Pathfinder Decommissioning: Reactor Vessel Packaging and Transportation

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INTRODUCTION

During the early days of nuclear plant operations in the United States, Northern States Power Co. (NSP) built and operated the Pathfinder Atomic Power Plant near Sioux Falls, SD. The plant's 66 MWe reactor first went critical in l964. After several years of low power testing, the plant went into commercial operation in 1966. After 1 1/2 years of limited power operations, the reactor underwent its final shutdown on September 16, 1967.

After establishing that the plant required structural and design upgrades, NSP made an economic decision in 1968 to keep the nuclear reactor permanently shutdown. NSP began to repower the Pathfinder Plant with gas-fired boilers in 1968. The reactor was defueled, then placed in SAFSTOR (i. e., mothballed) during 1969 and 1970. Its operating license (10 CFR 50, "Licensing of Production and Utilization Facilities") was surrendered for a possession-only license (10 CFR 30, "Domestic Licensing of Byproduct Material"). Following conversion, Pathfinder was placed back into commercial operation as a fossil-fueled peaking plant. It continues to operate to this day.

The present phase of Pathfinder decommissioning began in the late 1980's when NSP examined the feasibility of completing work while radioactive waste sites were available and disposal costs were relatively low. Following NSP's decision to decommission the unused nuclear plant, NSP conducted several meetings with the US Nuclear Regulatory Commission (NRC) to discuss the proposed project. In Jan 1990, an NSP decommissioning team arrived on site; and in July 1990 began to dismantle nuclear portions of the plant. Except for hiring contractors and laborers when expertise or resources were not available within the company, NSP managed and conducted the entire decommissioning.

The scope of decommissioning included:

a. The reactor building, the reactor vessel and the contents of the reactor building.

b. The fuel handling building and its contents.

c. The fuel transfer vault between the reactor building and the fuel handling building.

Radioactive material and residual contamination contained in the fossil-fired plant was not included in the scope of this project.

The Pathfinder reactor vessel was lifted out of its building on May 14, 1991. NSP applied for and was granted a Certificate of Compliance by the NRC for shipping the reactor vessel as a Type A package (49 CFR 170, "Hazardous Material Regulations"). Between May and August, NSP prepared the package for its cross-country trip. And between August 7 and 11, 1991, the vessel was shipped in one piece to a commercial disposal facility near Richland, WA.

This paper discusses background material related to Pathfinder decommissioning, and emphasizes the packaging and transportation of the decommissioned Pathfinder reactor vessel.

VESSEL REMOVAL CONSIDERATIONS

During the SAFSTOR decommissioning program (1968-1969), the nuclear steam supply system (NSSS) was dismantled to the extent necessary to render it inoperable and incapable of being restored to service. All nuclear fuel was removed and shipped off-site. The vessel was drained and connected to a vacuum pump to remove residual water from non-drainable cavities. The control rods and blades were placed in the vessel, and the vessel was filled with gravel. The internals were left in place. The vessel head was reinstalled and bolted to the vessel using studs and nuts.

Later, as the actual decommissioning plan took shape, two vessel removal alternatives were considered:

a. One-piece removal and disposal.

b. Segmentation of the vessel and internals and transport for disposal in shielded shipping containers.

The segmentation alternative required extensive remote tooling and individual segment handling. Cutting would have generated large quantities of smoke and debris which would have required extensive contamination control measures such as access tents, high efficiency (HEPA) filters and remote handling tools. There would have been additional worker exposure due to the extensive time required to segment, load and ship each piece. The selected alternative of one-piece shipment did not require extensive tooling, handling contamination controls or high worker radiation exposure. However, there were considerable costs associated with building and certifying the package which was shipped.

The vessel and internals package contained 2.08×10^{13} Bq (562 curies) of radioactivity as activated and contaminated material. This amount of radioactivity did not warrant the effort to segment and package the vessel and internals. Based on the vessel activation and shielding analysis, the vessel and internals qualified as Low Specific Activity (LSA) material and the package qualified as a Type A container.

