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In the past, nuclear reactor pressure vessels (RPVs) have been disposed of either by segmenting them into many small pieces and placing these pieces into liners and shielded casks for transport to disposal sites or by placing the entire reactor vessel (sometimes minus the closure head) inside a large, thick steel shielding can that serves as the transport cask. These methods are very costly and 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 [>900-MW (electric)] commercial reactor. There is an alternative to these methods that is more effective in both cost and person-rem exposure.

DESCRIPTION OF WORK

For the Trojan Nuclear Plant's Reactor Vessel And Internals Removal (RVAIR) project, Burns and Roe Enterprises developed a process of large [1100-MW (electric) reactor] *one-piece* reactor removal shielding that does not use a steel can. This 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:
    a. reduced overall burial volume compared to a large can to enclose the vessel
    b. reduced grouting volume requirements
    c. reduced volume and weight of the required shielding
    d. reduced fabrication costs compared to a can that completely encloses the reactor
    e. reduced package weight and associated transporter costs
2. reduced worker radiation dose
3. reduced burial site disposal volume, i.e., conservation of a national asset, compared to either of the other two alternatives
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 radioacive materials containment. This is a crucial requirement for any shielding system.
2. The system has been reviewed and accepted by the U.S. 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 nonintegral manner to the reactor, without any welding of the shielding to the RPV structure. This is very important because 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.

Figure 1 illustrates the forgoing shielding/packaging concept.

Figure 1. Shielding Packaging Concept

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 one-half the estimated exposure and far below the estimates for vessel segmentation, and the total project was completed for about $4 million less than estimated and approximately one-half the cost of vessel segmentation.