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Plutonium Immobilization Project - Robotic Canister Loading

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PLUTONIUM IMMOBILIZATION PROJECT - ROBOTIC CANISTER LOADING

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INTRODUCTION

The Plutonium Immobilization Program (PIP) is a joint venture between the Savannah River Site (SRS), Lawrence Livermore National Laboratory (LLNL), Argonne National Laboratory (ANL), and Pacific Northwest National Laboratory (PNNL). When operational in 2008, the PIP will fulfill the nation's nonproliferation commitment by placing surplus weapons-grade plutonium in a permanently stable ceramic form and making it unattractive for reuse. Since there are significant radiation and security concerns, the program team is developing novel and unique technology to remotely perform plutonium immobilization tasks. The remote task covered in this paper employs a jointed arm robot to load seven 3.5" diameter, 135-pound cylinders (magazines) through the 4" diameter neck of a stainless steel canister. Working through the narrow canister neck, the robot secures the magazines into a specially designed rack pre-installed in the canister. To provide the deterrent effect, the canisters are filled with a mixture of high-level waste and glass at the Defense Waste Processing Facility (DWPF).

PROCESS DESCRIPTION

"Can-in-Canister" (CIC) refers to the system for immobilizing and protecting excess plutonium in the PIP. Five components work together to form the system – the puck, bagless transfer can, magazine, rack and DWPF canister. The plutonium-ceramic puck is the basic component of the immobilization scheme. Twenty pucks are placed in each 20" long can and sealed by a remote welding process. Automated equipment then inserts four sealed cans into each magazine and closes the magazine with a mechanical, snap-type permanent closure. Other automated equipment then takes magazines to a staging area.

In the loading area, a DWPF canister with pre-installed rack is brought into the facility on an automated cart. A three degree-of-freedom telescoping bridge robot with a three degree-of-freedom manipulator obtains a magazine from storage, carries the magazine to the canister, manipulates the magazine through the canister throat into the rack, then inserts additional magazines until seven are loaded. Loaded canisters are then taken to the DWPF, where they are filled with a molten mixture of high level waste and glass. After cooling, the canisters are inspected and sent to a secure repository.

EQUIPMENT DESCRIPTION

Magazine

Magazines hold the cans in place during remote operations and later in the DWPF facility when the glass mixture is poured into the canister. Magazines are made of schedule-10 304L stainless steel pipe with many laser-cut oval perforations to permit glass to surround and adhere to the cans. They are 7-feet long and have a 3.5-inch outside diameter. Loaded magazines weigh 135 pounds. At the top of the magazine is a gripper knob and at the bottom is a cone-shaped device to assist in guiding the magazine into the magazine rack. During pouring, glass flows through the magazine slots and surrounds the cans, forming a tough glass-metal matrix surrounding the cans. Twenty-one magazines were fabricated and tested successfully with non-radioactive glass. Figure 1 is a photograph of an unloaded magazine before testing.

Rack

A pre-installed framework, or "rack," (Figure 2) inside the DWPF canister determines final loaded positions for the seven magazines. The rack serves several purposes:

- keeps the magazines in a predetermined, symmetric orientation inside the canister
- provides both lateral and vertical latching to reduce the possibility of magazines leaving their positions
- lends strength during canister handling, transportation, and glass pouring
- contributes to non-proliferation by supplying a structural connection for the seven magazines in the glass-metal matrix.

The rack is designed to provide structural support while minimizing both mass and resistance to glass flow. It is constructed entirely of stainless steel and consists of four scalloped plates and one bottom plate joined by seven solid round bars. The bottom plate is supported several inches above the bottom of the canister with seven radial struts. The struts and bottom plate have large openings to permit unobstructed glass flow. Seven "sockets" in the bottom plate (Figure 3) provide the resting surface for magazines. The sockets accept the cones at the bottom of each magazine. Snap rings at the cone/socket interface constrain the magazine vertically, while unique "butterfly" latches on the scalloped plates constrain lateral movement. (The operation of the lateral latches is demonstrated in the frames of Figure 4.) Three identical racks were fabricated and tested successfully with non-radioactive glass.

