure 4). As a result, the top loading furnace is the preferred choice for can handling during densification.

An isolation chamber, and spares, should be designed and fabricated for placement inside the furnace cavity. The isolation chamber would serve as a vessel to contain the radioactive waste material (calcine/frit) in the unlikely event that the process can is breached during the HIPing action in the furnace. Assuming a top loading furnace, the process can would be lowered into the isolation chamber and the grapple mechanism released. The grapple mechanism would then be removed so that the overhead handling system could engage the isolation chamber top closure assembly and place this unit into position. The necessary devices to lock the top closure to the body of the isolation chamber (which HIP vendors have not yet defined) would be remotely operated and the chamber readied for placement into the HIP furnace. An alternate method would be to design the top closure for engagement by the grapple mechanism.

The overhead handling system would engage the isolation chamber lifting interface (bail) and the entire unit, with the process can, would be placed into the heating cavity of the open HIP furnace. The overhead handling system would be disengaged and the system retracted clear of the HIP furnace area. The top closure system for the furnace (vendor furnished) would be remotely actuated to move the closure plug over the furnace cavity and the plug would be lowered into the cavity. The plug would be locked into position to provide a pressure boundary for the HIP densification process. The operator would control the overhead handling system as well as the furnace top closure system from outside the HIP cell area from appropriate control panels/consoles. Viewing would be provided by appropriately located shielding windows with assistance from CCTV if necessary.

At this point the can would be sealed in the isolation chamber within the HIP furnace and the densification process remotely started by the operator from a control console/panel outside the HIP cell area. Previous research at ICPP and other facilities have demonstrated that the HIP process control system would operate the furnace to densify the can by applying approximately 20,000 psi (pounds per square inch) inert argon atmosphere at approximately 1000° C. During this process, furnace temperatures, measured by thermocouples, would be monitored and controlled automatically.

The authors of reference 62 (describing a slurry-fed in-can melter process, part of which is similar to the HIP process) concluded that the following were desired features of a furnace for melting materials in a can:

1) an inert argon atmosphere to preclude oxidation of the container,and

2) independent temperature control of furnace heating zones, and

3) secondary containment around the can.

The argon gas inert atmosphere would require radiation/contamination monitoring to detect possible can breaching during the HIP process. Monitoring of the argon gas would provide the first alert that a possible can breach has occurred during HIPing. This monitoring would need to be accomplished in a shielded area outside the HIP furnace cell in order to discriminate from the background radiation field and provide accurate information on the condition of the process can.

After the process can has been HIPed, it would be cooled down and depressurized automatically within the furnace by the system controls. The furnace top closure would be removed, the isolation chamber lifted out of the furnace and moved to a convenient location. The isolation chamber top closure would be removed and the can lifted out in preparation for the next phase of the process.

3.14 Process Can Failure

Should there be an indication of a process can failure (breach) in the isolation chamber during the HIPing operation, the furnace system would be immediately shut down and the contents cooled for removal. Once the top closure is removed, the overhead handling system would be used to remove the isolation chamber with the failed can inside. The assumption is made that the isolation chamber completely contains the process can contents for all likely failure scenarios, ie. weld failure, can wall cracking, etc. Therefore, the chamber should prevent the spread of contamination into the HIP furnace or surrounding areas.

The recommended approach in dealing with a breached process can would be to lower the isolation chamber, with the failed can inside, down into the lower decon/survey area for transfer to a rework cell. This task would be accomplished by using the transfer cart at the decon work station to move the isolation chamber (with failed can inside) back into the main handling corridor.

For a process can that has been breached, the isolation chamber would be transferred by the overhead handling system to a transfer cart station that would allow the isolation chamber to be moved into a rework cell as shown in Figure 4. This rework cell would have shielding doors that would allow transfer cart access. Transfer of the isolation chamber in the rework cell from the transfer cart to a work station could be accomplished by a remotely controlled jib boom crane, or possibly a remotely controlled arm with an electro-machanical manipulator attached. The remote arm approach may be the preferred method if disassembly and removal of the isolation chamber and process can is required for final disposition. The assumption is made that the process can must be emptied and any powder calcine/frit material returned to the can fill area for reprocessing. A further assumption is that the isolation chamber and empty process can cannot be decontaminated to low level conditions and, therefore, must either be reprocessed by some method or cut up and repackaged for disposal in a canister overpack.

The rework cell would be equipped with remote handling and cutting equipment for repackaging into a container that could also be sealed (welded) closed at this station. This container would be routed to the canister overpack area by first going through the lower level decon/survey station, then up into the HIP furnace area for final transfer to the canister loading/sealing station.

