Reactor Vessel Head Disposal Campaign for Nuclear Management Company

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ABSTRACT

After establishing a goal to replace as many reactor vessel heads as possible – in the shortest time & at the lowest cost as possible – Nuclear Management Company (NMC) initiated an ambitious program to replace the heads on all six of its pressurized water reactors. Currently, four heads have been replaced; and four old heads have been disposed of.

In 2002, NMC began fabricating the first of its replacement reactor vessel heads for the Kewaunee Nuclear Plant. During its fall 2004 refueling outage, Kewaunee's head was replaced & the old head was prepared for disposal. Kewaunee's disposal project included:

--Down-ending
--Draining
--Decontamination
--Packaging
--Removal from containment
--On-Site handling
--Temporary storage
--Transportation
--Disposal

The next two replacements took place in the spring of 2005. Point Beach Nuclear Plant (PBNP) Unit 2 and Prairie Island Nuclear Generating Plant (PINGP) Unit 2 completed their head replacements during their scheduled refueling outages. Since these two outages were scheduled so close to each other, their removal and disposal posed some unique challenges. In addition, changes to the handling & disposal programs were made as a result of lessons learned from Kewaunee. A fourth head replacement took place during PBNP Unit 1's refueling outage during the fall of 2005. A number of additional changes took place. All of these changes and challenges are discussed in the paper.

NMC's future schedule includes PINGP Unit 1's installation in Spring 2006 and Palisades' installation during 2007. NMC plans to dispose of these two remaining heads in a similar manner.

This paper presents a summary of these activities, plus a discussion of lessons learned.

INTRODUCTION

Because of recent industry incidents and mandated inspection requirements, Nuclear Management Company (NMC) elected to replace all six heads on its Pressurized Water Reactor (PWR) vessel heads. The first four heads were replaced within 12 months; and of the remaining two, one is scheduled for replacement in the spring of 2006 and the remaining one during 2007.

From the very beginning of its Reactor Head Replacement Campaign, NMC aspired to complete its project in a superb manner. Its Mission Statement summarized this ideal: Replace the NMC reactor head closure systems in a world-class manner and with a team that fulfills the customer's expectations for safety, reliability and cost effectiveness.

Because of the number of heads being replaced and the desire to fulfill its mission statement, NMC elected to utilize a packaging system for the old heads that optimized the balance between containment of the radioactive material and reusability of the package.

To contain the radioactive material, the packaging system utilized an upper (see Fig. 1) and lower closure that sandwiched the flange of the head. Once installed, the closures were never removed. This ensured containment of the radioactive material and minimized radiation exposure by not having to remove the packaging closures for reuse on subsequent shipments. The closures were fabricated from 2.5 cm thick (1 inch) steel plate. In addition to providing shielding, the 2.5 cm plate (1 inch) provided the necessary strength for safely handling the package while minimizing the cost of the discarded packaging material.

The remaining shielding and tie-down components needed to comply with US Department of Transportation (DOT) regulations for transport were external to the closures. This allowed recovery of these components for reuse once the head was received at the disposal site.

Fig. 1. Disposal package upper closure assembly.

Kewaunee Replacement

NMC's first candidate for head replacement was Kewaunee Nuclear Power Plant, located in northeastern Wisconsin. Mitsubishi Heavy Industries, Inc. began fabricating Kewaunee's new head in 2002, and delivered it during August 2004. During its fall 2004 refueling outage, Kewaunee's head was replaced and the old head was prepared for disposal.

Before the new head could be moved into Kewaunee's containment, the old head was required to be removed. To accomplish this, a rail system was installed from outside containment, through the equipment hatch and into containment. The rail system was multifunctional in that it provided a location to set the heads, provided the means to transfer the heads in and out of containment, and provided a means of upending/downending the heads.

The Lower Closure Plate (LCP) of the old head package was staged on top of the rail system. Absorbent socks were placed on top of the LCP to collect any incidental water from the control rod drive mechanisms (CRDMs). The joint between the LCP and the head mating surface was sealed with a silicone caulking compound [RTV (room temperature vulcanizer) silicone sealant]. Once the old head was lifted from the vessel, it was transferred to the rail system and set onto the LCP. During the head's travel from the cavity to the LCP, a radiation survey was performed to confirm the previously completed characterization of the head and to allow for the isotopic activity values to be updated for shipment.

