DECONTAMINATION AND DECOMMISSIONING METHODS AND MANAGEMENT OF THE RESULTANT WASTE PRODUCTS

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ABSTRACT

The nuclear industry has been active in developing cost effective techniques for decontamination and decommissioning of nuclear sites and facilities for more than 40 years. Important to the planning and implementation of physical decommissioning procedures is knowledge of past and current successful practices. A brief overview is given of selected Department of Energy's decontamination and decommissioning projects, types of waste generated, and curie content, radiation levels, shipping containers, specific methods for managing waste, and release levels are given. A specific problem is identified for to managing radioactive wastes, and a practical method for reduction of radioactive waste volume is described.

INTRODUCTION

This paper provides a description of selected decontamination and decommissioning (D&D) techniques with emphasis on waste management. The approach presents an overview of four selected projects as examples of D&D methods, radioactive wastes generated, and overall waste management. The discussion includes unique project features, radioactivity dose levels and concentrations, types of wastes, shipping containers, and the specific methods applied in managing wastes and site release protocols.

Decontamination and decommissioning, and associated waste management are not new undertakings. For instance, we know of the decommissioning of the Shippingport Plant that was completed in 1989, the Elk River Plant completed in the mid 70's, and the Hallam Plant that was decommissioned in the mid 60's. Additional experience has been gained from defense related waste management activities in the 50's, and the cleanup of several nuclear laboratories and research reactors over the last 40 years. At present, there are a large number of sites that have been cleaned up, and released by DOE and predecessor agencies. Clearly, U.S. Government agencies have been managing and disposing of radioactive waste since the early 40's. With more than 40 years of waste management experience there are reasons to believe that we are now at the end of the beginning phase.

Shippingport Station Decommissioning Project

Shippingport Station Decommissioning Project was completed in 1989 with the site taken to greenfield condition and released without radiological restrictions. Shippingport was this nation's first commercial scale nuclear power plant. The Shippingport plant was a four loop pressurized water reactor designed by Westinghouse and constructed in 1955-1957. It operated from 1957 through 1982, generating over 7 gigawatts of electrical power to the residents of the Pittsburgh area. Power plant reactor operations were terminated in 1982, and the plant was defueled by 1984. Physical decommissioning work started in 1985 and was completed in 1989. During this time period, 214,000 cubic feet (7925 cubic meters) of waste was generated and shipped for disposal at the DOE Hanford Reservation. Shipments included two Type A shipments, and a Type B shipment. The Reactor Pressure Vessel/Neutron Shield Tank package was classified conservatively as a Type B package to assure compliance with transport requirements. The remainder of the waste shipments were classified as low specific activity. Table I is a list of radioactive waste shipment data from FY 1984 through FY 1989.

The first waste sent off site was radioactively and non-radioactively contaminated asbestos. Approximately 500 cubic yards (380 m^3) of installed asbestos insulation were removed and packaged for disposal. The total disposal volume was 2088 cubic yards (1586 m^3), indicating a nominal swell factor of 4 to 1. All asbestos was packaged in double poly-film bags and transported in wood overpack boxes. The removal of asbestos was compounded by the radioactive contamination which required special handling and containment procedures. For example, wetting agents were used to suppress airborne fibers, containment tents were erected as barriers, and full dress anti-contamination clothing and respirators were required for worker protection during the removal process (1).

Over 49,000 lineal feet of non-contaminated carbon steel pipe, and over 54,000 lineal feet of contaminated stainless steel pipe was removed from the plant. This included over 1300 carbon steel valves and 1500 stainless steel valves (2). Similarly, the electrical components such as conduit and cable, motor control centers, transformers, and cable trays were removed, packaged, and shipped as low level waste for burial at Hanford (3).

The 7,925 cubic yards (6,063 cubic meters) quantity of radioactive waste from the decommissioning of Shippingport was disposed of at a cost of $3.426 million (U.S. 1989 dollars). These data result in a unit cost of $432.30 per cubic foot ($565.07 per cubic meter) for radioactive waste treatment, packaging, preparation for shipment, and disposal.

