RADWASTE CONCERNS DURING NUCLEAR PLANT DECOMMISSIONING

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ABSTRACT

The expected issue in 1983 of new NRC rulemakings on decommissioning will require licensees to give increased attention to planning the ultimate disposal of nuclear facilities. This paper addresses the radwaste management aspects of a nuclear plant decommissioning effort. Matters discussed include waste types and quantities, disposal approaches and some ideas for reduction in wastes quantities. Planning for the decommissioning of the Shippingport Atomic Power Station in western Pennsylvania is the authors' principal point of reference.

INTRODUCTION

Decommissioning Background

The Nuclear Regulatory Commission is preparing to issue in 1983 new rulemakings on the decommissioning of nuclear facilities. An advanced look at the thinking of the NRC staff can be found in NUREG-0586-"Draft Generic Environmental Impact Statement for the Decommissioning of Nuclear Facilities." Emerging NRC regulations will require not only detailed planning as the end of life approaches and decommissioning is imminent, but will necessitate early assessment of decommissioning options, consideration of funding mechanisms, incorporation of decommissioning concepts into the design of facilities and other actions by licensees - all before an operating license is granted. The identification of, and planning for the disposal of radioactive wastes from a decommissioning project will be a major concern when considering the final disposal of a nuclear plant.

Point of Reference - The Shippingport Station

The authors are involved in current work at Burns and Roe to perform the engineering and planning for the decommissioning of the Shippingport Atomic Power Station in western Pennsylvania, under contract to the Richland Operations Office of the U.S. Department of Energy. UNC Nuclear Industries is providing technical direction for DOE. Nuclear Energy Services of Danbury, Connecticut is a subcontractor to Burns and Roe. Although Shippingport is not an NRC-licensed facility, one of the major objectives of DOE for this project is to provide concepts, data, procedures and general information to the nuclear industry which will be of value to future decommissioning efforts.

The Shippingport Atomic Power Station, located 25 miles (40 km) northwest of Pittsburgh on the Ohio River, was built in the 1950's. The plant operated as a conventional PWR until it was converted to a light water breeder in 1976. Shippingport terminated operation in October 1982. After a two-year period of end-of-life testing and defueling, the plant will be available for dismantling in late 1984.

The Shippingport Station is a small unit (nominal 70 MW(e) output) and its chamber-type containment structure is unique. However, the character of nuclear waste products from the decommissioning effort and measures to dispose of the wastes, are no different from that which will occur when disposing of a modern-day full-sized plant.

RADWASTE MANAGEMENT AND THE DECOMMISSIONING MODE

In planning the Shippingport decommissioning, three modes were considered:

- o Immediate dismantlement.
- o Safe storage followed by deferred dismantlement.
- o Entombment.

Immediate dismantlement is the alternative chosen by DOE for Shippingport. This consists of complete removal of all radioactive material at the site promptly after termination of operation and defueling. Immediate dismantlement costs less than the other options and makes the site available for reuse. However, this option generates a larger volume of radwaste than the other alternatives. Tables I and II are comparisons of the relative radwaste quantities for the different decommissioning alternatives as reported in the Environmental Impact Statement for the Project.

TABLE I

LIQUID RADWASTE VOLUMES
FROM SHIPPINGPORT DECOMMISSIONING
(in cubic meters)

Decommissioning Alternative	Existing Radioactive Liquid Inventory (a)	Flushing Inventory
Immediate Dismantlement	2,650	284 (b)
Safe Storage Followed by Deferred Dismantlement	2,650	117 (b)
Entombment	2,650	117 (b)

(a) Includes primary loop piping, steam generators, pressurizer, reactor vessel, canal crane lock, deep pit and fuel storage area as well as existing resins and evaporator concentrates.

(b) Includes primary system water flushes and canal and selected building floor and wall washes.

TABLE II

ESTIMATED VOLUMES OF SOLID RADWASTES
FROM SHIPPINGPORT DECOMMISSIONING

Decommissioning Alternative	Concentrate from Processed Liquids	Other Solid Radwaste Burial Volume
Immediate Dismantlement	84 m^3	11,700 m^3
Safe Storage Followed by Deferred Dismantlement	84 m^3	3,300 m^3
Entombment	84 m^3	3,200 m^3

By way of comparison, an average 1000 MWe PWR with a condensate polishing system will generate approximately 487 m^3/yr of unsolidified radwastes for disposal. As can be seen from these waste quantities, the management of the radwastes during the decommissioning of even a smaller nuclear plant is a major undertaking.

