# RESEARCH REACTOR AND FUEL DEVELOPMENT FACILITY

# DECOMMISSIONING EXPERIENCE AND TECHNOLOGY

Gary S. Hoovler, Paul M. Myers and Colin S. Caldwell
The Babcock & Wilcox Company
Lynchburg, Virginia 24501

## ABSTRACT

This paper discusses the technology and experience gained in research reactor and fuels development facility decommissioning programs carried out by Babcock & Wilcox (B&W) at one of its NRC-licensed sites in Lynchburg, VA. The projects included two buildings that housed plutonium/uranium fuels development laboratories, four low-power critical experiment facilities, and two (megawatt-level) research reactors. However, this paper concentrates on the experiences with the plutonium/uranium fuels development laboratories and critical experiment facilities. These were comprehensive projects that included: developing the decommissioning and quality assurance plans; interfacing with the U.S. Nuclear Regulatory Commission, performing the actual decontamination/dismantling work; performing decontamination and final radiological surveys; and volume reducing, packaging, certifying, classifying, and shipping the radioactive waste for disposal. This broad experience has involved handling radioactive contamination from the following sources:

- Low- and high-enriched U-235 fuel
- Depleted uranium
- Mixed oxide fuel (Pu/UO
- Thorium fuel
- U/Al alloy fuel
- Fission/activation products (beta-gamma)

Areas of generic application to future projects are highlighted in this paper.

## INTRODUCTION

### Fuels Development Laboratory Facilities

Two laboratory buildings have been decontaminated and are undergoing the formal decommissioning process for "unrestricted use." One of these buildings was used for preparing, testing, and analyzing a variety of nuclear fuels and housed numerous laboratories and U/Pu fuel handling facilities. These areas represented over 35,000 $ft^2$ of floor space that had to be decontaminated and decommissioned. As an output of this decommissioning work, about 1,000 55-gallon drums of Class "A" waste and 14 500 $ft^3$ coffins of Class "C" waste were packaged and shipped for burial.

### Critical Experiment Facilities

B&W decommissioned four low-power nuclear criticality experiment facilities. These facilities used a variety of fuels including $UO_2$, $PuO_2$-$UO_2$, and $ThO_2$-$UO_2$. Three of these facilities were dismantled, their licenses terminated and decommissioned and the licenses transferred to a Special Nuclear Materials (SNM) License. The fourth facility has been decommissioned and is awaiting approval from the NRC. Special instrumentation, procedures, and analyses were used to measure and determine the radioactive contamination levels present at the facilities as decontamination activities proceeded.

### Test and Research Reactors

B&W operated a 6-MW test reactor between 1958 and 1971 and a 1-MW pool-type research reactor between 1962 and 1980 at the nuclear research center in Lynchburg, VA. The test reactor, its containment building, and all reactor core equipment and primary coolant systems had previsouly been decontaminated and decommissioned with termination of the reator license. The research reactor and all associated reactor equipment and coolant processing systems were decontaminated and decommissioned to "unrestricted use" with termination of the reactor license.

### Technology Department

The above projects required the development of first-of-a-kind technology and the resolution of technical problems that have generic implications. For example, precision techniques for rapidly measuring plutonium, uranium, and thorium isotopes at the one-to-ten picoCuries/gram level were developed and used for soil samples were analyzed by a high-resolution gamma spectrometric technique developed by B&W for these projects. Segregation, detailed characterization, classification, and comparative measurements of packaged TRU waste were also accomplished. The research reactor was the first such facility in the United States to be released to the new five microrem/hr above-background final survey criteria mandated by the NRC. The release criterion to which this work was performed is shown in Table I.

A sophisticated data tracking and project control approach was used for the more recent decommissioning projects. The personal-computer-based system managed decommissioning records and activities including project scheduling, budget control, data processing, survey results, waste volumes, inventory, and location, data analysis for preparation of shipping manifests, and reports for the NRC.

