Reactor Vessel Removal: Improving Performance
Big Rock Point Lessons Learned

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ABSTRACT

The Big Rock Point (BRP) reactor vessel was successfully removed, packaged in a Type B shipping container, transported, and buried. The process took almost 4 years of work by many people and a variety of companies. This paper will discuss several areas that can reduce schedule time, resulting in reduced cost and employee dose exposure. For maximum cost effectiveness, these lessons should be applied during the planning stages when developing baseline cost and schedule, As Low As Reasonably Achievable (ALARA) budgets, and work processes.

INTRODUCTION

BNG America (formally BNFL Inc.) was awarded the Major Component Removal Contract for BRP in 1998. BNG America assembled a team of experienced personnel and companies to provide the engineering, licensing, container fabrication, and rigging expertise. Sargent & Lundy was chosen as the design authority for the Type B container and brought extensive commercial nuclear experience in the area of container licensing. Having the right team with the right experience and key personnel for the task was the Number One lesson learned. This combination allowed the team to overcome numerous obstacles.

CONTINGENCY WORK PLANS

Contingency plans for off normal events must be established in detail. This enabled work to continue with little interruption when events occurred. These plans were a form of risk management taken to the working level.

Work procedures for each major task were developed detailing the approach to the task, the hazards involved, and controls to mitigate the hazards, and the roles and responsibilities of both individuals and organizations. In addition, planning sessions were held to brainstorm “what if” scenarios to capture possible off normal events or issues that could stop the work from proceeding. These included such things as unanticipated contamination, higher dose levels, adverse weather, precursor events not taking place, and possible procurement delays.

For each of the credible risks that could adversely affect safety, cost, and schedule, a contingency plan and steps were developed and attached to the major work plan. This allowed the field supervisor and engineer to consult these plans if a change were encountered and implement it without further review and approval. On several occasions, this process saved a tremendous amount of schedule time that would have been required to write a new work plan with more reviews and approvals while the job was stopped. Instead, this process allowed the field personnel to make notifications to management, re-brief the crews, and continue with the work.

In addition to having contingency work plans, it was important to clearly note what could and could not be performed in parallel. This saved time when temporary holds were placed on work and allowed the field crews to move on to parallel work while the issue that stopped the task was resolved. For complicated tasks a sequence diagram similar to a Primavera (P3) schedule was drawn up to show parallel and sequential work steps.

EXTRA TIME NEEDED TO REMOVE INTERFERENCES

Spending the time and dose needed to ensure all possible equipment clearance interferences were identified and removed prior to attempting to remove the reactor vessel paid dividends. BRP had very limited access in and around the reactor cavity. Very small interferences, such as mirror insulation brackets which used to attach the insulation to the reactor vessel could stop the actual lift. Fig. 1 shows the limited amount of clearance between the reactor vessel and the reactor cavity wall. The photograph shows a cut reactor support plate and a small nozzle capped with a mechanical plug. The wing nut on the mechanical plug is touching the cavity wall.

During construction in the early 1960's, the reactor vessel at BRP was placed into containment and the biological shield constructed around the vessel. There were no design considerations to facilitate the removal of the reactor vessel. In addition, the BRP reactor vessel was designed to leak neutrons to support ex-vessel experiments early in its operating life. This design feature resulted in very highly activated vessel walls and biological shield. Because of the high dose levels entries to cut and remove penetrations and interferences were kept to the minimum amount. However, once reactor removal began, small items such as clips used to hold mirror insulation and other small interferences required additional work while the vessel was on the crane hook.

It is very unlikely that such a high dose reactor vessel removal will be encountered in the future, but ensuring there is adequate clearance within the reactor cavity by removing interference will ensure a problem free lift and removal. One item that stopped the BRP lift on a temporary basis was a small part of a pipe sleeve protruding from the cavity wall. The pipe sleeve was not an issue until the vessel was lifted, and one of the lower nozzle stubs caught and stopped the lift. This problem required a lot of effort to identify and caused unplanned employee dose.

