The Multi-Canister Overpack - Hanford's N Reactor Spent Nuclear Fuel Container

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Fluor Daniel Hanford, Inc.
Richland, Washington

Hanford Management and Integration Contractor for the
U.S. Department of Energy under Contract DE-AC06-96RL13200

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L. H. Goldmann
Duke Engineering & Services Hanford, Inc.

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THE MULTI-CANISTER OVERPACK — A CONTAINER FOR THE HANFORD SITE'S N REACTOR SPENT NUCLEAR FUEL

Louis H Goldmann
DE&S Hanford, Inc.
P. O. Box 350, M/S R3-86
Richland, Washington 99352-0350

INTRODUCTION

Beginning in 1944, nuclear reactors operated to produce plutonium at the U.S. Department of Energy's Hanford Site; production continued until 1988. Some 2,100 metric tons of the irradiated fuel from these reactors remains at the Hanford Site unprocessed. This is due to the operational shutdown of the processing facilities, which were permanently closed in 1990. This fuel inventory now in storage at the Hanford Site's K Basins is mostly N Reactor fuel, a co-extruded, metallic uranium alloy clad in Zircaloy-2. Before irradiation, the fuel's enrichment varied up to 1.25% uranium-235.

The K Basins are water pools that provide fuel cooling, personnel shielding, and storage of the spent nuclear fuel (SNF). These concrete pools, their covering buildings, and support facilities, which are very near the Columbia River, are approaching retirement, and the fuel will be removed from its location close to the river and put into a more modern upland dry-storage facility.

The Hanford Site has developed an integrated process strategy for this irradiated fuel, including sorting and cleaning the SNF in the K Basins, loading the SNF into multi-canister overpacks (MCO), drying the fuel at the Cold Vacuum Drying Facility (CVDF), and transporting the dried fuel to the Canister Storage Building (CSB) for validation testing and, finally, interim storage. This presentation provides a description of the MCO and an overview of the proposed use of the MCO as a container for spent fuel.

BASIC CRITERIA

The most basic criteria for the MCO are to prevent a nuclear criticality and contain the SNF and associated byproducts. The MCO also serves a functional need as (1) the innermost SNF container in the on-site transportation packaging, (2) the process vessel for the SNF during bulk water removal and processing at the CVDF, and (3) the container for the SNF during handling, process validation, and interim storage at the CSB.

The selected design pressure for the MCO is 3.2 MPa (450 lb/in^2 gauge) at 405 K (270 °F). The maximum selected leakage rate for the mechanical seal is 1×10^{-5} standard cm^3/s. The maximum selected leakage rate for the welded cover cap is 1×10^{-7} standard cm^3/s. The design life is 40 years, potentially extendable to 75 years.

THE MULTI-CANISTER OVERPACK DESIGN

Early in the performance specification phase of MCO development, the literature was reviewed and the applicable design code selected. The desire was for the MCO to be a most robust and durable container for the SNF. Transportation packages traditionally have the most stringent requirements, so even though the MCO is not a shipping container, NUREG/CR-3854, *Fabrication Criteria for Shipping Containers*,[1] was selected as a guideline. Because of the curie content and activity of the expected payload, the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*,[2] Section III, Subsection NB, was recommended for the structural boundary and Subsection NG for the criticality control features. As shipping packages do not normally contain pressure relief systems, process ports, process tubes, or high-efficiency particulate air (HEPA) filters, the MCO Project realized there likely would be exceptions to the requirements in Subsection NB in the finished MCO design.

Structural Boundary

In the mature design, (Figure 1) the MCO represents the first boundary for the SNF during shipping, processing, and storage. The structural boundary for the MCO is composed of the lower end cap, the shell wall, collar, and the shield plug assembly. Later in the process and on the time line, the MCO cover cap becomes part of the MCO assembly.

(1) The lower end of the MCO is a machined cap made of 304L stainless steel, nominally 5.1 cm (2 in.) thick on the end face. A pocket at the bottom of the cap collects bulk water for removal from the MCO. The minimum thickness for the lower end cap is 1.3 cm (0.5 in.) where it is welded to the shell wall.

(2) The shell wall of the MCO is a 61-cm- (24-in.-) outside-diameter pipe section with a 1.3-cm- (0.5-in.-) thick wall section. The shell wall is made of 304L stainless steel.

(3) The collar is made of XM-19 (Nitronic 50[1]). The shell wall, collar, and lower end of the MCO will be manufactured and pressure and leak tested together with the shield plug assembly before use at the Hanford Site.

