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Plutonium Immobilization - Puck Handling

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Abstract

The Plutonium Immobilization Project (PIP) will immobilize excess plutonium and store the plutonium in a high level waste radiation field. To accomplish these goals, the PIP will process various forms of plutonium into plutonium oxide, mix the oxide powder with ceramic precursors, press the mixture into pucks, sinter the pucks into a ceramic puck, load the pucks into metal cans, seal the cans, load the cans into magazines, and load the magazines into a Defense Waste Processing Facility (DPWF) canister. These canisters will be sent to the DWPF, an existing Savannah River Site (SRS) facility, where molten high level waste glass will be poured into the canisters encapsulating the ceramic pucks. Due to the plutonium radiation, remote equipment will perform these operations in a contained environment. The Plutonium Immobilization Project is in the early design stages and the facility will begin operation in 2005. This paper will discuss the Plutonium Immobilization puck handling conceptual design and the puck handling equipment testing.

1. Introduction

The PIP goals are to immobilize surplus plutonium and protect the plutonium in a high level waste radiation field. To accomplish these goals, the PIP will use three main processes; conversion, first stage immobilization, and second stage immobilization. The conversion process includes; receiving and unpacking a variety of plutonium shipping containers, processing the various plutonium forms into plutonium oxide powder, and storing the powder. The first stage immobilization process includes; mixing the plutonium oxide powder with ceramic precursors, pressing the blended materials into a puck, inspecting the pressed puck, loading the pucks on a furnace tray, loading the trays into the furnace, sintering the pucks, transferring the pucks from furnace trays to transport trays, loading the pucks into a stainless steel can, welding the can closed, inspecting the can, and storing the can. The second stage immobilization process includes; loading cans into magazines, loading magazines into DWPF canisters, transporting canisters to DWPF, and filling the canisters with high level waste glass. Due to the plutonium radiation, remote equipment will perform these operations in a contained environment.

Figure 1 is a first stage immobilization plan view, from the press to can inspection, and this paper will discuss these operations. The layout utilizes two identical and separate glovebox lines. Each contains a press area, a furnace line, transfer area, and a puck examination station. The material transport system will move the pucks to the sintered puck storage area and when needed to one of three can loading gloveboxes. Twenty pucks will be loaded into each can and the cans will be sealed via a weld. The sealed cans will be inspected and transferred to the can examination area.

Figure 1 - Puck Handling Plan View

The PIP requirements include a production rate of one DWPF canister per day, remote operations, and containment for all operations. To meet the one canister per day production rate, the facility must be able to press and sinter 560 pucks per day, load twenty-eight metal cans per day (20 pucks per can), load seven magazines per day (4 cans per magazine), and load one canister per day (seven magazines per canister). The pucks are expected to produce one Rad per hour at their surface. This high radiation rate will require that the PIP operations be performed remotely. In order to contain all the radiation sources, all operations will be performed in gloveboxes. The following sections describe the PIP processes from press unloading to can inspection and the equipment conceptualized for each task.

2. Press Area Operations

Each press area contains a robot and a tray stacking station. Airlocks separate the press area from the furnace line and the vertical lift (elevator) system, see Figure 2. The second press allows half of the system to continue operating when one press is down for maintenance (total system throughput is still limited by the number of furnaces). This ability to continue will help the facility meet production requirements. The dual presses will cut the press robots timing constraints in half.

Process flow for the furnace trays begins with a stack of five empty furnace trays at the press area stacking station. The stacking station presents one empty tray at a time to the press robot. The unsintered pucks, nominally 1.375 inches (34.925 mm) high by 3.500 inches (88.900 mm) in diameter, will be removed from the press by a six-axis robot and placed in a deburring/prep station for flash removal. After flash removal, the pucks will be placed by the robot on a standard lab type scale for weighing and then placed in a visual or laser (or combination of both) inspection system for automated inspection. This will include inspection for cracks and other defects as well as dimensional inspection. Reject pucks will be placed in a reject standard can by the robot and sent via the transfer conveyor system to another part of the facility for reprocessing.