Fig. 1. Clearance between reactor vessel and cavity wall

GROUTING OF THE REACTOR VESSEL PRIOR TO REMOVAL SAVES DOSE

Grouting the vessel prior to removal to reduce dose levels during the preparation work and actual removal should be the first consideration. BRP was unable to grout the vessel until after it was placed into the shipping container because the crane capacity was insufficient to lift the combined weight of the vessel and grout.

BRP used the installed containment crane to remove the reactor vessel and place it into a Type B container. The lift was very near the working capacity of the crane and therefore the vessel could not be grouted prior to lift. The lack of added crane capacity increased the amount of employee dose received both during reactor vessel preparation work and during the actual lift and placement into the container. Had the project used a larger capacity external crane and cut an access into the containment, the result would have been much lower exposure.

The approach used filled the internal of the vessel with Low Density Cellular Concrete (LDCC) with a density of around 25 to 30 pounds per cubic foot. This is about half the density of water and provided significant shielding. It also reduced the overall weight of the vessel for subsequent shipping. During BRP reactor vessel preparations work, all the nozzles penetrating the vessel were cut and capped. For the upper nozzles, water was added to just below the nozzle to ensure maximum shielding while performing the work. However, the work on the lower nozzles required the vessel to be almost completely drained. Therefore the work was performed without the benefit of the shielding provided by the water. The use of LDCC would have simplified the work by allowing the workers added stay time and the overall dose would have been significantly lower. The BRP reactor vessel was grouted using LDCC once it was placed into its shipping container.

SIMPLIFY THE CAPPING OF THE REACTOR NOZZLES

Following nozzle cutting, the nozzle ends were capped for two reasons; the first was to ensure the grout from inside the vessel would not flow into the annulus of the shipping container. The design called for two different densities with the internal grout density higher to maximize shielding and the annulus a lower density to keep the weight of the package down. The second reason for capping the nozzles was for contamination control, especially airborne contamination during removal.

Spot welding, then using epoxy resin when installing caps on the RV nozzles saved time and employee dose. The work process called for placement of mechanical plugs within the inside diameter of the small nozzles and welding ¼ inch steel plates over the large nozzles. The mechanical plugs installed quickly and performed their function. The steel plates took longer to install and often were hard to weld due to location and the fact that most nozzles were not cut square to the plate's surface. These complications took more time and, therefore, generated more dose. Some large nozzles could not be welded completely, so a two-part epoxy completed the seal.

In the end it was determined that, for the purpose the caps would serve, they should be spot welded into place and epoxy used to seal the caps. This approach used a fraction of the time and dose compared to a full seal weld and was very effective. Since the grout was very low density and was placed in lifts of no more than 8 feet at a time, the largest pressure on any cap was less than 2 pounds per square inch. Fig. 2 shows the reactor vessel lifted clear of the cavity. In this photograph you can see the upper nozzles. The one nozzle with the white material is the cap that was spot welded with epoxy applied to complete the seal.

