SEGMENTATION AND REMOVAL OF THE CAROLINAS-VIRGINIA TUBE REACTOR (CVTR) MODERATOR TANK

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Special tooling was designed and deployed to segment the Moderator Tank (MT) at the CVTR Parr site near Jenkinsville, South Carolina. The MT, or reactor vessel, had to be segmented into sections to fit within three hardware liners and three custom built boxes. The MT was the most activated component remaining on site and included over 1,000 Ci of activation products This work was completed in approximately 12 months from tool conception to final packaging with no spread of contamination and no generation of secondary wastes, minimizing personnel radiological exposure

Facility Description

The CVTR facility went critical in 1963 as the first commercial nuclear power plant in the southeastern United States. The plant encountered two refueling outages during its operational life. In 1967, the plant was closed and the facility was placed in a shutdown condition. In June 2005, the Carolinas-Virginia Nuclear Power Associates (CVNPA) sought proposals for the removal of the remaining activated components from within the Reactor Building. With contact dose readings in excess of 90 R/hr, segmentation of the MT would have to be performed remotely and with the assurance that the spread of contamination to clean areas of the reactor building would not occur. Additionally, since the MT had been entombed within a bioshield not capable of containing water, cutting would have to be performed dry without the benefit of shielding typically provided by the water of a spent fuel pool, cavity or canal. Furthermore, selected processes could not spread contamination to otherwise clean areas of the reactor building.

Figure 1 shows the MT as part of the reactor assembly. The tank was an upright cylindrical vessel, 111 inches in diameter and 190 inches high, closed at the bottom with an ellipsoidal head. The vessel was fabricated of type 304 stainless steel. The cylindrical side shell was 3/16 inch thick, while the bottom head was 5/8 inch thick. The top of the vessel was open to the header cavity. The upper 46 inches of the tank, or the weir region, was reduced in diameter to 88 inches by an inner cylindrical shell to reduce the contained volume of heavy water. The top of the shell formed the outlet weir and controlled the depth of liquid in the tank during operation. Aggregate shielding, consisting of borax, barites sand, and steel punchings, was contained in the annulus space of the weir region below the overflow region. Eight structural members extended radially outward from the weir region of the tank to bearing pads mounted on the concrete primary biological shield, or bioshield.

Moderator flow was introduced through a single 6-inch pipe nozzle at the center of the bottom head. The desired flow distribution in the tank was produced by an inlet baffle and a perforated distributor plate near the bottom of the tank. Moderator flow was upward through the distribution plate, over the weir, and downward through four 6-inch outlet lines.

Thermal shields, which surrounded the sides and bottom of the MT, were installed to attenuate the core, capture gamma radiation, and lower the neutron flux to levels that prevented excessive thermal gradients in the concrete bioshield. The side shields consisted of eight vertical, rectangular carbon steel slabs having a uniform thickness of 9 inches. The eight slabs formed an octagon-shaped enclosure around the MT. The bottom thermal shield consisted of two 9-inch thick plates that fitted together, tightly conforming to the inside face of the side shields. Cooling of the thermal shields was accomplished by the flow of component cooling water through carbon steel channels welded to the back of each plate.

