# THE EXPERIMENTAL BOILING WATER REACTOR (EBWR) DECONTAMINATION AND DECOMMISSIONING (D&D) PROJECT

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## ABSTRACT

The Experimental Boiling Water Reactor (EBWR) operated from 1956 to 1967 at power levels ranging from 20 to 100 MW. At the time of the plant shutdown, the reactor fuel was removed, and the facility placed in dry lay-up.

Decontamination and decommissioning (D&D) funding is being provided through the Department of Energy (DOE) Surplus Facilities Management Program (SFMP) to clean up the facility to nonrestricted use levels. The D&D project was started in Fiscal Year (FY) 1986 and is targeted for completion in FY 1994. This paper details the work completed, underway, and future planned work. The different waste types generated to date on the project and waste handling techniques at the Argonne National Laboratory (ANL-East) site are also described.

## INTRODUCTION

The EBWR was built as a test reactor to demonstrate the feasibility of operating an integrated power plant using a direct cycle boiling water reactor as a heat source. The reactor was designed to produce 20 MW of heat which was fed directly to a turbine-generator producing 5 MW of electricity. Construction was initiated in 1955, and full power operation was first achieved in December 1956.

Following intermittent operation at power levels up to 62 MW, the EBWR was modified in 1962 to increase its power output capability to 100 MW. The modifications included the addition of a reboiler plant to utilize the additional 80 MW of thermal energy, in addition to the 20 MW used by the turbine-generator.

The EBWR was later loaded with a core containing plutonium and operated in support of the Atomic Energy Commission's (AEC) Plutonium Recycle Program. The role of the EBWR in the DOE/AEC programs was completed in July 1967, and the plant was permanently shut down and placed in a dry lay-up condition.

The facility was placed in DOE's SFMP in 1976. It is currently undergoing D&D which will allow the facility to be reused by other DOE research programs.

## FACILITY DESCRIPTION

Argonne National Laboratory currently occupies a 1,700-acre (690 hectares) reservation in DuPage County, Illinois, approximately 22 miles (35 kilometers) southwest of downtown Chicago. Laboratory structures and support facilities occupy approximately 200 acres (81 hectares) of the site, with the remaining acreage devoted to landscaped areas and forest. The location of EBWR is in the 300 West area of the ANL-East Site.

During its early operating life, the EBWR Facility consisted of the Nuclear Power Plant within the containment building, a connected office/service building, associated electrical switch gear, and a cooling tower. A reboiler building containing equipment designed to dissipate excess thermal energy was added later. The reboiler building was cleared of its equipment, decontaminated, and converted to other uses in the 1970s, and is not a part of the EBWR D&D Project. The facility cooling tower was previously dismantled and disposed of, and the office/service building has been converted to office space. Therefore, these areas are outside the scope of this project. However, circulating water piping leading from the containment building to the cooling tower and piping to the reboiler building remained in place. This piping required removal, surveying for radioactivity, and disposal in accordance with the D&D criteria.

### Containment Building

The containment building is a circular, domed structure made of steel plates welded together that originally formed a gas-tight envelope around the power plant. It rises 63 feet (19 meters) above, and extends 56 feet (17 meters) below, ground level and has an inside diameter of approximately 80 feet (24 meters). Below ground level, the steel shell is 5/8-inch thick (1.6 centimeters); above ground level it is 3/8-inch thick (0.95 centimeters). The interior of the steel shell is lined with a two-foot (0.61 meters) thickness of reinforced concrete below the main floor level. Above the main floor, to a height of 25 feet (7.6 meters), there is a one-foot (0.30 meters) thick concrete lining. At the 26 foot (7.9 meters) height, a one-foot thick (0.30 meters) concrete ceiling slab faced with a 3/8-inch (0.95 centimeters) thick steel plate completes the concrete envelope surrounding the power plant inside the containment shell.

The building contains a main floor and three lower floors on which all the power plant equipment is located.

