# Department of Energy

Brookhaven Site Office
P.O. Box 5000
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JAN 2 2 2010

Mr. Chek Beng Ng
New York State Department of
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Division of Environmental Remediation
625 Broadway – 11th Floor
Albany, New York 12233

Mr. Doug Pocze
Federal Facilities Section
U.S. EPA – Region II
290 Broadway – 18th Floor
New York, New York 10007-1866

Dear Mr. Ng and Mr. Pocze:

SUBJECT: BROOKHAVEN NATIONAL LABORATORY (BNL) INTERAGENCY AGREEMENT (IAG): AREA OF CONCERN (AOC) 31, HIGH FLUX BEAM REACTOR DECOMMISSIONING PROJECT, FINAL COMPLETION REPORT FOR REMOVAL OF THE CONTROL ROD BLADES AND BEAM PLUGS

Enclosed please find two copies of the above referenced final report. There were no comments from the U.S. Environmental Protection Agency or the New York State Department of Environmental Conservation. The Suffolk County Department of Health Services had only minor editorial comments. These comments were incorporated in the final report however they did not change the content of the report.

If you have any questions, please contact Lisa Santoro of my staff at (631) 344-3429.

Sincerely,

J M Sattler, for

Thomas J. Vero
Brookhaven Project Director
Office of Environmental Management

Enclosure:
As Stated

cc:
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# High Flux Beam Reactor Decommissioning Project

## Area of Concern 31

FINAL COMPLETION REPORT FOR
REMOVAL OF THE CONTROL ROD BLADES
AND BEAM PLUGS

**January 2010**


**Prepared by**

Brookhaven Science Associates

Environmental Restoration Projects

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# EXECUTIVE SUMMARY


This report documents the completion of a non-time-critical removal action for the removal, packaging, shipment, and disposal of control rod blades (CRBs) and beam plugs (BPs) from the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory, managed by Brookhaven Science Associates (BSA) for the U.S. Department of Energy (DOE).

This work was authorized by the *Action Memorandum, High Flux Beam Reactor, Removal Action for Control Rod Blades and Beam Plugs*. The activities covered three major areas of work: removal of the CRBs; removal of the BPs; and packaging, shipment, and disposal. This removal action was undertaken to reduce the radioactive material inventory while taking advantage of the availability of shipping casks and disposal sites.

There were 16 CRBs, divided into main and auxiliary groups, each containing eight CRBs. In addition, there were nine activated BPs. All CRBs and BPs were removed, packaged, transported, and disposed of at DOE's Nevada Test Site (NTS). All associated secondary waste from the CRB task was packaged into sea-land containers and disposed of at a licensed disposal site, Energy Solutions (ES) of Utah.

This work was performed in accordance with the *Comprehensive Environmental Response, Compensation and Liability Act* (CERCLA), the National Contingency Plan (NCP, 40 CFR 300), and the Interagency Agreement among DOE, the U. S. Environmental Protection Agency, and the New York State Department of Environmental Conservation. This action is consistent with the final remedy documented in the Final Record of Decision for Area of Concern 31 High Flux Beam Reactor dated February 2009 (ROD).

The waste management plan for the removal of low-level radioactive waste from the HFBR was based on historical documentation as well as radiological engineering review and direct survey. The components were loaded into three DOE-certified Type B casks, one Type A package, and several low-level waste packages and were transported by highway for disposal at the NTS. More than one-third of the HFBR radiological inventory was safely removed, packaged, and transported from BNL to NTS or ES of Utah. Waste minimization was effected through burial of each package and its contents. Outreach was performed with points of contact for the affected regional Council of States Governments and with Offices of Emergency Management; police, fire, and sheriffs' departments; the Department of Transportation, Department of Health, and others in the local New York area which includes Suffolk County, Nassau County, Westchester County, and New York City.

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# ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASUREMENT

| | |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| BNL | Brookhaven National Laboratory |
| BP | Beam Plug |
| BSA | Brookhaven Science Associates |
| COC | Certificate of Compliance |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act. |
| CFR | Code of Federal Regulations |
| Co-60 | Cobalt-60 |
| CRB | Control Rod Blade |
| Ci | Curies |
| DOE | U.S. Department of Energy |
| DOT | U.S. Department of Transportation |
| DSA | Documented Safety Analysis |
| EPA | U.S. Environmental Protection Agency |
| ERP | Environmental Restoration Projects |
| ES | Energy Solutions of Utah (disposal contractor) |
| ft | feet |
| HFBR | High Flux Beam Reactor |
| in. | inch |
| LSA | Low-Surface Activity |
| MSA | Management Self-Assessment |
| NCP | National Contingency Plan |
| NRC | U.S. Nuclear Regulatory Commission |
| NTS | Nevada Test Site |
| ORR | Operational Readiness Review |
| PRAP | Proposed Remedial Action Plan |
| R/hr | Roentgen per hour |
| RCT | Radiological Control Technician |
| RDAS | Radiation Detection and Alarm System |
| ROD | Record of Decision |
| RWP | Radiological Work Permit |
| S&M | Surveillance and Maintenance |
| SMAC | Shielded Multi-Use Type A Container |
| TSR | Technical Safety Requirements |
| WMF | Waste Management Facility |

