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## Plutonium Immobilization Canister Loading

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## PLUTONIUM IMMOBILIZATION CANISTER LOADING

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### ABSTRACT

The disposition of excess plutonium is determined by the Surplus Plutonium Disposition Environmental Impact Statement (SPD-EIS) being prepared by the Department of Energy. The disposition method (known as "can in canister") combines cans of immobilized plutonium-ceramic disks (pucks) with vitrified high level waste produced at the SRS Defense Waste Processing Facility (DWPF). This is intended to deter proliferation by making the plutonium unattractive for recovery or theft.

The envisioned process remotely installs cans containing plutonium-ceramic pucks into storage magazines. Magazines are then remotely loaded into the DWPF canister through the canister neck with a robotic arm and locked into a storage rack inside the canister, which holds seven magazines. Finally, the canister is processed through DWPF and filled with high level waste glass, thereby surrounding the product cans. This paper covers magazine and rack development and canister loading concepts.

### 1. Background

The total Plutonium Immobilization Program (PIP) involves several production stages. Figure 1 shows a schematic of the total process. Plutonium and uranium oxides are mixed with ceramic precursors using blending and granulation equipment. Green ceramic pucks are formed in a cold press and then sintered in a furnace. The sintered pucks are then canned in a leaktight stainless steel can using a process developed at Westinghouse Savannah River Corp. (WSRC) and called Bagless Transfer. These product cans are then loaded into long magazines and the magazines are loaded through the neck of the DWPF canister. There are four product cans per magazine and seven magazines per canister (see figure 2). The canisters are then stored or transported to DWPF. The final step is filling the canisters with high level waste glass at DWPF. All functions will be performed remotely. The canister loading process is part of the Can-In-Canister Project as shown in the schematic (figure 1).