Figure 2 - Press Area and Furnace Line

The press robot fills the furnace tray with 16 pucks, then the stacking station moves the loaded tray to the furnace line and presents another empty tray to the robot. After five furnace trays are loaded and stacked on the furnace line, the stack (80 pucks) is complete and ready to move toward the furnaces. Because green pucks do not travel through the elevators or overhead transfer system to reach the furnaces, contamination concerns for these areas are significantly reduced. This simple path will reduce agitation and vibration of the green pucks. Because the loaded stack does not travel through the elevators or overhead transfer system, the design load for these systems can conservatively be reduced from 200 pounds (90.72 kg) (five loaded furnace trays plus furnace door) to 30 pounds (13.61 kg) (one loaded transfer tray). This is significant because the overhead transfer system lines traverse almost the entire facility.

3. Furance Line Operations

Once in the furnace line, the stacked trays will be loaded onto a bottom loaded furnace door section and lifted into position by customized vertical lifting and positioning equipment. After the green pucks have been sintered in the furnace, the stacked trays and door section will be lowered from the furnace and the stacked trays will be lifted from the door section by a pick and place or hard automation device for placement on a transfer cart. The stacked trays will then be transported by the transfer cart and magnetic conveyor system through the airlock to the furnace tray cool and storage area.

The furnace lines are also used to return stacks of empty furnace trays from the transfer area to the press area. Coordination of two-way traffic for the furnace trays is facilitated by the long furnace cycle time required for sintering the pucks. Because the furnace trays remain in the furnace lines, contamination in the elevators and overhead transfer system should be further reduced. Additionally, this simple movement concept reduces the expected wear and tear on the furnace trays, which are relatively fragile due to their ceramic construction and heating/cooling cycles. The simple movement also reduces the risk of toppling a stack of trays. Because furnace trays and green pucks do not enter the elevators, no airlocks should be needed in the overhead transfer system. Inventory control for the furnace trays will be simplified since they remain in the furnace lines. The required inventory of furnace trays and green pucks could be decreased due to direct flow between the press and the furnaces. Eliminating the need to use the overhead transfer will reduce the need for storage and reduce travel time.

4. Transfer Area

When a loaded stack of furnace trays arrives, the stacking station positions one tray at the transfer robot. The robot removes the pucks from the furnace tray, weighs, inspects, and places them on a transfer tray. Puck weigh and inspect after sintering is required to ensure sintered puck dimensional and physical requirements are met prior to can loading. Rejects will be placed in a reject can and sent by the conveyor transfer system to another part of the facility for reprocessing. The sintered puck transfer tray will be designed to contain a specified number of pucks for transport to puck examination and can loading. The design and number of pucks in the transfer tray will depend on capacity of the transfer conveyor system and unloading requirements at can loading, although 16 pucks on a transfer tray is the present concept. After the furnace tray is emptied, the stacking station replaces it with another loaded furnace tray. Furnace tray unstacking will be accomplished by a pick and place machine or hard automation. When the transfer tray is full (20 pucks), it moves on the conveyor to the puck inspection area for puck examination. The five empty furnace trays may be restacked and returned by the conveyor transfer system back to the press line for unstacking, green puck loading, and restacking.

5. Puck Examination

The transfer trays loaded with sintered pucks will be sent to the puck examination area. The examination will include non-destructive assay (NDA) and non-destructive examinations (NDE) from neutron counters, segmented gamma scanners, and x-ray fluoresces. Approximately four pucks from each 80 puck batch will be assayed and examinated, while the remaining will be sent to the sintered puck storage. Those failing NDA/NDE inspection will be returned via the conveyor transfer system for reprocessing and recovery. Based on inspection results, additional pucks from the 80 puck batch may receive assay and inspection. Following NDA/NDE, the sintered pucks will be stored and then sent to can loading. Empty transfer trays will be returned to the sintered puck loading station in the furnace lines for stacking and storage. Transfer tray storage will also be accomplished by a pick and place machine or hard automation similar to the furnace tray stacking equipment located in the press and furnace glovebox lines.