The retrieved calcine/frit powder material could be pneumatically transferred back to the can fill area. Partially densified (HIPed) calcine/frit waste material would probably also need to go through a size reduction process back to a powder form for pneumatic transfer back to the can fill area.

An alternate method of correcting partial densification could be the application of selective laser sintering as described in reference 63. This involves applying a computer controlled, raster scanned laser beam to successive thin layers of of loose powder. Each layer is fuzed as a unit and also fused to the previous layer, creating a completely bonded waste form. This fused material could be packaged in a sealed can for transport back up to the upper handling corridor area. At this point, the sealed can with waste contents inside would be placed in an overpack canister similar to the HIP process can as discussed in the next section. Other potential solutions for repair are discussed in reference 64. Any auxiliary equipment or tools required for rework should be provided in the rework cell area.

3.15 Process Can Final Survey/Decontamination

After the process can has been removed from the HIP furnace isolation chamber, a final survey and decon (if necessary) should be performed before the densified cans are placed into the overpack canister. The overhead handling system, using a grapple mechanism, would move the HIPed can from the furnace area to the adjacent survey/decon station area, shown in Figure 4. The grapple mechanism would be designed to interface with, and accomodate possible distortions in, the HIP can lid handling flange.

Survey and decon could be accomplished by the use of a turntable system in conjunction with master-slave manipulator(s) or possibly a remote type arm mechanism. Access to the survey/decon area (cell) could be by sliding shield type doors as shown in Figure 4. Assuming there has been no breach in the process can and that the HIP furnace has been kept clean from contamination, a survey of the HIPed process can should reveal no external surface contamination. However, should there be surface contamination, a non-wetting decontamination technology such as the CO_2 system could be used to clean the outside of the process can before being placed in the canister overpack. After the process can has been surveyed, cleaned as necessary, and determined to be not contaminated, the next phase in the flow diagram (Figure 1) is ready to be initiated.

3.16 Canister Overpack, Weld, and NDE

The overhead handling system with attached grapple device would engage the HIPed process can in the survey/decon station area and transport it to the canister overpack station through an adjoining shield door. The recommended approach for loading the HIPed process cans into the canister overpack is from the top while the canister is vertical. This approach should minimize any damage potential to the process can as it is lowered into the overpack canister. The operator controlling the handling system would use direct viewing provided by shielding window(s), augmented as necessary by CCTV. Initial information indicates that two HIPed process cans would be loaded into a canister overpack as discussed in reference 32. The empty canister overpack would be oriented at a work station such that the operator could load each can individually and verify proper positioning before the next step is initiated.

The next step, as shown in Figure 1, is the sealing of the canister overpack. Due to lack of design information and repository acceptance criteria for the overpack canister, the recommended approach at this time for the canister closure is to design a lid or cap structure with a flange assembly similar to that on top of the process can. This approach would reduce the number of handling devices (grapple type mechanisms) that the overhead handling system must interface with. The lid should be self-centering with an appropriate mating joint configuration that would allow an automatic welding process to join the lid to the overpack canister to form a watertight, high integrity seal. Any of several commercially available automatic weld processes could be used for canister closure. Once the preferred welding method for overpack canister closure has been chosen by the other DOE sites that use the vitrification process for waste immobilization, the Calcine Immobilization Program should evaluate the feasibility of adopting this same method. Figure 5 shows the HIP canister overpack station.

The canister overpack station could also serve as the weld/NDE station for performing the closure seal and inspection. As shown in Figure 5, the canister closure weld could be performed by a remote arm system that also could serve to perform the NDE inspection.

The empty canister overpacks and closure lids would be introduced through the upper maintenance and loadout station. This area is similar to the air lock system on the opposite end of the process stream where the empty process cans are introduced. The empty overpack canisters and lids could be brought into the loadout station by truck or forklift. If this area is used for interim storage of waste canisters, then some type of remote handling method would be required to bring the canisters and lids into this part of the facility due to the high radiation fields.

The last two steps in the flow diagram (Figure 1) are shown in dotted format to indicate that they have not been included in this document. After the canister overpack closure weld is completed and the NDE indicates acceptance, the canister could be surveyed and decontaminated for one last time or the unit could be moved to an interim storage location on site. The canister overpack would require survey and might require decon before shipment off-site to the geologic repository, but possibly not for interim storage. Until more information is available on disposition of the waste canisters at the completion of the waste processing program, it is assumed that interim storage would be provided on site in or near the WIF.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 General

The flow diagram in Figure 1 and the discussion of the handling operations for calcine immobilization using the HIP process indicates that overall, this is a complex issue requiring early integration of remote design criteria. The remote concepts described and recommended in this document are aimed at keeping individual remote operations as simple as possible while at the same time keeping the entire HIPing process stream flowing smoothly with an assurance of high reliability to meet the requirements for calcine immobilization.