To prepare the vessel for shipment, it was filled with grout to fix the gravel in place; attached piping was cut off and openings were sealed; then the vessel was lifted from the reactor cavity, moved through the reactor building dome and laid on its side. Once the vessel was removed and enclosed in a tent, any remaining attachments were cut away. The asbestos insulation was removed and the vessel certified clean. A cylindrical steel shield was welded to the vessel shell. An impact limiter consisting of Hexcel (discussed below) and wood was installed on the vessel shell surface to protect the vessel a postulated transportation accident. The outer 6 mm (1/4 inch) shell protected the package during normal conditions of transport. The vessel package was lifted horizontally and placed on saddles installed on a flatbed railcar for transport to a disposal facility near Richland, WA.

When fully prepared, the vessel package weighed 2.63×10^5 kg (290 tons), not including tie-downs or other supports. The package was transported by rail from the Pathfinder site in Sioux Falls, SD to Richland, WA. The Type A container package was shipped in an exclusive use vehicle (railcar) as part of a special train. A special train was used because the package was high and wide, not because ofnuclear concerns. The reactor vessel package was unloaded from the railcar and transported for a short distance to the disposal site by truck.

LOGISTICS

Burlington Northern Railroad (BN) was selected to transport the reactor vessel between Sioux Falls, SD and Richland, WA. NSP leased a 12-axle heavy haul rail car from Westinghouse, WECX 305, to transport the vessel between August 7 and 11, 1991. Besides the BN crew, NSP staffed the train with three employees in the business car to provide technical expertise, maintain communications, and conduct radiation surveys. These personnel were not required by regulations to accompany the vessel during transit, but NSP considered it prudent to do so.

A two-way communications and tracking network was established by NSP. The network incorporated the DOE's TRANSCOM (Transportation and Communications System, Version 2.2), a lap top computer, cellular and IMTS (Improved Mobile Telephone Service) telephones, FAX equipment and an auto-paging arrangement.

TRANSCOM is a satellite-based transportation and communications system used by the US DOE to track shipments of various items throughout the United States. DOE provided TRANSCOM equipment and support for the Pathfinder decommissioning project because:

a. NSP solicited the system for back-up communications in areas not covered by the nation's cellular phone network.

b. DOE wanted to demonstrate its system on an actual rail shipment. DOE uses the system routinely to track trucks, but had experienced only limited use on rail shipments.

c. DOE wished to demonstrate a solar-powered TRANSCOM unit as explained below.

The TRANSCOM system used in conjunction with the Pathfinder vessel shipment consisted of two separate units:

a. One unit mounted on the business car maintained two-way communications between personnel on the train and a Shipping Coordinator stationed in Minneapolis, MN.

b. A second unit (tracking only) was mounted on the vessel itself. The solar unit (designed to be self-sustaining with a battery back-up power supply) was a US DOE research and development effort to test tracking an unattended rail car.

PACKAGE DESCRIPTION

The vessel package is shown on Figure 1, and is based on TLG Engineering, Inc. Drawing No. N04-22B-001, Pathfinder Vessel Transport Package. The package was essentially a cylindrical container which measured 10.4 m (34ft, 0.5 in) in length by 4.0 m (13 ft, 2 in) in diameter, and weighed 2.6×10^5 kg (580,000 lbs). The package consisted of the reactor vessel, internals, gravel, grout, steel shielding and impact limiter. The internal steel components of the package were neutron activated and included a variety of radionuclides, primarily cobalt-60 (Co^{60}), iron-55 (Fe^{55}), nickel-63 (Ni^{63}) and nickel-59 (Ni^{59}). A small amount of surface contamination existed on the interior surfaces of the vessel, but was generally bound to the surfaces by the grout.

Total activity was 2.1×10^{13}Bq (562 Ci). Most of the source term consisted of activated metal that was not readily dispersible. The remaining source term was 3.52×10^9Bq (95 mCi) consisting of a thin corrosion film bound to the surfaces of the vessel and internals. The maximum specific activity of the package was 9.18 x 10^6Bq (0.248 mCi) per gram. Since this value is less than 1.11 x 10^7Bq (0.3 mCi) per gram, the package qualified as a Low Specific Activity (LSA) package. In accordance with regulations (10 CFR 71, "Packaging and Transportation of Radioactive Material"), the package was exempt from the requirements for Type B packages, and qualified as a Type A package. If analysis had shown the package to be Type B, NSP would have considered alternate methods for disposing of the vessel.