The volume of packaged waste transported by truck and rail was approximately 7,555 cubic yards (5,780 m^3) at

TABLE I

Shippingport Station Decommissioning Project
Radioactive Waste Shipment Data From FY 1984 Through 1989

Contents	Package Type	Number of Packages	Volume (ft^3)	Weight (Lb.)	Radioactivity (Curies)
Asbestos	FMI-S-112	1	112	2,315	0.343
	CPC S-96	31	4,061	123,070	1.609
	ASP-101	259	33,670	179,305	0.540
Compressed Waste	17H Drums	116	858	27,365	0.039
Concrete	17H Drums	156	1,154	89,640	0.068
	FMI-S-112	6	672	26,040	0.010
Lead	FMI-S-112	17	1,904	98,455	0.141
	SE-1	9	113	38,898	0.035
Metallic Waste	17H Drums	32	237	20,565	0.002
	CI TMB-V	2	758	16,898	0.126
	CPC B-12V	11	616	35,000	0.026
	CPC S-96	42	5,502	198,040	8.086
	CPC S-119	3	330	8,175	1.210
	CPC-S-282	1	373	18,040	0.373
	FMI-S-112	498	55,776	2,166,095	31.770
Soil	17H Drums	48	355	23,435	0.240
	CPC B-12V	1	56	3,500	0.001
	FMI-S-112	13	1,456	42,495	1.202
Solidified Sludge	17H Drums	737	5,454	430,665	3.838
	FMI-S-112	3	336	5,995	0.458
Solid Waste	FMI-S-112	436	48,832	1,333,060	16.310
	17H Drums	159	1,176	38,548	0.357
	CPC B-12V	8	448	25,500	0.014
	ASP-101	111	14,430	84,680	0.289
	CPC S-96	77	10,087	356,815	9.570
Spent Resins	NUHIC-120	21	3,570	124,405	40.816
One-Piece Components	Self-Contained	25	11,560	1,003,600	24.269
RPV Package	Type B	1	9,800	1,798,000	16,467.000
TOTALS		2,824	213,897	8,368,599	16,608.750

Package Type Legend

17H Drums	55-Gallon full open head, DOT specification
CPC S-96	Steel box, Container Products Corp.
FMI-S-112	Steel box, Fab Masters, Inc.
ASP-101	Plywood box, SSDP design
NUHIC-120	Polyethylene cylinder, TFC Nuclear Associates
CI TMB-V	Steel box, Capital Industries
CPC-S-282	Steel box, Container Products Corp.
Self-Contained	Component Serves as its own package
RPV Package	Reactor Pressure Vessel/Neutron Shield Tank Package

a cost of $1.179 million (U.S. 1989 dollars). This included more than 200 motor carrier exclusive use truck shipments and a single railroad shipment of eight gondola cars loaded with primary pumps, the pressurizer, heat exchangers, tanks, and other components, all of which served as their own shipping containers (4). These data result in a unit cost for truck and rail transportation of $156.06 per cubic yard ($203.98 per cubic meter)·

The DOE Hanford Reservation assessed a burial cost of $5.92 per cubic foot in 1986 for low level wastes. By 1989, the unit cost had increased to $27.06, an increase of $21.14 per cubic foot. The total solid waste disposal cost was $2,438,000 over the life of the project for the 7,925 cubic yards (6,063 cubic meters) of waste buried at Hanford. These data result in an average disposal cost of $307.63 per cubic yard ($402.11 per cubic meter).

The most significant technical feature of the project was preparation, one piece removal, and shipment of the reactor pressure vessel/neutron shield tank package, which was shipped as its own container. Several papers and much documentation is on record for this work (5,6,7).

Waste management control procedures included requirements for all packages to be surveyed, tagged, and logged as to the contents and concentrations. Quality Assurance personnel inspected the boxes, observed their loading, and maintained very detailed records for each box and each shipment. The prior planning, execution and quality control exercised by General Electric/M.K. Ferguson were excellent.

