

Methods to Estimate Equipment and Materials that are Candidates for Removal During the Decontamination of Fuel Processing Facilities

D. R. Duncan O. J. Valero
Westinghouse Hanford Company

R. A. Hyre J. A. Pottmeyer
J. S. Millar J. A. Reddick
Los Alamos Technical Associates, Inc.

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Westinghouse P.O. Box 1970
Hanford Company Richland, Washington

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**METHODS TO ESTIMATE EQUIPMENT AND MATERIALS
THAT ARE CANDIDATES FOR REMOVAL
DURING THE DECONTAMINATION AND DECOMMISSIONING
OF FUEL PROCESSING FACILITIES**

Regi A. Hyre
James S. Millar
Judith A. Pottmeyer
Julie A. Reddick
Los Alamos Technical Associates, Inc.
8633 Gage Boulevard
Kennewick, Washington 99336

Darrel R. Duncan
Oscar J. Valero
Westinghouse Hanford Company
P.O. Box 1970
Richland, Washington 99352

ABSTRACT

The methodology presented in this report provides a model for estimating the volume and types of waste expected from the removal of equipment and other materials during Decontamination and Decommissioning (D&D) of canyon-type fuel reprocessing facilities. This methodology offers a rough estimation technique based on a comparative analysis for a similar, previously studied, reprocessing facility. This approach is especially useful as a planning tool to save time and money while preparing for final D&D. The basic methodology described here can be extended for use at other types of facilities, such as glovebox or reactor facilities.

INTRODUCTION

Located in the southeastern region of the state of Washington, the Hanford Nuclear Site began chemical processing operations in 1944. Now over five decades later, a number of facilities on the Hanford Site are preparing for final decontamination and decommissioning (D&D). To assure that the necessary resources are available to handle the waste generated as a result of D&D, estimates of the volume and characteristics of the expected solid waste are required.

The Plutonium-Uranium Extraction (PUREX) Plant (Canyon 202-A) is a fuel reprocessing canyon facility that is similar in construction to other onsite and offsite fuel reprocessing canyon facilities. It is also one of the first major facilities that will be scheduled for D&D at the Hanford Site (1). This report presents the methodology used to estimate the characteristics and volumes of equipment and other materials that might be removed and processed as solid waste during the D&D of the PUREX Plant. Comparison of the PUREX D&D solid waste volumes to other canyon facilities yields solid waste estimates that may benefit future waste estimation and decontamination activities at Hanford as well as other U. S. Department of Energy (DOE) facilities.

PUREX PLANT

The PUREX facility consists of a canyon, four galleries, and a service annex. The canyon is a thick-walled, heavily shielded concrete structure that houses the equipment used for radioactive processing. The canyon area is 306.3 m (1,005 ft) long, 9.3 m (30.5 ft) wide, and 31.7 (104 ft) high. A single row of 12 process cells is contained within the canyon (1). The functions of these 12 cells, as well as the equipment they contain, are described in Table I.

TABLE I. PUREX Canyon Cell Functions, Equipment and Volumes.

Cell	Function	Equipment	Cell Volume (m ³)
A,B,C	Metal dissolution	Dissolvers, Dissolver Towers, Scrubbers, Heaters, Silver Reactors, Process Tanks, Jets, Filters	590
D	Metal solution storage	Metal Solution Storage Tanks, Metathesis Solution Storage, Coating, Waste Receiver, Pumps, Jets, Samples, Agitators	1,095
E	Feed preparation and cladding waste treatment	Centrifuges, Catch Tank, Coating Waste Tank, Rework Tank, Feed Makeup Tank, Recovered Product Tank, Scrubber, Pump, Jets, Agitators, Samplers	1,196
F	Waste treatment and process ventilation	Nitric Acid Absorber, Condensers, Pumps, Tanks, Samplers, Concentrators, Jets, Agitators	3,639
G	Solvent treatment system	Pulse Column and Generator, Tanks, Decanter, Turbo-mixer, Pumps, Jet, Agitators, Samplers	1,836
H	First decontamination system	Tanks, Concentrator, Condenser, Pumps, Samplers, Jets, Pulse Columns, Pulse Generators	927
J	Partition system/ No recovery	Tanks, Concentrator, Condenser, Pumps, Samplers, Jets, Pulse Columns, Pulse Generators	1,853
K	Uranium decontamination and concentration system	Pulse Columns, Tanks, Pulse Generators, Concentrators, Condensers, Pumps, Jets, Agitators	1,432
L	Plutonium decontamination and concentration system	Pulse Columns, Tanks, Pulse Generators, Concentrators, Condensers, Pumps, Jets, Agitators, Stripper/Condenser	758
M	Equipment decontamination and storage and Plutonium nitrate storage	Tanks, Pumps, Hood, Samplers	253