Canister Loading Robot

The Canister Loading Robot is uniquely designed for the canister loading process. It is a three degree-of-freedom telescoping bridge robot with a three-degree-of-freedom manipulator. While in the loading position, canisters are stationary, in a vertical orientation, and do not rotate. Therefore the Canister Loading Robot must provide all movement necessary to load magazines into a canister and lock the magazines to the rack. This ship-in-a-bottle approach to canister loading begins when the robot inserts the loaded magazine into the canister throat. The robot is capable of three motions once inside the canister neck: tilt, rotation and vertical translation. During loading operations, rotation is used to align the magazine radially with a socket. Then tilt is used to rotate the magazine through the rack's butterfly latches, and finally the vertical translation is used to lower the magazine to its stored position. The wrist holding the gripper is designed to ensure the magazine remains vertical at all times. It does this through a 4-bar link to the robot mast and free play between the magazine knob and gripper fingers.

The canister loading robot has not yet been built, however three mockups were constructed and operated to demonstrate feasibility. The first mockup was a test stand that contained a magazine and a single socket, with an arm that provided tilt and vertical translation. It was used to develop the butterfly latches and magazine/socket interface. The second mockup was a gripper attached to an existing bridge robot, and it was used to develop the gripper and magazine top. It also proved that a magazine could be moved apart from operator intervention across a building and then lowered through a canister throat without touching the throat sides. The final mockup is a fully autonomous, free standing robot that includes both rotations and the translation to seat a magazine in the socket. This demonstrates that the magazine can be locked into place inside a prototypical rack, and that the robot can load all seven rack positions without indexing the canister.

The third mockup is also being used to develop the user interface and control system for the three-degree-of-freedom manipulator attached to the bridge robot. An Allen Bradley 504 series PLC controls all three axes of movement (vertical movement, arm rotation, and tilt.) Each motor has encoder feedback (DC Servomotor) so the system controls acceleration, position, and velocity for each motion. To avoid having to return to a "home" position following restarts, absolute encoders are also provided for each motor. It is currently envisioned that the robot would begin the loading process by automatically moving the magazine from the storage location through the canister throat. Next, the operator would manually drive the magazine into one of the sockets using remote viewing. The canister loading robot would then load the remaining six magazines by indexing from the first one. During manual operation, the operator controls the robot through three joysticks. The operator chooses joystick and automatic functions from a menu displayed on a touch screen at the control station, keeping the control station clear and uncluttered.

PIP development will continue through 2001, then SRTC will prepare a series of System Design Descriptions. These documents will become the design basis for the Architectural and Engineering Firm chosen to build the PIP facility.

