REMOVAL AND DISPOSITION OF THESURRY UNIT 2 RPV HEAD

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ABSTRACT

The Dominion owned Surry Unit 2 Nuclear Power Plant recently performed a Reactor Pressure Vessel (RPV) head replacement. This was the fourth replacement for the Dominion owned plants and was unique because it was the only one of the four plants to have the old RPV head packaged and dispositioned with the control rod drive mechanisms (CRDM’s) in tact. Until the Surry Unit 2 head replacement project all commercial PWR plants, which had dispositioned their old RPV heads, had either removed the CRDM’s and packaged the heads and CRDM’s separately, or placed the old head with intact CRDM’s in a mausoleum for on-site storage. This innovative approach to packaging the old head with intact CRDM’s resulted in a savings of 16 hours of critical path time and approximately 16 man-Rem of exposure; and allowed for off site disposal of this radioactive material.

WMG, Inc, a radioactive waste specialty company located in Peekskill, New York, designed the first-of-a-kind Intact Vessel Head Transport System (IVHTS). WMG was contracted by Dominion to package and dispose of the North Anna and Surry old RPV heads. Design of the IVHTS packaging was completed in July 2003 and fabrication was completed, on an accelerated schedule, by September 2003. An integrated function and load test was performed to ensure proper function of the down ending system with the packaging. The testing was completed in September 2003 with sufficient time to support delivery of the packaging and down ending system to the power plant for the outage. In fact, all equipment was delivered to the plant in time to allow for pre-assembly and hands-on training of the crew. The refueling outage began the first of October 2003 and was completed the beginning of November. The old head packaging installation was successfully completed the second week of the outage, without incident. The packaged head was moved to an interim storage location, adjacent to the dry fuel storage area, where it stayed until it was loaded onto the barge and shipped to the RACE processing facility in Memphis, Tennessee in October 2004.

This paper presents the results of the first use of the IVHTS packaging. It provides an overview of the major regulatory and design requirements associated with the packaging, transportation and disposition of old RPV heads; and chronicles the transportation and processing of the old Surry Unit 2 RPV head. The specific topics that are covered include radiological characterization methodology, shielding design, packaging design, transportation, and disposition.

INTRODUCTION/BACKGROUND

Dominion Power, the owner of North Anna Units 1 and 2 and Surry Units 1 and 2 hired WMG in November 2002 to disposition all four of their old RPV heads. The old RPV heads from the first three (3) Dominion plants (North Anna Unit 1, Unit 2, and Surry Unit 1) were packaged without the CRDM's. Due to scheduler constraints the CRDM's were removed and reused at both North Anna plants and the Surry Unit 1 plant. Dominion was faced with expending a significant amount of exposure and cost to remove, package, and dispose of the CRDM's for Surry Unit 2. In an effort to reduce exposure and cost Dominion solicited help to streamline the process. WMG met the challenge by way of the design of a unique patented packaging design that would house the old RPV head and the CRDM's. Dominion accepted this approach and authorized WMG to fabricate this new packaging. As with the previous packaging designed and fabricated by WMG, the IVHTS packaging was designed in accordance with DOT and NRC regulations to meet all of the transport and disposal requirements. The IVHTS packaging design is also unique in that it is reusable.

WMG applied to the Department of Transportation (DOT) for a manufacturer's exemption from provisions of 49CFR Part 173 for packaging and transportation of old RPV heads in this IVHTS packaging system. The DOT approval was granted, via exemption #DOT-E 13297, in April 2004. The Manufacturer's Exemption authorizes WMG to fabricate new packaging and/or reuse existing packaging for the dispositioning of RPV heads.

CHARACTERIZATION

The first step in the process of designing the packaging for the Surry Unit 2 RPV head with intact CRDM's was to characterize it. Waste characterization is the process which is utilized to determine both the waste classification for disposal in accordance with 10CFR61 (Reference 1) and the transportation classification in accordance with 49CFR173 (Reference 2). The primary nuclide distribution for the RPV head and CRDM's was determined based upon smear sample analysis (i.e., "Part 61 analysis"). Dose-to-curie conversion factors were established via detailed three-dimensional models and calculations then these conversion factors were applied to survey data to establish the amount of curies of each of the radionuclides.