Remote handling methods recommended in this document represent proven technology based on past operating experience. However, as newer emerging technologies for remote handling operations are developed, these should be given consideration where applicable for this program. As an example, the overhead handling systems envisioned for the HIP process cans and the overpack canisters could be similar to that shown in Figure 6.

While the recommendations in this document are based on proven remote handling concepts, program specific hardware in several areas should be evaluated and tested to assure success for the calcine immobilization program. These systems and/or equipment should be designed, mocked up, tested, and evaluated to make sure that the remote handling can be performed as required.

4.2 Specific Areas Requiring Further Development

The program specific areas of remote handling and operations requiring further development in the near term, should the HIP process be pursued, are:

1) Remote Can Filling Operations, Including Compaction

Small scale testing of both the mass flow batch hopper with extending nozzle and the fluidized bed approach directly from the filling vessel should be pursued to determine the best method for can filling. The results from this testing and evaluation program should form the basis for large scale mock-up and testing to verify adequate can filling. This is of paramount importance to achieving the desired waste form and ensuring that the remote handling technology is fully developed to support the selected can filling option.

2) Remote Inertial Welding Equipment

This would include further development of the friction welding parameters and configuration development of the process can top flange and lid. While the friction welding concept has been demonstrated in a vacuum on a prototype test unit, using a large lathe as the spindle driver, more development work is required to finalize design of the weld plug portion of the lid for proper mating with the can top flange structure. The optimum hole size in the can top for filling operations should be determined in the near term in order to finalize the weld parameters and define the equipment size. Also, since the recommendation is to use the friction welding equipment with an appropriate cutting device to remove a defective weld, development work in this area should be initiated in the near term.

3) Process Can Top Flange Structure

Design, testing, and evaluation of the process can top flange structure must be made to determine deformation limits after the HIPing process. This information is also required in order to develop the grapple device mechanism for handling the process cans by the top flange structure. Currently, there is an ongoing activity to develop a prototype HIP can lid design. Initial thermal testing of a prototype has been completed with minimal distortions in the handling ring area. HIP tests on intermediate scale cans, with the prototype lid design, are scheduled for the near future.

4) Double Door Port System

Evaluation and development of the double door port system as a sealing interface for mating the HIP process can to the filling and welding stations is important for control of process dust and contamination. This system should be a simplified version of the double door sealed transfer system currently in use at ICPP to reduce the number of remote operations and increase reliability.

5) Cart Transfer Systems

Proceed with design, testing, and evaluation of cart transfer systems in conjunction with process can handling in order to optimize cart simplicity, demonstrate high reliability, and develop alignment/locking mechanisms for the can/cart and can/work station port interfaces.

6) Other Remote Handling Equipment

A grapple mechanism should be developed concurrently with the process can lid design for attachment to the overhead handling system. The grapple mechanism should be simple, yet rugged, with high reliability, and of a proven fail-safe design for interfacing with the HIP process cans and the overpack canisters.