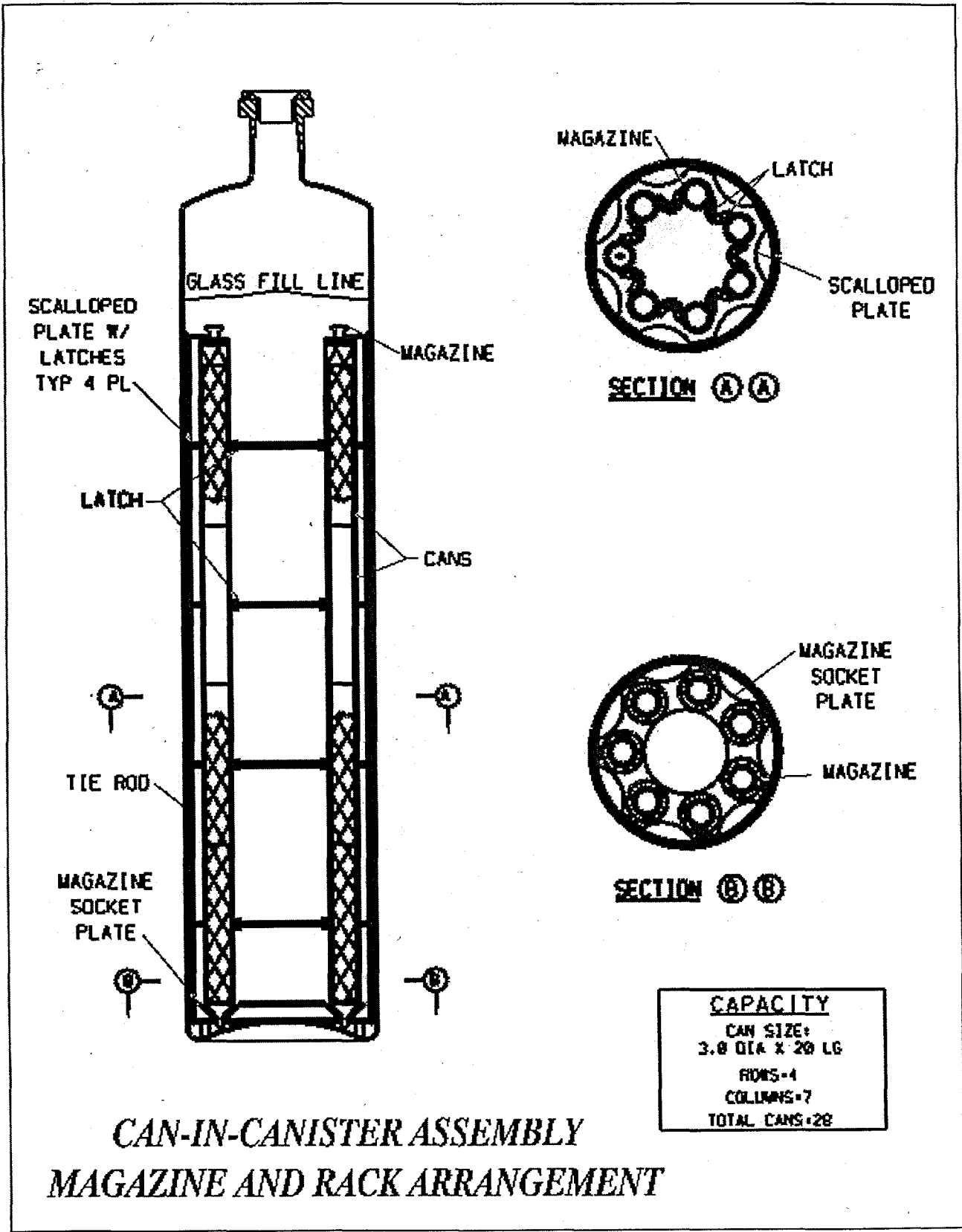


Figure 2 – Can-in-canister assembly – magazine and rack arrangement

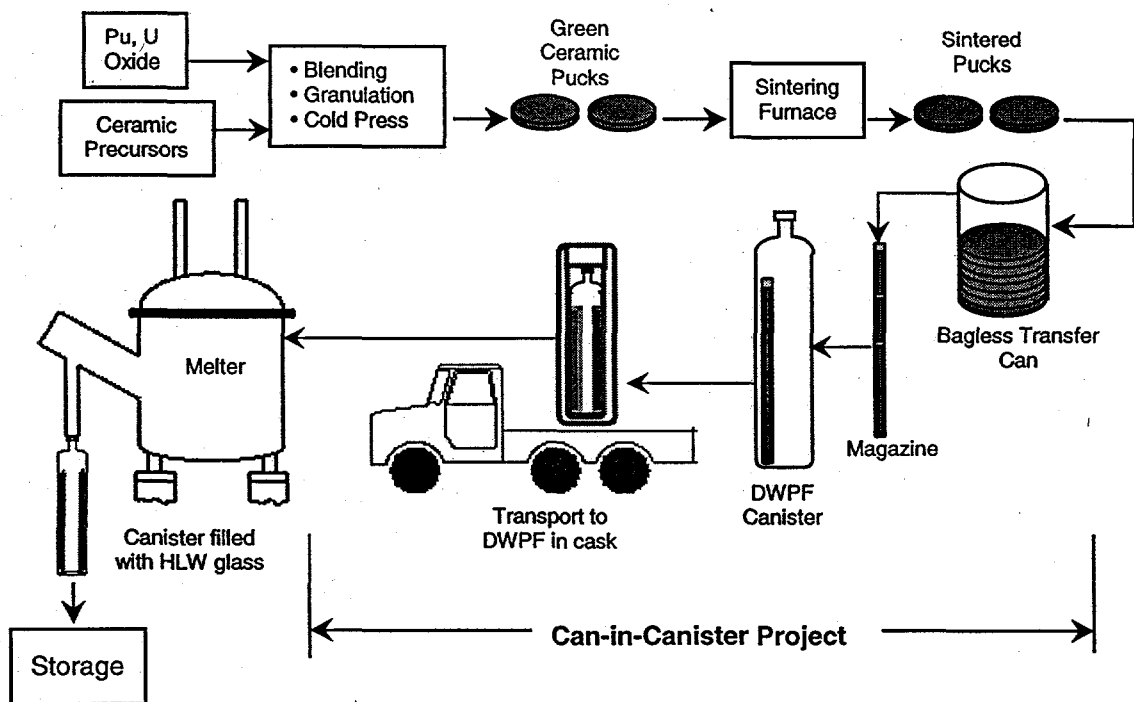


Figure 1 – Pu Immobilization Process showing Can-In-Canister Project Scope

## 2. Canister Loading

The process under development will remotely load DWPF canisters with magazines containing product cans through the canister neck. The canister vendor will fabricate and install empty storage racks inside the canister before welding on the top head. The rack will accept seven magazines and retain them with automatic latches. Details on the rack design will be discussed later.

As presently envisioned, DWPF canisters with the rack pre-installed enter the facility's canister loading area on a chain-driven rail cart. While in the loading position, canisters are stationary, in a vertical orientation, and do not rotate. A telescopic, four degree-of-freedom bridge robot is used to load each canister with seven magazines. The robot is equipped with a tool-change plate that carries a manipulator arm and gripper arrangement for magazine handling operations. The wrist holding the gripper will be designed to allow the magazine to hang vertical at all times. The manipulator adds an extra-degree-of freedom for a total of five.

