DEVELOPMENT AND TESTING OF A TRU WASTE SHIPPING AND STORAGE CONTAINER

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ABSTRACT

This paper describes the development of a high gamma activity TRU waste container and waste encapsulation method designed to meet requirements for transport to and retrievable storage at the DOE Hanford, Washington radioactive waste site. The design and testing of the container to meet DOT Special Form requirements and the remote handling methods developed for encapsulation of the waste to meet Hanford site specific requirements are discussed.

INTRODUCTION

Irradiated nuclear fuel waste generated in the course of conducting hot cell research and development programs is generally classified as transuranic (TRU) waste because the concentration of alpha emitting TRU nuclides in the fuel normally far exceeds the 10CFR61 limit of <100 nCi/gm for non-TRU waste. Since such TRU wastes are not acceptable for near-surface disposal, they cannot be shipped to any commercial radioactive waste disposal sites. However, they may be placed in long term retrievable storage at the Department of Energy (DOE) Hanford Radioactive Waste Storage and Disposal Site, provided they are owned by the DOE or have been generated under DOE sponsored programs, and are packaged to meet Hanford waste storage site requirements.

Approximately 100 kg of irradiated fuel waste generated in the General Electric Vallecitos Nuclear Center (GE-VNC) hot cells under two DOE sponsored fuel development programs[1] was approved by the DOE for transfer to the Hanford TRU Waste Storage Site. Negotiations with Rockwell Hanford Operations (RHO), operator of the waste site, and Westinghouse Hanford Co. (WHC) resulted in a plan whereby the waste was to be encapsulated in inner containers by GE-VNC to meet waste site and transport requirements. Encapsulated waste was then to be transported to WHC hot cell facilities in NRC licensed GE-VNC shipping casks, transferred to EBR-II Spent Fuel Storage Casks by WHC, and delivered to RHO for emplacement in retrievable storage.

WASTE PACKAGE REQUIREMENTS

The requirements for radwaste storage set forth in the RHO waste manual[2] and in the Department of Transportation (DOT) regulations[3] for radioactive materials transport provided the basis for the design of the waste package. Additionally, requirements for remote handling and those established by previous WHC experience in packaging similar waste materials were included in the design of the waste package. These combined requirements are as follows.

RHO waste site requirements:

- The waste material must be doubly contained.
- Both containments must remain leaktight under site storage conditions.
- Removable contamination on the outer surfaces of both containments must not exceed the following limits:

  alpha - 100 dpm/100 cm^2
  beta gamma - 1000 dpm/100 cm^2

- The dose rate at the outer surface of the package must not exceed 200 mRem/hr.
- The decay heat of the package contents must not exceed 300 watts.

Transport requirements:

- The fissile content of the package must not exceed 500 gm U-235 equivalent mass (U-235 mass plus 1.66 times Pu plus 1.66 times U-233 mass). This is the limit for the GE Model 200 transport cask. The Hanford site limit for the storage cask is 3000 gm total fissile.
- The inner container must meet the requirements of 49CFR173.403(z) for special form encapsulations.

MODIFICATION OF HANFORD WASTE PACKAGE DESIGN

Irradiated mixed oxide fuel waste generated in the WHC hot cells has been previously packaged for retrievable storage at Hanford by encapsulating the fuel in 10 cm (4 in.) and 13 cm (5 in.) diameter welded stainless steel containers, and placing the containers inside an EBR-II Spent Fuel Storage Cask. In the preliminary GE-VNC design evaluation, it was noted that the relatively small diameter inner container limited the package waste capacity to approximately 7 litres

(0.25 ft^3). Alternatively, use of a single 13 cm (5 in.) diameter inner container would increase package waste capacity to approximately 12 litres (0.41 ft^3). Such an increase in capacity would reduce the total number of packages required for fuel waste stored at GE-VNC by about one-third, and thereby reduce total encapsulation, transportation, handling, and storage cask costs by the same fraction.

The large diameter, single inner container concept was proposed to RHO and accepted with the provision that the EBR-II cask design be modified to incorporate a lid closure seal which would qualify the cask as the second leaktight containment of the package. Development and qualification of the required cask closure seal was successfully carried out by WHC in parallel with GE-VNC container design and special form qualification activities.

WASTE CONTAINER DESIGN

The waste container is a 13 cm diameter (5 in. Schedule 40) Type 304 stainless steel pipe section, closed at each end with dome shaped Type 304 stainless steel welded caps (Fig. 1 and 2). The overall outside length of the container is 93 cm (36.5 in.), as prescribed by the cavity size of the EBR-II cask. A stepped "weep" hole is provided in the top end cap to prevent internal gas pressure from increasing while making the top cap circumferential weld and to permit helium to be introduced for leak testing the welds. A stainless steel ball is also welded to the top cap to facilitate remote hot cell handling of the cap and completed container.

