Innovative Approaches to Large Component Packaging

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ABSTRACT

Radioactive waste disposal often times requires creative approaches in packaging design, especially for large components. Innovative design techniques are required to meet the needs for handling, transporting, and disposing of these large packages. Large components (i.e., Reactor Pressure Vessel (RPV) heads and even RPVs themselves) require special packaging for shielding and contamination control, as well as for transport and disposal. WMG Inc designed and used standard packaging for RPV heads without control rod drive mechanisms (CRDMs) attached for five RPV heads and has also more recently met an even bigger challenge and developed the innovative Intact Vessel Head Transport System (IVHTS) for RPV heads with CRDMs intact. This packaging system has been given a manufacturer’s exemption by the United States Department of Transportation (USDOT) for packaging RPV heads. The IVHTS packaging has now been successfully used at two commercial nuclear power plants.

Another example of innovative packaging is the large component packaging that WMG designed, fabricated, and utilized at the West Valley Demonstration Project (WVDP). In 2002, West Valley’s high-level waste vitrification process was shut down in preparation for D&D of the West Valley Vitrification Facility. Three of the major components of concern within the Vitrification Facility were the Melter, the Concentrate Feed Makeup Tank (CFMT), and the Melter Feed Holdup Tank (MFHT). The removal, packaging, and disposition of these three components presented significant radiological and handling challenges for the project. WMG designed, fabricated, and installed special packaging for the transport and disposal of each of these three components, which eliminated an otherwise time intensive and costly segmentation process that WVDP was considering.

Finally, WMG has also designed and fabricated special packaging for both the Connecticut Yankee (CY) and San Onofre Nuclear Generating Station (SONGS) RPVs. This paper presents the approach that has been successfully used for planning, implementing, and preparing for the disposition of large components such as those mentioned previously. It addresses the major regulatory and design requirements for packaging, transporting, and disposing of these components. The specific topics that are covered include radiological characterization, shielding, packaging design, on-site handling and movement, off-site transportation options, a brief discussion on disposition, and lessons learned.

INTRODUCTION

Radioactive waste comes in all shapes and forms, which provides for many opportunities to develop special packaging. Innovative design of specialty packaging can eliminate the need for expensive segmentation efforts and result in large savings in personnel radiation exposure, transport, and disposal, thereby reducing cost and increasing safety. Comparative analyses and cost comparisons must be performed to evaluate the best means for preparing and disposing of radioactive waste. Many variables have to be weighed to determine the viability of packaging large, whole components, versus segmenting the components and packaging smaller component pieces, and the byproduct waste from the segmentation process. There are many challenging opportunities for developing creative packaging, which is the main theme of this paper.

NOMENCLATURE

The following lists the terms and acronyms used throughout this paper:

RPV – Reactor Pressure Vessel

CRDM – Control Rod Drive Mechanism

IVHTS – Intact Vessel Head Transport System

MFHT – Melter Feed Holdup Tank

CFMT – Concentrate Feed Makeup Tank

DOT – United States Department of Transportation

DOE – United States Department of Energy

NRC – United States Nuclear Regulatory Commission

CFR – United States Code of Federal Regulations

D&D – Decommissioning and Dismantlement

WAC – Waste Acceptance Criteria

RQ – Reportable Quantity

WVDP – West Valley Demonstration Project

LSA – Low Specific Activity

SCO – Source Contaminated Object

BACKGROUND

WMG Inc is a small business located in Peekskill, New York. WMG has been instrumental in characterizing radioactive waste for the commercial nuclear power industry. WMG’s RADMAN software is used for characterizing and manifesting radioactive waste in 95% of the commercial nuclear power plants in the United States. WMG recognized the need for specialized packaging for large components in the 1990s with the emergence of large component replacements such as the Salem steam generators. WMG was instrumental in the development of new regulations that allowed for packaging, transporting, and disposing of large components. WMG designed special packaging for the Connecticut Yankee (CY) RPV and developed segmentation and packaging plans for numerous RPVs. WMG has also been involved with the packaging, transport and/or disposal of the Trojan RPV, Yankee Rowe RPV, Connecticut Yankee RPV, Maine Yankee RPV head, SONGS RPV head, Davis Besse RPV head, North Anna Units 1 and 2 RPV heads, Surry Units 1 and 2 RPV heads, and the Farley Units 1 and 2 heads. WMG has been involved in some aspect of the disposal of almost every large component in the United States.