Experimental Boiling Water Reactor Decommissioning Project

The Experimental Boiling Water Reactor is located at Argonne National Laboratory near Chicago. It was built as a test reactor to demonstrate the feasibility of using a direct cycle boiling water reactor. Initial operation was in December 1956. It was designed to produce 20,000 kW (thermal) at 600 psig which was fed directly to a turbine generator. The reactor was later modified to produce 100,000 kW (thermal). It was next loaded with a core containing plutonium and operated in support of the AEC's Plutonium Recycle Program. The plant was shut down in 1967 and all nuclear fuel removed. It was, in effect, a Safstor operation until decommissioning started in late 1986. The goals for this project are to clean out the building, to remove the reactor vessel, all equipment and all radioactive contamination, thus leaving the building free for other use without radiological restriction. Currently, all piping, electrical, and mechanical components have been removed. The remaining work includes removing the reactor internals, cutting up the reactor vessel and irradiated portions of the biological shield.

The piping and mechanical equipment were removed using conventional powered band saws, saber saws, oxy-acetylene gas torches, and a plasma-arc torch. The turbine and condenser were lightly contaminated, and were cut up and grit blasted to free release limits. The remainder of the building was wiped down and vacuum cleaned during the early work phase. At the completion of the project, a thorough decontamination and radiological release survey will be performed by ANL technicians. Remaining hot spots will be cleaned up and then an independent verification survey will be conducted in accordance with DOE policy for independent verification.

Efforts currently are being directed to completion of fuel pool work prior to segmentation of the internals, and to writing procedures for the underwater segmentation of reactor internals. In addition, laborers are being trained to the new cutting equipment for the removal and segmentation of the reactor vessel. Last summer, ANL metallurgists took core samples from the reactor vessel for analysis. A final report on their findings, entitled "Chemical and Gamma Count Analysis of the Primary Vessel Wall of the EBWR Wall", is scheduled for completion in 1991.

The requirement to reuse this building and to minimize demolition, led to the decision to remove the vessel by segmentation rather than a one piece removal. Also, the presence of a wooden "blast shield" around the reactor vessel precluded use of thermal cutting techniques. For these reasons, project management decided to use a high pressure water jet for the segmentation operations. This machine also will be used to cut the concrete biological shield. The machine operates at 35,000 psi (2400 bar) and uses garnet as the abrasive grit; it is capable of cutting 3 inches (7.6 cm) per minute in carbon steel. There are approximately 600 linear feet of cuts in the reactor vessel. The reactor vessel is 2.375 inches (6 cm) thick, 7 feet (2.13 m) in diameter, and 23 feet (6.9 m) long.

It is estimated that the EBWR D&D project will generate approximately 18,000 cubic feet (510 cubic meters) of low level radioactive waste for off site disposal. This will consist of the reactor pressure vessel, the internals, process and drain pipe, ion exchangers, pumps, filters, tanks, and contaminated building materials, primarily concrete and wood. The curie content is estimated to be 425 curies, with the majority as expected in the reactor pressure vessel. Table II is a list of the waste generated from the EBWR project since 1986.

The EBWR project, because of its requirement for reuse of the building and to avoid flame cutting, affords the industry another opportunity to demonstration reactor segmenting processes. The Elk River project in the late 70's, segmented the reactor vessel using a plasma arc torch while Shippingport used one-piece removal rather than segmentation. The Department is supporting a comprehensive

TABLE II

Experimental Boiling Water Reactor

Waste Removal Through 1990

Contaminated Material	Volume or Weight	Disposition
Asbestos	36 ft^3	ANL-W Landfill
Lead	400 pounds	ANL-E Stored on Site
Ion Exchange Columns (2)	18,000 pounds	ANL-E Stored on Site
Water Treatment Prefilters (2)	2,000 pounds	ANL-E Stored on Site
Liquid Waste	5,600 gallons	Treated & Evaporated
Piping, Conduit, Misc. Equipment	108 yds^3	ANL-E Landfill
Turbine	15,000 pounds	INEL
Tanks	12	ANL-E Landfill
Reactor Vessel and Internals	4,000 ft^3 estimated	DOE-RL Hanford

Total curie content is estimated to be 425 curies with the majority expected to be in the reactor vessel and concrete shielding.