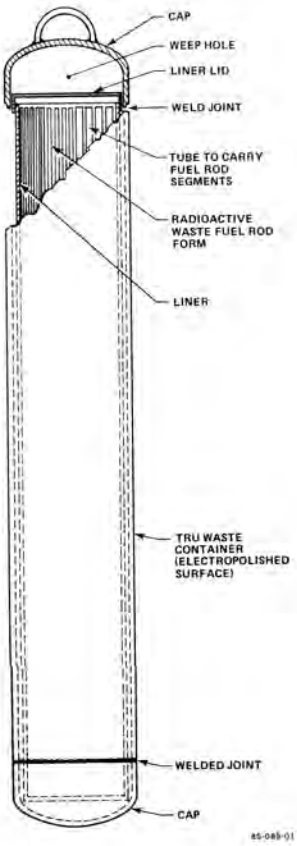

Fig. 1. TRU container loaded with waste.

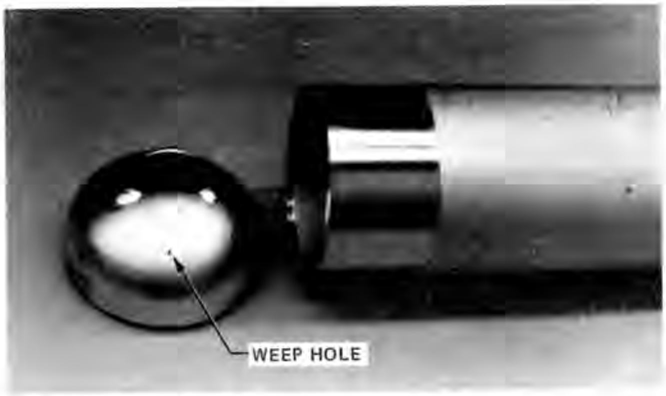

Fig. 2. Top end of container and cap.

Type 304 stainless steel was selected because of its good corrosion, mechanical, and weldability properties, and also because this material had been previously accepted by RHO for WHC fuel waste containers.

Because of concerns over meeting the container contamination limits, we elected to have the external surfaces electropolished. This treatment provided smooth surfaces which could be easily decontaminated by dry wiping in the event the container became excessively contaminated during hot cell handling operations.

In support of the container design effort, the conceptual design was analyzed using Finite Element methods. The objective of this analysis was to identify an area of low stress for the placement of the weld joint. In this analysis, the design was subjected to internal pressure and collapse loadings. The value of the pressure used in the analysis was given by the gases entrapped in the container at postulated accident temperature. An inelastic analysis of the container identified the collapse loading.

Two finite element models were employed in the analysis. One model used a two node, axisymmetric shell element based on the shell theory. The second model was a three dimensional (3D) model composed of a triangular shell element which combines plate and constant strain membrane theories (Fig. 3). The

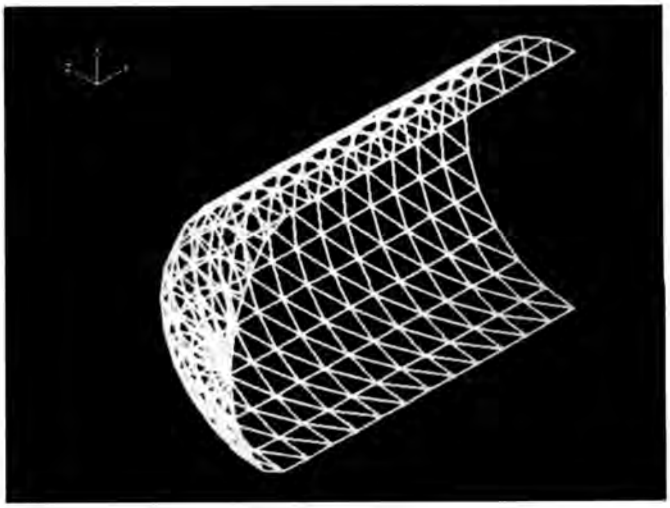

Fig. 3. Three dimensional stress analysis model.

axisymmetric model was used for the internal pressure and head-on collapse analyses while the 3D model was used in the center of gravity (cg)-over-corner collapse analysis. The head-on and cg-over-corner terms refer to the orientation of the container and the plane toward which it collapsed. Dynamic properties of material were used in all collapse analyses. The analytical results indicated that stresses at the weld area are within the capacity of the material to withstand the applied load. This was demonstrated by the Special Form Impact test which is covered in a later section of this paper.