Details of the Plutonium Fuels Development Laboratory and Building A/CX-10 Central Experiment Facility decommissioning operations, highlights from these projects, and the applicability of this work to future projects are provided in the following sections.

TABLE I

Release Criteria

- Equipment/Building Surfaces NRC Reg. Guide 1.86 - "Termination of Operating Licenses for Nuclear Reactors," Revision 0, June 1974
  U: 5000 DPM/100 $cm^2$ - fixed plus removable
  1000 DPM/$100^2$ - removable
  Th: 1/5 of Uranium
  Pu: 1/50 of Uranium
  Most B-beta-emitters: same as Uranium
- Soil Contamination Release Criteria "Standard Review Plan for Termination of Special Nuclear Material Licenses," Enclosure to SECY 81-576, October 5, 1981
  U: 30 pCi/gm
  Th: 10 pCi/gm
  Pu: 25 pCi/gm
- Radiation
  - Reactor Fuels Development Laboratory
    10 microrem/hr at 1 meter
  - Critical Experiment Laboratory
    5 microrem/hr at 1 meter

## PLUTONIUM FUELS DEVELOPMENT LABORATORY (BUILDING C)

### Facility Description

The existing structure known as Building C of the B&W Lynchburg Research Center (LRC) is the result of several additions to a small laboratory completed in 1962. Building C is a single story building of concrete block construction with outside dimensions of 225 feet by 174 feet at its greatest width. There is a small basement under one of the laboratories. The building contains about 24,000 square feet of laboratory, office, and support space. There were approximately 10,250 square feet in the laboratories housing bench-scale and pilot plant equipment, ventilation, and personnel protection equipment for the handling of radioactive materials. There was sufficient office space to house up to 38 technical, support, and supervisory personnel. The building also contains two vaults formerly used for storage of SNM, a room containing a boiler and a chilled water supply system, a laundry, and a large storeroom. Finally, the building contains a fan room with associated air stack that serves an adjacent building as well as Building C.

### History of Operations

The first work performed in the original building were bench-scale experiments converting thorium nitrate to thorium oxide. An expansion in 1964 added pilot scale equipment preparation of thorium - urania nuclear fuel by a sol-gel process.

R&D with plutonium-bearing fuels was initiated in new laboratories added in 1965. A major building expansion was completed in 1968 to permit $PuO_2$-$UO_2$ ceramics work for the Fast Flux Test Facility (FFTF) fuel fabrication program. Experiments with plutonium nitrate solutions were conducted in gloveboxes installed in various laboratories.

Uranium fuel projects were initiated in laboratories that were vacated at the conclusion of the FFTF Program. These projects included work with uranium chemical solutions and uranium fluoride, uranium chloride, and uranium oxide powders. Uranium fuel R&D included pelletizing uranium dioxide, firing and grinding the pellets, and performing various tests on the finished fuel.

The uranium used in Building C included depleted natural, low-enriched, and high-enriched material.

A limited amount of beta-gamma contaminated material had been brought into Building C for analysis and the waste was solidified and placed in waste drums for disposal. Sealed containers of beta-gamma contaminated materials from reactor sites were also stored there.

At the time decontamination bagen, some former laboratory space had been converted to office use. These offices as well as existing laboratory areas had to undergo comprehensive decontamination.

### Sequence and Status of Decontamination/Decommissioning Project

All activities in Building C were performed under B&W's nuclear materials license SNM-778 issued by the NRC. Decontamination of Building C for unrestricted release began in 1982. A decommissioning plan was submitted to NRC for information in March 1983. The decontamination of Building C was undertaken in three phases. The different zones involved in each phase are shown in Fig. 1. The decontamination and survey reports were submitted to NRC in May 1985 and October 1985, respectively. The decontamination and release surveys of Phase 3 are complete, and final report was submitted in January 1987.