Non-Contaminated Material		
Asbestos	2,538 ft^3	ANL-E Landfill
Lube Oil	565 gallons	Recycled
High Density Concrete Blocks	53,300 pounds	ANL-E Stored on Site
Lead Bricks	4,900 pounds	ANL-E Stored on Site
Lead Shielding	2,300 pounds	Recycled
Concrete Blocks	8,800 pounds	ANL-E Landfill
Condenser	50,000 pounds	Recycled
Generator	35,000 pounds	Recycled
Building Debris	4,000 ft^3	ANL-E Landfill
Miscellaneous Iron	20,000 pounds	Recycled
Piping, Conduit, Misc. Equipment	120 yds^3	Recycled
Turbine	20,000 pounds	Recycled

Waste Packages

ANL M-3A Bin	12 gauge steel angle iron reinforced 4 ft x 5 ft x 6 ft high 8,000 pound load limit
ANL M-3A Half Bin	4 ft x 5 ft x 3 ft high 8,000 pound load limit
DOT 17H Drums	

technology transfer program at EBWR, as was done at Shippingport, to make data from these markedly different approaches available to the industry.

Space Nuclear Auxiliary Power-8

Another interesting decommissioning project is the decontamination and decommissioning that removed the nuclear auxiliary power system developed for the space program at the Santa Susana Field Laboratory near Los Angeles. The Space Nuclear Auxiliary Power-8 (SNAP-8) ground prototype and flight system reactors were constructed in the late 1950's and early 1960's with tests continuing at the SNAP Ground Prototype Test Facility into 1969. At that time the reactor fuel, the small reactor, and sodium-potassium systems were removed. The decontamination of the building was first started in 1978 but halted in 1979 for budget planning cycle considerations. Before the work was halted, project workmen removed a number of contaminated hold-up tanks, piping, miscellaneous support systems, and equipment. However, remaining in place at that time, in essentially a safe storage mode was an activated steel duct, shielding sand, and an activated stainless steel vacuum vessel that had surrounded the reactor in three concrete underground vaults. When the project work was restarted in 1988, the first task was removal of the sand, which was found to be wet from groundwater intrusion into the vaults. The water intrusion was controlled by installing a pump into an existing french drain system around the underground vaults and a pump in the building. A small differential head (12 inches higher on the exterior) is being maintained to prevent contaminated water from flowing back out of the building until all work is completed in the building.

Approximately 80 tons (72 tonnes) of shielding sand had to be removed first, followed by the duct portions. The degree of difficulty was high in these locations due to constrains of space and access. For example, the vaults were slightly larger than the 5 feet (1.5 meter) diameter ducts in some areas and 45 feet (13.7 meters) below grade. The accumulated sand and duct had to be removed to provide access for removal of the reactor vacuum vessel. The reactor vacuum vessel was 6.5 feet (1.9 meters) in diameter and 14.5 feet (4.4 meters) high, with 0.375 inch (1.0 cm) stainless steel walls, and contained approximately 7 curies of activation products. It was confined in a 14 foot (4.3 meters) square room. The walls of this room were lined with steel plate, and had two feet of concrete shielding within it. This shielding concrete contains steel shot, instrumentation thimbles, cooling coils and rebar. All of this concrete shielding is activated and has yet to be removed. There are approximately 58 curies, identified mainly as Iron-55, remaining as activation products in the structure. The vacuum vessel was segmented using a remote plasma arc torch pivot arm developed by the Energy Technology Engineering Center of Rockwell International mounted on an in-service inspection manipulator. The shield concrete is being removed with a hydraulic ram mounted on a tractor. The backhoe controls have been modified for remote manipulation using a TV camera. The removed segments of the reactor vacuum vessel are packaged into six shielded special sized boxes bought to fit the Hittman 300 overpack, the containers are presently stored on site waiting shipment for burial at Hanford.

