REMOVAL, TRANSPORTATION AND DISPOSAL OF THE MILLSTONE 2 NEUTRON THERMAL SHIELD

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ABSTRACT

Some PWR reactors equipped with neutron thermal shields (NTS) have experienced severe neutron shield degradation to the extent that removal and disposal of these shields has become necessary. Due to the relative size and activation levels of the thermal shield, disposal techniques, remote material handling and transportation equipment must be carefully evaluated to minimize plant down time and maintain disposal costs at a minimum. This paper describes the techniques, equipment and methodology employed in the removal, transportation and disposal of the NTS at the Millstone 2 Nuclear Generating Station, a PWR facility owned and operated by Northeast Utilities of Hartford, CT. Specific areas addressed include: (1) remote underwater equipment and tooling for use in segmenting and loading the thermal shield in a disposal liner; (2) adaptation of the General Electric IF-300 Irradiated Fuel Cask for transportation of the NTS for disposal; (3) Equipment and techniques used for cask handling and liner burial at the Low Level Radioactive Waste (LLRW) disposal facility.

INTRODUCTION

In 1983 the Millstone 2 nuclear generating station, owned and operated by Northeast Utilities, determined the reactor's neutron thermal shield (NTS) had embrittled and deteriorated to the point that removal and disposal was the most prudent option available. The utility contracted with Pacific Nuclear Systems, Inc. (PNSI), Federal Way, Washington to provide for the shield's removal and transportation, and with US Ecology, Inc. of Louisville, Ky. for disposal services. Of critical importance to the utility was minimization of plant down time, personnel radiation exposure and maintaining budgetary and schedule constraints.

To achieve these goals, a plan was implemented which required the development and testing of several new hardware components and the close coordination of several companies, who had responsibility for critically discrete portions of the project. Additionally, the plan included a dry run test of equipment and procedures to completely and satisfactorily demonstrate the methodology and hardware to be employed in this project.

THERMAL SHIELD REMOVAL AND SECTIONING

The Millstone 2 NTS was composed of stainless steel approximately 7.6cm (3 inches) thick, 3.5m (11.5 ft.) long and having an outside diameter of 4.1m (13.6 ft.). It weighed approximately 27.2t (30 tons) and had recorded radiation peaks of 5,000 R/hr.

The NTS was removed from the reactor's core barrel by sectioning it into six 60° arc segments using a remotely operated underwater milling machine, provided by Power Cutters, Inc, (PCI). After sectioning, the NTS segments were temporarily stored in underwater shielded vessels. During this time a cask wash-down pit (CWP), located adjacent to the fuel pool, was modified for the next phase of the NTS removal/disposal.

The CWP was flooded with demineralized water and the NTS sections were moved to a specially designed holding fixture which had previously been positioned in the CWP. The underwater milling machine was moved from the reactor and positioned in the CWP for the purpose of further sectioning the NTS into sizes that could be more easily handled for shipping and disposal.

Utilizing remote under water tooling and viewing equipment, the first of the six NTS segments was moved from the holding fixture and placed vertically in the milling machine's cutting stand. The machine's hydraulically operated milling head was positioned against the NTS section and the cutting operation began.

Moving at approximately 12.7mm to 25.4mm/minute (1/2 - 1 in/minute) and at a depth of 12.7mm (1/2 in.), the 51mm (2 in) diameter cutter required approximately two hours to complete one vertical pass. A total of six passes were needed to cut off a 20° arc segment. A 76mm (3 in) diameter hole was machined into the segment 20cm (8 in) from its upper end and a cable lifting sling was remotely installed through the hole using underwater grippers and reach rods.

The 20° section was removed from the cutting stand and replaced in the holding fixture. The remaining portion of the 60° segment was repositioned in the cutting stand and the entire operation was repeated until each 60° segment was reduced to three 20° arc segments.

Cutting chips resulting from the NTS milling operation were remotely gathered and placed in specially designed drums for further processing and waste disposal. These chips were ultimately encapsulated in a mixture of U.S. Gypsum's Envirostone™ and subsequently sent to a LLRW disposal facility.

