ONE-PIECE REACTOR REMOVAL AND DISPOSAL

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ABSTRACT

In the past, nuclear reactor pressure vessels (RPVs) have usually been disposed of by either:

- Segmenting them into many small pieces and placing these pieces into liners and shielded casks for transport to disposal sites, or

- Placing the entire reactor vessel (sometimes minus the closure head) inside a large, thick steel “shielding can” that serves as the transport cask.

The above methods create additional radwaste for disposal, and are very costly, time consuming, and segmentation exposes the workers to significant radiation dose. Also, placing the RPV into a “shield can” has usually been done only on relatively small research reactors, never on a large full size (greater than 900 MWe) commercial reactor. There is an alternative to these methods that is highly effective at reducing waste disposal volumes, cost and radiation exposure. This alternative consists of applying close-fitting external shielding to the outside of the reactor, removing the reactor in one-piece, leaving the internals inside of the reactor and disposing of the entire package via one shipment and one reduced volume package. This method was successfully proven on the 1130 MWe Trojan Nuclear Plant Reactor Vessel and Internals Removal (RVAIR) project that was completed in 1999.
INTRODUCTION

Portland General Electric Company’s Trojan Nuclear Plant is an 1130 MWe (net) Westinghouse 4-loop PWR. It is located on the Columbia River in Rainier, Oregon. It was shutdown in January 1993 after approximately 17 years of operation. The reactor vessel is approximately 17’ in diameter by 42 ½’ long. The reactor contained approximately 155 curies of internal surface contamination and 2.01 million curies of activated metal at the time of disposal. The disposal site for the decommissioning waste from the Trojan plant was the US Ecology low-level radioactive waste disposal site in the State of Washington.

For the Trojan Nuclear Plant’s Reactor Vessel And Internals Removal (RVAIR) project, Burns and Roe Enterprises developed a process of large (1100 MWe reactor) one-piece reactor shielding that does not use a large, external steel can or any segmentation of the vessel or internals. The Burns and Roe approach was to keep the externally applied shielding jacket weights and volumes to a minimum while still meeting all applicable NRC and DOT dose requirements for radwaste transport on public roads and rivers. This process, and the benefits it makes feasible, is described in this paper.

DESCRIPTION OF THE WORK

Burns and Roe’s one-piece reactor shielding process applies external shielding to the surface of the RPV for radiation shielding and qualifies the entire RPV with this shielding as the shipping package. This process provides several significant advantages to the owners of the RPV, including:

1. Major cost savings, estimated at $15 million for the Trojan project, compared to cutting up the vessel for disposal. These cost savings arise from some of the following design features and advantages:

   - Reduced overall burial volume compared to a large can to enclose the vessel.
   - Reduced grouting volume requirements.
   - Reduced volume and weight of the required shielding.
   - Reduced fabrication costs compared to a can that completely encloses the reactor.
   - Reduced package weight and associated transporter costs.

2. Reduced worker radiation dose.

3. Conservation of a national asset, compared to either of the other two alternatives, due to reduced burial site disposal volume.

4. Enhanced brittle fracture capability of the RPV due to tightening of the shield on the vessel.

5. Creation of a shipping package that meets the highway shipping requirements for radiation packages, without using a shielding can or cask.
The Burns and Roe one-piece reactor shielding process is unique for the following reasons:

1. The shielding system does not in any way reduce the ability of the RPV to be its own radioactive materials containment. This is a crucial requirement for any shielding system.

2. The system has been reviewed and accepted by the Nuclear Regulatory Commission (NRC) as an acceptable method of shielding a radioactive (activated) reactor vessel in conjunction with using the vessel as its own containment for the contained radioactive materials.

3. The shielding is securely attached in a non-integral manner to the reactor, without any welding of the shielding to the RPV structure. This is very important, since any welding on the RPV exposes the workers to high radiation dose and can raise questions as to whether the integrity of the RPV has been compromised.

4. The shielding is installed in stages thus reducing worker radiation exposure by allowing much of the installation work to be done remotely using straightforward techniques that do not require sophisticated equipment or robotics.