6. Material Transfer System

The facility transfer conveyor system will be composed of three types of transport mechanisms - a horizontal transfer cart for use within glovebox lines, a vertical lift (elevator) system for connecting a glovebox line to an overhead transfer line, and an overhead transfer system for transporting payloads between glovebox lines. The horizontal transfer system will consist of a wheeled transfer cart inside a glovebox line magnetically coupled to a linear actuator beneath the glovebox floor. The linear actuator will move a platen containing a set of permanent magnets. This compliant platen is engineered to follow the underside of the glovebox floor surface with a fixed standoff distance. The platen's permanent magnets are coupled to magnetic iron strips on the underside of the transfer cart. The cart's movement is constrained in a straight line by using v-wheels on a matching floor mounted track. The transfer cart will be designed to support and move individual furnace trays, stacked furnace trays, sintered puck transfer trays, reject trays, and possibly bottom loaded furnace door sections (depending on furnace tray loading design and transfer system capacity). The transfer cart can also be driven into the vertical elevator shaft for transferring the payload to the elevator system. The elevator section of the conveyor system will also utilize a magnetic coupling to drive a self locking lead screw to lift the stacked trays, transfer trays, reject trays, and possibly furnace door sections with stacked trays. The elevator has forklift type tines that lift the payload from the transfer cart. The elevator hands off the payload to the overhead tunnel transfer system. The overhead system is conceptualized as an inverted version of the glovebox cart drive system with the drive mechanism externally mounted above the tunnel. The overhead system inside the tunnel would have a hanging payload cradle that captures the payload carried by the elevator. The overhead system can then deliver the payload to another glovebox elevator system.

It should be noted that depending upon furnace and transfer tray design and transport option selected (single, stacked, transport with furnace door, etc.) the cart, elevator, and overhead transfer system payload may vary from 30 to 200 pounds (13.61 to 90.72 kg). This may impact the conveyor drive technology selected. The payload handoff operation between the transfer cart, elevator, and overhead transfer system requires a common footprint for payloads since no actuated grippers are used by any of these systems. The length of single runs will impact technology choice (actuator driven, linear induction motors, etc.). Maintaining glovebox lengths and distances between adjacent elevator shafts to less than 60 feet will allow use of demonstrated SRS technology. A glovebox transfer cart and elevator system has been mocked up at SRS. However, no overhead system has been demonstrated. This concept requires orthogonal relationships between any glovebox line, elevator shaft, and overhead tunnel.

7. Airlock Considerations

Double door airlocks will be placed on either side of the press section of the press line glovebox to contain Pu ceramic dust created during pressing and green puck handling operations. The furnace tray stacking station may be located inside or outside the press glovebox section, depending on whether the furnace tray stacking equipment can function acceptably in a dusty environment. Locating the stacking station inside the press glovebox area will result in ten times fewer airlock opening and closing cycles during the life of the facility since the individual trays (5 per stack) will not have to travel back and forth between the green puck loading station and furnace tray stacking station through the airlock. In addition, locating airlocks in the horizontal glovebox transfer lines will most likely result in a transfer cart design utilizing six or more wheels (possibly staggered) to bridge the gap in the cart rails created by the airlock doors. Otherwise, an airlock design that seals against the "v" rails would have to be developed with particular attention being paid to seal wear during airlock door opening and closing cycles. In addition, airlocks to isolate the elevated horizontal conveyor section during stacked furnace tray/green puck transfers are considered to be beneficial in preventing contaminated Pu ceramic dust from spreading to other parts of the facility.

8. Can Loading - Tray Staging

The tray staging system within the can loading glovebox will be two tray lift stations, see Figure 3. Each station will lift a puck transport tray, by the outer edges, from the transport cart to stage the tray. The puck robot can access pucks on either tray and the transport cart can pass under an occupied lift station to access the other lift station. Transport tray concepts hold up to 20 one pound (0.45 kg) pucks and the tray will weigh approximately 10 pounds (4.54 kg), so the tray staging lift units must be able to lift a 30 pound (13.61 kg) payload. The tray lift station size will be driven by the transport tray size. The transport tray is approximately 20 inches (508 mm) by 20 inches (508 mm), so the tray lift stations will be about 18 inches (457 mm) long by 30 inches (762 mm) wide by 10 inches (254 mm) tall. The lift height will provide sufficient clearance for the cart carrying a tray to move under a lifted tray. The tray staging system parts will be fabricated from 304 stainless steel where possible and all moving parts will be covered when possible. The magnetically coupled lift stations design will allow the drive motors to be outside the containment for easier maintenance and cleaning.