VESSEL AND INTERNALS

The reactor vessel was fabricated from 75 mm (3 in) thick carbon steel ASME A212 Grade B plate with integrally bonded (Lukens clad) 304L stainless steel cladding. The flanges and nozzle forgings conformed to the ASTM A105 Grade II and were weld overlaid with stainless steel having a chemistry similar to Type 304 except that maximum free carbon content at the clad surface was below 0.050%. The overlay was stabilized with a small amount of niobium. The vessel head was fabricated from the same carbon and stainless steel cladding materials as the vessel shell. The head was secured to the vessel flange by 48 head studs and nuts.

The vessel internals were all fabricated from Type 304L stainless steel with the exception of the boiler boxes which were Zircaloy-2. The other principal contents of the vessel were the control rods and blades that were disposed of in the reactor vessel. These components were fabricated from boron stainless steel and contained boron pellets.

During SAFSTOR decommissioning, the Atomic Energy Commission ordered the vessel filled with pea gravel (6 mm (1/4 in)). The gravel filled all cavities uniformly with the exception of one area at the side of the vessel. At this location there was a "hot spot" with a radiation reading of about 6.0 mSv (600 mR/hr), whereas other readings at the same elevation were about 1.5 mSv (150 mR/hr). To stabilize the gravel and to fill the void spot, the vessel was pumped full of grout. Other than the filling of the void, no direct credit was taken for the shielding effectiveness of the grout in the shielding analysis.

SHIELDING

Based on the shielding analysis of the vessel package with a 40 per cent void fraction in the gravel, 50 mm (2 in) of steel shielding were added to the vessel package to meet the US Nuclear Regulatory Commission (NRC) and the US Department of Transportation (DOT) transport regulations. The shielding was made up from a 44 mm (1-3/4 in) thick plate welded to the vessel shell, extending 0.9 m (3 ft) below the elevation of the core bottom and 1.5 m (5 ft) above the elevation of the core top. Figure 1 shows the shield extending 1.8 m (6 ft) below and eight feet above the core midplane. The remaining 6 mm (1/4 in) of steel shielding was fabricated in a cylindrical shape to form the outer shell for the Hexcel and wood impact limiters. The 50 mm (2 in) of steel shielding was sufficient to reduce the external exposure rate to less than 0.1 mSv (10 mRem/hr) at two meters.

IMPACT LIMITER AND TIE-DOWNS

The impact limiter was used to absorb the energy of impact from the postulated one foot drop during normal conditions of transport. The impact limiter was fabricated from wood or pre-crushed Hexcel (trademark name of the Hexcel Corporation; Dublin, CA); a honeycomb configuration of aluminum attached to the vessel surface. Two types of Hexcel were used; a low density Hexcel configuration attached to the vessel shell region extending over the entire length of the vessel. A higher density Hexcel was used to compensate for the loss of low density Hexcel in the region where the 0.3 m (12 in) wide vessel support saddles were located (at the vessel upper and lower shell spring lines). The Hexcel was attached to the vessel, and then covered by a 6 mm (1/4 in) thick steel cylindrical plate to protect the Hexcel from inadvertent damage. The minimum Hexcel thickness was .2 m (8 in) located at the center region of the shell, surrounding the 44 mm (1-3/4 in) thick shielding section. The Hexcel thickened to approximately 0.28 m (11 in) for the remaining region of the vessel shell. Rounded and hard-to-fabricate areas were surrounded by wood which was cut and pieced into restricted spaces.

The tie-downs used for the package shipment consisted of two 10 cm (4 inch) steel bands. The bands were attached to the support saddles. The vessel rested on the two circumferential saddles located at the vessel shell spring lines. There were no direct attachments to the vessel shell or Hexcel material for vessel tie- down except for a circumferential weld of the shield to the vessel.