The robot is capable of three motions once inside the neck of the canister. Two rotations ( $\theta_1$  and  $\theta_2$ ) and a translation ( $z$ ). During loading operations, the ( $\theta_1$ ) rotation is used to align the manipulator arm in the correct radial orientation. The ( $\theta_2$ ) rotation is used to move a magazine to the proper radial position, and the  $z$  translation is used to lower the magazine to its stored position. The portion of the robot that enters the canister is shown in Figure 3 below.

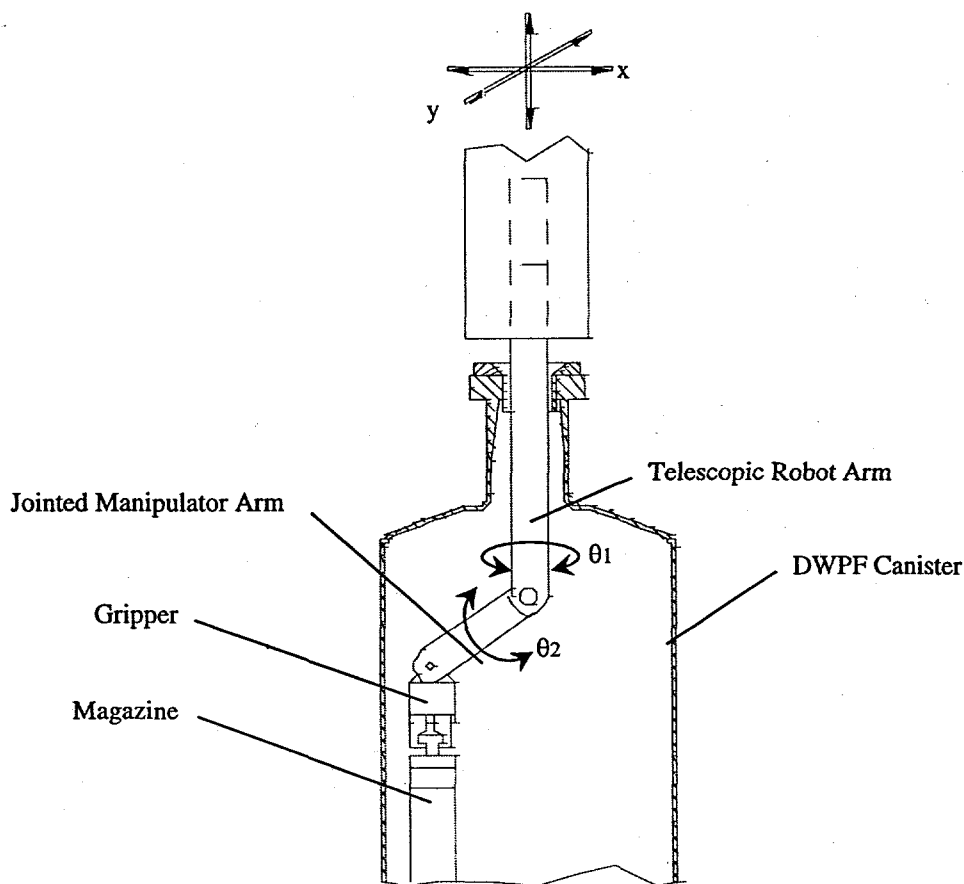


Figure 3. Sketch of canister loading equipment and motions.

Figure 4 shows the operation sequence for loading the magazine into the canister within the immobilization plant. Step 1 shows the bridge robot in the full up position and the magazine located over the canister neck. Step 2 shows the magazine lowered into the canister. At this point, the operator will rotate the arm to align the magazine with the latches mounted in the storage rack through use of miniature cameras mounted in the arm. In step 3, the manipulator arm has been pivoted to engage the magazine into the lateral latches (Detail Figure 8). Step 4 shows the telescoping arm lowered to seat the magazine into a socket plate. The bottom end of the magazine has a locating cone that matches the socket in the socket plate. The magazine is then released by opening the gripper and the robot motion is reversed to remove the arm from the canister. Figure 5 shows a cross section of the canister loaded with seven magazines.