(4) The shield plug assembly includes the locking and lifting ring (304N stainless steel), plug body (304L stainless steel), process tubes (304/304L stainless steel), and the penetrations and devices necessary for interface to operating and safety equipment. The devices at the ends of the penetrations from the interior of the MCO form a portion of the MCO pressure boundary. The diameter of the MCO at the shield plug is less than 64.3 cm (25.31 in.). The over all length of the MCO at this configuration is 416.6 cm (160 in.). The process plug valves, port plugs, cover plate bolts, and 3.8-cm (1.5-in.) diameter set screws used to make the MCO main seal are made of Nitronic 60 austenitic stainless steel. The selection of this material allows the use of these threaded devices without benefit of lubricants.

(5) The MCO cover cap includes a lifting rim similar to the one on the locking and lifting ring. The cover cap is made of 304L stainless steel and is 9 cm (3.5 in.) thick on the end face. The cap is secured to the collar with a circumferential weld. When the cover cap is installed and sealed, the importance of the underlying shield plug assembly is diminished somewhat. The MCO's length after the cover cap is installed is less than 426 cm (167.7 in.).

The MCO structural boundary is designed and will be manufactured in accordance with the standards in the ASME *Boiler and Pressure Vessel Code*,[2] Subsection NB, with some exceptions. The MCOs will not be "N" stamped. The MCO design pressure is 3.2 MPa (450 lb/in^2 gauge) at 405 K (270 °F). The maximum temperature allowed after fuel is inserted into the MCO is 405 K (270 °F). Temperatures as high as 648 K (707 °F) would be allowed with a slight reduction in allowable operating pressure. Fully loaded with fuel, the heaviest MCO weighs less than approximately 8,911 Kg (19,640 lb).

Shield Plug Penetrations

Penetrations are bored through the shield plug (Figure 2) to the interior of the MCO. The penetrations terminate on the outside of the shield plug as ports with devices and fittings that allow the MCO to interface with operating and safety-related devices. Three devices are associated with the penetrations: two process valves (ports 2 and 3, shown in Figure 2) and one pressure relief device (port 4, not shown). Fittings and covers that go over the devices offer additional sealing features for the MCO. A fourth port (port 1, not shown) is available if needed but will be plugged during normal conditions.

The two process valves on the external face of the MCO are connected to process equipment. These process connections are used to introduce fluids into and remove fluids from the MCO. The long axial process tube path (port 3) has a nominal inside diameter of 1.5 cm (0.6 in.); the path connecting to the internal HEPA filters (port 2) has a nominal diameter of 2.5 cm (1 in.). Both port paths 3 and 4 are protected by wire screens (2-mm mesh openings) on the interior of the MCO to prevent larger particles from being moved out of the MCO.

A bank of four HEPA filters is welded to the underside of the shield plug. The HEPA filters, which are not testable after the MCO is assembled, are connected to two penetrations (ports 1 and 2) in the MCO shield plug. During vacuum drying, gases exit through port 2 via the HEPA filters. These HEPA filters serve to minimize the potential for contamination leaving the MCO.

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[1]Nitronic is a trademark of Armco, Inc.

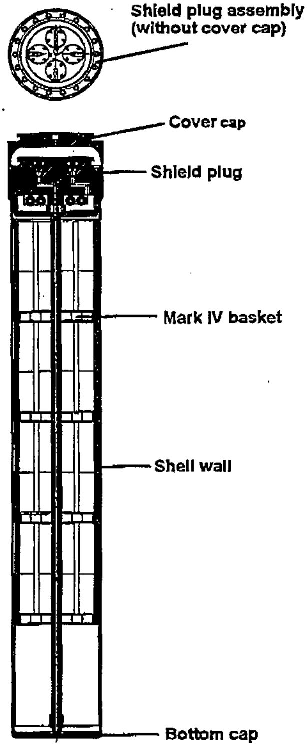

Figure 1. Multi-Canister Overpack Longitudinal Section.

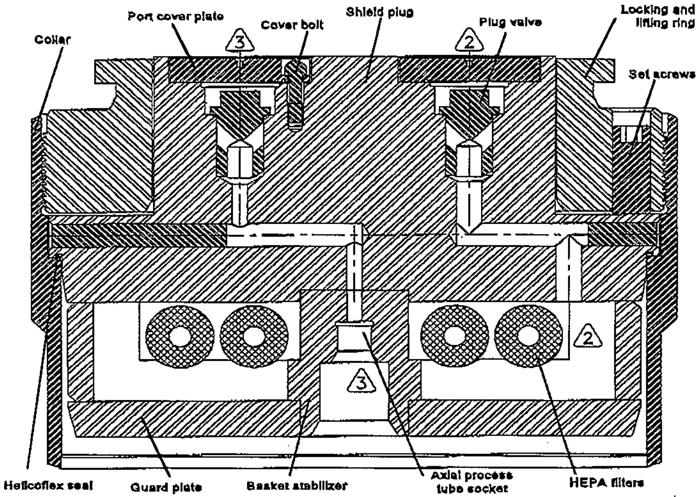

Figure 2. Shield Plug and Collar Section.