The 49CFR173 transportation classification was established by comparing the surface activity of the RPV head and CRDM's to the LSA and SCO limits, and by comparing the nuclide activities to the corresponding A_2 values in 49CFR173. Based upon this comparison evaluation, the Surry Unit 2 RPV head was classified as > Type A, LSA material.

Accurate and current radiological and physical data is extremely important for accurate characterization of the waste. Complete operational power history of the reactor (including any and all fuel failures), the most recent radiological surveys of the RPV head and CRDM's, and all available smear samples of parts and pieces of the RPV head, reactor internals, and reactor coolant system piping near the reactor were obtained from Dominion for Surry Unit 2. Dominion also provided the "N-1" survey and smear data from the Spring 2002 plant outage (i.e., one cycle prior to the removal outage).

Physical data was collected for the development of an accurate model. This data included the specific dimensions and weights for the head and the CRDM's. The manufacturer's drawings provided this information as well as information on the materials of construction. A detailed, three dimensional shielding model of the RPV head with CRDM's attached was developed using this drawing information.

Additional requirements were evaluated to confirm that the RPV head shipping/disposal package design met all of the 49CFR173 transportation criteria which include (but are not limited to): the conveyance limits; the 3-meter unshielded dose rate limit, the exclusive use shipment criteria, the reportable quantities (RQ) limits, and the "Industrial Package" requirements. The Surry Unit 2 IVHTS package was designed such that it met all of the non-exempt 49CFR173 transportation criteria.

The Surry Unit 2 IVHTS package also had to be designed such that it would satisfy the waste acceptance criteria (WAC) for the disposition facility, which was in this case the RACE processing facility located in Memphis, Tennessee. 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.

Characterization Method

Characterization is a two-step process, which is required to document that the Department of Transportation (DOT) and disposition facility requirements for transport and disposition, respectively, are met. First, a detailed three-dimensional shielding model of the Surry Unit 2 head with intact CRDM's was prepared from the manufacturer's drawings. This model was used as input to QAD-CGGP-A. The nuclide distribution was established from the Part 61 analyzed smears obtained from the inside surfaces of the RPV head. The nuclide distribution was used in conjunction with the shielding model results to determine dose-to-curie factors for the survey measurement locations. Finally, the total activity of the interior surfaces of the RPV head and CRDM's was calculated using the measured dose rates and the dose-to-curie factors. The activity from activation of the RPV head and CRDM's was not considered because the neutron flux at the RPV head and/or CRDM region was too low to result in any discernable change in the total activity levels.

The resultant total contamination activity was homogeneously distributed on the interior surface area to obtain a surface contamination level (i.e., in Bq/cm^2 or $\mu Ci/cm^2$). The activity was decayed to the anticipated shipping date to obtain the approximate total activity and the total surface contamination level.

DOT Regulations for Package Design

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:

(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) Packages must meet the contamination control limits specified in 49CFR173.443;
(4) External radiation levels must comply with 49CFR173.441; and
(5) For LSA material and SCO the shipments must be "exclusive use"

The Surry Unit 2 head with intact CRDM's was evaluated, based upon these regulatory requirements, and this evaluation determined that it would have to be shipped in an Industrial Package (IP). The Surry Unit 2 RPV head with CRDM's attached exceeded the criteria for shipment in a "strong tight" container because it is greater than a Type A quantity of material

Shielding Evaluation

The IVHTS packaging was 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:

(1) 2 mSv/h (200 mrem/h) on the external surface of the package (49CFR173.441(b)(1))
(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 (49CFR173.441(b)(2))
(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 (49CFR173.441(b)(3))
(4) 0.02 mSv/h (2 mrem/h) in any normally occupied space (49CFR173.441(b)(4))

The IVHTS packaging is designed with the capability to add internal and external shielding, if necessary, to ensure that the packaged component meets these criteria. The maximum contact and 2-meter dose rates for the Surry Unit 2 head package were 1.1 mSv/h (110 mrem/h) and 0.08 mSv/h (8 mrem/h), respectively.