Battelle Columbus Laboratories Decommissioning Project

The Battelle project site is at the Battelle Columbus Laboratories, located in Columbus and West Jefferson, Ohio. The Battelle project consists of decontaminating 15 buildings that have varying degrees of radioactive contamination as a result of their private and public sector work in nuclear research since 1943. The Battelle facilities have an NRC license for work done for the private sector. However, the vast majority of radioactive work at the site was done for the Department of Defense, Air Force, and the DOE predecessor agencies. DOE has accepted the lead role for managing the decontamination of the facilities since the majority of residual contamination is the result of DOE work.

In 1986, the Battelle Columbus Laboratories were taken into DOE's Surplus Facilities Management Program for surveillance and maintenance prior to decontamination. In 1988, the preparations for decontamination began, and at the beginning of 1990, three buildings had been completed. Work is in progress on three others. Eventually, these buildings or portions of them are to be decontaminated and returned to Battelle, the owner, for alternate uses. Nine of the buildings are in the city of Columbus, just across the street from the Ohio State University. Six buildings are approximately 16 miles away at West Jefferson, Ohio. This project is scheduled for eight years and roughly estimated to cost $147 million.

The majority of the buildings contain low levels of radioactivity yielding radiation levels much lower than 1 mR/hr, however, one building has a large hot cell with material in it reading over 250 R/hr. Table III is a list of the contaminated buildings. The names of the buildings give an indication of the work performed in them.

BCL decontamination methods and wastes management procedures use a broad range of approaches. For example, the first three buildings were wiped down and vacuum cleaned. In a few instances, scabbling of concrete was done for hot spot decontamination. Also, a roof fan was removed and volume reduced by compacting prior to shipment as low specific activity material.

The BCL site characterization and the radionuclides inventory indicate that the principal contaminants in this

TABLE III

Battelle Columbus Laboratories Decommissioning Project

Building or Facility	Area To Be Decont. (ft^2)	Est. Waste Volume (ft^3)	Estimated Curies
King Avenue Site			
A. Research Laboratory	1,895	400	2×10^{-6} U
1. Foundry	18,254	2,400	2.3 U
2. Metalworking	15,347	775	7.0×10^{3} U,Th
3. Materials	69,242	6,900	8 U, Th
4. Radiochemistry	7,428	930	1.8 U, Th
5. Machine Shop	36,535	1,300	6.8 U, Th
6. Chemistry	2,226	500	2.5 U
7. Chemistry	5,672	300	5 U
9. Mechanical Engineering	1,525	100	<1 U, Th
West Jefferson Site			
JN-1 Hot Cells	--		6,000 Mixed Fission Prod.
JN-2 Critical Assembly Lab	1,257	100	5 U, Th
JN-3 Retired Research Reactor	--	25,500	15 U
JS-1 Hot Isostatic Processing	523	800	<1 U
JS-10 Explosive Containment	1,925	800	< 0.1 U, Th
JS-12 Ballistic Facility	1,434	800	< 0.1 U, Th
Soil Contamination	15,000	81,375	20 Am-241, Cs-137, Pu-239, Co-60

laboratory project are uranium, cesium-137, cobalt-60, americium-241, plutonium-239, thorium, and some of their daughter products. The initial estimate of suspect transuranic (TRU) waste is approximately 3400 cubic feet (96 cubic meters). The TRU waste is being packaged into contact handled waste (less than 100 mR/hr at contact) to comply with Hanford acceptance criteria. A total of 6055 curies are estimated to be produced during decommissioning of this project. The majority of the curie content is located in the hot cells.