5. The shielding is first mechanically fastened, using features that enable rapid installation. Then, the shielding is welded to itself (not to the reactor vessel) so that it is impossible for it to come off of the vessel, except using significant cutting equipment. The prior mechanical attachment of the shielding provides worker radiation protection during the welding process. Multiple finite element analyses were used to demonstrate that the reactor shell stresses were below the acceptable allowable values required by 10 CFR 71.

6. The system allows two of the reactor’s nozzles to be used as parts of a longitudinal restraint system for the final package. By using these nozzles, the complexities of a more elaborate and expensive system are avoided. Multiple finite element analyses were used to demonstrate that these nozzles could not be overstressed under any of the 10 CFR 71 design conditions of transport.

Figures 1, 2 and 3 illustrate the above shielding/packaging concept. They depict the shielding components, how the reactor is placed inside the shielding, and the final one-piece RVAIR package with the shielding fully installed on the outside of the reactor vessel.
Fig. 1. Schematic of reactor Vessel Shielding
Fig. 2. Illustration of Reactor Installation Into Staged Shielding
Fig. 3. Lowering Shielded Reactor Onto Cradles and Cradle Support Steel
WASTE PACKAGE DESCRIPTION

The RVAIR package as described above was designed as a one time, exclusive use Type B shipping package in accordance with 10 CFR 71 “Packaging and Transportation of Radioactive Material”, with approved exemptions. Exemptions were approved for alternative approaches to the 1’ and 30’ drop requirements. These exemptions involved a more realistic definition of the probable drops that the package could experience. For example, a 30 foot drop was found to be incredible, since based on the package physical configuration, the highest distance the reactor vessel could drop was only 11 feet. This drop height, as well as a horizontal drop orientation, was used in lieu of the usual drop of 30 feet in any orientation. The Nuclear Regulatory Commission (NRC) did not issue an actual Type B C of C for the RVAIR package, but they did approve the package for a one time, exclusive use shipment. The RPV was classified as Class C waste for shallow land disposal as defined by 10 CFR 61 “Licensing Requirements for Land Disposal of Radioactive Waste”.

The reactor vessel contained all of the internal core support structures, which were constructed of stainless steel. The package enclosing the waste consisted of the reactor vessel and the upper closure head. No other closure mechanisms were used, except for closure plates welded over all of the cut nozzles on the vessel. No greater than Class C (GTCC) classified waste was removed from the internals, because the package was not considered to have any GTCC waste. This was accomplished because the waste contents in the reactor were found to meet section 3.9 of the NRC’s 1/17/95 “Issuance of Final Branch Technical Position on concentration Averaging and Encapsulation.”

RESULTS

The Trojan RVAIR was a highly successful project. All phases of the work were finished either on or ahead of schedule, the person-rem exposure was approximately ½ the estimated exposure and far below the estimates for vessel segmentation, and the total project was completed for millions of dollars less than had been estimated. Specific and significant results of this project are described below:

- One-piece package with internals was qualified as a Type B package (as exempted)
- Significant cost savings over segmentation, i.e., approximately $15-19 million overall
- Significant waste burial volume savings over segmentation (8,341 ft³ vs. 18,320 for vessel and internals)
- Savings in burial volume translates to millions in saved burial fees and project cost
- Increased transportation safety due to 1 shipment instead of 45 for the segmented case
- Reactor package qualified to be shipped with the most radioactive internals included in the shipment (total of over 2 million curies in package)
- Significant person-rem savings over segmentation (67 actual person-rem vs. 133 for segmentation)
- Largest One-Piece Reactor Package @ 1020 Tons
- Largest package with externally applied rolled shielding that was not welded to the vessel

Overall, this was a precedent setting project that has demonstrated a cost-effective method for handling and disposing large radioactive packages. Figure 4 shows the finished waste package on the barge that transported the RVAIR up the Columbia River to the disposal site.
Fig. 4. Final Reactor Package Loaded On Transporter and Barge