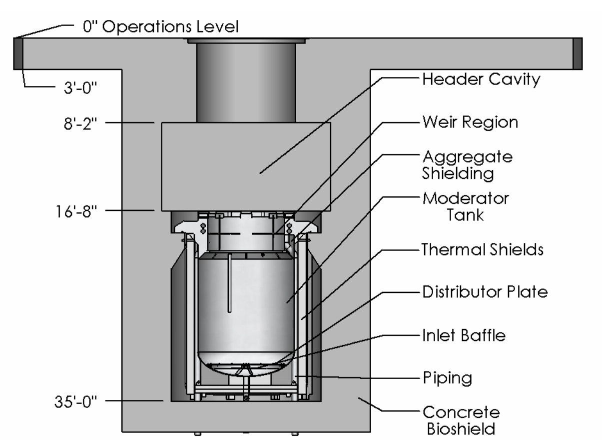

Figure 1, CVNPA Parr Site Reactor

Conceptual Tooling

Given that the stainless steel MT was characterized to contain at least 165 μCi/g of Co-60, mechanical segmentation techniques were chosen exclusively for segmentation. Segmentation debris resulting from mechanical segmentation techniques neither creates activated aerosols nor introduces other secondary waste products, thereby minimizing spread of contamination to other clean areas of the reactor building. Three different segmentation systems were deployed to reduce the MT into sections appropriate for disposal in hardware liners and packages. These systems included the C-HORCE, 38i and the pipe saw.

The C-HORCE, shown in fig. 2, is a circular frame capable of deploying an endmill cutter along a 375-degree polar axis. The C-HORCE was used to segment the distributor plate and remove the bolts that fastened it to the tank bottom using a standard endmill. Additionally, the C-HORCE removed a 56-inch diameter section of the bottom head of the MT.

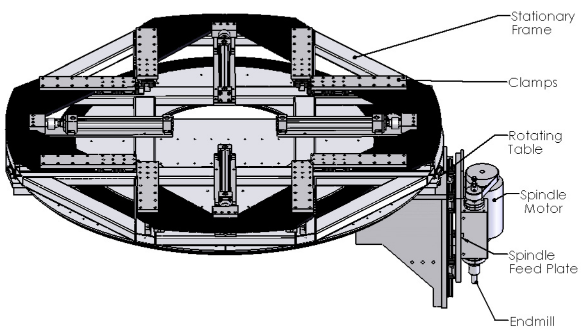

Figure 2, C-HORCE Endmill Configuration

Refitted with an alternate cutting head, as shown in fig. 3, to deliver a slot cutting blade about the frames perimeter, the C-HORCE was used to cut through the sidewall of the MT at four different elevations.

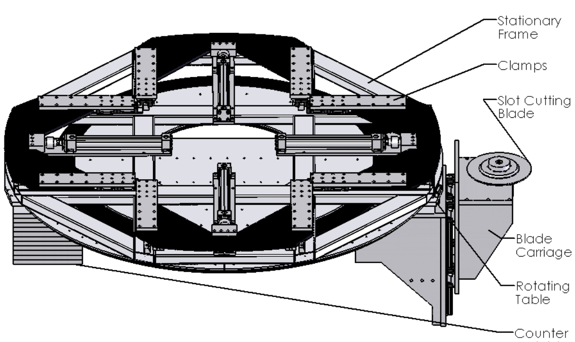

Figure 3, C-HORCE Slot Cutting Configuration

The 38i, shown in fig. 4, included a tower that clamped to the inside of the MT and was used to cut the bottom head and sidewall using a 38-inch 120-tooth carbide tipped saw blade. It also was used to segment through the double walled weir region of the MT with a total cut thickness in excess of 13-inches.