LINER AND CASK LOADING

A disposable liner was developed which could contain up to six 20° NTS segments. The liner was 4.1m (13.4 ft.) long, 94cm (37 in) in diameter and weighed approximately 1272kg (2,800 lbs.). It was specially designed to handle the 8.25t (9 tons) (six 20° sections) of thermal shield in both vertical and horizontal operational configurations.

The liner was equipped with hardwood strips running its entire length and spaced around the liner body's circumference. The wooden strips were designed to prevent damage to the critical gas sealing surfaces of the transport cask during horizontal removal of the liner during the disposal operation.

The liner's lid was designed to be remotely installed under water. The lid contained guide pins for proper orientation to the liner's body and an area in which a hook could be remotely inserted for liner handling in the pool and at the disposal site. Heavy mesh screen was designed into the liner's lid and also covered holes in the liner's bottom in order to facilitate water drainage prior to cask shipment.

Prior to loading the NTS segments into the liner, it was remotely placed in a submerged liner loading stand. The loading stand was approximately 2.5m (8.8 ft.) long, 1.9m (6.3 ft.) wide and 1.7m (5.4 ft.) tall. It was designed with a pivoting "liner support" section which was operated remotely by an underwater hydraulic cylinder. The cylinder was controlled by an operator's station located at the top of the pool. The cylinder and pivoting support section enabled the liner to be tilted from 0° to 15° off the vertical and held in position while the NTS segments were remotely lifted and positioned in the disposable liner.

As the first 20° NTS section was loaded, the liner was tilted to the 15° (off vertical) position. As subsequent sections were loaded, the liner was incrementally pivoted to a vertical position. When the last of the NTS segments was in place, the liner lid was remotely installed and it was ready for insertion in the transport cask.

The cask utilized for transportation of the liner and NTS segments was General Electric's IF-300, irradiated fuel cask (Nuclear Regulatory Commission Certificate of Compliance 9001), Fig. 1. Described generally, it consists of a stainless steel inner cavity, .95m (37-1/2 in.) in diameter and 4.3m (14 ft.) long. Surrounding and shrink-fitted to the inner cavity is a depleted uranium shield approximately 102mm (4 in) thick. An outer 38.1mm (1-1/2 in) thick stainless steel shell is shrink-fitted to the uranium to ensure good heat transfer characteristics. The total gross weight of the cask is 63.5t (70 tons). It has a maximum licensable inner cavity payload capacity of 9545kg (21,000 lbs).

The IF-300 is transported on a specially designed equipment skid and rail car. The equipment skid is designed for removal from the rail car in order to enable intermodal transportation of the skid and cask for short, heavy haul, distances.

Utilizing standard IF-300 procedures and support equipment, the cask was prepared and submerged into the CWP, adjacent to the liner loading stand. The liner was remotely grappled and transferred into the IF-300. The cask closure head was submerged and positioned on the cask. The cask was raised from the CWP, decontaminated and the head bolts torqued into their final position.

After draining the cask, performing required seal testing and verifying final contamination limits, the cask was moved to its waiting equipment skid and rail car in preparation for transport to the U. S. Ecology's LLRW disposal facility on the Hanford Reservation in Washington State.

INTERMODAL TRANSPORT OF CASK AND DISPOSAL SITE PREPARATION

The IF-300 required approximately 9 days to travel from Waterford, Connecticut to the Hanford Reservation at the Department of Energy's (DOE) 1100 Interchange Yard at Richland, Washington. It was then moved via the DOE railroad to a preauthorized transfer point on the reservation. At the transfer point, the intermodal highway hauling equipment was staged in preparation for transferring the IF-300 cask and equipment skid to a lowboy trailer.

Several weeks of advanced planning were necessary to insure success of the transfer operation. Prior to this project the cask and equipment skid had never been handled or transported via highway hauling equipment. Therefore, lifting of the equipment skid was crucial to preclude any damage to the cask system.

Fig. 1. General Electric IF-300 transportable cask.

Fig. 2. Cask removal from railroad transport car.