### Reactor Pressure Vessel and Internals

The reactor pressure vessel is contained within a shielded cell which extends from the main floor downward approximately 25 feet (7.6 meters) to the region of the pump floor. The vessel is made of carbon steel, clad with stainless steel on those surfaces which were in contact with reactor water or steam. It is approximately 7 feet 5 inches (2.3 meters) in outside diameter, 24 feet 8 inches (7.5 meters) in length, and has a nominal wall thickness of 2 1/2 inches (6.3 centimeters). Nine control rod drive tubes and four forced circulation inlet pipe stubs extend downward from the bottom of the vessel, penetrating the cell's bottom shielding plug. Two 12-inch (30 centimeters) diameter forced circulation outlet pipes also extend from the pressure vessel through the cell's 4-foot (1.2 meters) thick bottom shield. The vessel is closed by a forged steel coverplate approximately 9 inches (23 centimeters) thick which is retained by the reactor vessel studbolts.

The outside of the pressure vessel is covered by a layer of thermal insulation consisting of a stainless steel wool which is held in place by stainless steel bands and wire mesh. A dead air space separates the steel wool from the inner surface of the cavity steel cylinder, approximately 8 1/2 feet (2.6 meters) in diameter and made of 3/4-inch (1.9 centimeters) thick plate, which constitutes the inner boundary of the cell. Lead bricks are stacked against the outside of the cylinder to provide a gamma-radiation shield. Shield cooling coils made of copper tubing are fastened to the steel cylinder beneath the lead.

With the termination of the EBWR research program in 1967, the reactor was shut down, the fuel was removed and sent offsite for reprocessing, and the EBWR Facility was placed in dry lay-up. This deactivated condition was achieved by draining all liquids from the reactor systems, flushing them thoroughly, and then leaving all valves in their open position. Also, certain flanges were removed and in some cases holes were drilled at system low points. The fuel storage pit was drained, flushed, and decontaminated.

**Pre-D&D Radiological Condition**

In August 1979, a radiological survey was performed of accessible areas in the EBWR containment building. This survey showed that there were significant but not necessarily high radiation levels in various locations within the building, primarily due to the radioactive isotope Cobalt-60. After 12 years of safe storage, the highest radiation levels occur in the basement where a gamma reading of 300 mR/hr (3 mSievert/hr) was measured at a purification system regenerative cooler. Significant gamma radiation was also detected at the reactor liquid level column which measured up to 70 mR/hr (0.7 mSievert/hr), the steam dryer, the desuperheater, and along a piping run adjacent to the deaerator. These latter areas were measured at from 3 - 30 mR/hr (0.03 - 0.3 mSievert/hr) gamma. No radiological survey of the reactor vessel was performed in 1979. The radiological surveys made inside the containment shell indicated that, while localized areas would result in personnel exposures, workers would not be subjected to any unusually high backgrounds while performing the various operations, excluding the removal of the reactor vessel.

A radiation survey of the inside of the reactor vessel was performed in February 1989. The results of this survey showed that the radiation fields ranged from 2 R/hr (0.02 Sievert/hr) to a maximum of 100 R/hr (1 Sievert/hr).

Corings into the reactor vessel wall indicate radiation fields in the range of 10-20 mR/hr (0.01-0.02 Sievert/hr) (1). This is significantly lower than first predicted and removal of the reactor vessel will pose a minimal concern during dismantling of the reactor vessel complex. Consequently, the removal of the reactor vessel internals will pose the greatest occupational radiation exposure risk during the D&D work.

## FACILITY OBJECTIVES

The EBWR D&D Project is directed toward the following objectives:

- The removal of all radioactive materials associated with the EBWR Facility from the ANL-East site.
- The decontamination and clean-up of the EBWR Facility to allow its unrestricted reuse.

## PROJECT STATUS

**Project Approach Philosophy**

From the start of the D&D, the project has attempted to maintain a small but highly efficient workforce. Typically, there are from four to six D&D Waste Management technicians working with one to two Health Physics technicians, with each technician group having a foreman overseeing their work. In addition, the project utilizes former reactor operations staff as technical consultants and the services of a full-time senior engineer. These personnel report to the Project Manager.

Other groups, such as riggers, machine shop, and other engineers and support groups, provide general support on an as-needed basis.

Also, various efforts have been made to keep costs as low as possible, the dismantling techniques simple yet effective, and the tools easy to use or "worker friendly". This ideology is the result of various discussions with U. S. and other countries' D&D program personnel. In certain instances--like immediate dismantling for reactor replacement--simplicity is not necessarily the most economical approach. However, in *our case, our evaluation* showed that it was. Above all else, the first requirement is that the techniques used provide maximum worker health, safety and environmental protection.