WMG has developed innovative packaging to support the needs for transporting and disposing of numerous RPV heads from the commercial nuclear PWR plants mentioned above. The Surry Unit 2 RPV head was the first in the commercial nuclear power industry to be packaged and transported with CRDMs installed. WMG's patented innovative IVHTS packaging was used for the first time on the Surry Unit 2 RPV head. The use of the IVHTS packaging at Surry Unit 2 resulted in providing the client, Dominion Energy, with significant savings in critical path time and radiation exposure. WMG was most recently contracted by Westinghouse to package the Farley Units 1 and 2 RPV heads with the IVHTS. WMG is currently contracted by Curtiss Wright to package the new RPV head for Comanche Peak Unit 1 with a package that can be converted to an IVHTS for potential shipment of the old RPV head.

WMG was also instrumental in developing a new approach for removing large components from the West Valley Demonstration Project (WVDP). The three components of concern were located within the Vitrification Facilities "Vit Cell". These components included the Melter, MFHT, and CFMT. WMG was able to design and fabricate packaging that housed these large components and allowed for them to be safely handled, transported, and disposed. These innovations in packaging design saved WVDP many hours of time and exposure that would have been expended segmenting these components.

DISCUSSION

Every radioactive waste-disposal project requires a detailed plan. The first step in developing the project plan is to establish the scope of work. Waste inventories, with associated survey data, must be obtained to fully develop the scope of work. The starting point, which is also the key to the packaging development, is the radiological characterization of the material, or component, to be packaged for disposal. Characterization is defined below, and packaging methods and examples are also discussed in detail.

Characterization

Characterization is the basis for classifying radioactive material for transport and disposal. It is the first step in the process of defining the waste, and the first step in designing packaging to house, transport, and dispose of the waste. Waste characterization is the process that is utilized to determine both the waste classification for disposal in accordance with 10CFR61 [1] and the transportation classification in accordance with 49CFR173 [2]. The two sources of activation that must be determined are the surface contamination (i.e., from all surfaces in contact with the primary system in a reactor) and the activation products from exposure to a neutron flux (i.e., the segmented components from the reactor vessel and certain parts of a RPV head). Whenever possible, the nuclide distribution from surface contamination is determined via smear sample analysis (i.e., "Part 61 analysis"). Where appropriate, an activation analysis calculation using the Origen-2 [3] computer program is performed to estimate the "hard-to-detect" radionuclide concentrations important to classification under 10 CFR Part 61. This establishes the radionuclide inventory of the component. Dose-to-curie conversion factors are established via detailed three-dimensional models and calculations. Then these conversion factors are applied to survey data to establish the activity by radionuclide.

The 49CFR173 transportation classification is established by comparing the surface activity of the component to LSA and SCO limits, and by comparing the nuclide activities to the corresponding A_2 values in 49CFR173. Based upon this comparison evaluation, the component can be classified as either SCO or LSA material.

Accurate and current radiological and physical data is extremely important for proper waste characterization. Complete operational power history of the reactor (including any and all fuel failures), the most recent radiological surveys of the component, and all available smear samples of parts and pieces of the component provide important information that helps to more accurately characterize the component.

Physical data is collected to develop an accurate QAD-CGGP-A [4] geometry model. This model is used to determine the dose-to-curie conversion factors and to ensure that the disposal package is adequately shielded. This physical data includes the specific dimensions and weights for the component. The manufacturer's drawings generally provide this information, as well as information on the materials of construction.

Additional requirements are evaluated to confirm that the component shipping/disposal package design meets all of the 49CFR173 transportation criteria, which includes, but is not limited to the following: the conveyance limits, the three-meter unshielded dose rate limit, the exclusive-use shipment criteria, the reportable quantities (RQ) limits, and the "Industrial Package" requirements. The component package is designed so that it meets all of the non-exempt 49CFR173 transportation criteria.

The component package also has to be designed so that it will satisfy the waste acceptance criteria (WAC) for the disposal facility to which it will be delivered. The WAC ensures that the waste conforms to the licensing agreements established between the disposition facility and the particular state in which the facility is located.

Regulatory Requirements for Packaging LSA Material and SCO

The US DOT and the US NRC dictate the regulatory requirements for transport and disposal of radioactive waste. The packaging must be designed to meet the regulatory requirements for the associated waste classification.