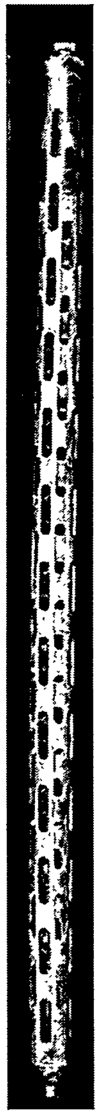

Figure 1:
Magazine

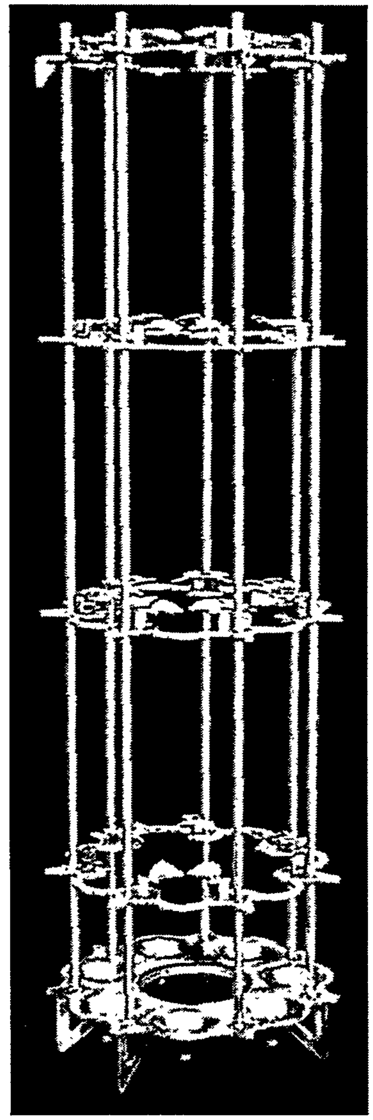

Figure 2: Prototype Rack

Figure 3: Sockets in bottom plate

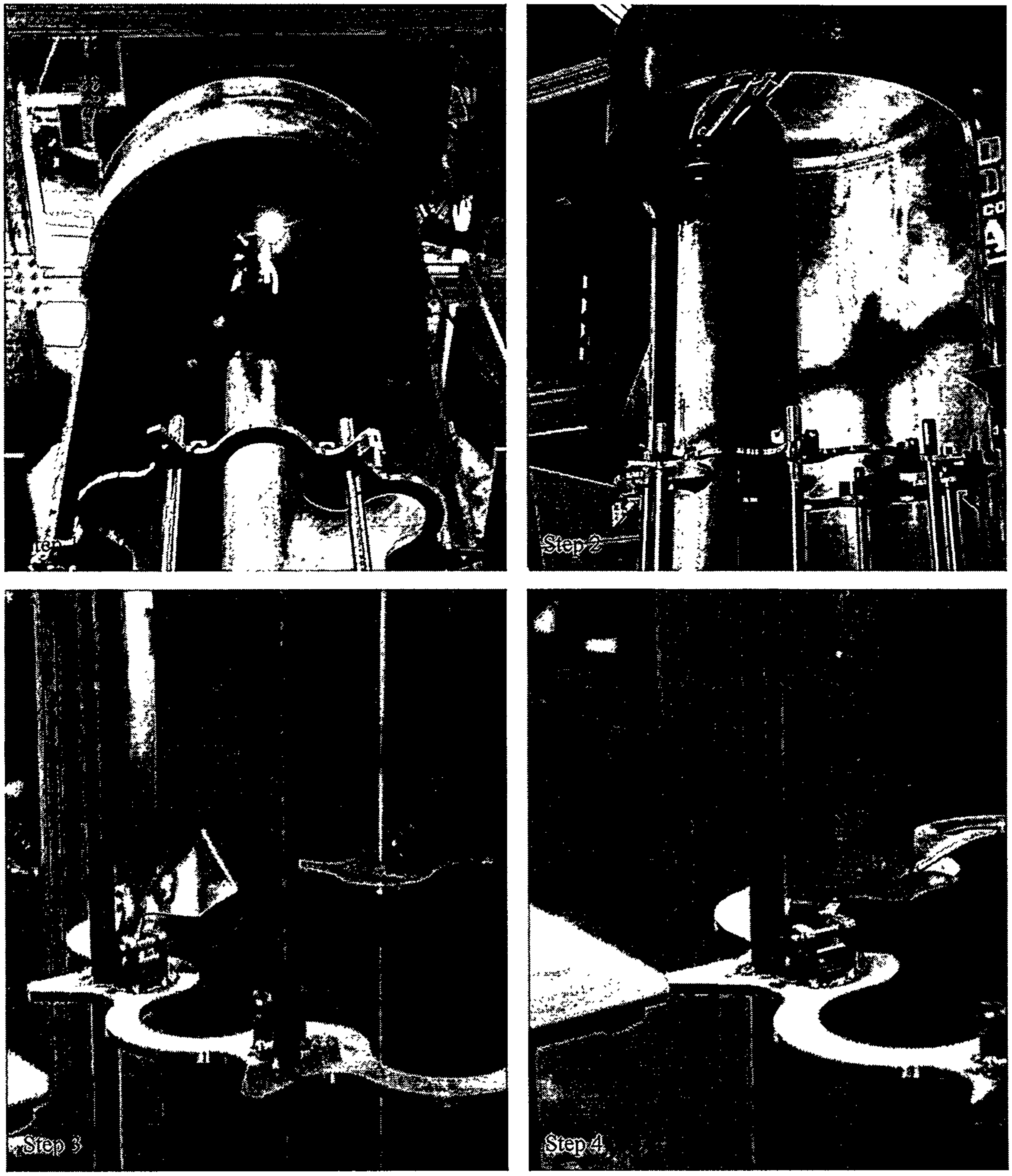

Figure 4: Step 1 shows the magazine lowered into the canister. In Step 2, the operator rotates the arm to align the magazine with the latches mounted in the storage rack using miniature cameras mounted on the arm. In Step 3, the manipulator arm pivots to engage the magazine into the lateral latches. Step 4 shows the latch engaged with the magazine seated in the socket.