LIQUID RADWASTES

Waste Characterization

The liquid wastes generated during decommissioning will be similar to those encountered in the maintenance and operation of nuclear power plants with two major differences: a) the chemicals and waste products from decontamination processes will be a major technical and operations concern; and b) the schedular constraints of decommissioning, coupled with the large quantity of wastes has a direct impact on the suitability of the existing processing equipment.

The liquids to be processed at Shippingport, in about an 18-month period, can be characterized as shown in Table III.

TABLE III

CHARACTERISTICS OF LIQUID WASTES
TO BE PROCESSED AT SHIPPINGPORT

Liquid Waste and Typical Source	Characteristics*
Borated Water, Fuel Canal & Reactor Coolant System	Radioactivity levels ranging from $2x10^{-7}$ to $2x10^{-2}$ μCi/ml. Borate is in the form of potassium tetraborate tetrahydrate ($K_2B_4O_7 \cdot 4H_2O$) ranging in concentration from traces to 106,080 ppm.
Chromated Water, Neutron Shield Tank	Concentration of 1000 ppm chromate as potassium chromate. Radioactivity level of $5x10^{-4}$ μCi/ml and tritium content of $4x10^{-3}$ μCi/ml.
Decontamination Liquids, Chemical Decontamination of Components	Mostly proprietary chemical solutions ranging in pH from 2 to 12. Solutions may be biodegradable, phosphate base or non-phosphate base, phosphoric acid based or solvent detergents. These materials may require pH adjustment or addition of anti-foaming agents prior to evaporation.
Spent Resin Slurries, Liquid Waste Processing	Resin Types and Volume Percent (estimated) HOH Mixed Bed 57% Ammonium Hydroxide Resin 3% Macroreticular Resin 18% Activated Carbon Depleted Media 22% Particle sizes range from 16 to 50 mesh and bulk densities range from 28 to 45 lbs./ft.^{3} (449 to 721 kg/m^3). Specific activity is estimated at 0.1 Ci/ft.^{3} (3.5 Ci/m^3).
Evaporator Concentrates, Liquid Waste Processing	Consists primarily of 30 weight % potassium tetraborate tetrahydrate. Specific activity is estimated at $25.5x10^{-9}$ Ci/ml ($25.5x10^{-3}$ Ci/m^3).

* Total radioactivity of the liquids, excluding evaporator concentrates and spent resins, is estimated at 1.36 Ci and the total tritium content is estimated at 6.7 Ci.

The magnitude of these wastes is great enough, and the time period to process them is sufficiently short, to make the processing of them a critical path for the decommissioning schedule. As a result, the wastes must be processed in a timely and efficient manner to prevent the field costs from escalating. Our experience at Shippingport shows that evaporator feed rates, bottoms concentrations, solidification equipment and transportation schemes which were adequate for normal plant operation may have to be modified to accommodate the liquid radwastes to be processed during decommissioning.

Wastewater Processing Methods

Prior to the fall of 1982, Shippingport was processing liquid wastes in an evaporator which had a feed rate capacity of about 1 gpm ($6.3x10^{-5}$ m^3/sec). Concentrates from the evaporator were solidified in 55-gal. drums with cement added by manually weighing the concentrates, adding an appropriate quantity of cement and mixing the drum contents with a drum roller. The plant's basic radwaste processing system was designed before 1957 and processed approximately 130,000 gal. (492 m^3) per year of liquid waste.

The decommissioning operations require the processing of approximately 500,000 gals. (1,893 m^3) of water over an 18-month period. Processing this much water in the given timespan would have been extremely difficult and would have taxed the old evaporator enough to cause breakdowns and schedule slippage. Fortunately, a new thin film evaporator, which had been planned for some time, was installed at the plant in the fall of 1982. This evaporator has a feed rate capacity of 5 gpm ($3.2x10^{-4}$ m^3/sec^2) and can produce 50 weight percent concentrates effluent. The installation of this evaporator greatly increased the plant capabilities for processing water.

While the evaporator has the capability of producing 50 weight percent concentrates, investigations revealed that there would be problems solidifying this concentration of residue with the existing equipment. It was determined that it would be more cost effective to limit the concentrates to 30 weight percent and use strap-on drum heaters to keep the residue from crystallizing. This evaporator concentration optimized the costs of new equipment versus increased shipping costs associated with lower concentrations of evaporator residue.

The evaporator will be used to process low purity wastes. These are wastes containing higher concentrations of dissolved and suspended solids and include such wastes as decontamination solutions, chromated water and miscellaneous radioactive contaminated water. All distillate from the evaporator is processed through polishing demineralizers and filtered and diluted prior to discharge to the Ohio River.

