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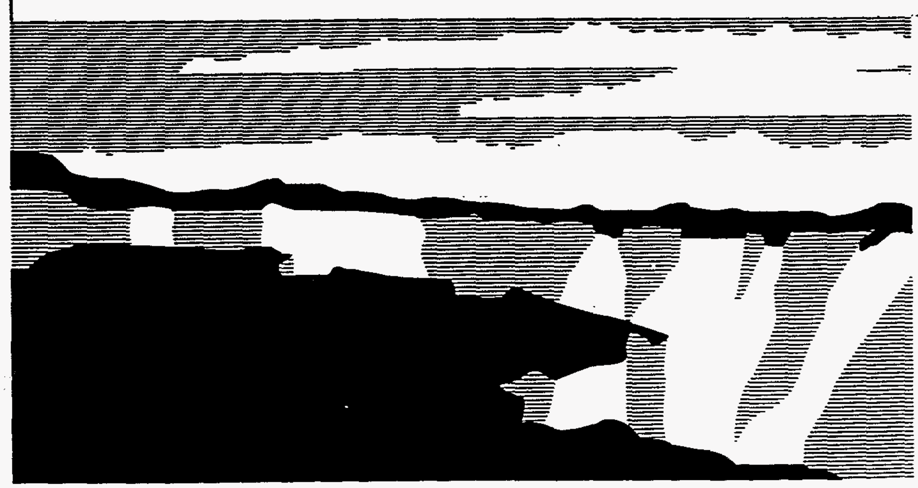

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Packaging of Plutonium Metal and Oxide in the ARIES Project

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ABSTRACT

The objective of the Advanced Recovery and Integrated Extraction System (ARIES) Project is to demonstrate technology to dismantle plutonium pits from excess nuclear weapons, convert the plutonium to a metal ingot or an oxide powder, package the metal or oxide, and verify the contents of the package by nondestructive assay. The packaged weapons plutonium will be converted to mixed-oxide reactor fuel or immobilized in ceramic forms suitable for geologic storage. The packaging of the material must therefore be suitable for storage until the material is further processed. A set of containers for plutonium metal and oxide has been developed to meet the needs of the ARIES process and the Department of Energy requirements for long-term storage. The package has been developed and qualified with the participation of private companies.

Introduction

Removal of nuclear weapons from the stockpiles of the United States and Russia, along with the need for stabilization of plutonium residues from production plants, has required development of containers for safe storage of plutonium, potentially over a period of decades. Schedule requirements of the ARIES Project demanded that containers be available in 1998. To meet this schedule, a simple design was developed for containers that would meet DOE-STD-3013. At the beginning of ARIES container development, the 1994 version of this standard (1) was in force. The 1996 version of the standard (2) did not introduce requirements that could not be met by the design in progress.

The development of the container design was iterative, with consultation with potential container manufacturers providing assurance that the containers could be easily and cost-effectively manufactured. Bodies and tops for both inner (material) and outer (boundary) containers were designed to be manufactured by standard deep drawing methods. Containers were designed in two sizes to meet project requirements, having a 6.5-in. height and a 10-in. height, both with 4.92-in. diameters.

A weldment was developed to meet the requirements of ASME IX: Boiler and Pressure Code (3). Plutonium metal or oxide is inserted into the material container, and the container is welded in a glove box. The inner container is then decontaminated by electrolytically removing a few atomic layers from the surface of the stainless steel along with associated radionuclides. The inner container is removed from the decontamination station and the glove box line after decontamination has been confirmed to less than 20 dpm/100 cm^2 removable contamination and total contamination of 500 dpm/100 cm^2, as required by 10 CFR 835, Appendix D (3). The inner container is then welded into the outer container. After every welding operation and decontamination, the container is leak checked to assure leak tightness to 10^{-7} std-cc/sec He, as required by ANSI N14.5 (4).

These storage containers can accept plutonium metal or plutonium oxide prepared to the requirements of DOE-STD-3013-96 (2). Multiple types of convenience containers can be used for plutonium oxide.

Design Requirements

The primary criteria used in the design of the storage package were obtained from DOE-STD-3013-96 (2). Additional requirements were imposed by the ARIES nondestructive assay (NDA) module. The design requirements are summarized below.