General procedure for decontamination operations performed in the building consisted of (a) removing all SNM, equipment and supplies, (b) removing service and utility lines that would not be needed during decontamination, (c) decontamination surfaces in the rooms, (d) removing drain lines, (e) excavating underlying soil, and (f) disposing of contaminated waste. Surveying for radioactivity was conducted during and after decontamination. Each successfully decontaminated area was isolated from other areas still being decontaminated in order to prevent recontamination. The decontamination operations were performed by skilled and unskilled laborers, lab technicians, and health physics technicians and professionals trained in approved decontamination procedures and surveying and anlytical procedures.

Several activities deserve special mention, for example: paint, floor tile, and tile cement were removed from most walls, ceilings, and floors. Removal was necessary because many of the walls and ceilings had been repainted and new floor tile had been installed as laboratories were converted to other uses. Potential existed for alpha contamination to be hidden under the new paint and floor tile. The paint was removed to expose either the base surface or the original layer of paint that had been applied prior to introduction of licensed material into a room. Paint was not removed from walls that had been erected after cessation of activities with SNM. (These were primarily walls in the front offices). Paint was not removed from walls in rooms where it was the original coat on where SNM had been excluded. Floor tile and tile cement were removed to expose the concrete floor surface. Walls, ceilings, and floors were surveyed for alpha radioactivity (the ceilings of offices were not surveyed). When contaminated areas were found, walls were decontaminated by removing portions of cinder block and floors were decontaminated by chipping up portions of the concrete floor. These areas were resurveyed and the iterative process of chipping and