High purity wastes such as the fuel canal water and rain water infiltration, will be processed by demineralization, filtration and dilution prior to discharge to the river. The existing radwaste system has the necessary equipment to handle this type of processing.

In order to provide a more reliable radwaste processing system and to speed up the processing operations, it was decided to set up the high purity and low purity waste processing systems as two independent processing trains tied together only at the effluent monitoring/discharge equipment. To achieve this arrangement, it will be necessary to install portable deminerlizers for polishing the evaporator distillate so that the existing demineralizers can be devoted to processing high purity wastes. Clean water collection and sampling tanks will have to be dedicated to the evaporator train and tied into the existing clean water discharge system. These changes can be accomplished with minor piping modifications. This processing arrangement gives reasonable assurance that water processing can continue even if temporary breakdowns occur.

Spent Resin Handling

At the onset of the decommissioning planning for Shippingport, spent resins were planned to be sluiced into steel liners, dewatered and shipped to a disposal site. Changing regulations covering spent resins then required that they be solidified or packaged in high integrity containers (HICs) at the time decommissioning would occur. Since approved HICs did not exist during the early phases of decommissioning planning, the solidification impacts and options had to be fully evaluated. The availability of HICs has now changed the resin disposal decision. HICs now seem best, with dewatering rather than solidification. Wastes from Shippingport are planned to be buried at the Federal facility at Hanford. Requirements at Federal burial sites are not necessarily the same as commercial sites. The use of HIC's will be reevaluated later, at a time closer to actual shipment and burial. The implementation of 10CFR61, "Proposed Licensing Requirements for Land Disposal of Radioactive Wastes," could further change plans for handling spent resins, if not for Shippingport, then for NRC licensed facilities. This changing regulatory situation bears close watching.

Primary System Decontamination

A major consideration in planning decommissioning is to determine if it is desirable to perform a gross chemical decontamination of the primary system. This will have an impact on the schedule and will generate additional quantities of liquid wastes for disposal. The benefits to be examined are reductions in cost of dismantling and reductions in occupational exposure to dismantling workers. The negative factors are the costs of decontamination and disposal of additional wastes (removed and redistributed from their current locations); and the additional occupational exposure required for the decontamination itself. Because Shippingport is a relatively clean plant, the benefits of a primary system decontamination are less than might be expected. On the cost-side of the ledger, the expense of performing the decontamination is increased by the need to take extraordinary measures to maintain or restore the operability of the primary coolant pumps, and other components needed for the operation, as the result of the two-year period of end-of-life testing and defueling between 1982 and 1984. For Shippingport, it was concluded that a primary system gross chemical decontamination was not warranted. However, it is not at all clear that similar conclusions will emerge for the typical full sized commercial plant in operation today.

SOLID WASTE MANAGEMENT

Solid Waste Types

Nuclear wastes in solid form from a decommissioning project will have a wide variation in size, weight and curie content. At one end of the spectrum are large, highly-activated plant components such as the reactor vessel and core support structures. At the other extreme, we find 55-gallon drums filled with low-level dry wastes such as gloves, swipes, and plastic. A more complete list looks like this:

- Large Activated Components (RV and Internals)
- Large Contaminated Items (Steam Generators, Pressurizers, Heat Exchangers, RC Pumps, etc.)
- Moderate sized major plant components (RC piping, isolation valves, pumps, tanks, etc.)
- Contaminated piping, valves, tubing and instruments
- Contaminated/Activated Concrete Rubble
- Activated Structural Components
- Contaminated Structural Components (much of which may be decontaminated to releasable limits)
- Miscellaneous trash and wastes

Reactor Pressure Vessel and Internals

One of the first issues to be studied for a decommissioning effort is the disposition of the reactor vessel and internals. The major competing schemes are segmentation or one-piece removal. For the Shippingport vessel we assessed five options, three of which were one-piece approaches and two of which involved segmenting the vessel. We looked at four approaches for disposal of the internals. For various combinations of vessel and internal options, a preliminary technical approach was devised to assure feasibility, then cost estimates and schedules were prepared and occupational exposures were calculated. The options were compared on a quantitative basis (it being determined that all were feasible) by adding to the direct costs, penalties for man-rem exposure (ALARA considerations) and for schedule elongations (consideration of time-dependent project costs) to arrive at a relative cost.

A one-piece approach, combining the reactor vessel and internals as one package, emerged as the favored option. The vessel will be prepared early in the project. The preparations include draining all water from the vessel and neutron shield tank (NST), severing all piping, equipment and instrumentation from the vessel and NST, filling the NST with concrete, adding a lifting beam and lifting skirt and cleaning the one-piece package. The final configuration of the vessel and its shielding is shown in Fig. 1.