PACKAGING

Package Design

Package design must be in accordance with the requirements of 49CFR173 (Reference 2). 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. The IVHTS package components were designed and fabricated in accordance with the requirements of the American Institute for Steel Construction (Reference 3) and ANSI/AWS D1.1 (Reference 4).

Package Description

The IVHTS packaging (Figure 1) was designed to provide containment comparable to that of an Industrial Package Type 2 (IP-2). The WMG patented IVHTS consists of the RPV head, including the full-length CRDM’s, a bottom shield and contamination cover plate and three cylindrical ring sections. The total package weight for the loaded IVHTS shipping/disposal package for the Surry Unit 2 head was approximately 12,690 kg (340,000 lbs). It was 4.67 meters (15’-4”) in diameter and 8.43 metes (27’-8”) tall.

The major features of the package included: coating of the exterior surfaces of the old head with a fixative to isolate the exterior surfaces; closure of the old head with a bottom plate to provide shielding and make the interior contaminated surfaces inaccessible; containment of the CRDM bundle within a bag; and gasketed sealing of the vertical and horizontal flanged surfaces on the package to provide a seal between the radioactive contents and the environs.

Sealing of the package to the old head flange was accomplished via closure studs, nuts, and washers that attached the package upper sections and the bottom plate to the old head. The outer face of the old head flange was covered with InstaCote.

As shown in Figure 1 the IVHTS package configuration consisted of three (3) carbon steel flanged cylindrical sections and a bottom plate, which was bolted through the old head flange. Each of the four package sections is discussed separately below.