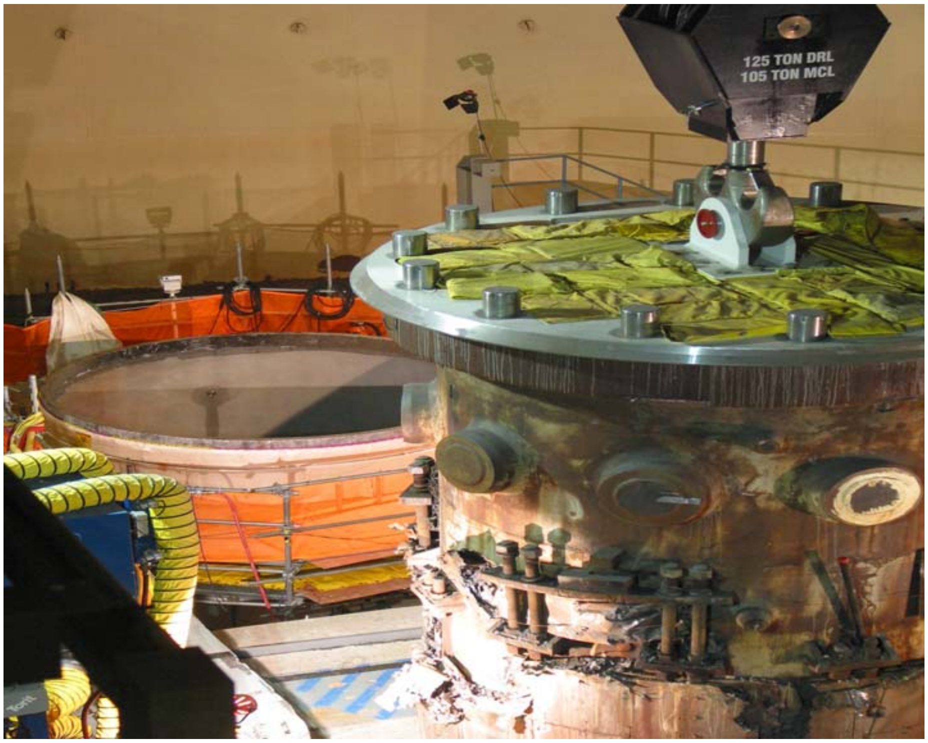

Fig. 2. Reactor vessel nozzles capped by welding and epoxy

REDUCTION OF EMPLOYEE DOSE DURING WELDING

Welding of the container lid resulted in higher dose exposure than expected. This was a consequence of the length of time it took to make multiple passes. The use of automated welding machines required personnel to change wire spools and make frequent adjustments and inspections. Therefore, it is recommended to plan for added temporary shielding and work platforms that allow for the added weight. Fig. 3 shows the welding set up used for the BRP lid welding.

The use of automated welding machines did not have the desired savings in expected dose. The container lid for BRP required a 4- inch full penetration weld that required a large amount of fill material. The wire spools were required frequent changeout and manual welding machine adjustments. The added dose would not have been an issue had the vessel been grouted prior to placement into the container. After the welding had commenced, it was obvious that the dose budget for welding would be exceeded. Additional temporary shielding was then added to the top of the container. In hindsight, for a similar situation where one could not grout prior to placement into the container, a better approach would be to place several feet of grout in the bottom of the container and place the vessel in the container. The lid should then be set in the correct location for welding and tacked in place. When the grout is set, the internal cavity of the reactor vessel can be filled with grout up to the upper nozzles covering the most activated parts of the vessel. Then the welding can be completed with much lower dose exposure.

Fig. 3. Welding of the reactor vessel container lid

VIDEO CAMERA USE

Expanding the use of cameras during removal to include the view under vessel movement, vessel position, and any potential interference would help avoid problems. BRP experienced a small piece of metal catching on the bottom of the vessel that stopped the lift after about 18 inches. The inference was only discovered by personnel making an entry and using mirrors to view the underside of the vessel.

Small video cameras are inexpensive, and cameras should cover every possible angle during the removal of any high rad component to look for interferences, monitor employee stay times, and provide interested stakeholders the opportunity to view the work from a remote location. Good lighting is also a must to ensure all aspects of the lift can be viewed. Extra cameras, cables, lights, and monitors should also be staged to account for failed, damaged, or inoperable equipment.

MIRROR INSULATION BRACKET REMOVAL

Removing mirror insulation and brackets prior to lifting the vessel prevents the material from catching on the cavity walls. BRP reactor cavity allowed only a ¾ inch clearance between the vessel and the cavity wall and, therefore, the crews were unable to remove all the mirror insulation, and individual brackets were removed with torches during the removal lift.