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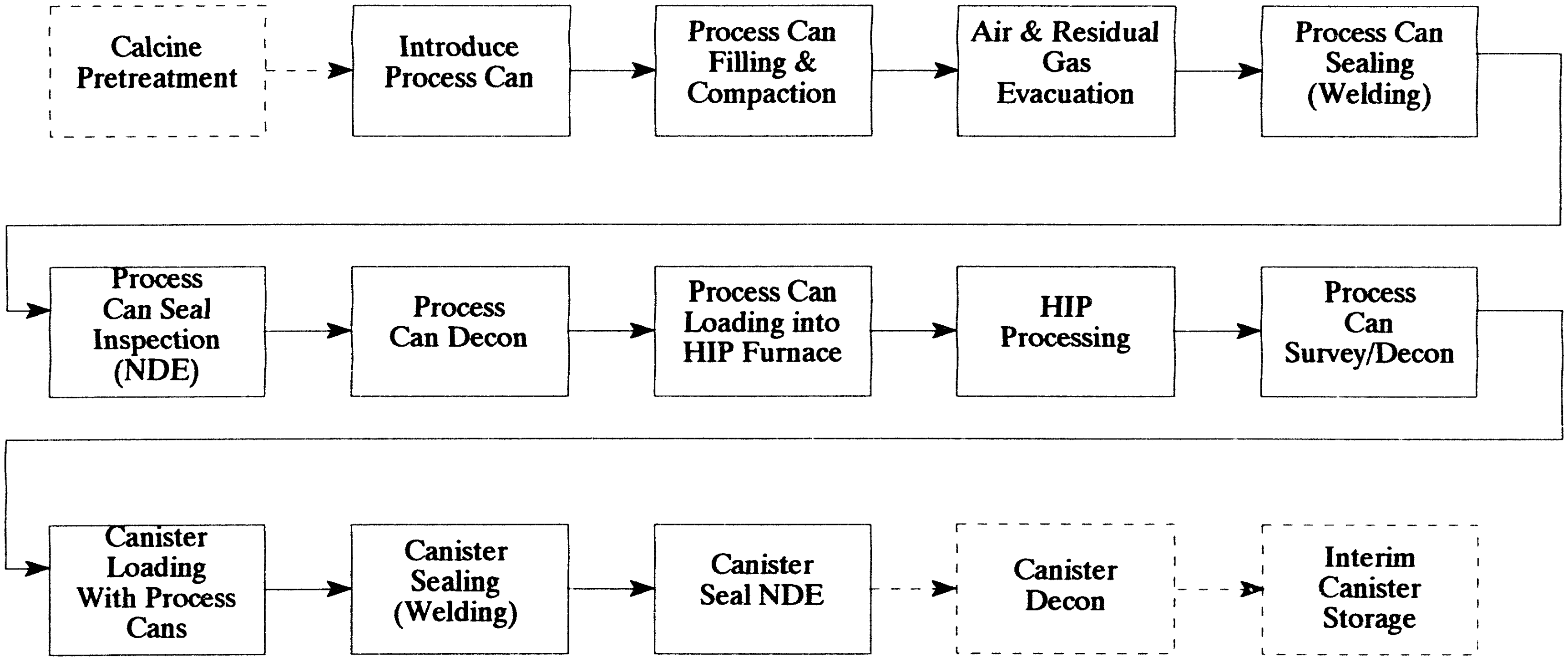
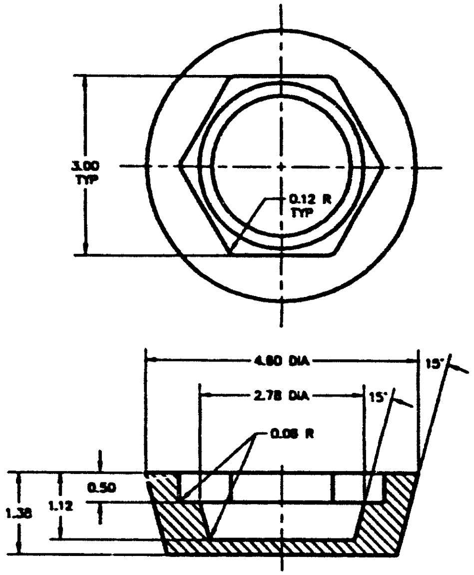
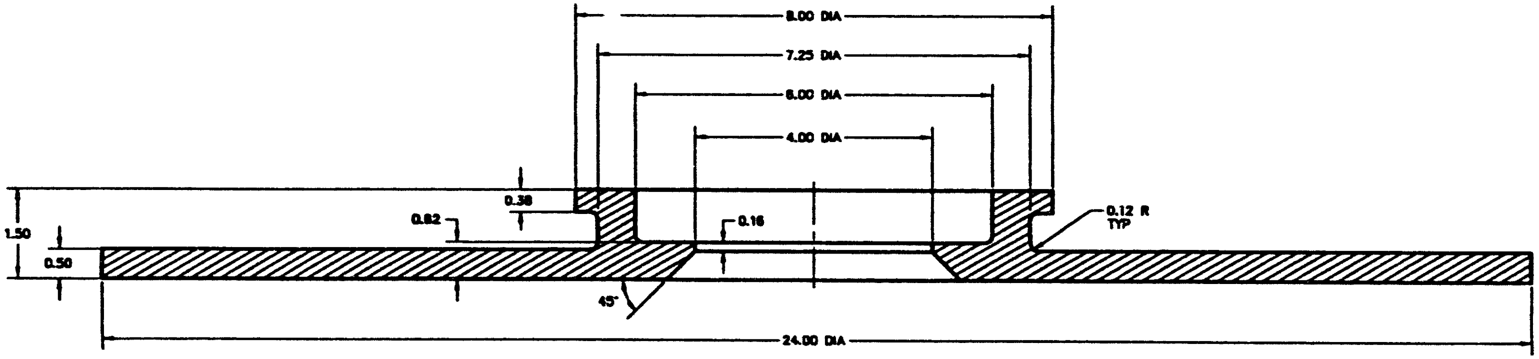