**Phase I Work**

Dismantling activities under this phase were begun in FY 1986. Typical activities carried out under Phase I were: establishing a base of operation in EBWR; assembling the D&D workforce; preparing the final environmental document (2) and project plan (3); and removing asbestos from throughout the facility.

Removal of asbestos from the EBWR Facility was the most time-consuming activity during Phase I. Significant preparation of areas for asbestos removal was required due to each level or area presenting a different piping configuration from previous work areas. In some cases, temporary flooring had to be erected or suspended under piping to allow workers access to the areas of removal. Originally, design of the piping systems provided ease of plant operation and maintenance; and, obviously, removal of the asbestos at the time of plant D&D was not considered. To remove about 500 cubic feet (14 cubic meters) of asbestos from an area, about 80 percent of the time was spent setting up equipment and the work area and only about 20 percent of the time was involved in actually physically removing the asbestos. A total of about 2,600 cubic feet (74 cubic meters) of asbestos was removed from the EBWR Facility during the Phase I D&D portion of this project. Of this total, only about 35 cubic feet (1 cubic meter) was radioactively contaminated and required disposal as radioactive waste. Phase I of the D&D was completed in FY 1988.

**Phase II Work**

Phase II of the D&D Project commenced in FY 1988 upon successful completion of the asbestos removal and other Phase I work. At the time Phase I work was completed, some removal of piping and equipment had been done to facilitate asbestos removal. However, work began in earnest in Phase II on removal of all remaining reactor systems and components. Reactor systems were removed and size reduced for packaging using conventional powered port-a-band saws, air saws, plasma arc torches and oxy-acetylene torches. Personnel radiation exposures were easy to manage due to the 21 year-long decay period during safe storage of the facility.

During these activities, there was an effort made to decontaminate some reactor piping systems. Much of this equipment was wiped down using wet wipes to remove some minor amounts of loose contamination. There had been some pipe system decontamination done at the time of plant shutdown in 1967. Pipe scale samples showed minimal loose or transferable contamination. Therefore, a large scale decontamination effort was not felt to be cost effective.

Decontamination of larger equipment items, such as the condenser and turbine units, was very effective. These decontamination efforts released about 90 percent of these components to the on-site scrap metal recycler.

**Phase III Work**

Phase III of the D&D project is currently underway at the facility. This work involves removal of the reactor vessel complex from the EBWR Facility. This phase of the D&D was initiated in FY 1989 with installation of the facility water filtration and transfer system. Additional facility utility modifications and work sequence detail planning is underway to facilitate the timely completion of the Phase III D&D activities, which should be completed in FY 1991.

The first dismantling work to be performed in this phase entails the removal, size reduction and packaging of the reactor vessel internals for disposal. The majority of this segmenting and packaging work will be performed in the water-filled spent fuel pool which was recently repainted and prepared for this work. Tools used for the size reduction will include: underwater plasma arc cutting, abrasive cut-off wheel, guillotine saw, and other tools attached to an X-Y mast with a telescoping arm or via long-handled poles. Components will be positioned on an aluminum worktable in the fuel pool. The worktable can be adjusted to allow work to be performed on individual components at water depths ranging from 5 - 15 feet (1.5 - 4.6 meters) underwater. The internal components will be transferred to the pool, size reduced, and the material packaged for disposal in an appropriate type of waste container. Close interactions with disposal site personnel and ANL-East Waste Management staff will determine the best waste packaging container for each component to assure minimization of waste volumes. This work is scheduled for FY 1992 completion.

Upon packaging of the reactor vessel internals for disposal, preparations will begin for the removal of the 37-ton (33,600 kilograms) reactor vessel itself. Several approaches were evaluated in an engineering study (4) on the best method for removal of the EBWR reactor vessel and the cutting techniques available to segment the vessel.

Based on the results of this study, it was decided that the segmenting of the reactor vessel will be performed using an abrasive water jet manufactured by FLOW Industries of Kent, Washington. This cutting technique can cut a variety of materials and has been used extensively by a wide range of industries from food processors (without abrasives) to defense contractors (with and without the abrasive). The technique has been used to cut concrete, aluminum, carbon steel and stainless steel within the nuclear facility decommissioning community. In addition, a relatively new, surplus unit was available from the Oak Ridge National Laboratory D&D Program.