- A minimum of two nested sealed containers.
- At least one container remains leak-tight as defined by ANSI N14.5 after a free drop from a 9-m height.
- Container materials are resistant to corrosion in the anticipated storage environment, not combustible or organic.
- Atmosphere inside containers precludes re-stabilizing the material contents.
- Containers will be leak-tight as defined in ANSI N14.5.
- Containers allow for NDA, material verification, inspection and surveillance.
- Containers will be permanently marked.
- Design hydrostatically proof-tested to 1.5 times the calculated theoretical maximum pressure, remaining leak-tight after the test.
- Inner container sized to fit into outer container with clearance for welding.
- Inner container allows for nondestructive indication of 100 psi pressure buildup or less.
- Exterior surfaces of the inner and outer containers and interior surface of outer container are free of external contamination as defined by 10 CFR 835, Appendix D.
- Maximum outside diameter of the outer container is 12.5 cm, and the maximum external height is 25.4 cm.
- Convenience container includes no organic materials.

Fabrication and Welding

The container package consists of three containers for plutonium oxide, and two for plutonium metal. The innermost container (convenience container) for plutonium oxide is a crimp-sealed food pack can containing no elastomers. The inner and outer containers are welded Type 304L stainless steel. The outer diameter of the outer container for both 6.5- and 10-in. sizes is 4.92 in. The outer container has a pintle fixture on the top for robotic handling. The wall thickness of the inner container for both sizes is a minimum of 0.040 in.; for the outer container, a minimum of 0.080-in. All containers have a 3/8-in. radius of curvature joining the cylinder top and bottom to the sides. Figure 1 shows the 10-in. container package. The containers are permanently marked with a laser marker. Markings are both human- and machine-readable.

Several fabrication methods, including deep drawing, spinning, and flow forming, were considered for the fabrication of storage package. Industrial firms were consulted for their recommendations on ease of fabrication. After evaluation of manufacturing feasibility, cost, reliability, and repeatability, deep drawing was selected as the manufacturing process for both the inner and outer containers. Issues related to can roundness, container wall thickness, alignment between can and lid, were all addressed early in development.

The inner and outer containers are sealed with a full penetration, autogenous weld. The weldment is performed with a gas tungsten arc process and meets the requirements of the ASME Section IX: Boiler and Pressure Vessel Code (3).

All weldments are performed in a helium atmosphere with an oxygen concentration of less than 50 ppm. Helium shield gas is used to aid in heat transfer and weld penetration, act as an oxygen barrier, and to keep the torch cool. Pulsed current is supplied by a programmable controller and power supply. The containers are welded in the vertical position. The can is rotated while the torch remains stationary. A fixture was fabricated to keep the lid aligned with the can body and maintain constant electrode-to-surface spacing.

The weld joint for both containers is a butt joint with no filler material added. A non-radioactive tungsten electrode is used for both containers. Pulsed current was used to minimize weld puddle sagging. The pulse peak current used for the inner container was 150 amps and for the outer container, 175 amps. The average current is 34 amps for the inner container and 75 for the outer container.

As part of the requirements of ASME Section IX: Boiler and Pressure Vessel Code (3), weld samples were subjected to tensile tests and face-and-root bending moment tests, and photomicrographs of the welds were taken. The weld meets container sealing requirements for DOE-STD-3013-96 (2). Because the containers are welded in a helium atmosphere, helium gas is encapsulated in the containers, which meets the DOE-STD-3013-96 requirement for a nonreactive atmosphere (2). The helium atmosphere also allows for leak checking the weld joint by placing the container in a vacuum chamber and detecting the presence of helium.

Testing

A comprehensive testing plan included all requirements specified in DOE-STD-3013-96 (2) and additional tests to obtain data on the handling characteristics and strength of the containers. Drop, crush, and pressurization tests were specified.

All container parts were fabricated by Toledo Metal Spinning Company, Toledo, Ohio. Before being welded, the containers were loaded with a non-radioactive metal payload to simulate plutonium oxide or metal loading. The container assemblies were welded at the Los Alamos National Laboratory. The containers were leak checked after welding. All of the 76 containers welded for testing had a leak rate of less than 1x10-9 std-cc/sec at one atmosphere. A Varian Portatest II leak detector was used.

The results of the tests follow.