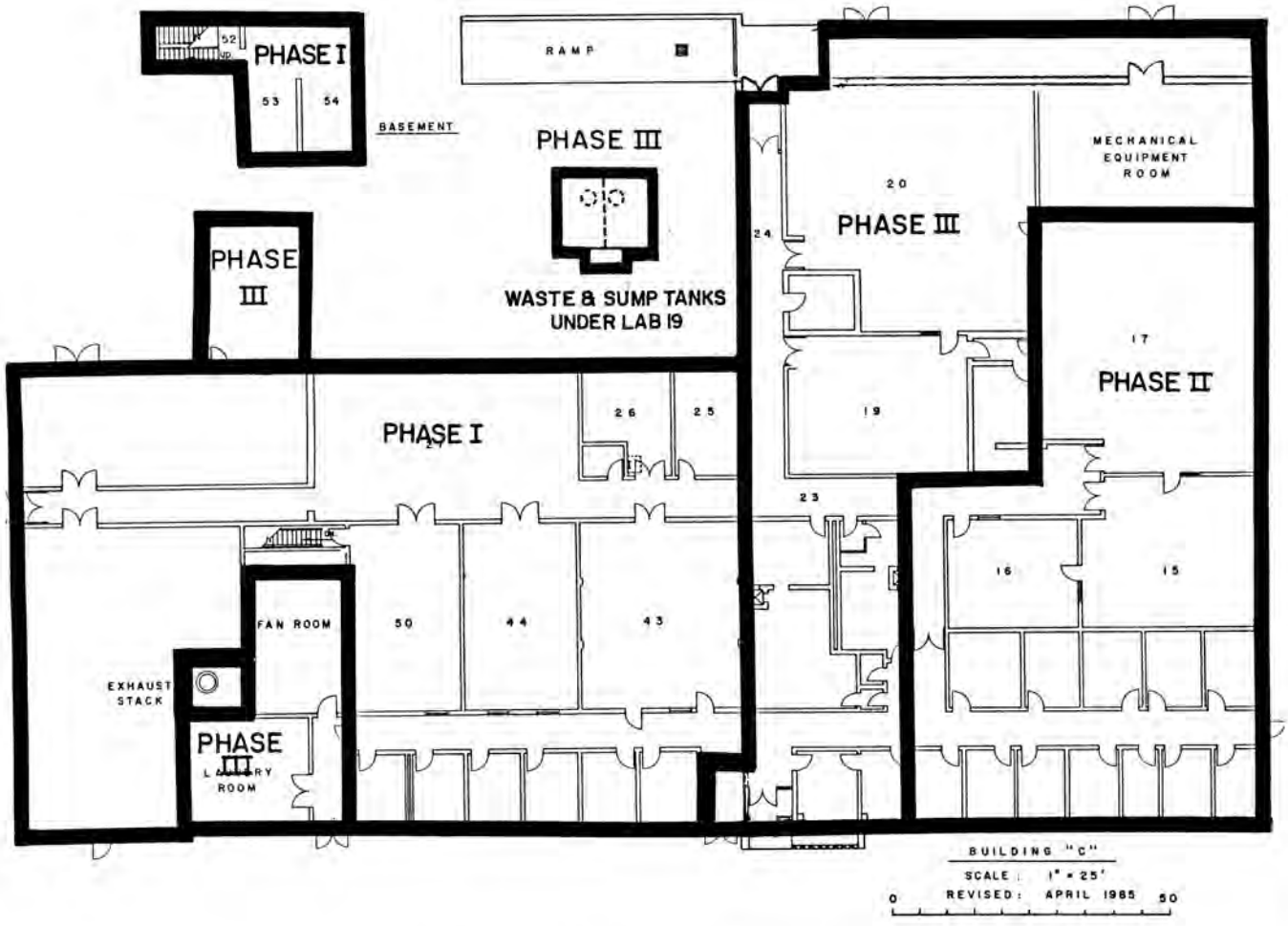


Fig. 1. Fuels Development Laboratory.

surveying was continued until release limits were met. These removed materials were disposed of as contaminated waste.

Hot and cold drain lines had been installed under the floor of Building C. The floor was removed from above each hot drain lines after the base concrete floor had been surveyed and released. This uncontaminated concrete rubble was disposed of as clean land fill. The soil was removed from above each hot drain lines and placed in 55-gallon drums. Samples were obtained from each drum for analysis by gamma spectroscopy. These analyses were used to determine the ultimate disposal of a drum's contents. Drums that satisfy the release criteria were retained for unrestricted disposal after verification survey is completed by the NRC. Drums that exceeded these criteria were shipped to an NRC licensed disposal site.

Each hot drain line was cut into sections, removed, and surveyed. If the surface activity was less than the specified limits, the pipe was released as clean scrap. Otherwise, the pipe was decontaminated to meet the limits or was disposed f as contaminated waste. All cold drain lines were surveyed for smearable alpha radioactivity. No contamination was found, therefore, these lines were not removed. (Experience indicates that pulling a smear cloth through the lines is a reliable method to identify radioactivity).

Samples were taken of the soil lying under the drain line after the pipe was removed. If analyses showed the radioactivity to be below the specified limits, temporary flooring was installed to isolate the pipe trench. If the activity exceeded these limits, further excavation was performed. Soil removal from a given area was continued until soil samples takne from the surface of the excavation showed the radioactivity to be acceptable (ALARA). Excavated soil was placed in 55-gallon drums. Samples were obtained from each drum or analysis by gamma spectroscopy. These analyses were used to determine the ultimate disposal of a drum's contents.

The NRC performed a confirmation survey/ inspection of Phase I in November 1985. The NRC has released the extensive underground excavations (required by hot drain leakage) for backfill. The release of Phase I building surfaces is pending NRC inspection of Phases 2 and 3.

In the course of the decontamination/survey project, over 200,000 measurements of fixed/removable contamination and of ambient radiation levels were made. These measurements were taken with a selected group of fixed and portable instruments including gas/low proportional counters, GM tubes, scintillations, ion chambers, and solid state gamma spectrometers. LRC prepared procedures for NBS-traceable calibration and for use of all radioactive measurement instruments, and

for performance and evaluation of surveys. A computer data base was developed for collating survey data and for evaluating this data relative to appropriate release limits.

## BUILDING A/CX-10 CRITICAL EXPERIMENT FACILITY

### Facility Description

The existing structure known as Building A is the result of several additions to a small critical experiment laboratory completed in 1956. Building A is a 1-1/2 story building of masonry and steel construction that contains about 20,000 $ft^2$ of laboratory, office, and support space.