# 1.0 INTRODUCTION

## 1.1 Purpose

This report documents the completion of the removal, packaging, shipment, and disposal of 16 control rod blades (CRBs) and nine beam plugs (BPs) from the High Flux Beam Reactor (HFBR) at Brookhaven National Laboratory (BNL).

The completed activities include:

- Detailed planning
- Preparation of the CRBs and BPs for removal from the confinement building
- Procurement of shipping casks/containers
- Removal, packaging, shipment, and disposal of CRBs and BPs
- Processing, shipment, and disposal of secondary waste

## 1.2 Removal Authority

Removal and disposal of the CRBs and BPs was authorized by the *Action Memorandum, High Flux Beam Reactor, Removal Action for Control Rod Blades and Beam Plugs* (Action Memorandum) (Appendix A). This action is consistent with the final remedy documented in the HFBR Record of Decision (ROD).

# 2.0 SITE DESCRIPTION AND HISTORY

## 2.1 Brookhaven National Laboratory

BNL is owned by the U.S. Department of Energy (DOE), and is one of the 17 DOE national laboratories. BNL conducts research in the physical, biomedical, and environmental sciences, as well as in energy technologies and national security. The Laboratory also builds and operates major scientific facilities available to university, industry, and government researchers.

The U.S. Army used the site, formerly known as Camp Upton, during World Wars I and II, and the site was used as a Civilian Conservation Corps Camp between the wars. In 1947, ownership was transferred to the Atomic Energy Commission for peaceful research on atomic energy and materials. The site was subsequently transferred to the Energy Research and Development Administration in 1975, and finally to the DOE in 1977. These later transfers were the result of agency name changes, not changes in function.

BNL is located in Suffolk County on Long Island, about 60 miles east of New York City (Figure 2-1). Approximately 1.4 million people reside in Suffolk County and approximately 450,000 reside in Brookhaven Township, within which BNL is situated. The BNL site covers almost 5,300 acres, much of which is wooded. BNL has operated since 1947 as a research facility for national science and technology programs, and is expected to continue this mission for the foreseeable future.

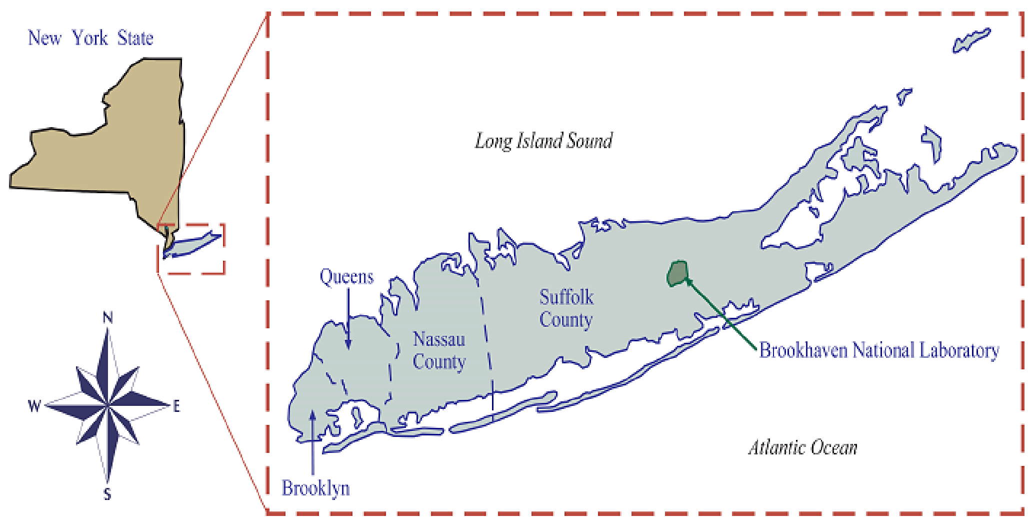



Figure 2-1. BNL location.

Most BNL facilities are located near the center of the site in a developed portion that covers about 1,700 acres. The HFBR Complex is within this central portion (Figure 2-2) of the BNL property. The complex covers about 13 acres, which is less than one-hundredth of the developed site.