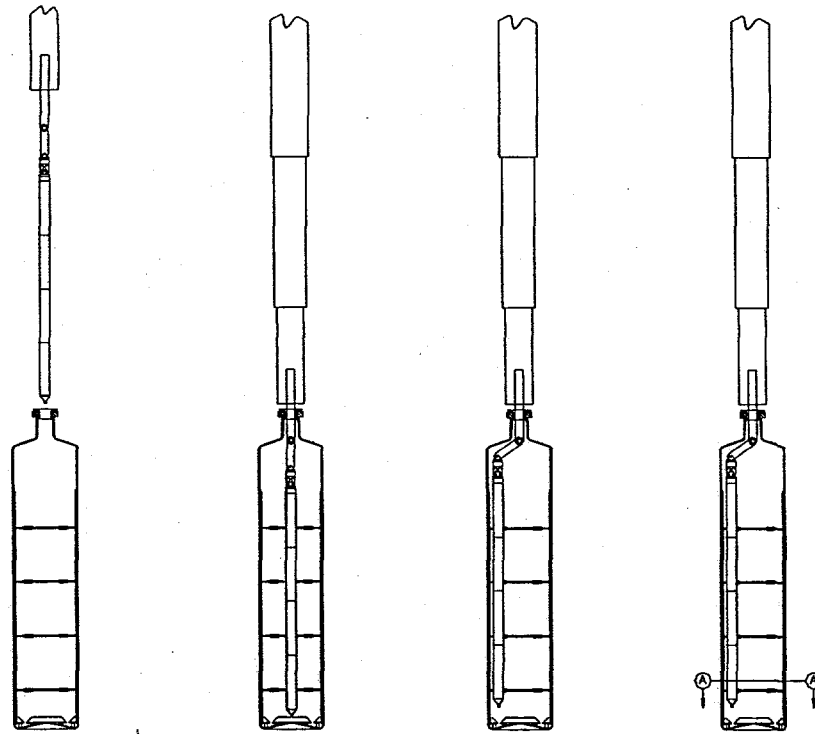


Figure 4 Canister Loading Sequence

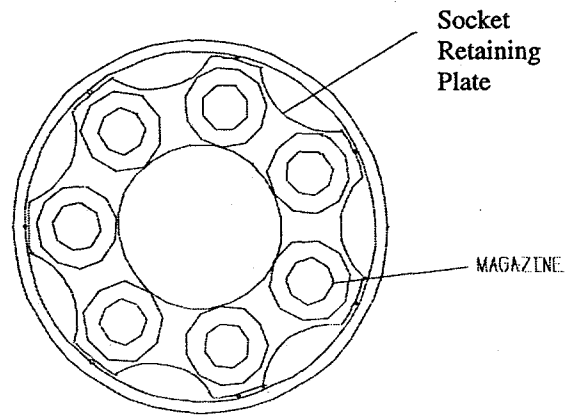


Figure 5 Section A-A, Canister Cross Section



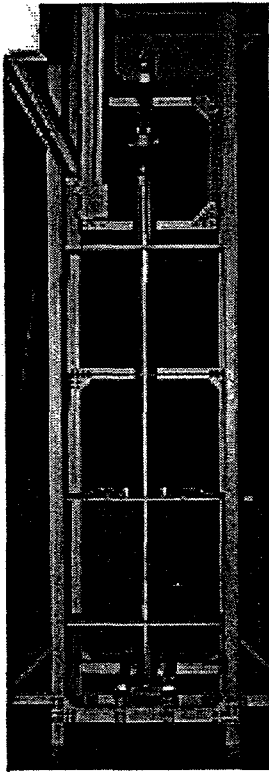


Figure 6 - Magazine Loading Test Stand with pipe Magazine

A test stand has been built to test different types of latches and grippers (figure 6). The test unit simulates the pivoting of the elbow and magazine into the latches and lowering the magazine into the socket plate. Initial testing of these components has been very successful. A complete canister loading arm is being designed and fabricated for testing in the summer '99.

### 3. Storage Rack Design

#### 3.1 Function

In the Plutonium Immobilization Project, seven magazines will be remotely loaded through the neck of a DWPF canister and placed into positions determined by an internal framework, or "magazine rack" inside the canister. A photograph of a prototype rack with a magazine installed is shown in figure 7. The rack serves several purposes: (1) It keeps the seven magazines in a pre-determined, symmetric orientation inside the DWPF canister; (2) The rack provides both lateral and vertical latching to reduce the possibility of magazines leaving their positions; (3) The rack lends strength during canister handling, transportation, and glass pouring; and (4) The rack contributes to non-proliferation by supplying a structural connection for the seven magazines

in the glass-metal matrix, (5) Promotes even/complete glass flow around all magazines.

#### 3.2 Assumptions & Requirements

A number of assumptions were used in developing the rack design, and they are listed below:

- 1) The rack will be installed inside the DWPF canister during canister fabrication.
- 2) The rack will hold seven 3.5" (89mm) diameter magazines that are 87" (2.2m) tall.
- 3) The magazine will hold four 3" (76mm) diameter cans that are 20" (0.5m) long.
- 4) Magazine loading will be performed through the neck of the canister using a jointed arm robot.
- 5) Vertical and lateral latching is required on the magazine rack.
- 6) There will be one scalloped plate installed at each can level. One scalloped plate will be provided for each row of cans to provide structural support
- 7) Lateral latches are not required at each row of cans. Latches are only required to meet transportation and handling loads. The concept design has lateral latches only at two rows of cans, the first (top) row and the third row. (The socket plate also provides lateral restraint for the magazines.