The original building consisted of a heavily shielded high bay, an adjacent storage room, a sub-assembly room used in the preparation of reactor experiments, a counting room, health physics laboratory, a reactor control room, electronics shop, physics laboratory, rest rooms and offices. This is shown as Zone 1 of Fig. 2.

The first addition to Building A (Zone 2) was made in 1957. This addition has two floors, and was built under the CX-10 Construction Permit. The first floor comprised a heavily shielded high bay, a rest room, sub-assembly room, physics laboratory, and offices. The second floor, which is an extension of the original building, consisted of a second high bay (Bay 2), a storage room, control room, former chemistry laboratory, electronics shop and offices. Bay 2 was constructed to house two low-power critical equipment reactors.

The second addition to Building A (Zone 2 in Fig. 2.) was made in 1958. This was a two-floor addition, which housed a pool-type reactor that was originally licensed in September, 1958 for 200-kW operations, and later increased in 1-MW. The first floor consisted of an open work area and the lower portion of the reactor pool. In 1962, an autoclave for testing under PWR conditions was added with its associated heat exchanger, pumps and valves in this area. The second floor comprised the upper portion of the pool, the

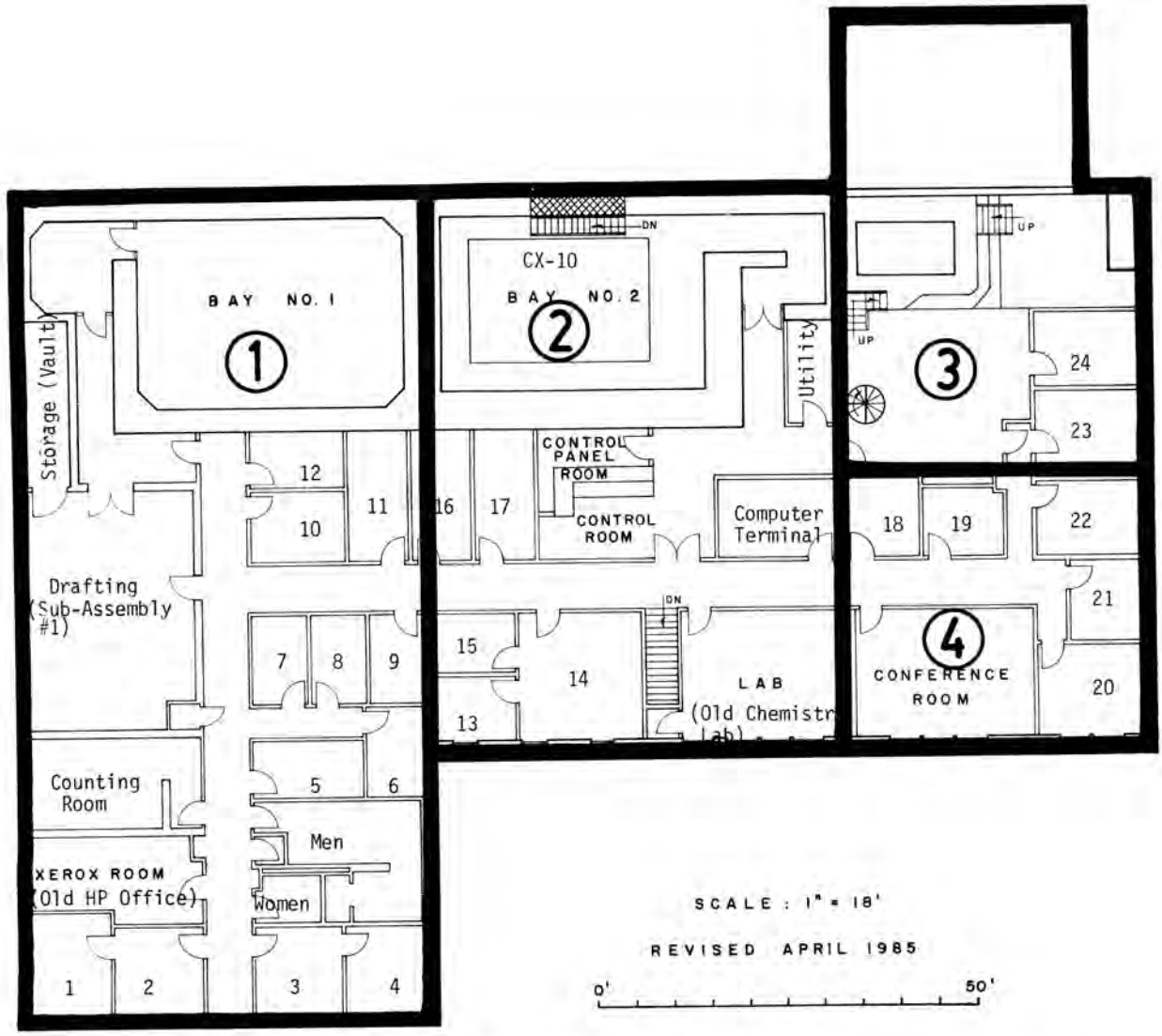


Fig. 2. Building "A" and Critical Experiment Facilities Second Floor.

control room area, and later, the autoclave control panel area. The first and second floors, a heat exchanger room and a cooling tower were licensed under AEC License R-47. These areas were released for unrestricted use and the license terminated on July 20, 1982.

The third addition to Building A (Zone 4 of Fig. 2.) was begun in 1963. This two-floor addition was not used to handle licensed material.

History of Operations in Building A

The first building contained Bay 1, which housed two low-power light-water tank-type critical experiment reactors. The CX-1 reactor license was issued on March 20, 1957, and the CX-19 license was issued on January 22, 1958. Both of these reactors ceased operation in 1971. Auhtorization from the Atomic Energy Commission to dismantle these facilities was received on March 8, 1973. Subsequent to a confirmation inspection, the facility licenses were terminated by the AEC and released for unrestricted use on June 6, 1973. Bay 1 was then added to areas under control of SNM-778. Except for short-term storage of a single sealed source, no radioactive material has been used or stored in Bay 1 since the decommissioning.