A 1.8-m- (6-ft-) thick concrete wall separates the cells from the galleries (1). The storage, sample, pipe and operations, and crane cab galleries parallel the north wall of the canyon and are located at different levels, one above the other. The pipe and operations gallery, located below the crane cab gallery, contains instrument transmitter racks, electrical motor controls, steam and cooling water supply lines, and the piping and associated valves used for transferring nonradioactive solutions. The next level down is the sample gallery, which contains the remote samplers used for obtaining process solution sampled from the cell equipment. The storage gallery area, the level below the sample gallery, was used for storage of dry chemicals and spare equipment.

The service annex is adjacent to the north of the gallery section and consists of two separate areas (1). The larger, main area houses the maintenance shops, offices, lunchroom, locker room, radiation zone entry, ventilation air and supply room, a switch gear room, compressor room, central control room, and the aqueous makeup facility. The smaller laboratory area contains the analytical laboratory, the headend control room, and a switch gear room.

In addition, PUREX contains two tunnels used for interim storage of failed or obsolete process equipment that was too radioactive or bulky for removal from the PUREX Plant. Since the estimation methodology presented in this report is based on the PUREX canyon cells, more detailed information on the PUREX tunnels is not presented.

In 1956, the PUREX Plant began recovering uranium and weapons grade plutonium from irradiated aluminum-clad uranium metal fuel from the Hanford Site reactors. The plant was modified in 1967, to reprocess zirconium alloy clad fuel from the N Reactor in order to recover plutonium, uranium, and neptunium.

Three semi-distinct operating areas reside within the PUREX Plant: the head end, where fuel elements were chemically de-clad and the irradiated fissile materials dissolved; solvent extraction, where the dissolved fuel was separated and purified; and the N Cell area, where purified plutonium was either loaded out as nitrate solution or transformed into an oxide.

In October 1990, the DOE - Richland Operations Office (RL) directed Westinghouse Hanford Company to initiate transition-to-standby activities for PUREX. The standby condition was achieved in September 1992. In December 1992, the Assistant Secretary for Environmental Restoration and Waste Management authorized plans to terminate the PUREX Plant and directed DOE-RL to proceed with shutdown planning and terminal cleanout activities (1).

At the completion of the Stabilization Campaign in 1990, the feed stock left in PUREX from the 1988 shutdown had been processed and removed from the plant. Bulk chemicals, solutions used to test the processing equipment, the PUREX process solvent, recovered nitric acid, and a small quantity of pre-1972 reactor fuel were left in the plant. During the subsequent transition-to-standby phase, these materials were left untouched.

The deactivation project will remove, reduce, and/or stabilize the major remaining radioactive sources and hazardous chemicals within the PUREX Plant. Completing these activities will reduce the risk to workers and the public and will allow for a reduced level of the PUREX Plant will be transferred to the Hanford Surplus Facilities Program pending eventual D&D (2).

Final D&D will include closure of secondary containment; the end-state of the equipment, systems and material left in place, including material in the "containment building;" final disposition of the vessels and equipment in the tunnels; and closure of the tunnels (2).