The general transport (packaging) requirements are specified in 49CFR173.427, "Transport requirements for low specific activity (LSA) Class 7 (radioactive) materials and surface contaminated objects (SCO)." The general requirements specified in this section of the CFR include the following:

1. The external dose rate must not exceed an external radiation level of 10 mSv/h (1 rem/h) at 3 m from the unshielded material
2. The quantity of LSA and SCO material in any single conveyance must not exceed 100 times the A_2 limits
3. LSA material and SCO that are or contain fissile material must conform to the applicable requirements of 173.453
4. Packages must meet the contamination control limits specified in 49CFR173.443

5. External radiation levels must comply with 49CFR173.441
6. For LSA material and SCO the shipments must be “exclusive use.”

The component must be evaluated, based upon these regulatory requirements, to determine the type of packaging required for transport and disposal. Most of the RPV heads that WMG has characterized have exceeded the criteria for shipment in a “strong tight” container because they contain greater than a Type A quantity of material. This has resulted in the development of special Industrial Packaging (IP), such as WMG’s IVHTS packaging.

Shielding Evaluation

All packaging used to transport and dispose of radioactive material in the United States must be designed in accordance with 49CFR173.441, which provides the external radiation dose rate limitations for packages used for the transport of radioactive materials, as mentioned previously. Per 49CFR173.441, “…each package of Class 7 (radioactive) materials offered for transportation must be designed and prepared for shipment, so that under conditions normally incident to transportation… ,” the following criteria are met(49CFR17344(b)):

1. 2 mSv/h (200 mrem/h) on the external surface of the package
2. 2 mSv/h (200 mrem/h) at any point on the outer surfaces of the transport vehicle, including the top and underside of the vehicle
3. 0.1 mSv/h (10 mrem/h) at any point 2 meters (6.6 feet) from, in the case of an open vehicle, the vertical planes projected from the outer edges of the conveyance
4. 0.02 mSv/h (2 mrem/h) in any normally occupied space.

The component packaging should be designed with the capability to add internal and/or external shielding, if necessary, to ensure that the packaged component meets these criteria.

Package Design

Package design must be in accordance with the requirements of 49CFR173. The general design requirements are contained in 49CFR173.410 and .411. The shielding is designed such that the package will meet the dose rate requirements established in 49CFR173.441. All of WMG’s component packaging is designed and fabricated in accordance with the requirements of the appropriate American standards.

The specific package design attributes, which are addressed by 49CFR173.410, include handling, lifting attachments, exterior protrusions, water collection pockets, feature safety impacts, normal transport vibrations, chemical compatibility, and valves. The following is a list of each of the attribute requirements (49CFR173.410(a) through (h)):

(a) The package must be designed so that it can be easily handled and properly secured on a conveyance during transport.
(b) The package must be designed so that each lifting attachment has a minimum safety factor of three against yielding when used to lift the package in the intended manner. It must be designed so that failure of any lifting attachment under excessive load will not impair the ability of the package to meet other requirements.
(c) The package must be designed such that the external surface, as far as practicable, will be free from protruding features and will be easily decontaminated.

(d) The outer layer of the package must be designed to avoid, as far as practicable, pockets or crevices where water might collect.
(e) Any added features must not reduce the safety of the package.
(f) The package must be designed so that it is capable of withstanding the effects any acceleration, vibration or vibration resonance that may arise under normal conditions of transport without any deterioration in the effectiveness of the closing devices on the various receptacles or in the integrity of the package as a whole and without loosening or unintentionally releasing the nuts, bolts, or other securing devices even after repeated use.
(g) The package must be designed such that the materials of construction, including any components or structures, are both physically and chemically compatible with each other and the package contents.
(h) The package must be designed so that all valves through which the package contents could escape will be protected against unauthorized operation.

All of these attributes are incorporated into WMG's special packaging designs.

Special Packaging Examples

The IVHTS packaging (Fig. 1) was developed by WMG to meet the special packaging needs for the RPV heads with CRDM's left intact. It was designed to provide containment comparable to that of an Industrial Package Type 2 (IP-2) and can be sized and shielded to accommodate any RPV head. The WMG patent pending IVHTS consists of the RPV head, including the full-length CRDM's, a bottom shield and contamination cover plate and three cylindrical ring sections. This packaging was first used at the Surry Unit 2 nuclear power plant to house the old RPV with CRDMs intact (Fig. 2). The total weight for the loaded IVHTS shipping/disposal package for Surry Unit 2 head was approximately 12,690 kg (340,000 lb.). It was 4.67 meters (15ft.-4-in.) in diameter and 8.43 meters (27ft.-8-in.) tall.