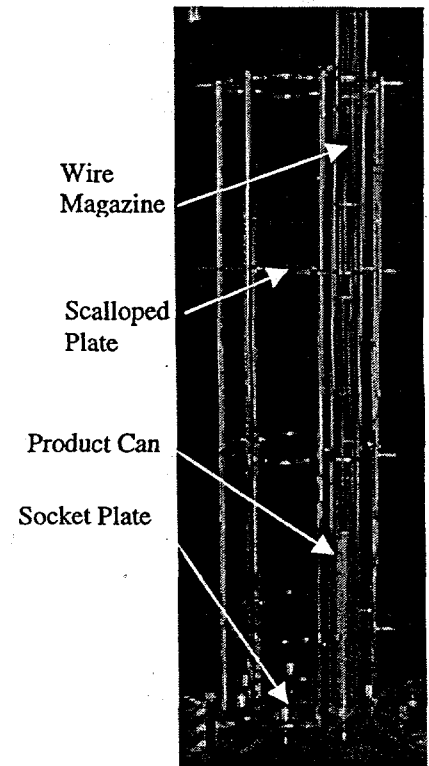


Figure 7 Picture of magazine storage rack with magazine

- 8) The rack's mass will be kept to a minimum for thermal considerations.
- 9) Where possible, the rack will minimize resistance to glass flow.
- 10) A minimum 2" (51mm) clearance will be provided between the socket plate and the canister bottom.
- 11) The rack will provide a minimum 2" (51mm) clearance between the magazine o.d. and the canister i.d.
- 12) No portion of the rack or installed magazine shall exceed a height of 91" (2.3m), the minimum procedural fill height for DWPF (as measured from the canister bottom).
- 13) The rack center must be free of obstructions to allow for  $\theta 2$  manipulator arm rotation.

### 3.3 Features

The rack shown in figure 7 is made-up of four scalloped plates and one socket plate which are joined by seven vertical  $\frac{3}{4}$ " (20mm) solid 304 series stainless steel round bars. Each plate is constructed of  $\frac{1}{4}$ " (6mm) 304 series stainless steel plate. The first scalloped plate is positioned roughly 10" (.25m) above the socket plate, followed by three more spaced 20" (.5m) apart. Plates are cut as shown to minimize mass and minimize resistance to glass flow. Lateral "butterfly" latches (figure 8) are installed on two of the scalloped plates (top and third from top).

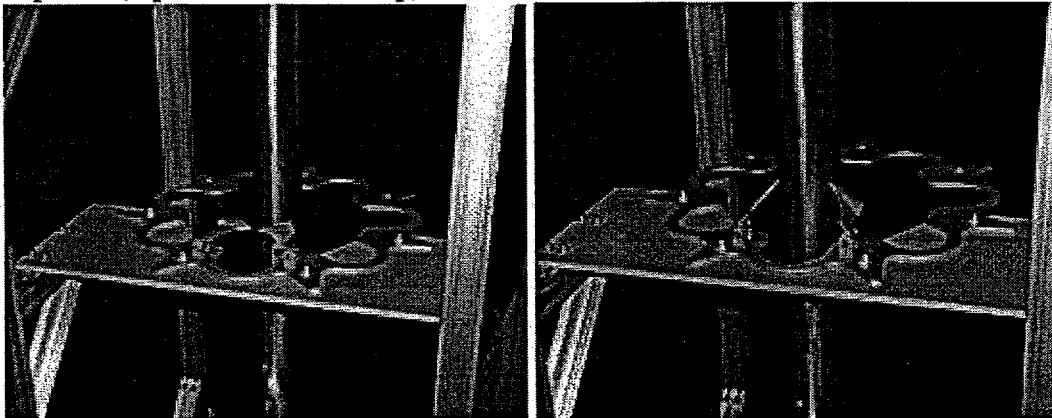
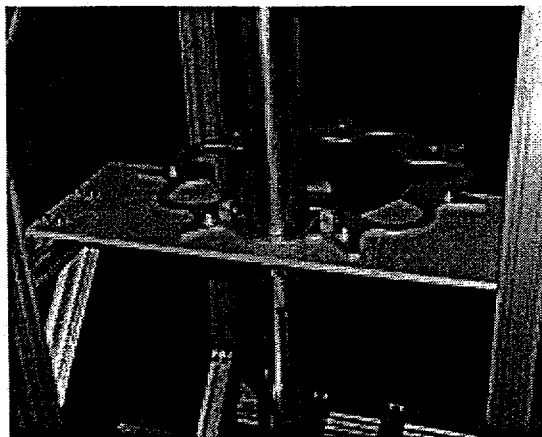


Figure 8 shows the sequence of latching the magazine into the canister's rack. (Top left) Magazine is shown in position along canister centerline just after canister entry. (Top right) Magazine is engaging butterfly latch. (Right) Magazine is securely engaged.