Once the head was on the LCP, it was stripped until only the CRDM pressure housings remained. A fixative was applied to the upper, lower and external surfaces of the head flange. The fixative was also applied to the inside of the stud holes. Twelve package closure studs were installed through the flange stud holes into the LCP and a flange tarp was positioned over the package closure studs. At this point the Upper Closure Assembly was brought into containment horizontally, upended and placed over the CRDMs onto the top of the head flange. Silicone RTV was used to seal the joint between the upper closure and the head flange. Nuts were installed on the closure studs and torqued to 1000 ft-lbs. During the torque sequence, the weld joining one of the stud blocks to the LCP failed. This prevented one of the closure studs from being torqued. Because the failed stud was located at what would be the top of the package once the head was downended, the decision was made to repair the stud once the head was removed from containment.

The packaged head was just over 4.0m (13 ft) in diameter, 7.9m (26 ft) high and weighed approximately 63.5 metric tonnes (70 short tons). A-frame trusses were installed on the head, and the head was lifted off the rails, and set onto a downending shoe and cart. Once connected to the shoe, the head was retracted from containment by drawing the shoe cart out the equipment hatch while simultaneously lowering the A-frame trusses with the polar crane. The curved design of the shoe allowed the head to transition from vertical to horizontal. Upon completion of downending, the head was radiologically surveyed and removed from containment onto a waiting hydraulic platform trailer. The platform trailer was also equipped with rails that mated up to the rails coming out of containment. This allowed the head to be placed onto the trailer without using a crane or gantry system.

The packaged head was then transported to the location were it was to be installed onto the conveyance used for transport to a disposal site in Utah (see Fig. 2). It was during the transport from the equipment hatch to the staging area that water leaked from the joint between the LCP and the head mating surface. Subsequent investigation revealed that the leak started as the head was exiting the equipment hatch. The majority of the water was spilled in the vicinity of the hatch and the remainder was spilled on the platform trailer. Other than at the hatch, no contamination was found along the heads travel route to the staging area.

Fig. 2. Old reactor head ready for disposal.

As a result of the leak, the old head was placed in one of the buildings previously used for storing the Kewaunee replacement steam generators. Once in the building, several steps were taken to recover from the leak. These included:

- Drilling vent and drain holes into the LCP to verify all free water was removed from the bowl of the head,
- Decontaminating the head in the leak affected areas,
- Resealing the joint between the LCP and the head mating surface, and
- Repair of the failed closure stud.

Upon completion of the recovery items the head was returned to the staging area and loaded onto the US Department of Transportation (DOT) certified conveyance. The conveyance consisted of a heavy duty four-axle tractor pulling a gooseneck trailer supported by 20 dollies. Overall length was approximately 48.7m (160 ft), width was 4.9m (16 ft) and height was almost 5.2m (17 ft). The conveyance was permitted for a loaded transport weight of 181,000 kg (399,000 pounds). The transport saddles were installed on and secured to the trailer. At this point, the head was driven under a gantry system and lifted off the platform trailer. The DOT conveyance was backed under the suspended head as the platform trailer pulled out. The head was lowered into the transport saddles and disconnected from the gantry. Transport shielding and tie-downs were installed.

A radiation survey of the conveyance revealed that the dose rate 2-meters from the side of the conveyance exceeded the 0.1 mSv/hr (10 mrem/hr) limit (actual was as high as 0.12 mSv/hr (12 mrem/hr)). Rolled 1-inch plate was obtained from a local vendor and welded to the upper closure assembly to bring the shipment into compliance with DOT radiation level regulations. Shipping and disposal paperwork was completed and the shipment was released for transport to the disposal site.

The head was characterized as a <A2 quantity of LSA-II material. As such the package was non-specification meeting the requirements of Title 49 of the US Code of Federal Regulations (49 CFR 173.24, .24a and .410). The contact dose rate was 1.4 mSv/hr (140 mR/hr) and the 2-meter dose rate was 0.08 mSv/hr (8 mR/hr). The isotopic distribution and activity are provided in the table below.