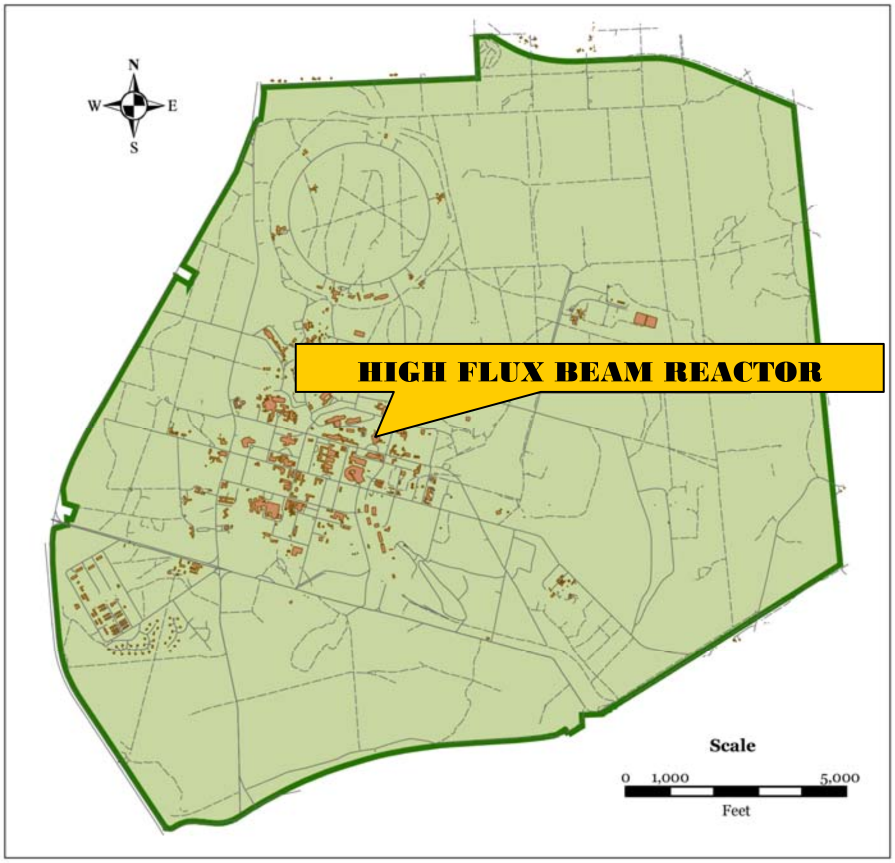



Figure 2-2. Location of High Flux Beam Reactor on BNL property.

The HFBR Complex consists of multiple structures and systems that were necessary to operate and maintain the reactor. The most recognizable feature of the HFBR is the hemispherical dome (see cover photo), which is the superstructure of the Confinement Building.

## 2.2 High Flux Beam Reactor

The HFBR (Figure 2-3) is a heavy water moderated, highly enriched U-235 fueled research reactor and operated from 1965 to 1996. It was used solely for scientific research, providing neutrons for materials science, chemistry, biology, and physics experiments. During a routine maintenance shutdown in 1996, tritium from the spent fuel canal was found in groundwater south of the reactor. Investigations revealed that the source of the tritium was a small leak in the ceramic tile-lined concrete pool where spent nuclear fuel was stored. Operations at the HFBR were suspended and the DOE considered what to do. All of the spent fuel was removed and sent to DOE's Savannah River Site in 1998. The pool was drained and a freestanding, double-walled, stainless steel liner with an instrumented low-point sump was installed to eliminate the potential for leakage to the environment. In November 1999, DOE announced it was permanently closing the reactor. The HFBR has been continuously maintained under a surveillance and maintenance (S&M) program from its initial operation in 1965.