HIP = Hot Isostatic Press

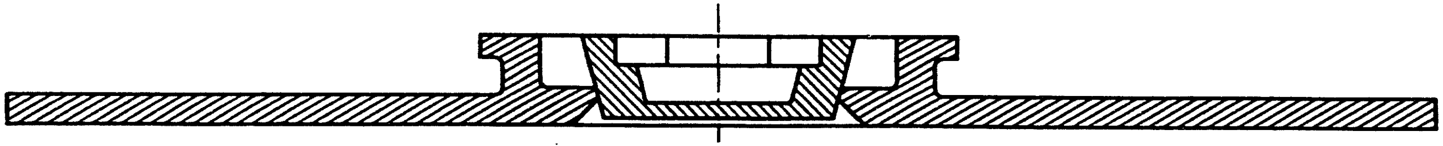
Figure 1. Calcine Immobilization Using the Hot Isostatic Press Process



PLUG DESIGN



LID DESIGN



LID WITH PLUG FRICTION WELDED IN PLACE

Figure 2. Proposed HIP Can Lid

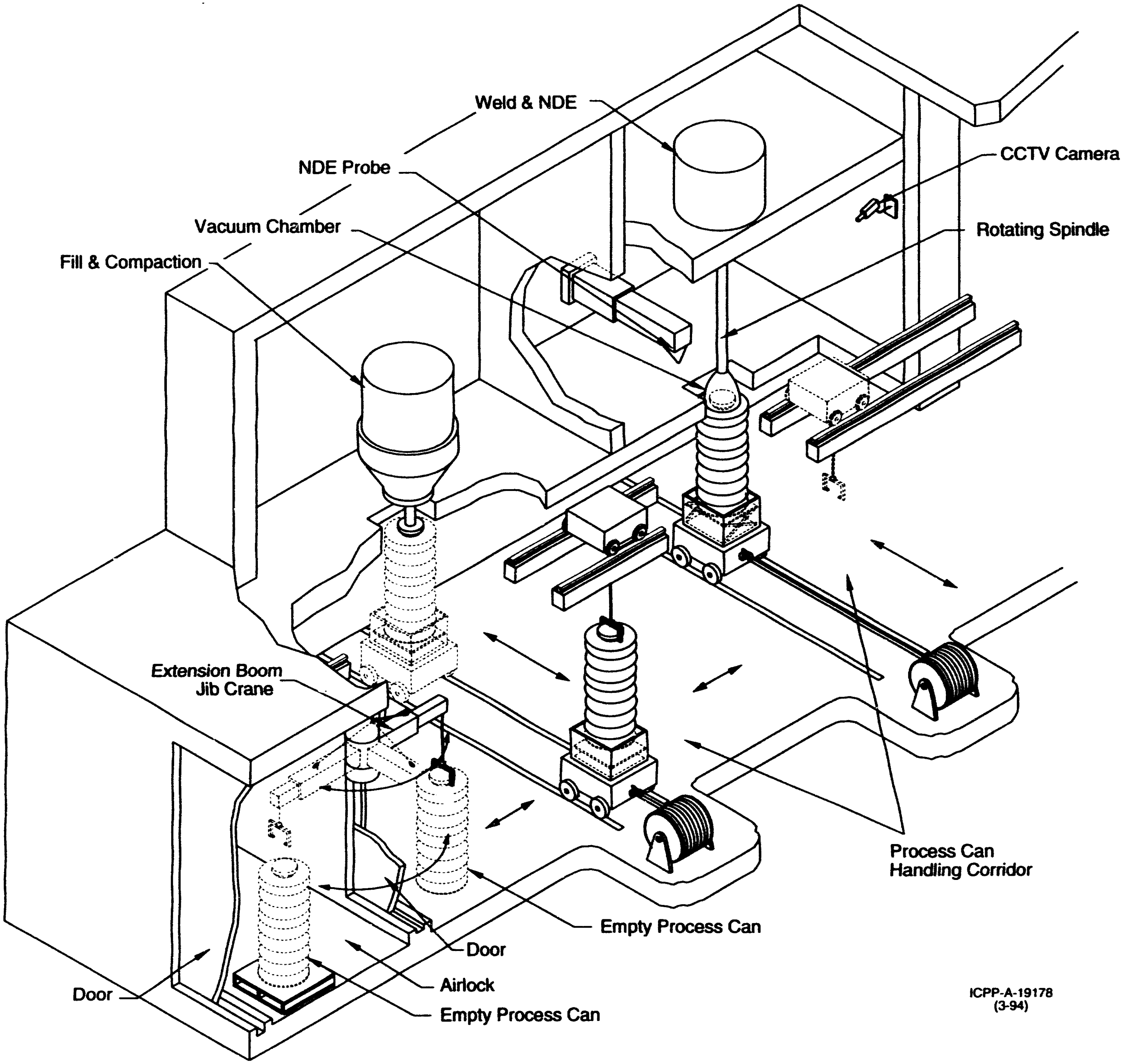


Figure 3. Process Can Introduction, Fill and Initial Compaction

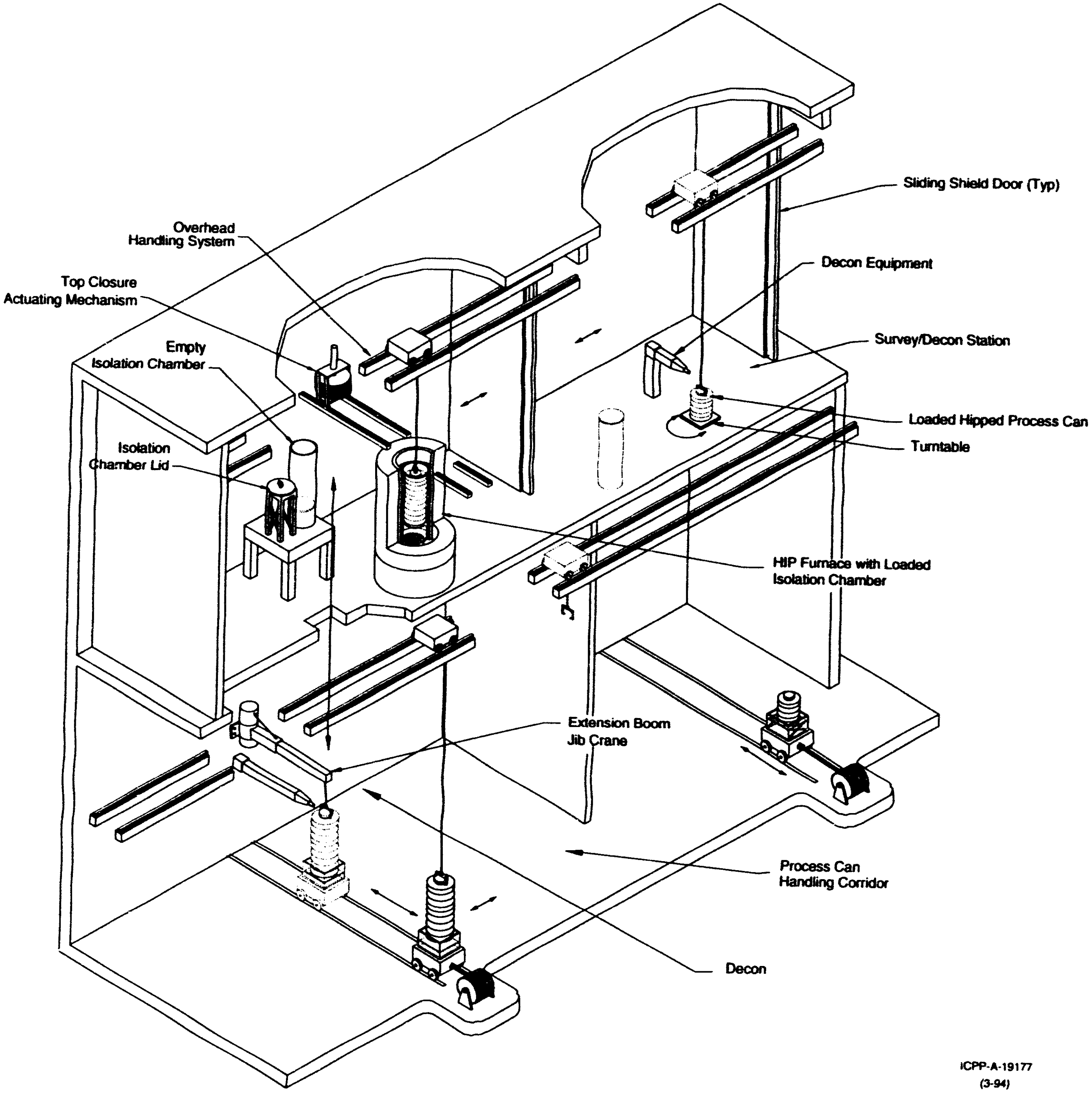


Figure 4. HIP Can Decon and HIP Processing in Top Loading Furnace

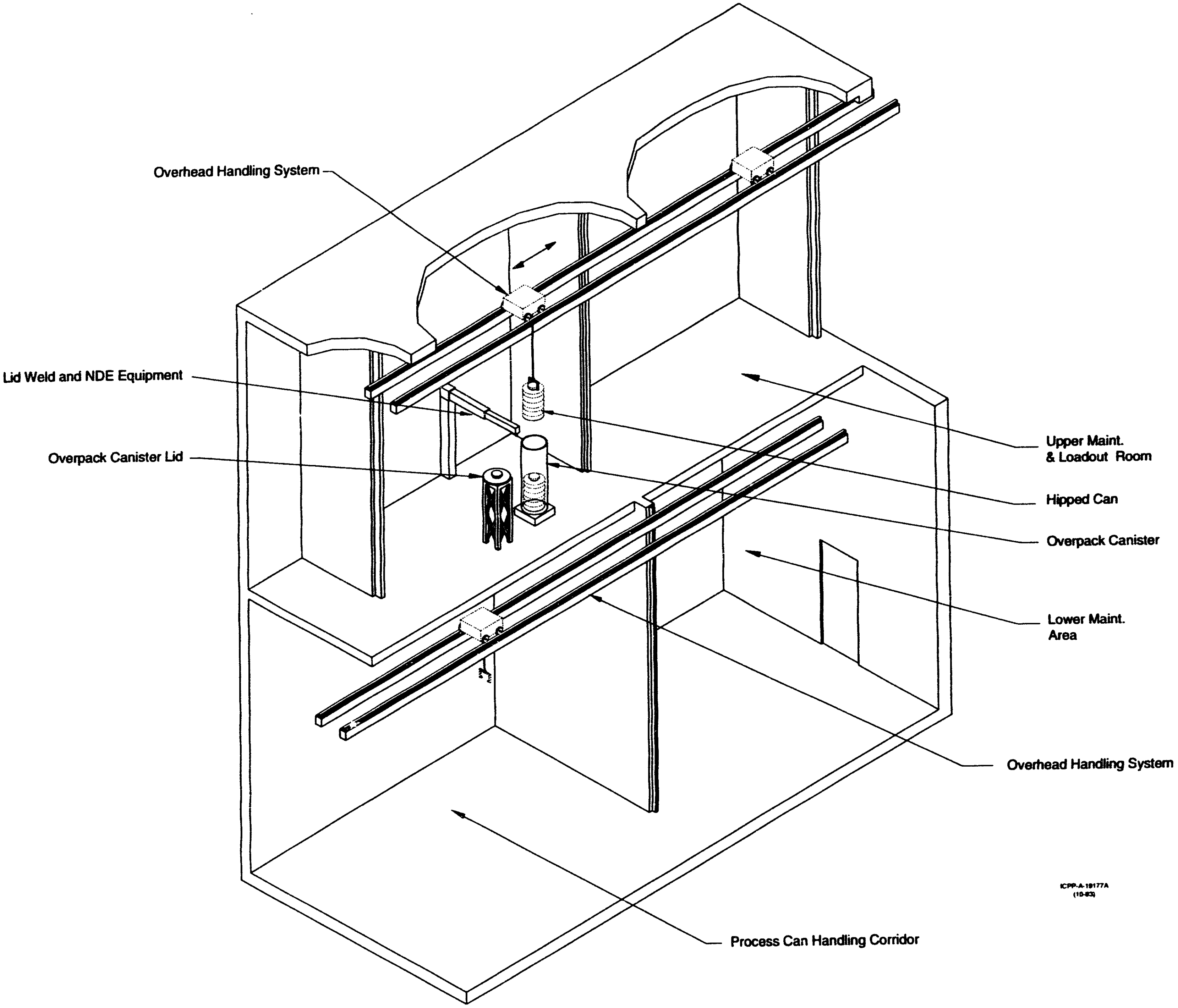