Table I. Kewaunee Reactor Pressure Vessel Head Shipment Activity

Activity Distribution	Curies (Ci)	MBq	Fraction A_2
H-3	6.39E-05	2.36E+00	5.93E-08
C-14	1.83E-01	6.77E+03	2.25E-03
Cr-51	1.94E-01	7.18E+03	4.04E-04
Mn-54	2.84E-01	1.05E+04	1.10E-02
Fe-55	5.26E+00	1.95E+05	4.94E-03
Co-57	3.04E-02	1.12E+03	1.19E-04
Co-58	8.24E+00	3.05E+05	3.74E-01
Fe-59	9.25E-02	3.42E+03	5.27E-03
Co-60	2.54E+00	9.40E+04	2.36E-01
Ni-63	2.83E+00	1.05E+05	3.49E-03
Zn-65	1.78E-02	6.59E+02	3.50E-04
Sr-90	1.36E-02	5.03E+02	1.68E-03
Nb-94	8.48E-04	3.14E+01	4.48E-05
Nb-95	5.43E-01	2.01E+04	3.05E-02
Zr-95	1.24E-01	4.59E+03	7.20E-03
Tc-99	1.26E-01	4.66E+03	5.18E-03
Ru-103	4.42E-03	1.64E+02	1.18E-04
Ag-108m	3.60E-02	1.33E+03	1.90E-03
Ag-110m	8.12E-03	3.00E+02	7.96E-04
Sb-124	2.85E-03	1.05E+02	2.24E-04
Sb-125	4.01E-02	1.48E+03	1.51E-03
Cs-134	3.48E-03	1.29E+02	1.87E-04
Cs-137	7.44E-03	2.75E+02	4.59E-04
Ba-140	3.23E-02	1.20E+03	1.25E-02
Ce-141	6.42E-03	2.38E+02	6.20E-04
Ce-144	6.11E-03	2.26E+02	1.19E-03
Pu-238	1.72E-04	6.36E+00	6.37E-03
Pu-239	5.40E-05	2.00E+00	2.00E-03
Pu-241	1.64E-02	6.07E+02	1.01E-02
Am-241	5.66E-04	2.09E+01	2.09E-02
Cm-242	2.13E-05	7.88E-01	8.62E-05
Cm-243	7.44E-05	2.75E+00	2.76E-03
TOTAL	2.06E+01	7.64E+05	7.45E-01

The shipment departed Kewaunee on the morning of November 15, 2004 and traveled from Wisconsin to Utah via Minnesota, South Dakota and Wyoming (see Fig. 3). Arriving at the disposal site during the late afternoon of November 22, the shipment was officially received by the site operator during the morning of November 23. Utilizing a crane along with custom rigging designed specifically for the head package, the head was off-loaded and positioned in the disposal cell during the afternoon of November 23, 2004.

Fig. 3. Transport routes for old reactor heads.

Lessons learned from Kewaunee included:

- Silicone RTV did not provide an adequate seal for this application. A rubber gasket covering the entire face of the mating surface where it contacts the LCP was incorporated into the package design.
- A 1-inch thick LCP resulted in excessive dose to personnel while handling the package. An additional 1-inch shield plate was incorporated on the head side of the LCP to reduce dose to personnel while assembling and handling the package.
- Downending the head may release water trapped inside CRDMs. Threaded vent and drain plugs were incorporated into the LCP design.
- The internal geometry of the head resulted in the absorbent socks being inadequate for their intended purpose. The packaging procedure was revised to require the addition of granular super-absorbent once the drain plug was reinstalled following the verification of no freestanding water inside the head.
- The initial assumption that the lower third of the CRDM bundle would be the major 2-meter dose rate contributor was incorrect. Supplemental transport shielding was designed to provide shielding for the entire upper closure assembly.
- Improper weld fusion between the weld material and base material caused the closure stud block failure. Fabrication specification revised to require a load test of each closure stud block.

Point Beach Unit 2 and Prairie Island Unit 2

NMC's next two replacements took place in the spring of 2005. Point Beach Nuclear Plant (PBNP) Unit 2 and Prairie Island Nuclear Generating Plant (PINGP) Unit 2 completed head replacements during their scheduled refueling outages. Since these two outages were scheduled so close to each other, their removal and disposal posed some unique challenges.

Probably the biggest challenge was that many of the contractor personnel involved with the heavy rigging and package assembly were supporting both outages. Additionally, some of the heavy rigging equipment was also required to support both outages.

While not related to the PBNP2/PINGP2 outage overlap, another challenge faced was that of freeze restrictions. Many northern states do not allow overweight shipments to travel on their highways during the spring thaw. With the PBNP2 outage beginning in April and the PINGP2 outage beginning in May, both were impacted by freeze restrictions. The State of Minnesota was the most restrictive and traditionally has the longest duration restrictions. Attempts were made to route the PBNP2 shipment around Minnesota, but the neighboring states to the south of Wisconsin were unable to accommodate the shipment. This resulted in the PBNP2 head being stored in the on-site truck bay until completion of the PINGP2 head shipment. The duration of Minnesota's freeze restrictions was such that the PINGP2 project, although starting a month after PBNP2, was able to remove, package and prepare the head for shipment and then still have to wait almost a week before releasing the shipment for transport.