9. Can Loading - Load Pucks into Puck Can

The puck robot, Cartesian type, will use a puck lifting tool to lift pucks from the transport trays and place them in the puck can. The puck robot will also handle can stubs, reject cans, and the helium hood. The puck robot's maximum payload will be the 30 pound (13.61 kg) puck can. The puck robot requires three degrees of freedom, X - Y - Z, and a gripper. The X axis will provide 52 inches (1320 mm) of travel, the Y axis will provide 40 inches (1016 mm) of travel, and the Z axis (up and down) will provide 40 inches (1016 mm) of travel. These travel limits will allow the puck robot to fit inside the 60 inch (1524 mm) long by 48 inch (1219 mm) wide by 60 inch (1524 mm) tall can loading glovebox. Each axis requires a repeatability of +/- 0.010 inches (+/- 0.254 mm) and a velocity range from 0 to 8 inches/second (0 to 203 mm/sec).

The gripper will lift the following items; the puck lifting tool, helium hood, puck cans, and can stubs. Each item has a 3 inch (76 mm) outer diameter or will have a 3 inch (76 mm) outer diameter lifting point, so the gripper will always grab the same shape.

The puck lifting tool will be used by the puck robot to pick up pucks and place them inside the puck can. The lifting tool will carry one puck at a time, so the maximum payload will be approximately one pound. The lifting tool will be a hollow pipe approximately 44 inches (1118 mm) long. The lifting tool lower 30 inches (762 mm) must fit inside the 2.88 inch (73 mm) inner diameter by 30 inch (762 mm) long puck can. The lifting tool will have a vacuum cup on the lower end and a 3 inch (76 mm) diameter grab point on the top end. The 3 inch (76 mm) diameter section will allow the robot gripper to firmly hold the tool. This grab point will be the top 4 inches (1.3 mm) of the tool and will never enter the puck can. The lifting tool requires an umbilical cord to provide the vacuum line for the vacuum cup.

Figure 3 - Can Loading Concept

10. Can Loading - Helium Hood and Hollow Plug

The helium hood will fill the puck can with helium and insert the can plug. The helium hood will perform the following operational steps. First, the hood will grab the can plug with a vacuum cup. Second, the puck robot will place the hood on the puck can. Third, the helium hood will seal to the puck can and pull a vacuum on the puck can. Fourth, the hood will insert helium into the can. Fifth, the hood will place the can plug into the can. To ensure helium is in the puck can, the system will pull a vacuum to 20 inches (508 mm) of mercury on the puck can, backfill with +3 psi of helium, pull the vacuum a second time, and backfill with helium. The helium hood requires position feedback (+/- 0.05 inches) and force control on the can plug insertion actuator to ensure the plug is inserted to the proper position. The hood requires an umbilical cord to supply the vacuum lines, helium lines, and plug insertion actuator power and position feedback cables.

11. Can Loading - Weld and Cut Can

The can welder will weld the can plug to the can wall from outside the can. The can loading bagless transfer system will use a commercially available TIG welder. The welder will be sized to fit around a 3 inch (76 mm) outer diameter can and the welding head must be compatible with the 0.040 inch (1.016 mm) thick 304L stainless steel can wall and 0.125 inch (3.175 mm) thick 304L stainless steel hollow plug.

The can cutter will cut the puck can and hollow plug in the weld area to separate the can of pucks from the stub. The can loading bagless transfer system will use a commercially available pipe cutter. The cutter will be sized to clamp around the 3 inch outer diameter cans and cut through the 0.040 inch thick can wall and the 0.125 inch (3.175 mm) thick hollow plug wall. The can and plug will be fabricated from 304L stainless steel.