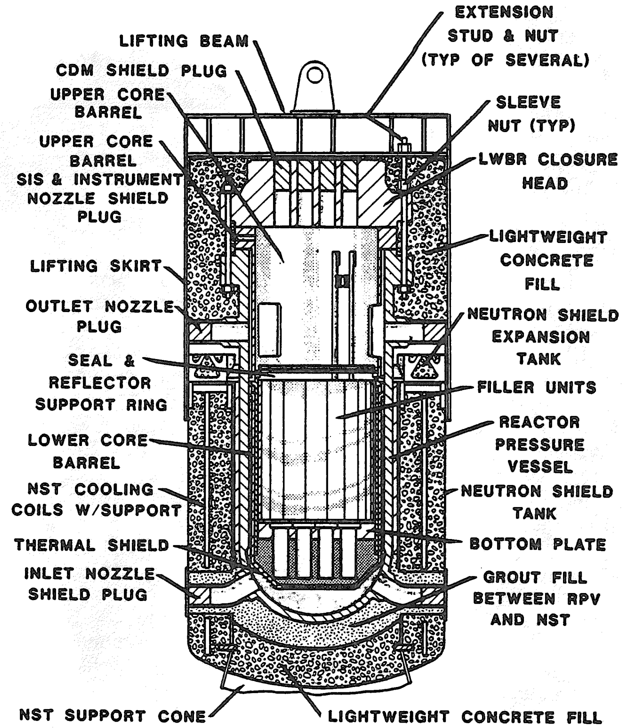

FIG. 1. — SHIPPINGPORT VESSEL PACKAGE CONFIGURATION

Some months later, the aboveground portion of the fuel handling building will be removed and the fuel canal prepared to provide adequate support for lifting and removal of the entire 770-ton (699,000 kg) one-piece package. In the latter stages of the project, the package will be lifted from its normal position, placed on a transporter which will take the package to a barge for the trip to the federal burial site in Hanford, Washington. The transporter and lifting apparatus are shown in Fig. 2.

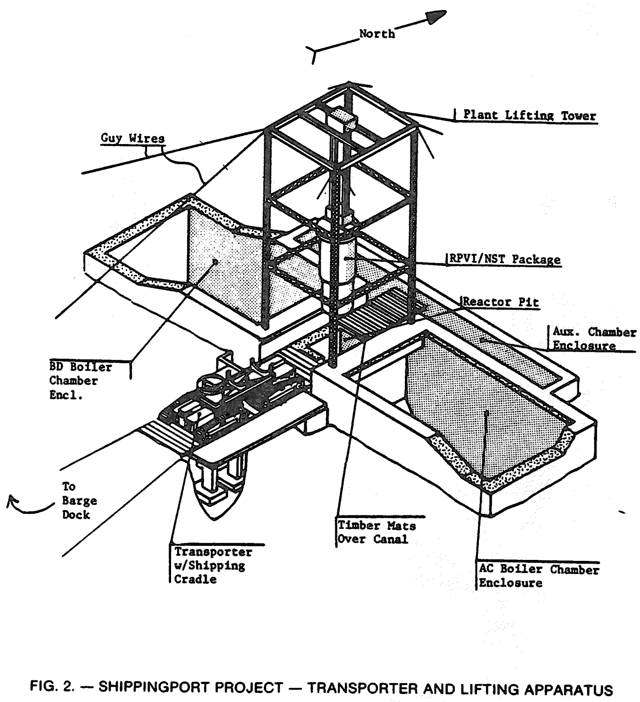

FIG. 2. — SHIPPINGPORT PROJECT — TRANSPORTER AND LIFTING APPARATUS

The one-piece removal technique has major cost, ALARA and schedule advantages to the project. Compared to a segmentation approach, the one-piece removal of the reactor vessel will reduce the overall schedule by one year, reduce the cost by about $7 million and reduce the occupational exposure by about 100 man-rem.

It is interesting to note that the size and weight of the Shippingport reactor vessel with core internals and associated shielding are similar to the expected size and weight of a 1,000 MW(e) PWR reactor vessel without the internals. Since shipping casks for core internals will probably be available on future decommissioning projects, Shippingport will provide a significant precedent for the handling and shipping of large radwaste packages over long distances. Table IV is a comparison of the final Shippingport package with the reactor vessel from a 1,000 MW PWR power plant.