Sub-assembly 1 (most recently drafting room) was a work and storage area associated with the CX-1 critical facility. Large quantities of highly enriched urania powder and metallic thorium were used to construct plate-type fuel assemblies in one of the first programs performed under CX-1. The highly enriched urania powder was also recovered in Sub-assembly 1 after the critical experiments were completed.

The counting room has been used for counting irradiated foils and wires in conncetion with the reactors at the LRC. No basic change has been made to the room since its construction.

The first Building A addition was built under the CX-10 construction permit and housed the CX-10 reactor, the CX-12 reactor, and several rooms where support operations were performed. The two reactors were housed in Bay 2. The CX-12 reactor was a split-bed facility licensed on September 24, 1958. It was dismantled and its license was terminated in 1971. This reactor was initially fueled with metallic U-Al foils. Subsequent programs using low-enriched urania in sealed pins were also performed.

The CX-10 reactor was licensed January 27, 1958, and used low-enriched uranium dioxide for fuel. The urania fuel was pelletized or swaged into aluminum or stainless steel rods. Each rod was seal welded. Some critical experiments were also performed in Bay 2 using sealed fuel pins containing thoria-urania pellets. The thorium to uranium activity ratio in this fuel was less than 5%. Although all CX-10 fuel was stored and used in Bay 2, no manufacturing or processing of the fuel took place there. The CX-10 ceased operation in September 1983. All fuel was shipped off site by January 1985.

Small quantities of enriched uranium in unsealed form were handling in a fume hood located in the chemistry laboratory located on the first floor.

The areas in the second addition were released for unrestricted use when License R-47 was terminated in July 1982. The areas in the third addition have not been used for the handling or storage of licensed material.

Sequence and Status of Building A Decommissioning Project

Activities with radioactive materials in Building A were performed under two NRC licenses - the SNM-778 materials license and the CX-10 reactor license. Release of all portions of Building A from NRC license control required two licensing actions: one to release portions of the building from SNM-778 control; and the other to terminate the CX-10 license and release the reactor area for unrestricted use.