Seals, Welds, and Closures

MCO pressure boundary and structure are established by a combination of seals and welds. The main seal between the shield plug and the collar is a Helicoflex[2] seal. This seal includes a high alloy wound spring center that is covered with austenitic stainless steel and silver. The seals for the process valves, plugs, and cover plates are all metal O-rings made of 700-series Inconel[3] and covered with gold or silver. These O-rings are constructed of a "C" section and are compliant in use.

The shell wall pipe, collar, and bottom are joined by welding, and the joints are inspected and examined before the MCO is loaded with fuel. This weld is also radiographically examined before it leaves the fabricator.

The shield plug is secured into the MCO using a mechanical closure. A threaded locking ring is placed into the MCO neck extension after the shield plug is inserted. Eighteen set screws move the shield plug into the seal to make a seal with the collar. The seal is maintained during thermal transients and drop accidents by developing and maintaining sufficient preload through the seal. This type of seal system was qualified during the prototypic testing program and by analysis. This closure operation is performed at the K Basin load-out pit.

The final closure of the MCO is accomplished when the cover cap is installed over the entire shield plug and then welded to the MCO shell wall collar. This field-performed closure weld is then leakage rate tested by using helium, which is introduced through the penetration in the cover cap, as the tell-tale. The closure weld also is designed to be examined by ultrasonic means. After examination of the closure weld, the cap penetration is sealed and similarly leakage rate tested. These operations are performed at the CSB.

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[2]Helicoflex is a trademark of Helicoflex Corporation.

[3]Inconel is a trademark of INCO Alloys International, Inc.

Basket Design

Criticality control features are designed to the ASME *Boiler and Pressure Vessel Code*, Subsection NG, as a minimum. The fuel element payloads come in two different enrichments. Fuel assemblies enriched to 0.95% uranium-235 or less are considered Mark IV fuel. Fuel assemblies enriched to more than 0.95% uranium-235 are considered Mark IA fuel. Mark IA fuel baskets require application of the Subsection NG design allowables and will not be "N" stamped.

Fuel exists in the basins as essentially whole fuel elements and as scrap. As a result, the basket designs evolved into scrap and whole fuel baskets for each of the fuel enrichments. Type 1 baskets (Figure 3) hold 48 Mark IA (higher enrichment) intact fuel elements and have a criticality control exclusion void built into the basket. Type 2 baskets hold 54 Mark IV intact fuel elements and do not need the exclusion void. Type 3 baskets hold Mark IA (higher enrichment) scrap fuel (fragments) and also have a criticality control exclusion void built into the basket. Type 4 baskets (Figure 4) hold Mark IV scrap fuel (fragments) and do not need the exclusion void.

The baskets all contain a center tube and a structural plate to support the fuel. The center tube for the Mark IA baskets is 16.8 cm (6.6 in.) in diameter, and the center tube for the Mark IV basket is 9.5 cm (3.7 in) in diameter. This portion of the baskets is 304L stainless steel. In addition, the scrap baskets have a copper shroud, fins, and inner pocket for the scrap fines. This copper assembly aids in the transfer of heat out of the central basket fines area to the MCO shell wall. The copper is needed during the final stages of the MCO drying process.

The maximum length varies for each type of fuel, and as a result the overall heights of the baskets are different. Six Mark IA baskets or five Mark IV baskets will fit into an MCO. Any commingling of Mark IA and Mark IV baskets will be sensed by the MCO loading system at the K Basin load-out pits.

Each basket has a grapple interface that is on the inside surface of the central tube near the top of the basket. This circular grapple groove is used to pick up and move the baskets in the basins and to load the fueled baskets into the MCO at the load-out pits. The grapple interface is large enough to accommodate the axial process tube's outer diameter of 3.3 cm (1.3 in.) and its insertion down through to the bottom of the MCO. This insertion occurs when the completed shield plug assembly is lowered into the MCO at the K Basin load-out pit.

The MCO baskets also have to accommodate such functions as reliable engagement and stacking, water drainage, and gas flows inside the MCO.