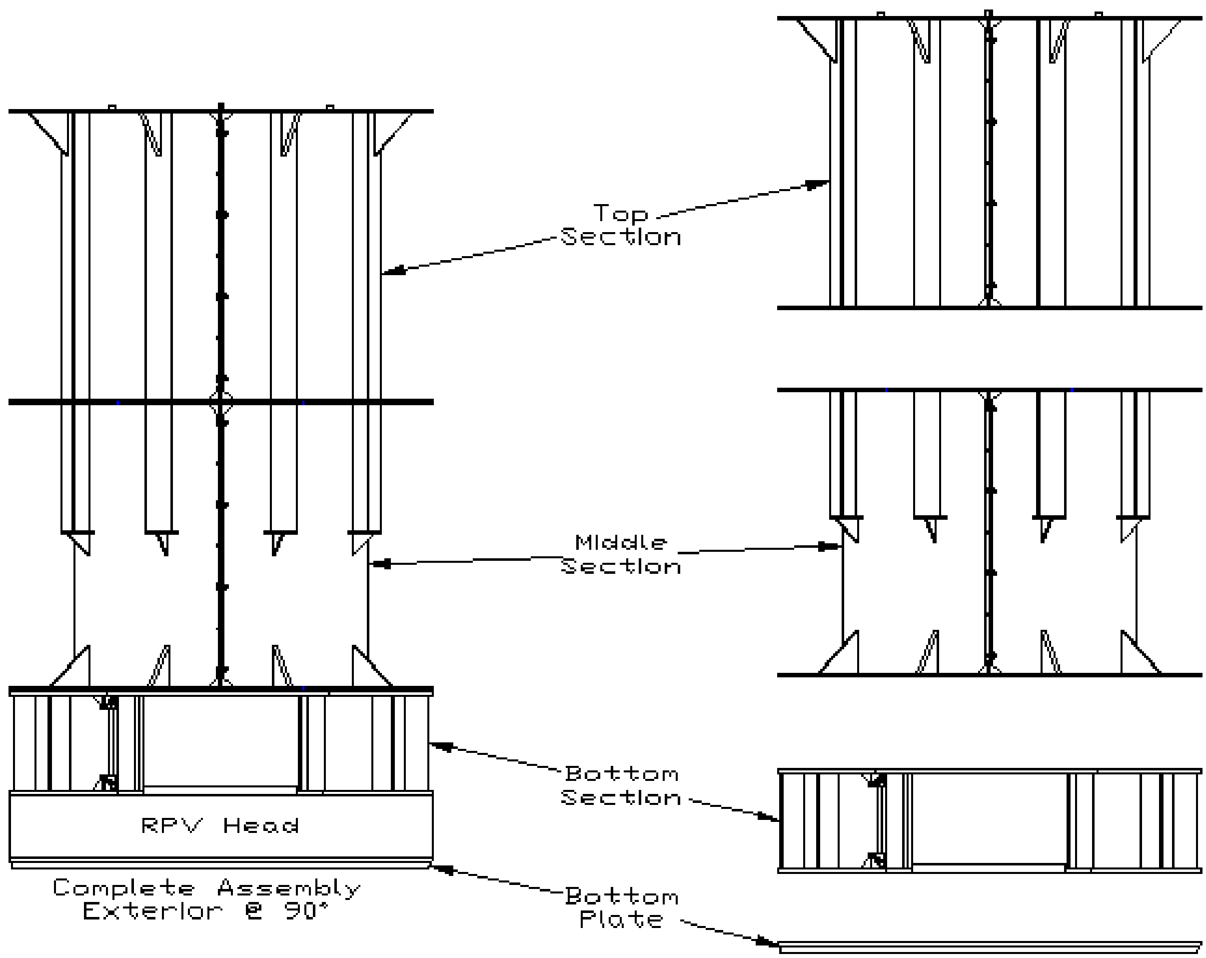

Fig. 1. Intact Vessel Head Transportation System (IVHTS) configuration

General Package Design Requirements

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:

(1) The package must be designed so that it can be easily handled and properly secured on a conveyance during transport (173.410(a)).
(2) 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 (173.410(b)).
(3) 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 (173.410(c)).
(4) The outer layer of the package must be designed to avoid, as far as practicable, pockets or crevices where water might collect (173.410(d)).
(5) Any added features must not reduce the safety of the package (173.410(e)).
(6) 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 (173.410(f)).
(7) 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 (173.410(g)).
(8) The package must be designed so that all valves through which the package contents could escape will be protected against unauthorized operation (173.410(h)).

All of these attributes were incorporated into the Surry Unit 2 packaging design.

Fig. 2. Surry unit 2 RPV head package on transporter

TRANSPORTATION

Transportation Mode Selection

Transportation encompasses movement of the packaged component from the site of origin (in this case the Surry Nuclear Power Plant) to the disposition facility (in this case the RACE processing facility in Memphis, TN). The modes of transportation, which were evaluated for the Surry Unit 2 RPV head, included rail, truck, and barge. Air transport was not an option because the expense was prohibitive.

Rail transport is subject to rail accessibility at the site of origin, railcar availability, and rail clearances along the travel path. The site of origin must have a rail spur that has been maintained, or is in a condition such that it can be refurbished without a great expense of time and money. For shipments of this size railcar availability is not generally a problem. Availability of a clear rail transport path from the shipping point of origination to the transport destination can also be a considerable issue with rail shipments. In the case of Surry Unit 2, the lack of an active rail spur was the main reason that rail transport was not considered. The cost associated with upgrading the rail spur into the site was not warranted since the truck and barge shipping options were very viable.

Dominion originally chose truck transport as the option of choice. Barge shipment, although a viable option, was not initially selected because Surry had not previously transported rad waste via barge and were not comfortable with this option. The original trucking company, which had the most experience shipping large radioactive components, was not allowed to perform the trucking due to Dominion's concern about pending litigation that this trucking company was involved with. As a result a new trucking company had to be selected. WMG developed a bid specification and began the process of finding another qualified trucking company that could ship the approximately 12,690 kg (340,000 lb) package from Surry, Virginia to Memphis, Tennessee. It took four months to secure a trucking company that had a large enough truck, and the hazardous materials license, to transport radioactive waste. The Oregon based trucking company that was selected had a "beam and dolly" truck, which was capable of hauling in excess of 14,930 kg (400,000 lbs).