PUREX ESTIMATE

The PUREX Plant contains many process vessels, chemical storage tanks and other types of equipment that are candidates for removal and decontamination. To develop an estimate of the type of waste and volume of removal candidates, it was necessary to obtain information on the size, weight, material of construction, internal equipment and contents/contamination of the canyon process cells.

The large number of items involved and the allowable time precluded a survey of dimensions and weights for each piece of PUREX equipment based on inspection of individual as-built drawings. The as-built drawings represent the most up-to-date information, but would involve a fairly slow process of review and reproduction. For the PUREX estimate, approximately 5% of dimension and weight data were obtained from drawings, and 37% from certified vendor information files (CVI) (1). The only disadvantage is that without the as-built drawings there is no positive verification that the items described in the files are the items actually installed in the plant. Many of the CVI files specifically call out vessel or assembly weights, therefore they were very useful.

The items not identified using prints or CVI files contain estimates based, when available, on information located in the PUREX Technical Manual (3), or on known values for similar pieces of equipment. Dimensions obtained from the technical manual do not include flanges or connectors or support structures. The technical manual also does not provide equipment weights. An item by item inspection and consultation of prints would be necessary to support actual D&D work.

The following waste types, based on the definition documented in the *Hanford Solid Waste Acceptance Criteria* current at the time of publication, were recognized in the development of this estimate (4).

- **Transuranic (TRU) Waste**—Without regard to source or form, TRU waste is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g of waste matrix. Transuranium radionuclides are radionuclides, radium sources and ²³³U in concentrations greater than 100 nCi/g of the waste matrix are managed as TRU waste.
- **TRU Mixed Waste**—TRU mixed waste meets the definition above for TRU waste and contains dangerous waste in addition to the radioactive components. Dangerous wastes are defined in the Washington Administrative Code (WAC 173-303-040).
- **Low Level Waste (LLW)**—LLW, as defined in DOE Orders 5820.2A and 5400.3, is radioactive waste not defined as high-level waste, TRU waste, spent nuclear fuel, or by-product material. All LLW is also classified according to Category 1, 3, and greater than Category 3 concentration limits. These limits are based on the waste classification system developed by the Nuclear Regulatory Commission (NRC) in 10 CFR 61; however, it should be noted that these categories are not synonymous with Class A, C, and >C definitions.
- **Low Level Mixed Waste (LLMW)**—LLMW is low level waste that contains dangerous waste, as defined in WAC 173-303-040.
- **Nonradioactive Dangerous Waste**—Any nonradioactive solid waste that has been contaminated by hazardous chemicals, as defined in WAC 173-303, is regulated as dangerous waste.

The goal of the current deactivation effort is to minimize dangerous wastes; therefore, equipment is assumed to be non-hazardous, unless a known hazardous component is present (1). Equipment classified as hazardous or mixed wastes include the dissolvers, which contain zirconium hulls and mercury thermowells, and the silver reactors, which contain silver salts. Nonradioactive, nonhazardous wastes are identified only as *solid waste*.

The waste volume estimates reflect those expected to be generated by all D&D activities prior to actual building structural component disposal. This includes volumes expected to result from removal of all the process equipment, piping, and fixtures that can be removed with relative ease, such as unbolting or cutting, leaving bare cell and canyon walls.

METHOD APPLICATION

Once a detailed study of a model facility is complete, other similar facilities may be estimated by scale. This methodology can save time and money while providing critical information to support planning activities for current and future solid waste treatment, storage, and disposal (TSD) facilities and operations. In this case, facilities similar in construction and process to the PUREX facility were selected.

The estimates obtained in the PUREX Plant study were applied to several other major canyon facilities located at the Hanford Site to characterize and estimate the volume of solid waste that will be generated during D&D. These facilities include the following: B Plant (221-B), T Plant (221-T), U Plant (221-U), the Uranium Trioxide (UO₃) Plant (224-U & 224-UA), the Reduction Oxidation (REDOX) or S Plant (202-S), the Plutonium Concentration Facility for B Plant (224-B), and the Concentration Facility for the Plutonium Finishing Plant (PFP) and REDOX (233-S) (5).