WELD DEVELOPMENT AND QUALIFICATION

A standard manual TIG-arc filler weld procedure was selected and easily qualified for the non-remote bottom end cap weld. However, considerable effort was required to develop and qualify an automatic process for remote TIG-arc welding of the top end cap without the addition of filler material in the hot cell.

A minimum weld zone leak path of 40% of the container wall thickness was established as the primary criterion for qualifying a top cap welding procedure. This value was conservatively based upon the maximum stresses which would be developed in the weld zone due to internal gas pressure buildup under the special form 800°C (1472°F) heat test condition. A number of trial circumferential welds were then made in our welding shop using different weld joint geometries and process parameters. These welds were evaluated and the geometry and parameters which yielded the best quality weld were selected to serve as a basis for final development and qualification of a remote welding procedure. Parameters were also established at this time for seal welding the weep hole using a short section of Type 308 stainless steel weld filler rod inserted in the hole.

Concurrently, a special remotely operable welding fixture (Fig. 4 and 5) was designed and built for final qualification of the top cap circumferential and weep hole seal welds and in-cell production welds. This fixture holds and rotates the container in a vertical position by means of a free wheeling bottom end cup support and a chuck which grips it at the machined section just below the weld joint. The chuck is driven by an adjustable D.C. motor which is regulated by a controller located outside the cell. The welding torch is held by a clamp which is mounted to the fixture frame and which has rack and pinion arrangements for adjusting the torch in x, y, and z directions, as well as provision for rotation in the horizontal plane. The torch electrical cables are connected to a TIG-arc power supply located outside the cell by means of a special cell wall electrical plug. Special feeler gauges, designed for handling with cell manipulators, were also provided to permit the torch electrode tip to be accurately positioned for each of the required remote welding sequences (Fig. 5).

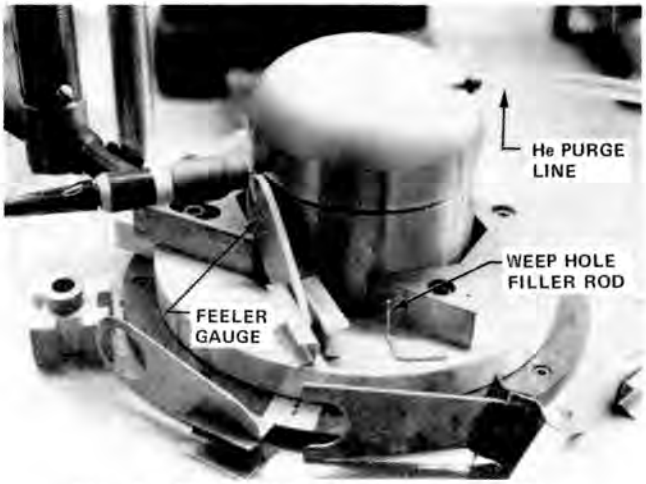

Fig. 5. Positioning of welding torch for circumferential weld.

Circumferential and weep hole test welds were made with the fixture using parameters which produced consistently acceptable welds. As a final step in qualifying the established welding procedures and operator, two prototype containers, each loaded with 36 kg (80 lbs) of steel rods to simulate radioactive waste loads (Fig. 6) were fabricated for Special Form testing. The welds of both containers were evaluated by destructive examination after these tests were completed and were found to satisfy all weld acceptance criteria.

Fig. 4. Welding fixture and transport cask setup in cell prior to loading waste.

Fig. 6. Prototype container loaded with simulated waste.

SPECIAL FORM QUALIFICATION

Impact and percussion tests of the two prototype containers were conducted for Special Form qualification according to the requirements of 49CFR173.469. After each of these tests, a test for helium leak-tightness was performed to assess the integrity of the containers.

The impact test consisted of dropping the container from a height of 9 m (30 ft) onto a flat, unyielding surface, in two different orientations. In one orientation, "head-on", the container was dropped vertically onto the impact surface. In the second orientation, it was dropped at an angle which positioned the center of gravity over the impact corner. For the percussion test, the containers were struck at the weep hole weld region by a 1.4 kg (3 lb), 25 mm (1 in.) diameter steel billet dropped from a height of one meter. The damage produced by these tests was negligible and the helium leak-tightness tests indicated no reductions in the integrity of the containers.

The Special Form heat test requirement was met by engineering analysis. The container was postulated to lose integrity by weld failure due to excessive internal gas pressure. Determinations of the maximum internal pressure and subsequent stress evaluations indicated that the integrity of the container would be maintained under the 800°C (1472°F) heat test conditions.

The bending test was not required because the length to minimum width ratio of the container does not exceed ten.