The can holder will support, raise, and lower the puck cans while they are in the bagless transfer system. The can holder will also hold and rotate the can while the can robot swipes the can for transferable contamination. The can holder maximum payload will be a filled 25 pound puck can plus the force required to push the can through the sphincter seal. The can holder will be shaped like a cup and sized to hold a 3 inch outer diameter can. The holder will have enough clearance to allow the can robot to remove the cans from the can holder. The empty puck can will be 30.0 inches long, 3.0 inches OD, and 0.060 inches wall thickness. After the can is welded and cut it will be 20 inches long.

12. Can Inspection

The can robot will load and unload puck cans in the bagless transfer system, maneuver swipes over the puck cans, load and unload swipes in the swipe counter, load and unload cans in the decontamination chamber, load and unload cans in the leak detector, and place puck cans on the transfer cart. The can robot maximum payload will be the 25 pound fully loaded puck can. The can robot requires 6 rotational degrees of freedom (DOF) and a gripper. The six DOFs allows the robot to maneuver the swipe over the cylindrical can surface and to load and unload puck cans at various stations. The can robot will need a minimum radial reach of 30 inches. This will allow the robot to reach all the stations inside the bagless transfer enclosure. A preliminary market search revealed that commercially available 6 DOF robots with a 25 pound payload have a radial reach greater than 5 feet. The can robot must perform the required tasks within the 72 inches long, 48 inches wide, and 60 inch tall bagless transfer enclosure. The can robot requires a repeatability of +/- 0.020 inches and each DOF requires a velocity range from 0 to 40 degrees/second. The gripper will hold 3 inch diameter puck cans and can swipes. Since swipes are typically very thin and hard for a gripper to handle, large swipes or a swipe holder will be used.

13. Equipment Tested

The following paragraphs describe the puck handling and can loading equipment tested by Westinghouse Savannah River Company (WSRC) and the Lawrence Livermore National laboratory (LLNL).

Puck Press - WSRC and LLNL tested presses and dies to determine press parameters. Commercial presses are capable of very high press forces, but this application requires approximately 2000 psi to ensure sintered puck integrity. The WSRC press uses simulated feed and the LLNL press uses simulated and radioactive feed.

Puck Handling Pick and Place Device - WSRC built a simple puck handling pick and place machine to test various grippers and suction cups for handling green and sintered pucks. Testing with this device determined that a two jaw gripper approaching from the side is the best option for lifting the delicate green pucks. Also, a three jaw gripper and vacuum cup approaching from the top is well suited for lifting sintered pucks.

Magnetically Coupled Transport System - WSRC built and tested a magnetically coupled transfer and elevator system. This demonstration unit proved the magnetically coupled concept is reliable and will be incorporated in the PIP.

Helium Hood - WSRC built and tested a prototype helium hood to test the concept. Initial test results show that concept will work and the system will be able to be operated remotely. Cycle tests will be performed to determine system reliability over time.

Can Loading Pick and Place - WSRC built a simple puck handling pick and place machine to test various vacuum cups for picking up sintered pucks and loading pucks into metal cans. A vacuum cup is required to load the sintered pucks since the puck OD is 2.65 inches and the can ID is 2.88 inches. This clearance is too small for gripper figures grab the puck OD and fit inside the can. Test results have shown the vacuum cup will work very reliably and that a pick and place device can load pucks into the metal cans.

Bagless Transfer - WSRC developed, built, and installed a bagless transfer system in the SRS FB-Line facility. This system uses a different size can than the PIP plan puck can, but several critical parameters will be the same.

The similar parameters include; can wall material and thickness, hollow plug material and thickness, clearance between plug OD and can ID, welding technique, and cutting technique.

14. Conclusion

WSRC completed a significant portion of the PIP puck handling conceptual design from the press to can inspection. During 1999, WSRC will continue to develop these conceptual designs and develop puck handling equipment. Equipment scheduled for development includes; a robotic system to handle unsintered pucks in the press area, a pick and place device to move pucks and reject cans through airlocks, a furnace tray stacking system, a magnetically coupled tray conveyor, a tray staging device, a Cartesian robot to load pucks in metal cans, and a vision system to allow the Cartesian robot to find the pucks. To ensure a successful PIP, more conceptual design, equipment development, and equipment integration work will be required before the facility operations begin in the year 2005.

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