With the contract in place the process of obtaining permit approvals through the Departments of Transportation (DOT) for the States of Virginia and Tennessee began. The Virginia DOT approved the truck transport after five months of deliberation. The Tennessee DOT however, would not approve the transport. Tennessee DOT argued that with major construction underway in Knoxville, Nashville, and Memphis simultaneously; and the fact that traffic control and road construction were hot topics that could tip the scales against the incumbent governor's reelection, there was no way that they would allow this shipment of radioactive waste shipment over their road system. Dominion had no leverage to force the issue because barge shipping of this package was a viable alternative to truck shipping.

Dominion requested WMG to pursue barge shipping of the package to RACE. WMG developed an RFQ and solicited quotes for barge transport. A contract was placed in July 2004 with Matrix Services to transport the package from the Surry site to the RACE processing facility. The Matrix scope of work included heavy hauling of the package at Surry and Memphis, loading and off-loading of the package to and from the barge, and the barge transport.

Transport – "The Journey"

The transport phase of the project began in July 2004, immediately following placement of the contract with Matrix Services. A significant planning effort had to be undertaken to complete the loading and shipment of the package by mid-September. Dominion had a narrow shipment window due to other previously scheduled work, including a planned outage. The project team established an open item list for tracking the major activities, which had to be completed, to accomplish this work effort. These activities included: notification of the US Coast Guard; selection of specific tug and barge for the project; performance of marine surveys of tug and barge to be used; obtaining soundings of the waterway surrounding the Surry barge slip; design and fabrication of package tie-downs; preparation of the barge deck for receipt of the package; completion of the land haul route evaluation; development of the barge shipping procedure; development of a transportation security plan; revision of the transportation and emergency response plan to support barge shipment; and development of a HazMat training plan in accordance with 49 CFR 172, Subpart H . All of these activities were completed by the end of August.

The project team began mobilization to the Surry site the first of September. By the middle of the second week all of the Matrix crew had been badged and trained. The Matrix crew and equipment were fully mobilized by the end of the second week. The barge arrived at the site on Sunday, 12th and the package roll-on was complete that day. The tie-down of the package was completed by Monday, September 13th and the barge pulled away from the slip (see Figure 3) the following morning on high tide, following completion of all of the courtesy notifications that Dominion had to make.

The barge-shipping phase had progressed smoothly up to this point in time. Hurricane season had just begun and the weather turned bad along the travel route. The tug and barge had to hold over in Newport News, Virginia until September 21st. They managed to get to Jacksonville, Florida by the 24th before Hurricane Jeanne impacted their travel and they were again forced to hold over and wait out the storm. On September 29th they got back underway and were able to complete the remainder of the journey unimpeded by weather. The tug and barge arrived at the Port of Memphis on Friday, October 8th. The entire journey took 25 days, which was 7 days longer that predicted, but 11 days were spent waiting out bad weather.

Off-loading the barge was completed successfully on Tuesday, October 12th via "Ichabod Crane", the 1250-ton stiff leg derrick crane at the Port of Memphis. It was loaded onto a heavy-haul transporter and rolled approximately 2.5 miles down the road on President's Island, to the RACE processing facility.

Fig. 3. Surry unit 2 RPV head package on barge

DISPOSITION

Disposition is the term used to encompass either the processing or direct disposal (i.e., burial) of radioactive waste or materials. Approximately half of the roughly one dozen PWR plants that have performed RPV head replacements to date have elected disposition over on-site storage. All but two of these plants have elected to dispose of their old heads at Envirocare of Utah’s LLW disposal facility. Two (2) of these plants had their heads processed at the RACE Processing Facility in Memphis, Tennessee. Surry Unit 2 was one of these two plants.