In order to estimate the waste volume, the cells (or process areas) in each facility were matched with the most similar cell(s) in PUREX. Cells were correlated based on knowledge of the equipment present, physical layout, and process history.

To develop the volumetric estimate of waste, similar cell processes were identified, and it was assumed that the density of equipment in the unknown cell was the same as the matching PUREX cell. The volumetric ratios for similar cells were calculated then multiplied by the amounts of solid waste (volume and weight) reported for each of the PUREX cells (1) to yield the estimates for each unknown cell. These cell estimates were summed over the entire

facility using the following equations(5):

$$\text{Estimated Waste Volume} = \sum \left(\frac{\text{Volume of Cell in X}}{\text{Volume of similar PUREX Cell}} \right) \cdot (\text{Volume PUREX Waste}) \quad (1)$$

$$\text{Estimated Waste Weight} = \sum \left(\frac{\text{Volume of Cell in X}}{\text{Volume of similar PUREX Cell}} \right) \cdot (\text{Weight PUREX Waste}) \quad (2)$$

where X represents the individual facilities. The same calculation was made for the pipe galleries:

$$\frac{\text{Estimated Volume}}{\text{Weight of Pipe}} = \sum \left(\frac{\text{Vol of Pipe Gallery in X}}{\text{Vol of Pipe Gallery in PUREX}} \right) \cdot (\text{PUREX Piping Volume Weight}) \quad (3)$$

Once the volumetric estimation was completed for each of the cells (or process areas) in a given facility, a waste class was assigned to the cell (5). The designation of waste classes was based solely on the best judgement of the authors and was grounded on knowledge of the processes and equipment present in a given cell. The piping in a facility was assumed to be designated in the same waste classes and proportions as the equipment in that facility.

EXAMPLE

The B Plant (221-B) is located in the center of the 200 East Area on the Hanford Site. The B Plant was originally constructed to chemically separate irradiated uranium fuel using the bismuth-phosphate process. The plant commenced operation in April 1945 and continued until 1952, when the bismuth-phosphate process became obsolete with the development of the PUREX method. The plant shut down until the early 1960's, when a series of renovations were made to support the extraction of various fission products from high-level liquid waste (5).

The final renovation, completed in 1968, facilitated a high-capacity solvent extraction and ion-exchange process. The campaign lasted from approximately 1968 until 1985 and resulted in the extraction of over 100 MCi of cesium and strontium (5).

A subsequent and final campaign involved 38,000 L of neutralized current acid waste (CAW) from double-shelled tank 101-AZ. Waste from this campaign still remains in the tanks in B Plant, but will be removed prior to decontamination and decommissioning (5).

Currently, B Plant stores chemicals used to treat LLW generated at the B Plant and the Waste Encapsulation and Storage Facility. It is used for the generation of demineralized water and for the conditioning of water used in heating, ventilation, and air conditioning units (6).

The B Plant is a lightly-reinforced concrete building, approximately 259-m (long), by 21-m (wide), and 23-m tall, covering an area of about 5,370-m² and occupying a volume of approximately 121,100-m³ (5). The canyon portion is about 247-m long and contains 40 canyon cells in a single row running the length of the canyon. The building is divided into three main areas: galleries (listed from the bottom up—electrical, piping, operating, and crane), canyon deck, and the cells. All interior and exterior walls, roof and floor slabs, and cell dividing walls are constructed of thick concrete to provide shielding from ionizing radiation.

To estimate the volume, weight, and type of solid waste present in the B Plant, the following conditions were assumed (5):

- The original equipment used for bismuth-phosphate separations accounted for the bulk of the equipment described in the *B Plant Safety Analysis Report* (7). This allowed the use of the *Hanford Engineering Works Technical Manual* (8) to corroborate information and supply missing information.

- All process chemicals from separations activities were removed from the plant, either by flushing or by use of the plant for the most recent cesium-strontium extraction process (the neutralized current acid waste campaign).
- The B Plant cells, which either performed the same general function or contained the same equipment as the PUREX facility, would produce the same D&D waste volumes. To estimate these volumes, B Plant cells were scaled to PUREX according to the volume of each processing cell and volume of equipment that cell contained.