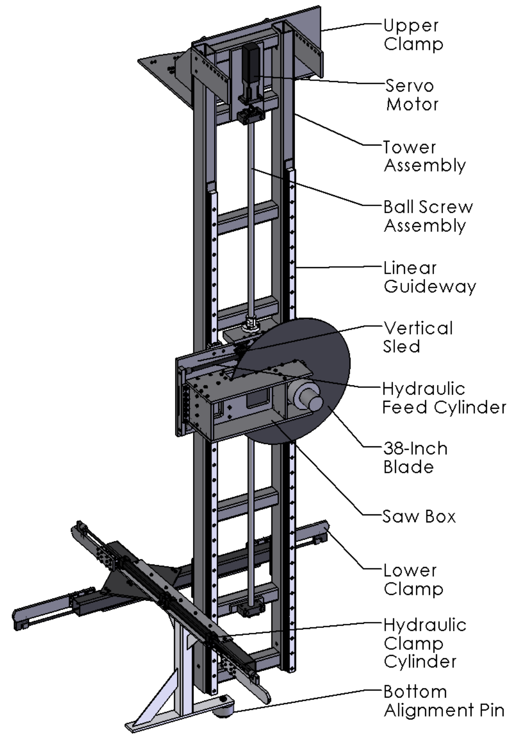

Figure 4, 38i

The pipe saw, shown in fig. 5, was used to cut the MT piping that included two 8-inch overflow pipes, a 6-inch inlet line and four 6-inch outlet lines. The pipe saw included a pneumatic clamping fixture that fed a customized reciprocating hacksaw through the schedule 40 stainless steel pipe without removal from the biological shield cavity.

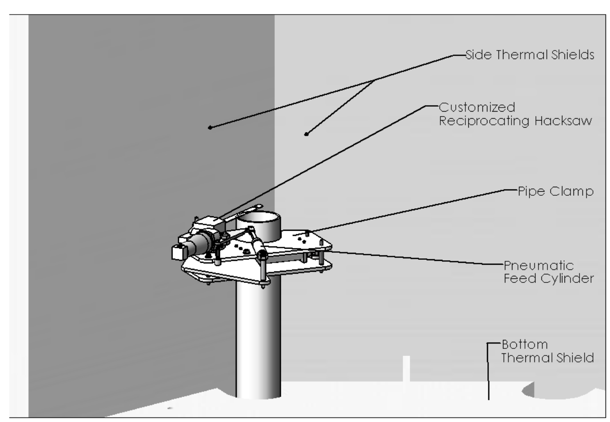

Figure 5, Pipe Saw

Moderator Tank Removal

Previous decommissioning activities removed the pressure tubes from within the MT. Minor amounts of loose debris remained within the MT. At the beginning of removal activities, the MT remained sealed within the bioshield below the header cavity liner and tank access ring. Activities associated with the removal of these exterior items were some of the initial activities required prior to the deployment of the segmentation systems. Once exposed, the internal components of the MT could be collected, segmented and packaged for disposal. The equipment was developed to remove the MT from the bottom up exposing the piping. Prior to removal of the last section of the MT, or the weir region, the exposed piping was removed using the pipe saw.

To obtain access to the MT for the segmentation equipment, entry was required into the header cavity. To reduce personnel exposure, a precast concrete plug was designed to fit within the weir region void where the previously removed neutron shield was installed.

Technicians used common hand tools to remove the header cavity liner exposing the access ring installed around the top of the MT. The access ring covered the annulus space between the MT and inner wall of the bioshield. Remnants of the ring were removed from the header cavity and packaged in staged waste containers.

The aggregate shielding packed within the annulus space of the weir region had to be removed prior to deployment of segmentation equipment. The abrasive properties of this shielding would have certainly damaged cutters used during tank segmentation and could result in uncontrolled spread of airborne particles if disturbed by the cutters. Using custom arbors and cutters, access holes were machined through the aggregate seal plate to expose the aggregate. Then, using a high powered HEPA vacuum equipment, the aggregate shielding was removed and collected within several barrels.

Previous decommissioning activities included the removal of the pressure tube guide sleeves from the distributor plate. However, the sleeves and fasteners were left in place on the distributor plate after they were unbolted. Using long handled tools, technicians collected and packaged this debris.

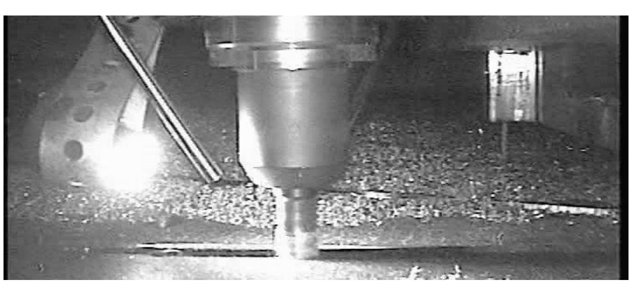

Figure 6, C-HORCE Endmill Configuration

The C-HORCE was then installed into the MT to segment the flow distributor plate into six 60-degree sections as shown in fig. 6. The C-HORCE deployed a ¾-inch endmill. With each pass of the cutter, nearly 0.010-inches of the plate was removed. Each 45-inch long cut would require as many as 140 passes. At the conclusion of the eight cuts, the C-HORCE was then used to machine the heads off of the 36 bolts that fastened the distributor plate to the MT. Each of these bolts were welded in place which eliminated the possibility to remove the plate by other mechanical means.