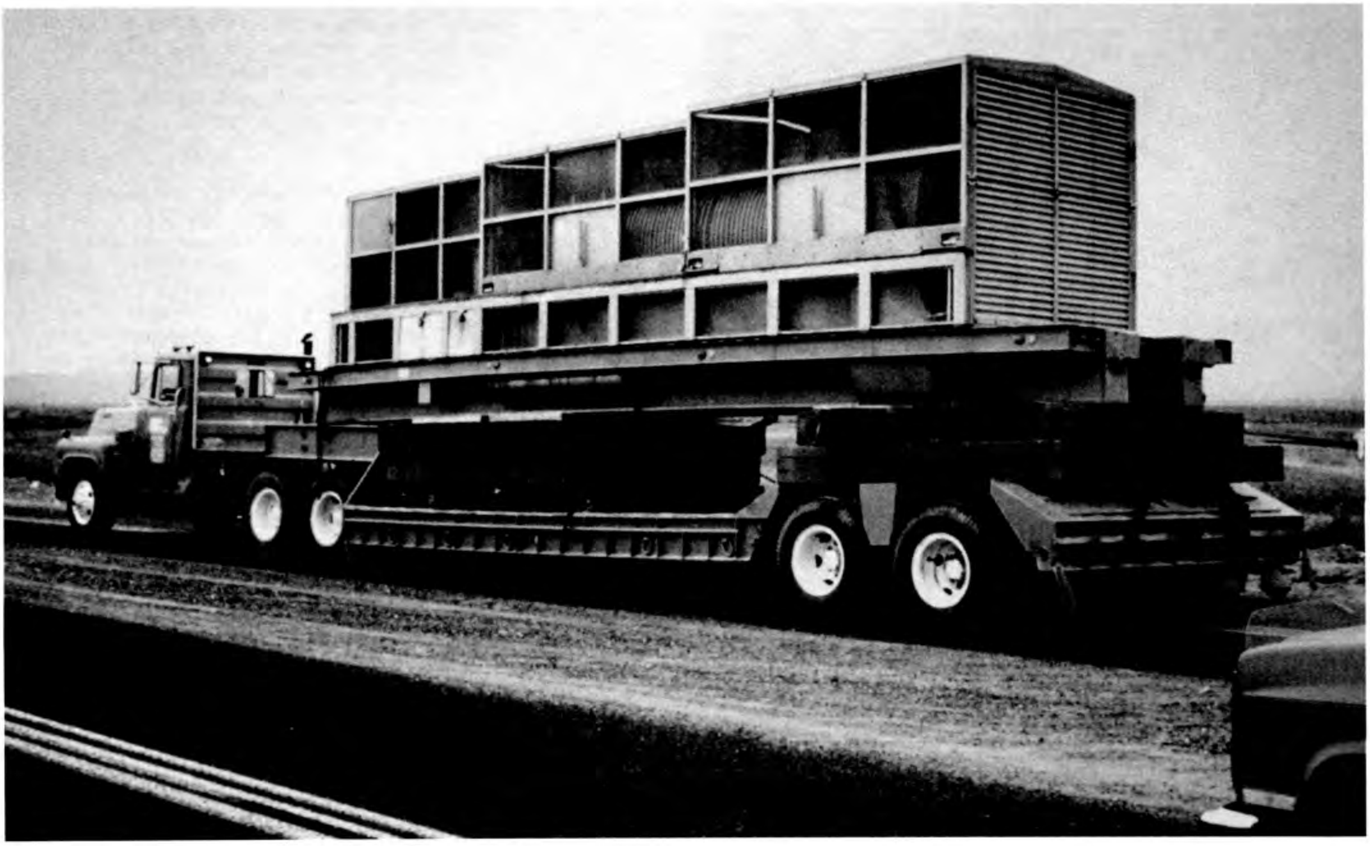

Fig. 3. Intermodal transport of the IF-300.

Lampson Universal Rigging of Kennewick, Washington provided the equipment and personnel for the transfer operation. Two 63.5t (70-ton) truck cranes were positioned and rigged to each end of the equipment skid. Working as a "team", the two cranes simultaneously lifted the 81.6t (90-ton) cask and equipment skid approximately car was removed and replaced by a 91t (100-ton) capacity lowboy trailer. The equipment skid was lowered and secured onto the trailer and the cask assembly was transported approximately 8km (5 miles) to the LLRW disposal facility, Figure 3.