A decommissioning plan for removing Building A from SNM-778 control was submitted to the NRC in June 1983 for information. The last CX-10 reactor test run took place in September 1983. In August of 1984, the CX-10 Reactor Decommissioning Plan was submitted to the NRC for approval. In the same month, shipment of the over 10,000 CX-10 fuel pins began. Fuel shipment was completed in January 1985, and the CX-10 Reactor Decommissioning Plan was approved by NRC in April 1985. Dimantlement of the CX-10 reactor and decontamination of Building A were completed in the spring of 1986. The final survey reports, one for the SNM-778 license one for the CX-10 reactor license, were submitted to NRC in June 1986, requesting that the NRC terminate the CX-10 license and release all of Building A for unrestricted use. NRC performed its confirmation inspection of Building A and CX-10 in July 1986. LRC is awaiting results of NRC's confirmation survey and action on its request for unrestricted release.

In the course of the Building A/CX-10 decontamination and decommissioning effort, over 40,000 measurements of fixed/removable contamination and of ambient radiation levels were made. These measurements were taken and analyzed.

DECONTAMINATION/WASTE DISPOSAL TECHNOLOGY HIGHLIGHTS

Soil Assay Program

Because of leakage from underground drain lines, extensive soil excavation was performed from beneath Building C and around Building A.

A method was needed for fast, inexpensive, and accurate assay of excavated soil and soil trenches. The following requirements were mandated by the projects:

a. Sensitivity - capable of assaying Pu, U, Th, and fission products in soil at pCi/gm concentrations.

b. Speed - fast enough to guide excavation effort without stalling the work progress.

c. Cost - inexpensive enough to ensure reasonable cost for processing the thousands of samples needed to measure the extent of contamination, to assay excavated soil (one sample per 55 gallon drums), and confirm that all surfaces of trenches were below NRC release limits.

Conventional radiochemistry was judged to be too slow, tedious, and expensive. Moreover, because of the small sample sizes used and the complexity of such techniques, significant potential for sampling and systematic experimental error was foreseen.

Gamma spectroscopy was therefore selected as the best method. B&W developed and implemented the necessary sampling, preparation, calibration, and analysis procedures. The method was fast (30 samples/

day), cost effective (less than one-tenth of radiochemical analysis cost), and provided comprehensive results (Pu, U, Th, and fission products were measured for each sample). Data storage and collation were automated by used of a computer-based data acquisition and analysis system. The method and system were used to successfully analyze about 8,000 samples in the course of the Building A and Building C decontamination projects.

Results were compared with independent laboratory radiochemical analyses, which corroborated the gamma spectroscopy results. The gamma spectrometric method was thoroughly evaluated by the NRC during its confirmation inspection of Phase I in November 1985. This evaluation included a review of adata and procedures, collections of duplicate samples for independent radiochemical analysis, and analysis by LRC of "blind" spiked samples from NRC. NRC has accepted B&W's results and has released the Phase I soil excavations so that backfill operations could be completed.

A technical report describing the above method was presented to industrial representatives in 1985. The technique was also adapted for assaying radioactivity in building debris such as paint chips, floor tile, concrete, and cinder block.

Masonry Decontamination Technology

Extensive decontamination of masonry and steel surfaces was needed. This meant removing paint (epoxy and latex), as well as floor mastic, from concrete and block surfaces. Extensive testing of numerous methods was performed. The preferred method was based on speed ($ft^2$ cleaned per hour), efficiency, manpower requirements, equipment reliability, and waste volume generated. Methods for removal of fixed contamination from bare concrete surfaces were also evaluated. The types of methods tested and the preferred methods selected are shown in Table II.