Typical abrasives used are garnet, aluminum oxide and iron fillings, with a particle size ranging from 40 to 120 mesh.

An abrasive water jet--to our knowledge--has never been used to segment a reactor vessel. The unit operates at a pressure of 35,000 psi (241 MPa). The cutting rate for segmenting the EBWR reactor vessel will be about 1 inch/minute (2.5 centimeters/min) and an approximate total cutting time of 120 hours for the entire reactor vessel removal effort. An overhead "A" frame hoist will be used to lift the vessel up and out of the reactor cavity. Four circumferential cuts will be made on the main vessel body, and these rings further size reduced for shipment. The bottom head and upper flange will be shipped separately.

Conservatively, we have estimated that 600 linear feet (183 meters) of cutting will be required, and this work will consume about 7,000 pounds (3,175 kilograms) of garnet abrasive and about 3,000 gallons (11,400 liters) of water.

**Phase IV Work**

Phase IV D&D will consist of the final facility decontamination and cleanout of the reactor cavity. This work will consist of removal of the lead brick shielding and removal of the carbon steel cavity liner. The majority of this material should be able to be disposed of as clean scrap. Some of this material will require disposal as radioactive waste, which is most likely for those materials near the former core region where the highest neutron fluences were present. Materials behind the upper half of the reactor vessel are very likely to exhibit no induced radioactivity and should be able to be recycled.

Activated concrete removal will be the last large scale portion of the D&D effort to be performed at EBWR. Currently, the projected removal method for the activated concrete entails use of the abrasive water jet and removal of only those areas of the bio-shield with activation above the unrestricted use levels.

## D&D WASTE HANDLING

The following types of wastes have been generated to date during this project: radioactive, hazardous, mixed (radioactive and hazardous) and other special wastes. Special wastes include items such as oils and recyclables and other mildly regulated or non-regulated materials. Handling of wastes from D&D operations is discussed in the following sections.

**Solid Radioactive Wastes**

To date, a total of about 5,500 cubic feet (156 cubic meters) of radioactive waste from the project has been disposed of or is awaiting shipment for disposal. All solid wastes from D&D operations are packaged within the facility or area undergoing D&D. For the EBWR D&D Project, ANL utilizes three types of waste packages. In most instances, wastes are packaged in a M-3A waste bin. This bin measures about 4 feet x 5 feet x 6 feet high (1.2 x 1.5 x 1.8 meters). The weight limit is 8,000 pounds (3,600 kilograms), and waste is typically packaged in a 1/2-inch (1.3 centimeters) thick plywood bin liner for double containment purposes. The bin is constructed of 12-gauge steel, and meets all requirements for a DOT Type A package, with the exception of pressure requirements. These bins are loaded, properly documented, and then sent to the Waste Storage area pending offsite shipment to the DOE Hanford facility, typically each calendar year in the summer. If possible, compactible wastes are baled to minimize the total waste volume to be disposed.

In cases where shielding is needed to comply with the DOT radiation level shipping requirement for contact dose rate, ANL uses a reusable, one-half Super Tiger liner insert for shielding during shipment to the disposal site. This liner will be used for several bins shipped from removal of the reactor vessel internals.

When the one-half Super Tiger does not provide adequate shielding for higher radiation dose items, a Type A or B shipping container as appropriate will be used for D&D wastes and the materials further size-reduced to fit into appropriately sized containers for the shipping cask. Again, this approach will be used for several shipments of higher radiation levels materials during shipment of size reduced reactor vessel internals.

**Liquid Radioactive Wastes**

Liquid radioactive wastes generated to date on this project have consisted of only scrub water, either suspected to be contaminated or known to be contaminated with radioactivity. This water is collected in 55 gallon (208 liters) drums using conventional wet vacuum equipment. This water is then transported directly to the Waste Management Facility for evaporation and concentration.

Once the water arrives at the Waste Management Facility, it is fed to a waste storage tank for holding. It is then directed to an evaporator/concentrator where the liquid volume is reduced by a minimum of 50 fold. Any remaining liquids are absorbed into a 55-gallon (208 liters) drum filled with a Hanford facility- approved absorbent material. These waste packages are then handled as typical solid radioactive waste packages.