The packaging has four major features: (1) coating the exterior surfaces of the old head with a fixative to isolate the exterior surfaces; (2) closing the old head with a gasketed bottom plate to provide shielding and make the interior contaminated surfaces inaccessible; (3) containing the CRDM bundle within a bag; and (4) gasketed sealing of the vertical and horizontal flanged surfaces on the package to provide a seal between the radioactive contents and the environs.

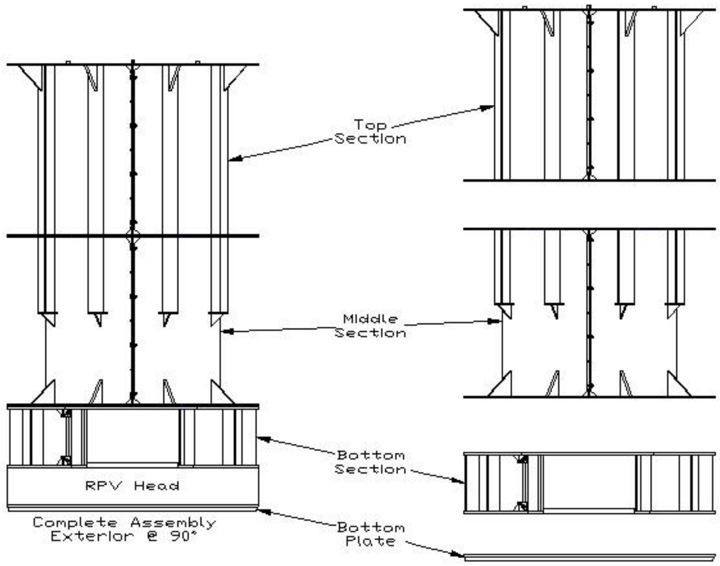

Fig. 1. IVHTS packaging

The package is sealed to the old head flange via closure studs, nuts, and washers that attach the package's upper sections and the bottom plate to the old head. The outer face of the old head flange is covered with a fixative coating. See Fig. 2 for a photograph of the Surry Unit 2 IVHTS.

Fig. 2. Surry Unit 2 IVHTS package

Several other examples of the WMG's specialty packaging designs include those used for packaging the WVDP Melter, Concentrate Feed Makeup Tank (CFMT), and Makeup Feed Holdup Tank (MFHT). The WVDP site was originally planned to remotely segment these three components that were located inside the Vitrification Cell at the site. WMG proposed, and was successful in convincing WVDP, to package these components intact, in lieu of remotely segmenting each component and packaging the pieces in smaller, standard, commercially available shipping containers.   The result of this effort was a substantial savings of time and money. WMG worked with the WVDP site, the rigging/handling subcontractor, and the transportation subcontractor to develop packaging that met all of the associated needs.

The package designs for the WVDP components required design interface, between WMG and the rigging and transport subcontractors, to incorporate the special interface needs associated with handling and transport of the components. For example, the Melter was mounted on steel wheels and moved out of the VIT Cell via an installed rail system. The rigging subcontractor augmented the existing rail system with their own rail and drum hoist system, to move the Melter out of the VIT Cell and through several buildings then finally into the specially designed packaging. The Melter container was designed with an integral rail system that aligned with the rigger's rails and allowed for the Melter to be rolled into it.

The CFMT and MFHT containers were designed with flat sides to accommodate rail clearance restrictions and allow the packages to be rail shipped. Like the Melter, the CFMT and MFHT packages were also designed with integral rail systems. Due to the unique geometry of the MFHT, it had to be rolled into the package while the package was tilted at a 45-degree angle. A special "saddle system insert" was required to hold the MFHT package at an angle during the loading operation. Once loaded, the MFHT package was rotated 45-degrees so that it could easily be shipped in the proper orientation. Special saddles and tie-down systems were designed and installed to allow for attachment of the packages to railcars.   Each of the WVDP component packages were also outfitted with special grout ports and shielded plugs to allow the components to be grouted into place within their containers. See Fig. 3 for a photograph of the WVDP specialty packages.