TABLE II

Masonry Decontamination

Techniques Tested and Used in B&W Projects

- Paint Removal Methods
  - Wire brush
  - Grinding
  - Dry sandblasting
  - Wet sandblasting
  - Industrial paint remover
  - Catalytic flame
  - Chipping *
- Tile Mastic Removal
  - Chemicals *
  - Dry sandblasting
  - Chipping
- Concrete Removal Methods
  - Scabbling *
  - Wet scrubbing *

* Preferred method

It is important to note that wide-area paint removal was required merely to perform accurate surface alpha radioactivity survey measurements, even though the initial levels of alpha activity were known to be low.

Retention Tank Decontamination

Three underground 5,000 gallon concrete retention tanks were decontaminated. Cleaning these tanks posed problems different from laboratory floors and walls. Tank sludge had to be removed, solidified, and disposed of. Tank surfaces were bare or coated with tar, not paint or tile. Since the tanks comprised enclosed spaces, special ventilation and respiratory protection were needed. Descaling, scabbling, and wet scrubbing were all successfully applied in cleaning retention tank surfaces.

Waste Disposal

Over 15,000 $ft^3$ of radioactive waste was segregated, classified, packaged, and shipped for disposal including Class A, Class C, and greater than Class C low-level waste. The waste forms included gloveboxes, laboratory equipment, filters, lab waste, radioactive sources, contaminated soil, and contaminated building debris.

## SUMMARY OF OTHER B&W DECOMMISSIONING EXPERIENCE AT LRC

Three additional company-operated, NRC-licensed nuclear criticality experiment facilities, a pool reactor, and a test reactor were also decommissioned by B&W in Virginia as listed in Table III.

## APPLICABILITY TO FUTURE PROJECTS

The project experience described in this paper has provided a number of important guides for future projects for new construction. Future building designs and operating methods should try to eliminate all buried drainlines and service lines that could carry or channel contamination into the soil. Drains should only be placed in lined high-integrity trenches that are directly accessible for monitoring and decontamination. Floor and wall surfacing and maintenance methods should be chosen so that appropriate radiation monitoring can be done during, and at end of, building life without first having to remove paint. This is primarily an issue in alpha-handling areas because even this paint layers will shield the alpha radiation. Detailed chronological recordkeeping of all space usage, isotopes handled, contamination incidents, surface maintenance treatments, and cognizant personnel should be maintained and reviewed throughout the building lifetime. The cost effectiveness of these preventive measures is difficult to judge, but the savings in future dose commitments for other facilities could emerge as a major factor. This is true even though the projects described in this paper resulted in negligible intake/uptake and less than 200 mR/yr maximum does to individuals performing the decontamination work.

Decontamination program planning, especially early and careful radiation surveying and coordination with regulatory agencies, has a major impact on the success of decontamination and decommissioning projects. Staffing and managing the overall project with dedicated teams is also required from the start. Special sampling measurement techniques for isotopic assay and surveying must be initiated early and approved by the regulatory agencies to ensure success. Finally, cost estimating should provide containgencies and for the lengthy final stages of obtaining regulatory confirmatory approval of terminal surveys and records. There is significant data base of this area of technology and project management now available to U.S. industry and government facility operators as a result of projects such as those described in this summary.

TABLE III

Other B&W Site Decommissioning Projects

| Facility | Description | Status |
|---|---|---|
| Lynchburg Pool Reactor R-47 | 1-MW Swimming Pool Reactor (High-enrichment U Fuel aluminum-clad) | Reactor license terminated, area released for unrestricted use on July 20, 1982. |
| Nuclear Criticality Facilities CX-1, CX-19 | Low-Power, Tank-type Critical Facilities (Pu, U, Th fuels) | Reactor license terminated and area transferred to SNM-778 license on June 1, 1973. |
| Babcock & Wilcox Test Reactor | 6 MW Test Reactor (high-enrichment U fuel) | Reactor license terminated and area transferred to SNM-778 license on February 5, 1973. |
| Nuclear Criticality Facility CX-12 | Low-Power, Split-Bed Critical Facility (hig enrichment U fuels) | Reactor license terminated and area transferred to CX-10 license on February 14, 1972. |