Figure 5. Canister Overpack/Weld/NDE, Upper Maintenance, and Loadout Areas

CIMCORP *Product Summary*

XR®100 Gantry Robotic System

The XR100 gantry robot at this installation transfers hot truck gears from heat treating furnaces to one of six oil quench presses, and an inspection station, and then palletizes the gears by size.

XR™100 SERIES OVERHEAD GANTRY ROBOT SPECIFICATIONS

MODEL	XR3100	XR4100	XR5100	XR6100
Degrees of freedom	3	4	5	6
AXIS	Travel (Std.) (Max. Speed)	Travel (Std.) (Max. Speed)	Travel (Std.) (Max. Speed)	Travel (Std.) (Max. Speed)
X ("Bridge" axis)[1]	7'-35' (36 ips)	7'-35' (36 ips)	7'-35' (36 ips)	7'-35' (36 ips)
Y ("Trolley" axis)[2]	11'-19' (36 ips)	11'-19' (36 ips)	11'-19' (36 ips)	11'-19' (36 ips)
Z (Telescoping tubes)	0"-81" (18 ips)	0"-81" (18 ips)	0"-81" (18 ips)	0"-81" (18 ips)
θx (Forearm yaw)	—	320° (57°/sec)	320° (57°/sec)	320° (57°/sec)
θy (Forearm pitch)	—	—	210° (57°/sec)	210° (57°/sec)
θz (Wrist roll)	—	—	—	330° (57°/sec)
Repeatability[3]	± 0.012 in.	± 0.012 in.	± 0.023 in.	± 0.023 in.