Fig. 3. WVDP specialty packages

WMG also designed and fabricated special packaging for the CY RPV for transport by both barge and heavy haul land transporter. WMG developed a segmentation and packaging plan, which allowed the reactor internals to be cut and repositioned within the reactor for packaging. This unique, patented, packaging system is designed so that the walls of the reactor vessel provide shielding around the internals, thus reducing the required wall thickness of the container. This single, large container resulted in a significant savings in money and exposure by reducing segmentation, handling, packaging, and transport activities.

WMG took the same approach for the SONGs RPV. The internals were removed, segmented, and repositioned within the reactor vessels and all contained within a single, large package. This package was designed for barge, heavy-haul transporter and rail with a Schnabel railcar.

The WMG RPV packages have six major features:

1. Removing the reactor pressure vessel nozzles and supports so that they do not extend beyond the upper flange of the reactor pressure vessel
2. Closing the reactor pressure vessel nozzles
3. Grouting the reactor pressure vessel interior to fix surface contaminants and the locations of reactor internals components and associated pieces
4. Applying a fixative to the exterior surfaces of the reactor pressure vessel to minimize the spread of contamination
5. Grouting the annulus between the exterior of the reactor pressure vessel and the interior wall of the Package
6. Sealing the closure studs, which attach the reactor pressure vessel to the Package at the top cover plate to provide a seal between the radioactive contents and the environs

A typical packing scheme for segmented internals is shown in Fig. 4 below.

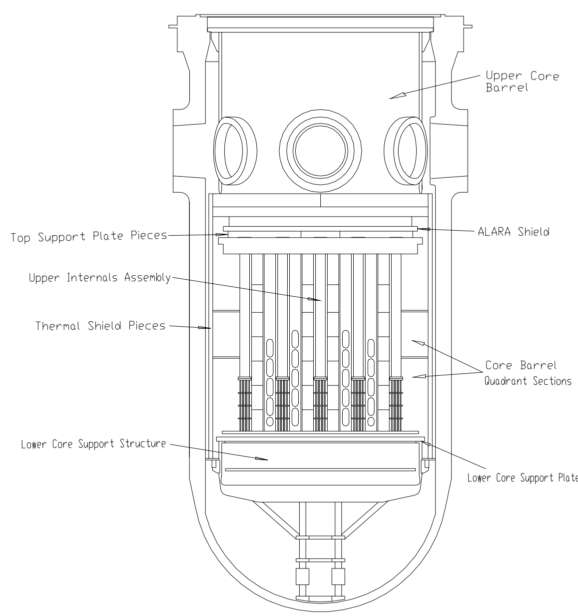

Fig. 4. Typical packing scheme for segmented internals

Package tie-down systems are an integral part of the packaging system for large components. The tie-down systems have to be designed to provide proper interface between each package and associated conveyance(s). The function of the tie-down system is to maintain the integrity of the package while keeping it secure to its conveyance, for each of the load case scenarios specified in the DOT regulations. WMG interfaces with the transport subcontractors early in the design process to ensure that these needs are met. Each tie-down system has its own unique nuances. Since no two large component packages are the same, each tie-down system must be specifically designed to accommodate the particular package. Most of WMG’s package designs include a unique, patented, shock absorption feature, which is an integral part of the packaging and in some cases, an integral part of the tie-down system.

One of the more challenging tie-down system designs developed by WMG was that for the SONGs RPV. It is designed for rail, truck, and barge transport. This package tie-down system consists of a skid-mounted cradle (saddle) assembly provided with tie-downs to secure the package during transport. Once the RPV package is loaded and tied down to the saddles, the complete cradle assembly forms a single integral unit that can be loaded on and unloaded from each transport conveyance. To meet the railroad clearance requirements the skid was designed with removable pinned beam attachments at the ends to extend the width of the skid for the barge configuration and to provide lifting (jacking) points. For rail transport by the Schnabel car, the skid incorporates the required Schnabel Car tension beams so that the tension skid will be integral to the complete cradle assembly. The package and skid are part of the structural system of the Schnabel Car during transport. The package and skid are held in place by a force couple that is developed in the tension beams (tension) and the Package (compression).

For land transport, the complete cradle assembly skid will be attached to the land transporter by a tie-down system welded and/or bolted to the skid and transporter frame.

For barge transport, the complete cradle assembly skid (with the pinned beam attachments) will be also be attached to the barge by a system of shear keys and tie-down brackets welded and/or bolted to the skid and transporter frame. Additional tie-down struts attached to the canister will be provided to accommodate the additional barge loading requirements.

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