In addition, changes to the handling and disposal programs were made as a result of lessons learned from Kewaunee. The thicker LCP design and rubber gaskets were utilized at both units resulting in significantly lower dose rates on the bottom of the heads and no leakage. During downending of the heads, a tygon tube was connected to the LCP drain port to verify that free-standing water was not present inside the head cavity. Less than a quart of water was collected from the PBNP2 head while no water was observed at PINGP2. Granular absorbent was used in both heads, and the supplemental transport shielding was required to meet 2-meter dose rate limits.

A change made to PINGP2's handling program not related to any previous lessons learned resulted in a significant reduction of critical path. PINGP2 elected to utilize a crane and the specialty rigging designed for the head package in place of a gantry system in order to remove the head package from the rails as it exited containment. The crane and rigging were also used to place the head package onto the DOT conveyance. Using this approach reduced critical path by at least two shifts.

Lessons learned at PBNP2/PINGP2 included:

- The LCP being 2" thick resulted in a horizontal transition through the vent hole that caused the granular absorbent to stop flowing. Additional personnel dose was received due to the increased time required to add absorbent. A hopper with a powered feed screw was designed for use on subsequent shipments.
- Fit up of the A-frames to the downending shoe was difficult due to a buildup of excess fixative inside the flange closure stud holes on the head. The package assembly procedure was revised to recommend that the four flange closure studs holes that receive the A-frames be decontaminated in lieu of applying fixative; or, if fixative was applied, to verify that no excess fixative had built up in the holes.

The shipment of the PBNP2 old head was rescheduled to coincide with the delivery of the new PBNP1 head since all the key players needed to deliver and off-load the new head were the same ones needed to load and transport the old head. This ended up being the week of July 4, 2005.

The new PBNP1 head was received, and the old PBNP2 head was removed from the on-site truck bay and loaded onto the DOT conveyance. However, shipment of the old head was delayed because the State of Minnesota shut down all non-essential services due to budget constraints. Issuing overweight permits was deemed a non-essential service. This resulted in a 5-day delay in releasing the PBNP2 head shipment.

Point Beach Unit 1

A fourth head replacement took place during Point Beach Nuclear Plant (PBNP) Unit 1's refueling outage during the fall of 2005. The package design remained unchanged from Unit 2 but the lessons learned were incorporated in the package assembly. The A-frame closure stud holes were decontaminated and the fit-up issue did not repeat. The power feeder for the granular absorbent was utilized and it reduced absorbent addition time by over 80 percent. The outage started on September 24, 2005 and the packaged head departed PBNP on October 18 with subsequent disposal in Utah on October 25, 2005 (see Fig. 4).

Fig. 4. Final disposal in Utah.

Collateral Waste

Nearly all collateral waste generated during NMC’s reactor head disposal campaign was disposed of as Class A LLW in Sea-Land containers (i. e., bulk waste) in Utah. Primarily, this waste consisted of control rod drive mechanism (CRDM) cooling fans, ductwork, missile shield handrails, brackets, driveline components, dummy cans, CRDM shrouds, should support rings, old CRDM’s and mirror insulation. None of these components were shipped off-site for decontamination or volume reduction. In addition, missile shields were shipped and disposed of separately.

The quantity of collateral waste generated during each head replacement depended on the plant and the extent of the replacement head modification. Specifically, the quantity of waste depended on whether or not the missile shield and/or the head assembly upgrade package (HAUP)) was included as part of the modification. Summary of collateral wastes:

a. KNPP – One (1) Sea-Land; no HAUP or missile shield

b. PBNP2 – Two (2) Sea-Lands, HAUP and missile shield
(A third Sea-Land was partially filled, but it was stored on-site until PBNP1’s outage.)

c. PINGP2 – Three (3) Sea-Lands, HAUP and missile shield

d. PBNP1 – Three (3) Sea-Lands, HAUP and missile shield

Future Plans

NMC's future plans include PINGP Unit 1's installation in spring 2006 and Palisades' installation during 2007. NMC plans to dispose of these remaining heads in a manner similar to the first four.