PATH SUMMARY

The MCO's path begins at the CSB where an empty MCO, with the locking and lifting ring installed, is placed into the onsite shipping cask. The cask–MCO assembly is put on the conveyance, and the MCO is taken to the K Basin facility and parked near a load-out pit. The cask–MCO assembly is removed from the conveyance, the locking and lifting ring is removed, and the MCO is further prepared for receiving fuel and placed underwater in the load-out pit. A loading funnel is placed in the MCO neck, and the MCO loading machine loads underwater the queued up payload of baskets. When loading is complete, the loading funnel is removed, the Helicoflex sealing area of the collar is cleaned, and a fully assembled shield plug with the long axial process tube installed is lowered into the MCO. The cask–MCO assembly's top is raised above the pool water, the shield plug area is dewatered, and the shield plug lifting fixture is removed. The exposed portions of the shield plug and collar of the MCO are decontaminated as necessary, and the locking and lifting collar is installed into the MCO collar's neck. The set screws are tightened and torqued to the design requirement.

The cask is now closed, and the cask–MCO assembly is inerted and placed on the conveyance. The conveyance is taken to the CVDF and brought into one of the processing bays. The cask lid is removed, and a process hood is mounted onto the MCO. Valve operators are mounted on the MCO's ports 2 and 3, the ports are opened, and the cask is heated slightly to assist in the drying of the MCO later in the cycle. The bulk water is drained out through the axial process tube, helium is introduced into the interior of the MCO, and the vacuum drying cycle begins. When the drying cycle has been completed, the MCO is backfilled with helium, the process equipment is disconnected, and the Helicoflex main seal is leakage rate tested. The MCO ports are sealed with blind cover plates, and the cask is sealed.

The conveyance with the cask–MCO assembly still on board is now taken to the CSB. While at the CSB, the cask–MCO assembly is moved from the conveyance to the receiving pit. There the cask is opened, and the facility handling machine removes the MCO from the cask. The machine places the MCO in a storage tube or in the MCO welding station. The first several MCOs taken to the CSB will be monitored by gas sampling at the welding station. Eventually all the MCOs will be moved through the welding station, where the cover cap will be installed on the MCO, and then back to the CSB storage tubes for interim storage.

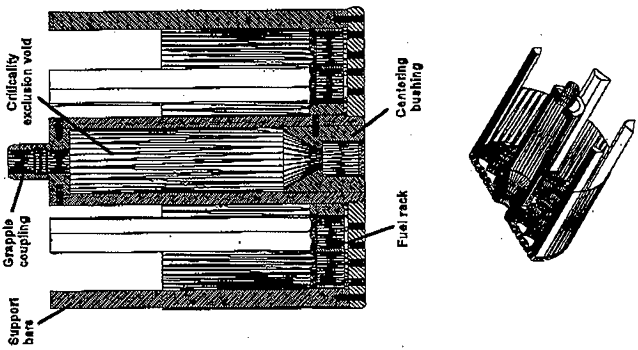

Figure 3. Mark IA Whole Fuel Basket.

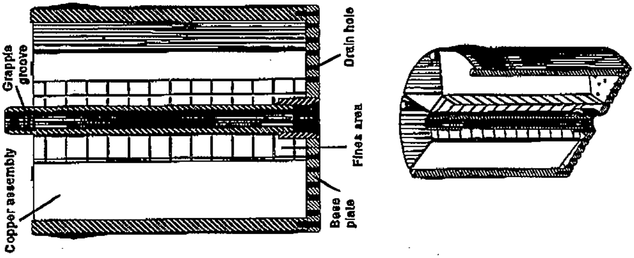

Figure 4. Mark IV Scrap Basket.

The empty cask is refilled with a new MCO, and the cycle is repeated. This SNF removal campaign is not expected to begin before July of 1999.

ONGOING ACTIVITIES

The MCO is undergoing a review in regards to eventual repository placement. The activity includes a review of Title 10, *Code of Regulations*, Part 71, "Packaging and Transportation of Radioactive Material,"[3] for suitability for transport to the repository and an associated nuclear criticality review of the MCO and the basket structure and makeup; an evaluation of the MCO in regard to post-repository receipt; and a long-term performance evaluation of the MCO once in the closed repository.

REFERENCES

[1]L. E. Fischer and W. Lai, *Fabrication Criteria for Shipping Containers*, NUREG/CR-3854, U.S. Nuclear Regulatory Commission, Washington, D.C., 1985.

[2]*Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers, New York, New York.

[3]10 CFR 71, "Packaging and Transportation of Radioactive Material," *Code of Federal Regulations*, as amended.