For example, cell 22 in B Plant was used for vessel ventilation and contains condensers, an ammonia scrubber, filters, heaters and a tank. PUREX cell F is most similar based primarily on process knowledge and supported by equipment similarity. It was used for waste treatment and process ventilation and contains a nitric acid absorber, condensers, pumps, tanks, samplers, concentrators, jets and agitators (see Table I). Cell 28, in B Plant, was used for solvent extraction and contains an ion exchanger column and tanks. PUREX cell G is most similar based on process equipment. It was used for solvent treatment and contains a pulse column and generator, tanks, a decanter, a turbo-mixer, pumps, agitators, and samplers (see Table I). Table II summarizes cells 22 and 28: the use of each cell, the approximate sizes of the equipment within the cells, and the cell volumes (5).

TABLE II. Current Functions, Equipment, and Volumes of B Plant Canyon Cells 22 and 28.

Cell	Function	Equipment (L x W x H or D x H in meters)	Cell Volume (m ³)
22	Vessel ventilation	Condensers (2) (0.6 x 3.7) Ammonia scrubber (0.6 x 4.9) Filters (3) (0.6 x 0.6 x 1.2) Heaters (2) (0.6 x 3.0) Tank (0.9 x 2.1 x 1.2)	143
28	Solvent extraction	Ion exchanger column (0.6 x 5.5) Tanks (2) (1.8 x 3.7) Tank (0.9 x 1.5 x 4.3)	143

Using the calculated ratios between PUREX cells and similar B Plant cells, an estimate of the volume and weight of equipment considered candidates for D&D was developed for each cell in the B Plant. Results for cells 22 and 28 are given as an example in Table III. The total equipment volume, considered candidates for removal during D&D, of B Plant is estimated at 1,585 m³. Its weight is estimated at 316,816 kg.

TABLE III. Volumetric Estimate of Solid Wastes from the D&D of B Plant Cells 22 and 28.

B Plant Cell	B Plant Cell Volume (m ³)	PUREX Similar Cell	PUREX Similar Cell Volume (m ³)	B Plant/PUREX Similar Cell Volumetric Ratio	PUREX Cell Equipment Volume (m ³)	PUREX Cell Equipment Weight (kg)	B Plant Estimated Equipment Volume (m ³)	B Plant Estimated Equipment Weight (kg)
22	143	F	3,639	0.0393	738	127,321	29	4999
28	143	G	1,836	0.0779	419	77,959	33	6075

Once the volume of equipment was estimated for each cell, the type of waste expected also was estimated. This resulted in a total estimate of the volume and waste type expected from B Plant.

CONCLUSIONS

This study was designed to achieve an initial rough estimate of solid waste that may be generated during D&D from the facilities included in this study. The estimates were not only based on historical data, available documents, and process knowledge, but also a structural or process area comparison of the facilities with the results presented in the PUREX study (1). Although a more detailed study would be required to maximize characterization accuracy, the information presented in this report provides a rough estimate that will help facilitate future planning and activities associated with solid waste treatment, storage, and disposal.

The estimation methodology provides a model for estimating the volume and types of waste expected from the D&D of other similar DOE facilities. The facilities with the greatest similarities to the PUREX Plant include the H and F Canyon Facilities at the Savannah River Site, which also use a PUREX process, and the Idaho Chemical Processing Plant, which uses another solvent extraction process. Although these four facilities differ in their size, capacity, and specific chemistry (due to plant specific feed fuel constituents, cladding, and the final product produced), the methods applied to the PUREX Plant provide a substantial knowledge base for the subsequent deactivation and D&D of these facilities.

The method of volume ratio estimation can be applied to other types of facilities such as nuclear reactors or glovebox line facilities. In fact, a detailed study has been completed for the Plutonium Finishing Plant (PFP or Z Plant) at the Hanford Site (9), which may serve as a scaling standard for other glovebox line facilities.

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