The socket plate has a 9" (230mm) opening in its center for glass flow. Seven sockets provide the bottom support for the magazines. The sockets accept the cone sections at the lower end of the magazines. In this concept, vertical latching is achieved at the cone/socket interface using snap rings. A 2.5" (64mm) carbon steel snap ring is installed in each socket groove of the rack. When the magazine is

installed, a groove on the cone section accepts a portion of the snap ring, locking the magazine to the rack. The lower plate is supported ~3" (76mm) above the bottom of the canister with seven radial struts. The struts match the contour of the DWPF canister bottom and have large cutouts to reduce mass and to permit glass flow.

### 3.4 Design History

The rack design was evolving as the conceptual design for the Plutonium Immobilization Project was being developed. The facility layout and processes were chosen in parallel with concepts for pucks, magazines, cans, racks, and remote equipment. A primary influence on rack design was the equipment and operations proposed in the canister loading area of the facility. Other direct influences on the rack design are captured in the assumptions listed above under "Rack Design."

An additional rack design requirement was to provide a clear and open center region to allow for unobstructed glass flow and  $\theta 2$  rotation. The magazine's radial positions were placed as far from the canister center as possible without exceeding the minimum two-inch clearance limit between magazines and the canister wall.

A customer requirement specified the need for one scalloped plate per product can in a magazine (The plates provide a potential increase in proliferation Resistance.). In the current design there are four 20" (.5m) cans per magazine, thus four scalloped plates are used in the rack design. The scalloped plates are positioned such that they align with the center of each can.

One purpose of the rack is to provide some type of lateral latching that keeps the magazines in a vertical orientation during handling and transportation. Several lateral latching concepts were considered. These included spring loaded latches, "clam-shell" devices, linked mechanisms, and gravity latches. At the beginning of the design process, the design team decided to avoid spring-actuated equipment due to reliability arguments. Clamshell devices are reliable and self-actuating, but it is difficult to ensure that they remain open during canister handling operations prior to magazine loading. Mechanical linkages were considered (e.g. latching that actuates under the weight of the magazine), but unfortunately these devices increase the number of moving parts in the rack. The "butterfly" or gravity method of magazine lateral latching was chosen after considering the concepts above (see figure 8).

## 4. Magazine Design

### 4.1 Function

In the Pu Immobilization facility, pucks will be seal welded into bagless transfer product cans. Automatic loading equipment will then put four cans into a magazine, which holds cans in the same way a flashlight holds batteries. Magazines serve the following functions in the immobilization program:

- Group cans into a cylindrical form suitable for insertion through the DWPF canister throat
- Hold cans in place inside the canister during transport and glass pouring
- Consolidate cans into a bundle to minimize handling in the PIP

### 4.2 Assumptions & Requirements

Some assumptions used in developing the magazine concept follow:

1. Each magazine holds four 20" (.5m) cans, each loaded can weighs approximately 25 lbs.(11.4kg)
2. Magazines will have the maximum amount of open area in the barrel to minimize resistance to glass flow.
3. After pouring, glass will surround the cans inside the magazine.
4. Magazine length cannot exceed 87" (2.2m)
5. OD cannot exceed 3 1/2" (89mm)
6. Each magazine must be remotely loaded with cans and remotely installed into the rack inside the DWPF canister.
7. Cans are not required to be individually restrained within the magazine.
8. The magazine interior and exterior must have a smooth, protrusion free surface which readily promotes sliding.
9. The mechanical strength of the magazine must be adequate to allow remote handling of the magazine loaded with product cans.
10. The magazine must support cans during pouring.

### 4.3 Features

The magazines are shown in figure 9. In the preferred design, either 3" (89mm OD) Sch 10 stainless steel pipe or 3.5"(89mm) x .120 (3mm) wall tubing is the material of construction for the barrel. The slots are laser cut into the barrel wall and both end pieces are machined from 304 SS solid stock. The "cone end" of the magazine is attached to the barrel with a snap ring. The top "mushroom end" is fixed permanently and is used for remote handling. The magazine ID is 3.25" (83mm) nominal to provide clearance for ease of loading.

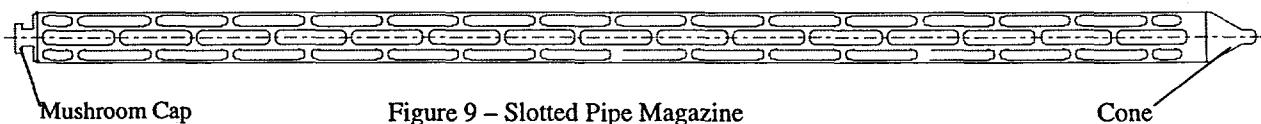


Figure 9 - Slotted Pipe Magazine

### 4.4 Design History

The WSRC design team identified and evaluated over 20 concepts for loading product cans into DWPF canisters. After carefully analyzing all the concepts, they chose a rigid magazine as the best method to remotely load cans into DWPF canisters.