The mirror insulation and brackets attached to vessel walls should be removed where accessible. Personnel using long handle torches should be staged and ready to burn off any brackets that may get caught on the cavity wall. These brackets proved to be a major nuisance during the lift as the brackets were welded to the vessel wall, difficult to locate, access and remove. This was exacerbated when lifting the vessel. If it was not perfectly centered within the cavity, the vessel would drag or catch the mirror insulation brackets. Taking more time prior to the lift to remove any brackets or mirror insulation can mitigate the risk of having to stop.

GROUT DENSITY TOLERANCE

Grouting the RV with low density grout should start with a wide density tolerance band, considering weight and shielding limitations. The package for BRP was a Type B container designed and fabricated under a 10 CFR 71 QA program and a Nuclear Regulatory Commission (NRC) approved Safety Analysis Report (SAR). The design had specified a density tolerance of only a few pounds for the grout which resulted in delays during mixing and placement of the grout as each batch was tested. In hindsight the lower the density, the more difficult it was to obtain on a consistent basis and a very tight tolerance on the density was not required. It was discovered that during the pumping of the grout that the density would increase. When sampled at the mixer, the grout was within specification. However, when sampled at the top of the container where it was injected, the density was too high. The process was mocked up, and it was determined that the grout would compress when pumped to a higher elevation. Then the grout would expand back to its lower density when placed into the vessel. LDCC was a series of air bubbles trapped within a Portland cement mixture, and it was found that the air bubbles would compress and expand back. Given the shielding and package weight constraints allowing for the largest tolerance in grout, density will speed the process and reduce waste from batches that are out of specification.

CRANE CAPACITY

Use a wide margin in lifting capacity to ensure that any contact between the vessel and the cavity wall will not impact removal. BRP crane capacity was just slightly higher than the RV load. When the vessel was not perfectly centered within the cavity, the added load due to the friction would stop the lift. Utilizing a lifting capacity well in excess of the package weight will help prevent stopping the lift due to the small interferences and drag from a tight reactor cavity (as discussed above). It also adds a greater margin of safety. The incremental cost between mobilizing a larger crane is insignificant compared to potential schedule impacts from a stopped lift.

REACTOR VESSEL LAY DOWN CONTINGENCY

As a contingency, develop a plan to support the RV after cutting it free of the supports should a problem occur. BRP experienced a problem where the holding brake for the crane was not functioning as it should, and the load had to be removed in order to correct the problem.

Plan for the unexpected such as a crane malfunction during the reactor vessel lift. A cribbing arrangement had been placed under the reactor vessel at BRP as a precaution should the vessel have to be set back down after the reactor supports were cut. It was decided when the crane problem was identified to place jack stands under the vessel flange to keep the vessel level rather than place the reactor vessel on the cribbing. The crane hook had to be removed to perform the corrective maintenance on the holding brake.

QA PROGRAM

Spend the resources needed to ensure a robust QA program and controls for the entire process. Early resource loading for QA did not provide the confidence needed by the customer and regulatory. The project took steps to increase QA oversight during the container fabrication, shipment, and transportation, and it paid dividends in providing assurance to the regulators and customer.

Once the reactor vessel is welded into the container and the container voids grouted, there is no going back. Therefore, ensuring that a robust QA program is in place to provide independent review and verify all the required steps have been taken will provide confidence to stakeholders that the package is fully compliant and ready for transportation to burial (Fig. 4. shows the BRP reactor container ready for off site shipment). Strong oversight and independent checks help answer questions from regulators and provides the confidence to the customer.

Fig. 4. BRP reactor package loaded onto a heavy haul trailer using hydraulic jacks

CONCLUSION

Each project has different challenges however, these lessons can be applied to any large component removal activity involving high radiation dose levels. It is obvious for facilities that have the luxury of allowing their reactor vessels to decay for 30 years or more have a much easier task in removing and shipping. Removal of high dose components can be safely accomplished with a lot of planning and thought given to limiting employee dose.