Based on the estimated volume of waste, it is anticipated that approximately 525 shipments (truck, semitrailer) may be required, consisting of 410 shipments of low level waste and 115 shipments of suspect TRU waste. A study will be done this year to evaluate possible volume reduction, exposure reduction, and cost reduction through packaging for remote handling of TRU waste. The DOE Hanford, Washington disposal site is being utilized for disposal of the low level waste as a continuation of its long standing relationship with Battelle. It is anticipated that the TRU waste will go to Hanford for interim storage, then to the Waste Isolation Pilot Plant (WIPP), once it is authorized for operation. All TRU waste shipped to Hanford will comply with the Small Stream Generator Plan which was approved in November, 1990 by the WIPP Waste Acceptance Criteria Certification Committee. The TRU waste shipment is on hold pending resolution of audit comments and discussion with the State of Washington.

The Battelle Columbus Laboratories, as an NRC licensed facility, is required to satisfy NRC release requirements as described in NUREG/CR 5512 Residual Radioactive Contamination from Decommissioning. The Department of Energy release limits are contained in DOE Order 5400.5 and include the ALARA concept (As Low As Reasonably Achievable). This is important in the case of the Battelle Laboratories Project because these buildings are close to release limits. Release protocols include decontamination and decommissioning and ultimate release to the owner, Battelle, for use without radiological restrictions. And, as has been done on all other DOE projects, achievement of release limits will be independently verified.

The project is planned for completion in 1998 and is presently on schedule. Completion percent at this time is about 10%.

CONCLUSION

At the beginning of this paper, it was noted that a significant number of project sites have been cleaned up and that nuclear waste management and waste disposal has been in progress for nearly 40 years. We are at the end of the beginning phase. We still have a long way to go to decommission our surplus nuclear facilities and to disposition this country's nuclear waste generated before we reach the point where we are handling waste as it is produced.

There are several areas of waste management that require our serious attention. Among them are spent fuel storage, transuranic waste storage and shipment, mixed hazardous and radioactive waste, and the large volumes of low-level waste currently in storage awaiting proper disposal facilities. Common denominators among these wastes are handling, packaging, transportation, and disposal. And, overlaying all these factors is the important element of waste volume. Over the past 15 years or so, the primary emphasis in waste management has been directed to the on-site reduction in the volume of waste generated. Subsequently, this would decrease the volume of waste to be packaged, transported, and disposed. This could reduce costs and worker occupational exposure. We know that the volume reduction methods using compaction, incineration, vitrification, and evaporation are in use.

As noted above, the BCL project has the problem of disposing of approximately 3,400 cubic feet (96 cubic meters) of transuranic (TRU) waste. This TRU waste contains approximately 6,000 curies. In order to ship it at the present limits for contact handling, the waste must be repackaged into DOT 17C drums and with less than 100 mR/hr surface readings. The initial requirements estimate for these wastes indicated 16,000 shielded drums would be required. These drums, when loaded to < 100 mR/hr surface readings, represent approximately 120,000 cubic feet (3,400 cubic meters) of waste to be handled, shipped, and disposed. There is a study in progress to determine the feasibility of packaging this waste as remote handled waste. Rough calculations indicate that if this waste were packaged to previous contact limit standards of < 200 mR/hr, the number of drums required would decrease and the volume for burial would also decrease by a factor of two. This decrease would have a significant positive impact on the project cost and schedule, since the large hot cells cannot be decontaminated until handling of this waste has been completed.

The effect of lowering the contact handled limits for drums received at Hanford has resulted in significant increases in disposal and storage costs and has increased the total volume of material to be treated as waste. Continued ratcheting lower of the contact handled limits may be counterproductive in the long term. Standards should be developed and a demonstration of TRU waste management techniques made to prove the effectiveness of packaging waste for remote handling. If remote handled TRU were acceptable to Hanford, the savings for this one project could be as high as $35,000,000 at the current $307 per cubic foot disposal charge [$307 x (120,000 ft^3 - 3400 ft^3]. This approach could also yield order of magnitude reductions in waste disposal volumes for the Battelle project and other projects and should be thoroughly reviewed.

The overview of these four projects is meant to be encouraging, to provide information on completed and ongoing projects. We have accomplished much in the past 40 years, but we have much work ahead, especially in the area of technical innovations to increase productivity by decreasing the volume of waste to be handled.

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