To ensure the feasibility of manipulating a magazine "through the throat" of a DWPF canister, a remote loading test was conducted using a test magazine constructed of 3" (89mm OD) Sch40 pipe and having prototypic loaded weight and overall dimensions. This successful test confirmed that the concept designs for the magazine's mushroom top and "cone in cup" bottom are adequate. Two methods to insert cans into magazines were developed: (1) end loading and (2) side loading. End loading requires cans to be pushed into a horizontal or vertical magazine and secured by snapping on the magazine end (Figure 10). Side loading magazines have a door through which each can is inserted into an inclined magazine and then allowed to slide into position motivated only by gravity. After the last can is in place, the loader snaps the door closed (Figure 11).

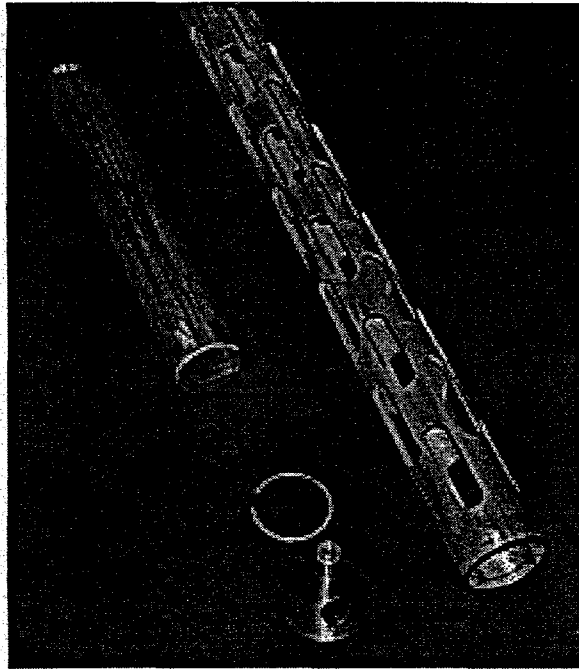


Figure 10 - Slotted pipe bottom load magazine

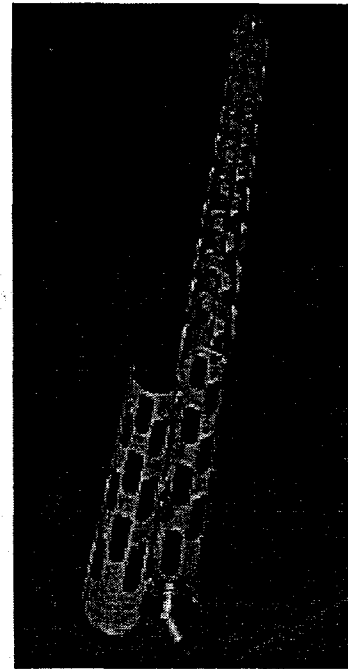


Figure 11 - Side Load Magazine

The design team also considered magazine construction and identified three possible forms:

- Welded wire frame (like a shopping cart)
- Wire mesh
- Perforated pipe

The team prepared basic requirements and sketches for side and end loading magazines, then submitted them to 25 job shops specializing in wire frame, perforated metal and expanded metal fabrication, as well as general fabrication shops. (The requirements were kept basic to encourage vendors to use their own expertise and experience.) Five vendors submitted designs for 10 magazines: 2 perforated pipe end loaders, 2 perforated pipe side loaders, 1 wire mesh side loader, 1 wire mesh end loader, 2 welded wire side loaders, and 2 welded wire end loaders. All ten designs were purchased (see figure 12 TBA).

In preparation for testing actual magazines, the team developed an incline loading mockup and demonstrated loading a magazine with gravity as the motive force. They also designed and began fabricating a test bed for demonstrating forced horizontal and vertical loading. Finite Element Analysis was used to analyze and modify vendor-submitted welded wire and wire mesh designs, however the models showed wire designs could not be made strong enough to adequately support the loads.

Vendor feedback showed one of the greatest problems to overcome in magazine design was the remote magazine closure, and wire magazines offered the greatest challenge. After experimenting with end closures consisting of tabs, wires, ball detents, and retaining rings, it was clear that retaining rings were the most reliable remote closure with the added benefit of taking up the least space (Figure 10). None of the vendors produced a wire magazine with an acceptable and removable side door. The door opening created a weak area that produced undesirable bending of the loaded magazine, and the doors themselves were either complex, fragile or had parts outside of the design envelope. WSRC chose to

cease development of the side load option and concentrate on end loading due to the fragility and greater cost of the wire magazines.