After the distributor plate sections were removed, the 38i was used to cut through the lower head of the MT as shown in fig. 7. The blade was plunged through the bottom head such that the inside edge of the cut was within a 56-inch diameter circle about the center of the tank. This allowed the removal of the center section of the lower head in one piece. The 56-inch limit was driven by the opening of the hardware liners.

Figure 7, Bridge view of 38i after lower head cuts

The C-HORCE was then reinstalled within the MT configured with the endmill cutter. In this application, the endmill was delivered about a 56-inch diameter circle connecting the lower ends of the previous 38i cuts shown in fig. 8. After the eight 45 degree arcs were completed, the C-HORCE was reconfigured to deploy a circular slot cutting blade that was used to segment through the MT sidewall connecting the upper region of the initial 38i cuts performed on the lower head shown in fig. 9.

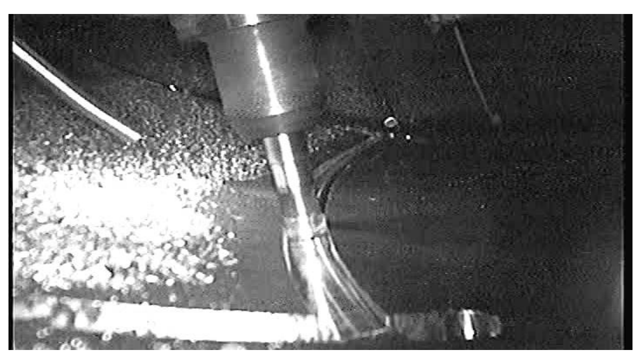

Figure 8, Cutting through the MT bottom head

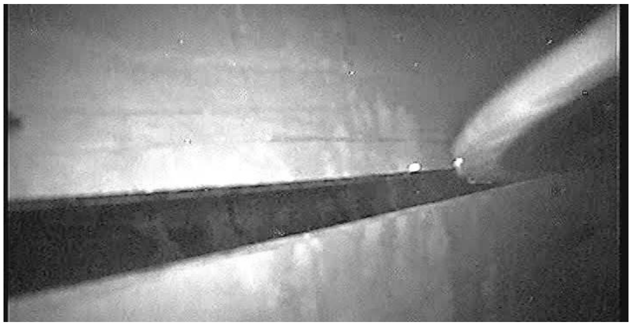

Figure 9, C-HORCE MT Sidewall Cutting

After the removal of the MT center and the remaining 45-degree sections of the lower head, the 38i was used to vertically cut the MT sidewall as shown in fig. 10. The length of the cut was limited to 32-inches. After eight vertical cuts were made, the C-HORCE would again cut and release the 45-degree sections of the MT. This sequence was repeated three times to remove the vertical sidewall section of the MT. These sections accumulated at the base of the cavity to be collected and loaded in one packaging campaign.