Four-Foot Drop Test. The purpose of this test was to determine the integrity of the container after a drop typical of what might be sustained in processing. This test is not required by DOE-STD-3013-96 (2). Two inner containers of each size loaded with 4.5 kg of simulated metal and two loaded with 4.5 kg of simulated oxide were dropped from 122 cm (4 ft). Visual examination of the containers after the drop test revealed minor scratches. Helium leak testing showed that all containers were leak-tight to less than 1×10^{-9} std-cc/sec after the test, and the presence of helium in the containers was verified.

Nine-Meter Drop Test. This test is required by DOE-STD-3013-96 (2). Three storage packages of each size loaded with 4.5 kg of simulated metal and three loaded with 4.5 kg of simulated oxide were dropped from 9 meters (30 ft). Visual examination of the containers after the drop test revealed minor deformations. Helium leak testing showed that all outer containers were leak-tight to less than 1×10^{-9} std-cc/sec after the test, and the presence of helium in the containers was verified.

Inner Container Crush Test. These tests were done to determine the strength of the design in possible handling incidents. They are not required by DOE-STD-3013-96 (2). For each size, one crush test was conducted using two pairs of inner cans filled with 4.5 kg of simulated metal; another was conducted with 4.5 kg of simulated oxide. One test fixed the impacting container in a vertical orientation, and the other test held it horizontal. The impacting container was released from a height of 61 cm (2 ft). Visual examination of the containers after the test revealed minor scratches. Helium leak testing showed that all outer containers were leak-tight to less than 1×10^{-9} std-cc/sec after the test, and the presence of helium in the containers was verified.

Storage Package Crush Test. These tests were done to determine the strength of the design in possible handling incidents. They are not required by DOE-STD-3013-96 (2). For each size, one crush test was conducted using two pairs of storage containers filled with 4.5 kg of simulated metal;

another was conducted with 4.5 kg of simulated oxide. One test fixed the impacting package in a vertical orientation, and the other test held it horizontal. The impacting package was released from a height of 3 meters (10 ft). Visual examination of the storage packages after the test revealed minor deformations. Helium leak testing showed that all outer containers were leak-tight to less than 1 x 10^{-9} std-cc/sec after the test, and the presence of helium in the containers was verified.

Hydrostatic Tests. Hydrostatic testing is required to 1.5 times the theoretical maximum pressure calculated as specified by DOE-STD-3013-96 (2) for the outer container. In addition, the deflection of the ends of the inner containers will be used to indicate pressures of less than 100 psi, as required by DOE-STD-3013-96 (2). Hydrostatic tests were conducted on five inner and five outer containers of both sizes. The change in container height was measured as the pressure was gradually increased to 750 psi. The pressure was further increased on three of each container until the container burst. For an internal pressure of 100 psi, the total length of the inner 6.5-in. container increases approximately 0.120 in., and the total length of the inner 10-in. container increases approximately 0.090 in. For an internal pressure of 500 psi, the length of the 6.5-in. outer container increases approximately 0.150 in. for an internal pressure of 500 psi, and the length of the 10-in. outer container increases approximately 0.150 in.

Burst tests were done to acquire data on material strength. They are not required by DOE-STD-3013-96 (2). The three inner 6.5-in. containers burst at pressures of 3456, 3513, and 3492 psi. The three inner 10-in. containers burst at pressures of 3230, 3002, and 3451 psi. The three outer 6.5-in. containers burst at pressures of 6444, 5345, and 6068 psi. The three outer 10-in. containers burst at pressures of 7496, 7400, and 6010 psi. Failure for all containers except the 10-in. outer containers initiated at the pressure fitting welded into the container for the test. Because these fittings are not a part of the container as it will be used, these burst pressures are minimum values that can be expected under actual working conditions. The 10-in. outer containers failed at the circumferential weld.

Conclusions

The design of long-term plutonium containers for the ARIES Project includes a minimum of two nested sealed containers fabricated of corrosion resistant stainless steel. The containers are welded in a helium environment and are leak-tight as defined by ANSI N14.5. The containers, including the convenience can, are free of organic material. The container storage package has successfully passed the drop and pressurization specified in DOE-STD-3013-96 (2) as well as additional handling and material strength tests. The design characteristics of the container package and the successful testing allow us to state that the containers meet DOE-STD-3013-96 (2).