CONTAINER LEAK TESTING

A special fixture was designed for remotely leak testing the top end circumferential and weep hole closure welds (Fig. 7). This fixture consists of an aluminum "bell" housing, an inflatable rubber gasket attached to the inside surface near the open end of the housing, and a vacuum line connection. The fixture is positioned over the end cap such that the gasket contacts the container surface below the circumferential weld. The gasket is then pressurized with air to form a vacuum tight seal between the housing and container surfaces. A vacuum line is connected between the housing and a helium mass spectrometer leak detector located outside the hot cell. After the vacuum line and space within the housing have been evacuated, standard helium leak detector procedures are followed to detect any leakage of helium from the container down to 2×10^{-8} atm-cc/sec.

Fig. 7. Helium leak test fixture installed over top of welded container.

LOADING AND ENCAPSULATION OPERATIONS

Detailed planning of each container load was required in order to maximize the amount of fuel loaded without exceeding the limits established for package dose rate, heat load, and fissile quantity. The dose rate limit proved to be the most restrictive limit, since it was found that neither the heat load nor fissile limits would be exceeded if the amount of fuel loaded did not yield a dose rate in excess of 200 mRem/hr.

Maximum allowable mixed fission product (MFP) activity values for the EBR-II cask were calculated based on the cask dose rate limit and MFP ages. Specific MFP activity values (Ci/in. fuel) were calculated for the burnup range (800 to 45,000 MWd/MTU) and decay time range (2 to 10 years) of the fuel to be shipped. These values were used to establish conservatively low fuel quantities for each container to assure that the cask dose rate limit would not be exceeded. Additionally, dose rate measurements were taken of each assembled load inside a Model 200 cask prior to final encapsulation. The measured dose rates were converted to dose rate values for the thinner shielding (127 mm vs. 149 mm lead) of the EBR-II cask as a final check that the 200 mRem/hr limit would not be exceeded.

The actual MFP quantities in the six containers shipped to Hanford ranged from 8600 to 12,400 Ci per container, and the corresponding EBR-II cask dose rates ranged from 80 to 190 mRem/hr. Because of the significant quantities of high burnup fuel present in each container, neutron generation in the fuel was found to contribute from 40% to 60% of the total measured cask dose rates. Actual heat loads and fissile quantities per container were in the ranges of 40-58 watts, and 270-375 gm, respectively.

In order to meet the stringent container surface contamination limits, special controls and procedures were established for the fuel loading and encapsulation operations. These controls and procedures required that all of the fuel items selected for a container be assembled in a loading cell and loaded into a container liner (Fig. 1) prior to transfer to the encapsulation cell. Contact of the liners with the highly contaminated cell surfaces during loading was minimized through the use of a special liner holding fixture. Immediately after loading, the liners were thoroughly wiped to remove gross external contamination which may have been acquired during the loading operation. The encapsulation cell was then decontaminated to non-smearable levels. The container body, cap, encapsulation equipment, and shipping cask were next installed in the lock (Fig. 4 and 5) and all required service lines were connected.

After positioning the empty container body in the welding fixture, its exposed upper surfaces were covered with aluminum foil to prevent contamination during the liner loading operation. Equipment operational checks were then completed and the liner was transferred into the encapsulation cell and lowered into the container. Following completion of the cap welds and leak testing, the container was removed from the weld fixture and dry wipe samples of representative surface areas were taken. The wipe samples were transferred out of the cell and counted for alpha and beta gamma activity. After the wipe checks showed that contamination levels were below maximum acceptable levels, the container was loaded into its shipping cask which was then prepared for shipment to Hanford. Each shipping cask cavity was equipped with a clean removable liner to prevent cross-contamination of the containers by any residual contamination which may have been present on the cask cavity surfaces.

The contamination controls described above proved highly successful in that the contamination levels of all six of the containers shipped to Hanford were found to be only 10% of the Hanford acceptance limits both after completion of encapsulation and after receipt by WHC.

CONCLUSIONS

A container for encapsulating TRU hot cell waste was designed and qualified to meet both Special Form transport and Hanford waste site retrievable storage requirements. The use of this container for packaging irradiated fuel waste on a routine basis was successfully demonstrated. This packaging method could be used to reduce the constantly increasing inventories of privately owned TRU waste stored at commercial hot cell facilities if legislation permitting acceptance of such wastes at DOE waste disposal facilities were enacted.

ACKNOWLEDGEMENTS

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REFERENCES

1. DOE Contract Nos. DE-AC02-77ET34001, "Demonstration of Fuel Resistant to PCI", and DE-AC02-80ET34031, "BWR Fuel Bundle Extended Fuel Burnup Program ".
2. RHO-MA-222, Rev. 1, "Hanford Radioactive Solid Waste Packaging, Storage, and Disposal Requirements", dated July, 1984.
3. Code of Federal Regulations, Title 49, Parts 171-178, "Requirements for Transportation of Radioactive Materials".