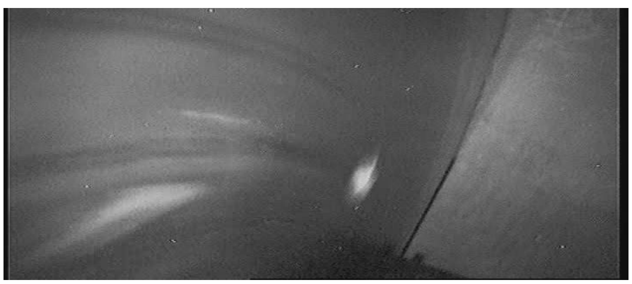

Figure 10, 38i Vertical Sidewall Cut

The 38i and C-HORCE were alternated to remove 4 separate elevations of MT sidewall. Technicians collected and disposed of these remnants using long handled tools and remote actuating plate clamps. As the sidewall was removed, the MT piping was exposed. Removal of the MT piping was complicated by the location of the thermal shields. Each of the four 6-inch outlet lines were essentially located in the corner made by the intersecting vertical side shields. Without sufficient clearance around the pipe for conventional pipe cutters, a special clamp was designed to deliver a modified air powered hacksaw shown in fig. 11.

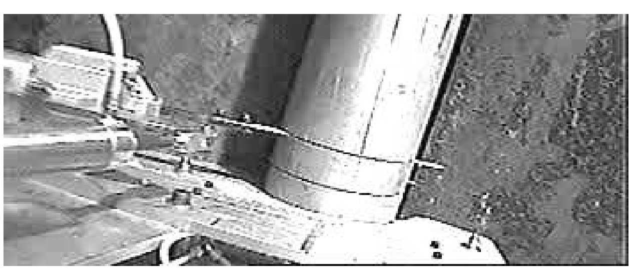

Figure 11, Pipe Saw cutting MT outlet pipe

The most challenging cut was the double walled weir region. The total cross sectional depth of the cut was 13.5 inches. The remaining portion of the MT was supported by structural members extending from this region. Special clamps and braces were designed and installed to allow the cutting shown in fig. 12 of this region of the MT without allowing it to collapse from its supports.

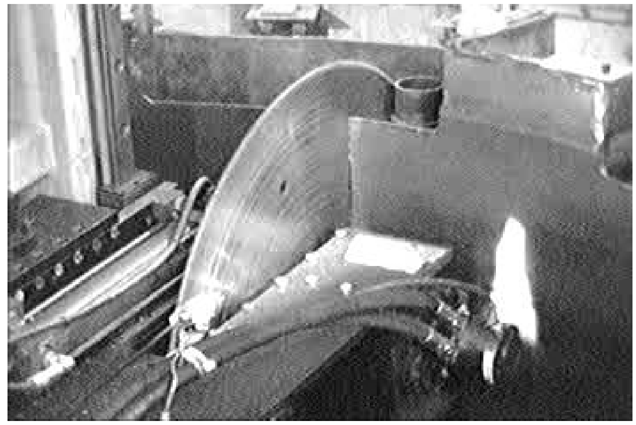

Figure 12, 38i cutting weir section

Conclusion

Formal concept and final engineering design began in January 2006. Each tool was subjected to integrated mock-up testing on a full scale model of the MT prior to delivery to the project site. The first equipment was delivered to the project site in May 2006 The MT segmentation activities concluded in December 2006 with no spread of contamination, no generation of secondary wastes and total accumulated exposure of 13.9 person rem as illustrated by fig. 13.

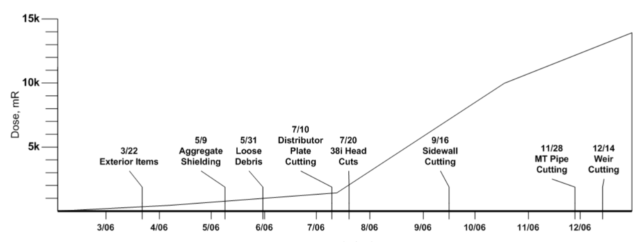

Figure 13, Schedule Timeline and Actual Accumulated Dose

The mechanical methods used to segment the MT introduced no secondary waste and created no contaminated aerosols. The segmentation debris or chips created were collected using a high powered HEPA vacuum system. These chips were collected in flexible bags and loaded into voids in the hardware liners. The cold cutting and milling processes created no contaminated aerosols allowing the CVNPA to immediately begin the final demolition phase of the decommissioning plan without delay of additional reactor building decontamination.