**Hazardous Wastes**

Material requiring disposal as hazardous waste is documented and transferred to Waste Management for appropriate disposal.

**Mixed Wastes**

To date, the mixed wastes accumulated have been materials which were used in the reactor systems during plant operations. Specifically, these include ion exchange columns with lead integrated into them as a shielding material and other lead brick and lead shot contaminated with radioactivity. Currently, we are evaluating whether it is cost effective to attempt to decontaminate these materials or whether disposal or holding for decay is more appropriate. Until a decision is made, this material is sealed shut and held in our material storage yard.

**Special Wastes**

Numerous miscellaneous wastes have been generated to date during this project. These types of material have consisted primarily of three materials: waste oils, high density concrete block, and scrap lead. After these materials are surveyed and cleared by Health Physics, the material is sent for recycling. Waste oils are sampled for a number of parameters and, if acceptable, are sent to a fuel blender in the Chicago area for use as a cheap BTU fuel. Over 500 gallons (1,900 liters) of waste oils have been disposed of from the facility since FY 1986.

Scrap lead is sold to a contracted scrap recycler. Over 6,500 pounds (2,950 kilograms) of scrap lead have been disposed of via this method since the project was initiated. Surplus lead brick, which amounts to over 16 tons (14,500 kilograms), is stockpiled for future reuse by ANL.

High density concrete block has been removed from three pipe chases adjacent to the EBWR reactor vessel. Over 32 tons (29,000 kilograms) of block were removed and reused by the project for shielding in upcoming work or reused by researchers at ANL for other work.

## WASTES GENERATED

The Summary Table shown below lists all types of wastes generated during the course of the D&D to date.

Wastes Generated to Date During EBWR D&D

| Waste Type | Quantity |
|---|---|
| Radioactive | 5,526 cu.ft. (156 cubic meters) |
| Mixed | 40,400 lbs. (18,325 kilograms) |
| Used Oils | 565 gal. (2,140 liters) |
| Lead | 39,475 lbs. (17,900 kilograms) |
| Concrete Block | 65,900 lbs. (29,900 kilograms) |
| Liquid Radioactive | 7,225 gal. (27,350 liters) |
| Asbestos | 2,574 cu.ft. (73 cubic meters) |
| Miscellaneous Scrap | 8,613 cu.ft., loose (244 cubic meters) 94.4 tons, bulk (85,600 kilograms) |
| Landfillable Material | 2,916 cu.ft., loose (83 cubic meters) 8.5 tons, bulk (7,710 kilograms) |

## PROJECT COST AND SCHEDULE

The D&D project schedule projected initiating the D&D in FY 1986 and completing the project seven years later in FY 1993. The Total Estimated Cost (TEC) to complete the project was estimated to be $14.3 million dollars--$13.6 million operating dollars and $700,000 of equipment money. Significant savings of $200,000 were realized by obtaining the abrasive water jet unit from Oak Ridge National Laboratory for the reactor vessel segmenting as compared to procuring a new unit.

The project experienced an unexpected shutdown of D&D work in FY 1987 due to budgetary constraints. This shutdown resulted in slipping the completion date by one full year to September 1994. Even with the longer-than-expected setup time the project is currently experiencing prior to resuming Phase IIIA of the D&D, the September 1994 completion date is still thought to be achievable.

## SUMMARY

In summarizing, the EBWR D&D Project has been proceeding well. The waste volumes being generated are lower than expected and costs are on budget. Unexpected schedule delays as a result of the DOE Tiger Team findings have prolonged the period required to start Phase III D&D.

Let me close with the three lessons learned from our project to date:

- For multi-program research facilities like ours at ANL, the small D&D crew concept works best. Keep your crew together and focused.
- Keep your chosen techniques as simple as possible unless it is absolutely necessary to use more complex technologies.
- Remember to build into D&D cost estimates adequate contingencies for that unseen delay or that extra clean-up required due to surprises unknown to anyone or that no one remembers.

As a part of our technology transfer program (5), which I have not discussed here, let me invite you all to visit our facility and see the EBWR facility while D&D work is underway.

## REFERENCES


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