TABLE IV

COMPARISON OF 1000 MW PWR
VESSEL PACKAGE WITH SHIPPINGPORT

Shippingport RPV/NST/Internals package:

Overall height	= 40 feet (12 meters)
Outside diameter	= 18 feet (5.5 meters)
total weight	= 770 tons (699,000 Kg)

Typical 1000 MW PWR vessel:

Overall height (without lifting beam)	= 41 feet (12.5 meters)
Outside diameter (without shielding)	= 16 feet (4.9 meters)
Vessel	= 340 tons (309,000 Kg)
Closure Head	= 81 tons (73,500 Kg)
Studs, etc.	= 20 tons (18,200 Kg)
Total weight (without internals)	= 441 tons (400,000 Kg)

With allowance for additional height for a lifting beam, and additional diameter and weight for shielding, the 1000 MW PWR vessel package is a comparable shipping package to that planned for Shippingport.

Other Major Components

The four steam generators at Shippingport consist of a heat exchanger section and a steam drum, connected by risers and downcomers. Only the heat exchanger is contaminated. Nozzle openings will be seal welded and the vessels shipped for disposal as their own containers. Similar action will be taken for the pressurizer and flash tank. For full sized commercial plants, ample experience is being generated for handling steam generators. At Surry and at Turkey Point, these components were removed in large sections, giving good experience which can be applied to future decommissioning.

Contaminated Piping

The state of technology today does not offer attractive options to ordinary nesting, boxing and burial of contaminated piping. Progress is being made in two areas which may offer advantages in the future:

- Electro-polishing techniques are being used to effectively remove contamination from metal objects, particulary for purposes of reducing occupational exposure. For decommissioning, significant benefits can be realized only if the piping can be certifiably decontaminated to releasable limits and thus avoid the need for disposal of radwaste. To date, economic and operational factors of electro-polishing have not been proven to be an advantage over conventional burial.

- Mechanical volume reduction techniques are receiving increased attention. In Europe, experimentation is going forward with high capacity compactors which could reduce the volume of contaminated pipe. Heavy duty shredders may find application. A Japanese firm is considering smelting techniques for volume reduction.

Contaminated Rubble

The disposal of contaminated or activated concrete rubble poses no particular problems in handling or shipment. However, it is often difficult to accurately estimate quantities in advance because uncertainties exist concerning the depth of penetration of contamination; and methods for physically removing the concrete vary with the situation and need to be carefully studied. Removal methods which generate large quantities of liquids need to be well justified since the liquids present difficulties in control of recontamination and they constitute a further disposal problem of their own.

It is important to take core samples to develop accurate information about contamination depth. Important also is the development of survey criteria and methodology to permit a removal/survey cycle which will minimize costs and result in a remaining structure that is radiologically releasable for unrestricted use (i.e., removal of a single thick layer of potentially contaminated concrete may assure that all contaminants are removed but could result in unnecessarily large quantities of radwaste, which are costly to ship and bury).

Costs for Decommissioning Radwaste Management

The total cost of the Shippingport decommissioning is estimated at about $73 million. Of this total, it is estimated that about $14 million will be devoted to radwaste processing and disposal operations. These costs cover the processing, packaging, transportation and burial of radioactive wastes. Not included in the waste management total are costs associated with decontamination, dismantling, work on non-contaminated parts of the plant, or engineering and planning. As can be seen from the above, the management of radwastes during decommissioning is a major part of the overall decommissioning effort.

Final Release Criteria

The quantities of radwaste generated during decomissioning will have some dependence on the final radiological release criteria for the site - particularly as this relates to soil. The U.S. Enviromental Protection Agency has the responsibility to establish this criteria but is not scheduled to do so for several years. The Department of Energy will establish a criteria for Shippingport. Current evidence is that no significant soil contamination exists at Shippingport, so decommissioning costs and radwaste quantities are not particularly sensitive to the selected criteria. Such a fortunate situation may not exist for other generating plants or for other types of nuclear facilities. It is a matter which needs to be given careful consideration.

CLOSING COMMENTS

A major objective, which was considered during all radwaste processing planning for Shippingport, was to utilize as much of the existing plant radwaste systems as possible and to minimize capital improvements or additions to these systems. For Shippingport's decommissioning, it was possible to meet this objective as a result of the timely installation of a new thin film evaporator. Also, the schedular constraints and waste quantities to be processed at Shippingport indicated that supplemental processing equipment would have been required if the new evaporator was not available. This experience suggests a potential future need for mobile radwaste processing equipment, other than demineralizers, to support future decommissioning projects.

As the issue of decommissioning becomes more important, it will be necessary for engineers and managers to have a full appreciation of the waste disposal problems presented by the dismantling of nuclear plants. The Shippingport project will provide data and experience which will be of value to the industry.