DETAILS OF CERTIFYING THE REACTOR VESSEL

The Pathfinder reactor vessel was certified as a Type A package in accordance with NRC Reg Guide 7.9. Technical details considered in certifying the package included the following: total curie content of 2.08×10^{13}Bq (562 Ci), decay heat generation of 4.67 watts, thermal evaluation from 311°K (100°F) to 233°K (-40°F) for a vessel wall stress of 1.65×10^{8}Pa (23.9 ksi), containment, boundary, closure, requirements for normal conditions of transport, activated materials, corrosion product layer, pressurization of containment vessel, shielding evaluation and effectiveness, source and model specification, tests and inspections.

SHIPMENT

The vessel shipment went smoothly and virtually without incident. Local television and radio stations, as well as newspapers and wire services, covered the story factually and fairly. NSP invited members of the Sioux Falls media to the plant site for the vessel sendoff. During the transit, most TV and radio stations knew that the train was coming through their town, so they covered the story on their local news broadcasts. Some curiosity seekers came out to see the train or take pictures. No anti-nuclear protestors were encountered.

Numerous US DOT Federal Railroad Administration (FRA) inspections were conducted before and during the transit. The NRC conducted radiation surveys in Sioux Falls before the vessel's departure; and the WA Department of Health conducted its own radiation surveys in Spokane and Richland, WA.

The only significant delay encountered during the transit was in Havre, MT. A FRA inspector reported deficiencies in the vessel car's braking system, which had to be repaired before the train could proceed. NSP coordinated communications between BN, the DOT inspection team and their management, Westinghouse (owner of the vessel rail car) and ITEL (Westinghouse's contractor during the vessel rail car's most recent overhaul). The braking system was modified at BN's repair shop in Havre and the discrepancies corrected to the satisfaction of the FRA inspectors.

PUBLIC RELATIONS

There was a noticeable lack of activists, protestors, media, etc. during the vessel shipment. Beyond Sioux Falls, outside interest was generally confined to curiosity seekers and passers by. The public treated the shipment for what it was: a big, heavy package that was not a problem. It was not a radiation threat and it did not endanger their health or safety.

NSP believes that this lack of concern can be attributed to advance publicity and communications. For over a year, state and local officials, as well as news media and the public, were kept informed on NSP's plans. Maps, pictures, descriptive data, question & answer sessions, local visits and public meetings helped answer concerns and potential problems.

NSP's SD Region personnel made considerable efforts to keep the Sioux Falls media fully informed on decommissioning progress. As a result, the vessel shipment started smoothly. This positive reporting at the beginning of the transit resulted in keeping the whole shipment in perspective.

LESSONS LEARNED

NSP managed Pathfinder decommissioning with its own employees rather than hire a contractor. The on-site crew remained small throughout the project. The decommissioning project was treated as little more challenging than a typical outage at one of NSP's operating nuclear plants. Where assets were not available, NSP hired outside labor for the duration of the need. This management philosophy resulted in considerable savings to NSP.

The reactor vessel was removed and shipped in one piece. One piece removal proved to be more cost-effective and resulted in less radiation exposure than if the vessel had been segmented.

Packaging and transportation relied on existing technologies: the vessel internals and gravel were stabilized with cement grout; steel was used for shielding; wood and honey-combed aluminum were used for shock-absorbing material; and an off-the-shelf heavy haul rail car was used for the shipment.

TRANSCOM, which provided accurate tracking and continuous two-way communications, was NSP's primary means of communications. Cellular phones were available for less than one-third of the trip. IMTS, a one-way phone link, was not functional. TRANSCOM was used often, even when the cellular phone was available.

Advanced public relations and on-going discussions with Burlington Northern Asset Protection, state agencies, and law enforcement officials before and during the trip provided a great deal of useful information. Advanced publicity and communications with the media yielded valuable results.

Although extensive on-site volume reduction was not practical, off-site volume reduction efforts paid big dividends.

NSP shipped its LLW off-site as early as possible when disposal costs were relatively low, thus saving a great deal of money.

REFERENCES

NRC Regulatory Guide 7.9, "Standard Format and Content of Part 71 Applications for Approval of Packaging of Type B, Large Quantity, and Fissile Radioactive Material", Revision 1, January 1980.

United States Code of Federal Regulations:
Title 10, "Energy"
Title 49, "Transportation"

Figure 1
Pathfinder Vessel Transport Package