[1] Bridge travel 5' less than runway length

[2] Carriage travel 3'9" less than bridge span

[3] These values are unidirectional and spacial and based on a 22 inch arm length. Arm length, robot size and end effector offsets effect repeatability. Consult the factory for the exact values for a particular application.

XR100 ROBOT MAIN ARM SPECIFICATIONS

Telescoping main arm tubes (Z axis)			DEAD VERTICAL LIFT ALONG Z AXIS (Tube load capacity [lb.], including weight of end effector)			
No. of tubes	Tube travel, max in inches	Tube speed max in ips	XR3100	XR4100	XR5100	XR6100
3	27	18	450	380	315	275
2	54	12	1100	965	890	850
1	81	6	2140	2005	1930	1890

XR100 ROBOT PAYLOAD (LB) – SPECIFICATIONS AT FACE PLATE

No. of tubes	Speed	XR3100	XR4100	XR5100*	XR6100**
3	18	450	380	100	100
2	12	1100	965	230	230
1	6	2140	2005	230	230

*With standard 22 in. arm

**Within 4 in. of face plate, with standard 22 in. arm

Note: θx and θy axis are limited to 6,000 in.-lb. of torque for one and two moving tubes.
θx axis is limited to 2,500 in.-lb. of torque for three moving tubes.
θz axis is limited to 1,000 in.-lb. of torque, independent of tubes.

CIMROC CONTROLLER SYSTEM SPECIFICATIONS

Position Control	Point-to-point, continuous-path and controlled-path positioning
Coordinate Frames	Cartesian, joint and tool-coordinates
Motion Types	Straight-line, time-optimized and relative moves; circular interpolation, point transformations, axis offsets
Controllable Axes	Continuous-path control of up to nine coordinated axes
Controls Architecture	1) 16-bit, multiprocessor-based distributed architecture 2) IBM AT®-based supervisor; Intel Multibus®-based motion control
Speed Control	Velocity programmed in floating-point format as either a percent of maximum, or as units/second (inches or degrees)
I/O Capacity	Up to 512 total analog and digital I/O channels in a variety of voltage ranges
Delay Function	User programmable
Programming Features	1) Standard programming languages including Pascal and 'C' 2) Standard PC-DOS® Operating System for off-line programming at any IBM PC® or compatible workstation 3) Versatile point-data manipulations 4) String and array functions 5) Concurrent operation 6) Unlimited program capacity
Operating Features	1) Self-diagnostics 2) User-definable function pushbuttons 3) Manual override for 1% to 120% of programmed speed
Teach Functions	1) Multi-level, application programmable teach pendant 2) Downloading of program and point data
Communications	1) Cell, host and factory communications with LAN support for ETHERNET® compatibility 2) ASCII and TTY serial communications over RS232C or RS422A ports
CIM Interfaces	Custom software support for CAD/CAM/CAE interfaces, data post-processing and application service routines
Application Packages	Intelligent interfaces for welding, vision, force/tactile sensing, and collision avoidance applications
Safety Features	1) Console and remote START, STOP and E-STOP connections 2) Controller status indicator 3) Console override speed selector
Operating Environment	40° F to 125° F (4° C to 52° C) with standard air conditioning
Input Voltages	AC 208/230/416/480 V ± 10% @ 50/60 Hz ± 1 Hz
Standard Configurations	1) 12 inch color CRT display 2) 5¼ in. floppy disk storage 3) 20 MB hard-disk storage 4) 640K dynamic RAM memory 5) 16 I/O motherboard with 8 digital inputs and 8 digital outputs 6) Full action, 87 character QWERTY style keyboard with 16 character numeric keypad and function keys 7) Four RS232C serial communication ports 8) NEMA-12 grade standard enclosure with air conditioning 9) Teach pendant
Optional Configurations	1) Additional, configurable hard-disk storage 2) Bubble memory 3) I/O expansion 4) Application programming 5) Attachable printer 6) Uninterruptable power supply 7) Realtime position monitoring 8) Auxiliary axis control 9) CNC data downloading

CIMCORP
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A Wartsila Company

Figure 6. Gantry Robotic System

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