Acknowledgments

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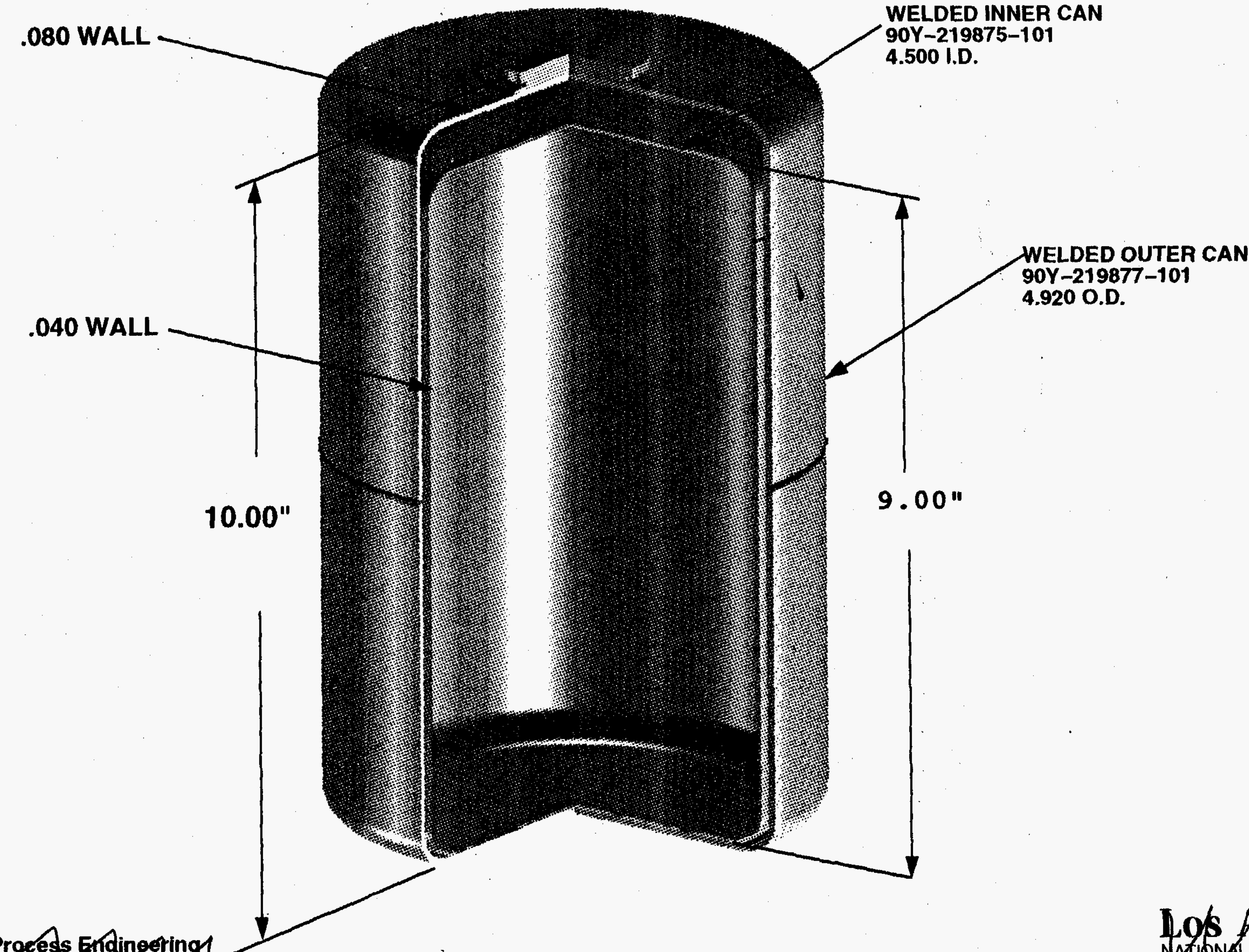
2. DOE-STD-3013-96, "Criteria for Preparing and Packaging Plutonium Metals and Oxides for Long-term Storage," United States Department of Energy, September 1996.

3. American Society of Mechanical Engineers(ASME) Boiler and Pressure Vessel Code, Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operations," 1995 Edition.

2. 10 CFR 835, Appendix D, "Surface Radioactivity Values," Code of Federal Regulations.

3. "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment," ANSI N14.5-1987, American National Standards Institute.

Fig. 1. ARIES **LONG TERM STORAGE** Package
~~OUTER CAN~~



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