Dominion elected to have RACE process the old Surry Unit 2 head, in lieu of disposing of it Envirocare of Utah. The RACE processing facility was much closer to the Surry plant, which translated to decreased transportation costs and less risk of a transportation accident.

Processing

Processing of radioactive material is best described as decontaminating a component to the maximum extent practicable, while minimizing the amount of waste (i.e., both primary and secondary) so that the maximum amount of material from the component can be re-used. This is the primary objective in the processing of old RPV heads and CRDM’s, such as Surry Unit 2.

The extent to which processing is completed is a function of the material make-up of the component, it's geometry, it's age, the condition of the surfaces to be decontaminated, the operating history of the reactor plant from which it came, and the selection of the method(s) used for processing. Depending upon the condition of the component, it may only need only minor work to remove the fixed contamination to a level that allows it to be scrapped or smelted. Radiological surveys (i.e., "smear samples") of the RPV head and CRDM's (as applicable), and the radiological characterization data, are reviewed by the processor to help determine how best to handle the component and which method(s) to employ for decontamination.

Processing of old RPV heads and CRDM's (as applicable) is performed in a series of steps and usually entails the use of more than one method. It can be an iterative "hit-or-miss" process depending upon the tenacity, depth, and extent of the contamination. Processing begins with receipt of the component and the rigging and handling, which is necessary to place the component into a location and an orientation that is manageable. At this point the processor may decide to cut the component into smaller, more manageable pieces prior to decontaminating the component. Once this has been accomplished the task of decontamination of the component begins. The methods that can be utilized for decontamination include, but are not limited to, sand blasting, grit blasting, high pressure water blasting, and chemical etching. The processor will select one of these methods, based upon the component attributes discussed above (i.e., tenacity, depth, and extent of the contamination.) and the component geometry.

The processor establishes a contamination goal for the decontamination process, which is referred to as a decontamination factor (DF). If the initial decontamination effort does not achieve the DF that was established, additional processing methods will be employed. Any of the other decontamination methods mentioned above may be utilized to achieve the DF. If the additional decontamination efforts do not reduce the level of contamination sufficiently, and if the processor has not already cut the component into smaller pieces, he may do so at this point in the process, to achieve better access to the pieces and hopefully to obtain greater success with the decontamination. If decontamination efforts are still unsuccessful the processor has the option to package the pieces in standard radiological waste shipping containers and transport it to a Low Level Waste (LLW) disposal facility (e.g., Envirocare of Utah) for burial.

The Surry Unit 2 old RPV head package was received at the RACE processing facility in a horizontal orientation. RACE hired Barnhart Crane and Rigging to perform all of the rigging and handling operations at the RACE facility. The package was first off-loaded from the heavy hauler then upended. Once it was in the upright orientation, removal of the top ring section of the packaging was performed. The partially package head was then down-ended and rolled into the processing facility bay so that the exposed CRDM's protruded into the building. Skirting and tarps were draped around the package and over the floor then the exposed portion of the CRDM's were cut off into smaller sections that could be easily handled and packaged in standard radiological waste shipping containers. The package was pulled back out of the building and upended again so the remaining ring sections could be removed. It was then down-ended (see Figure 4) and pushed back into the building and the cutting process was completed.

The final phase of the process was to decontaminate the underside of the head via grit blasting. After the decontamination was completed the head was cut into sections small enough to package in standard radiological waste shipping containers. These pieces of waste and the compacted CRDM's were shipped to Envirocare of Utah for disposal.

It took RACE approximately 30 days to complete the in-house processing of the Surry Unit 2 RPV head. All of the waste was disposed of within 90 days from receipt of the head at the RACE processing facility.

Fig. 4. Down-ending partially packaged Surry U2 head at RACE

REFERENCES

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2. 49CFR173, Subpart I, Class 7 (Radioactive) Materials, Revised October 1, 1998
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5. ANSI N14.2, American National Standard "Tiedown for Truck Transport of Radioactive Waste"
6. 10CFR71, Packaging and Transportation of Radioactive Material