The vendor-supplied magazines were tested to determine their suitability for remote handling. The test included remotely picking up the loaded magazine with a PAR gantry robot, moving it through a DWPF canister throat mockup into the loaded position, and then returning it to a test stand. Only two magazines worked as designed, both of which were pipe concepts from the same vendor. All six wire magazines were either too flimsy, too easily deformed, too costly, or too inconsistent in dimensions for further consideration. Two of the wire forms were so fragile that they were damaged in shipping. Another collapsed under the weight of a column of cans before the robot picked it up. Testing also showed that wire form and wire mesh magazines hang out of plumb when loaded with cans, making them difficult to manipulate. (Pipe magazines hang very close to plumb when filled with cans.) Wire forms are also much more difficult to restrain in the rack due to their open construction (which promotes hanging up on the rack latches) and flexibility.

After evaluating the ten magazines, SRTC combined the best features of all with our own ideas to produce the current designs for a bottom load magazine constructed from pipe or tubing with generous openings for glass flow. Additional modeling will identify glass flow characteristics, which will be verified with glass pour tests being conducted with full scale melter equipment. The test pours will also ensure there are no voids in glass poured around the magazine and that the magazine does not deform unacceptably. Several iterations of the current basic design will be submitted for the pour tests. The test subjects will vary in slot size and shape and magazine sidewall thickness.

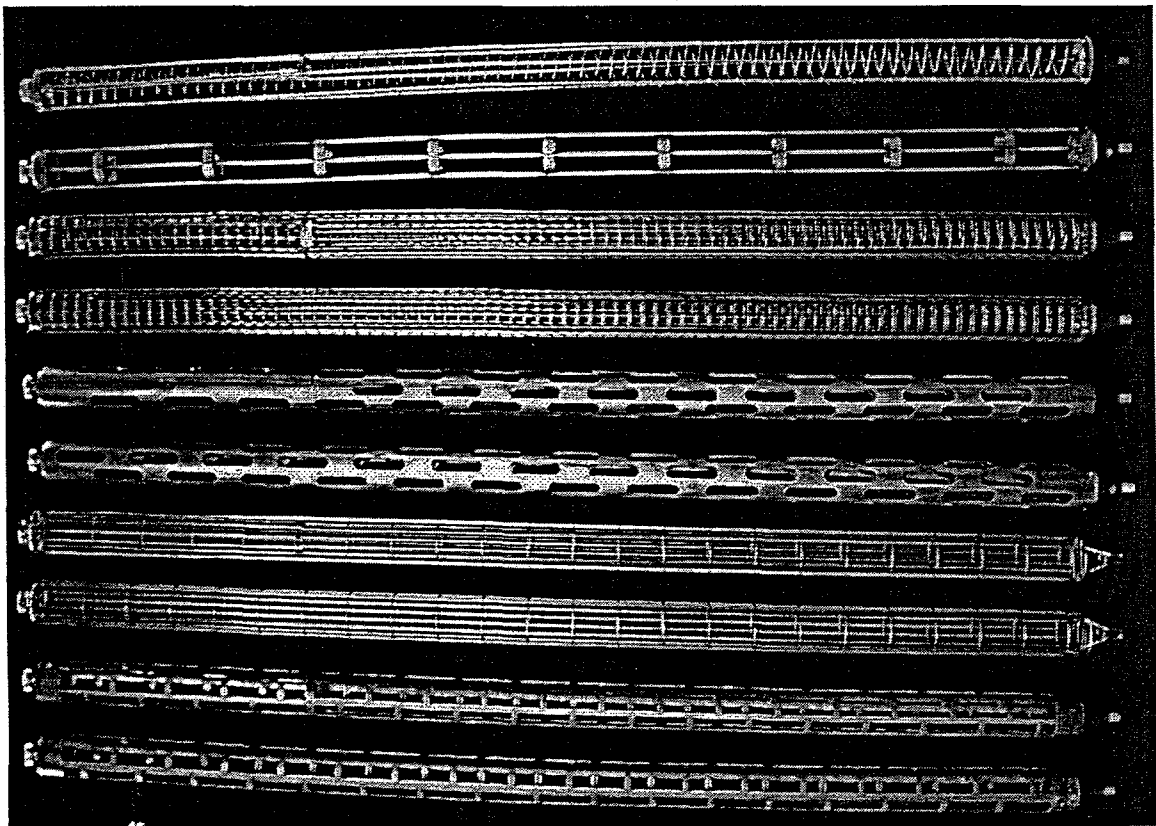


Figure 12 Magazines