Prior to the receipt of the cask assembly at the LLRW disposal facility, several advanced preparations were required. These consisted of:

a. Fabrication, testing and positioning of a cask turning fixture.
b. Excavation of the disposal area.
c. Installation and alignment of the cask handling crane.
d. Development of handling procedures and personnel training.

The disposal area consisted of a modified trench, designed and developed specifically for the Millstone project. The final disposal trench was 73m (240 ft) in length, 17m (55 ft) wide and 12m (40 ft) deep, Fig. 4. The trench was constructed in phased increments in order to take advantage of the cask turn-around time between loads. The incremental construction afforded the disposable liner a shorter travel distance out of the cask to its final disposal location, thus minimizing exposure to personnel and the environment. Additionally, the trench construction technique enabled better control of trench stability and spoil material management, both of which are critical in shallow-land disposal operations.

Fig. 4. Excavation of NTS Disposal trench.

Fig. 5. IF-300 positioned vertically in cask turning fixture.

A cask turning fixture was designed and developed to meet several cask handling requirements. These included:

a. Providing a stable platform for horizontal and vertical support of the IF-300 cask.
b. Providing a means of remotely rotating the cask from the vertical to horizontal position for liner off-loading.
c. Providing a means of protecting critical cask sealing surfaces during horizontal off-loading of the liner.
d. Providing a means of guiding the liner out of the cask and into the disposal trench.

The turning fixture was placed on wooden pads at one end of the disposal trench. A 218t (240 ton) Manitowoc Series II crawler crane was positioned in line with the center-line of the trench and turning fixture. Upon its arrival at the facility, the cask transport trailer was axially positioned behind the crane. This equipment arrangement provided an efficient and safe means for removing the cask from its equipment skid and placing it in the turning fixture.

CASK UNLOADING

When all the equipment was staged and verified to be operational, the cask was prepared for off loading. The equipment skid canopy covering of the cask was removed and surveyed once again for possible contamination. It was transferred from the equipment skid and placed in a stabilized vertical position in the turning fixture by the crane, Fig. 5.

A work scaffolding was erected around the cask to provide personnel access to the top of the cask for removal of the closure head. After untorquing the thirty two, 49mm (1-3/4 in) diameter stud bolts, the cask head was carefully removed and stored.

The cask handling crane was remotely reattached to the cask and it was rotated to the horizontal orientation in a controlled manner, Fig. 6. The turning fixture's cask seal protector was remotely lowered into position and a cable/hook assembly was remotely attached to the liner lid using a remotely operated feature designed specifically for this application.

The liner was pulled from the cask into the disposal trench by means of an earth moving machine located a safe distance from the liner, Fig. 7. When the liner had reached its final disposal location, backfilling of the area began. This backfilling operation continued until the radiation at the top of the disposal trench meet acceptable limits (100 mr/hr). The pulling cable was then disconnected by cutting it above the backfilled liner.

Decontamination of the turning fixture and the cask were completed prior to the up-ending of the cask and replacement of the lid. Decontamination consisted of cleaning the surfaces of the cask and any turning fixture components that showed contamination.

The processes for closure head replacement, cask lifting and general cask reinstallation on the equipment skid were reversed for the cask removal process. When the cask and equipment skid were secured, an exit survey was conducted. Shipping documentation was prepared and the unit was subsequently released. The equipment skid was returned to the railroad car in the same fashion that it was removed. The railroad car was returned to the commercial railroad for transit back to Millstone for the second and third load of NTS components.

Fig. 6. Rotation of IF-300 to the horizontal off-loading position.

Fig. 7. Disposable liner removal during dry run demonstration of NTS handling equipment.

CONCLUSION

The disposal of the Millstone 2 NTS was conducted in accordance with clear concise project management planning and engineering forethought. In all, three liners were disposed of totaling 163,000 curies with radiation peaks of 5,000 R/Hr. Project goals dictated that no personnel radiation exposure was considered acceptable during the disposal operation. And, in fact, no exposure to personnel was measured during any liner off loading/disposal operation. The exposure during decontamination had been recorded as high as 5mr/load due to material used in the cask fabrication.

The successful completion of the NTS disposal project has provided a significant advance in the area of irradiated hardware disposal. The techniques, equipment and methodologies developed and demonstrated as a result of this project, will continue to yield significant future benefits to the nuclear industry in this country.