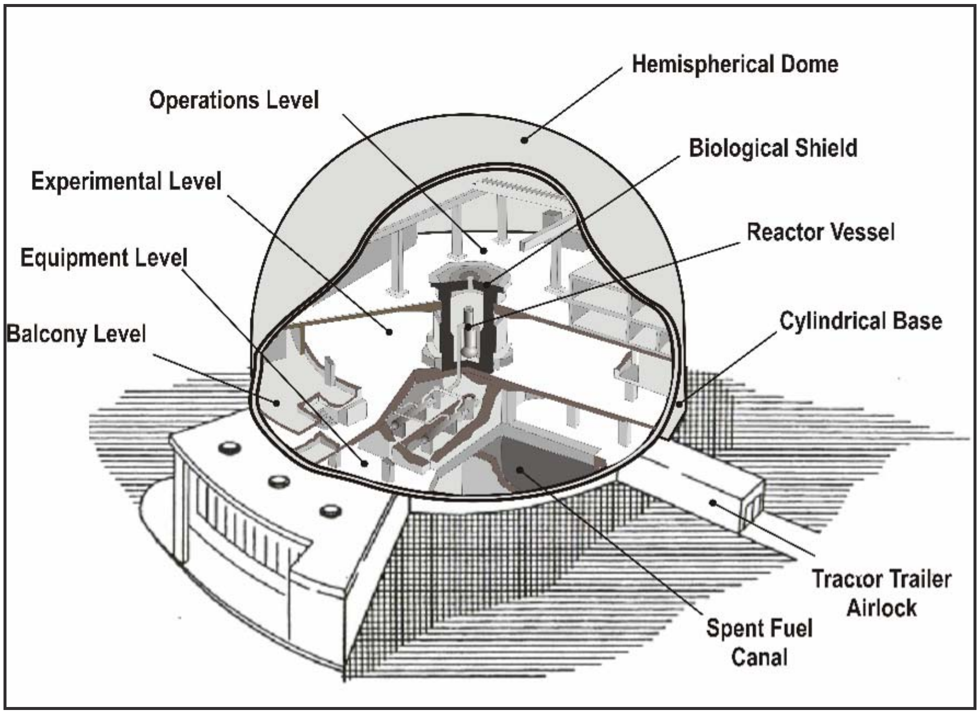



Figure 2-3. Cutaway view of the HFBR Confinement Building (Building 750).

## 2.3 Control Rod Blades

The nuclear fission process in the reactor was controlled by 16 CRBs which could be moved alongside the reactor core. The CRBs contained dysprosium and europium oxides ($Eu_2O_3$ and $Dy_2O_3$), serving as neutron "poisons" to absorb neutrons and thereby control the rate of nuclear reactions.

The CRBs were divided into two groups, with eight main CRBs which could be moved above the reactor core and eight auxiliary CRBs which could be moved below it. During normal operations, the neutron flux was maintained by withdrawing the CRBs approximately symmetrically from the top and bottom of the core as fuel burn-up progressed. Shutdown of the reactor was accomplished by covering the sides of the core with CRBs.

The main and auxiliary CRBs were identical in cross section, both being hollow right angles in shape (Figure 2-4). The blades were formed of composite section rolled plates. The main blades were 40.25 in. long and used both europium and dysprosium for neutron capture. A stainless steel coupling block was welded to each main blade.

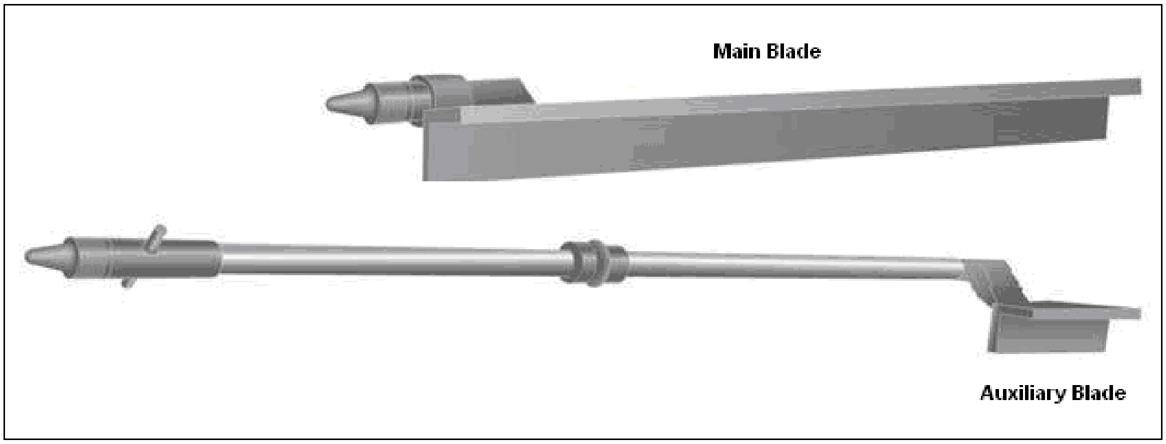



Figure 2-4. Main and auxiliary CRBs.

The auxiliary blades were 12.5 in. long and used only europium for neutron capture. At one end of the auxiliary blade a hinged coupling block connected the blade to an aluminum follower that terminated in the same type of coupling as the main blade.

## 2.4 Beam Plugs

A series of neutron "streams" or beams were established in a radial pattern around the reactor on the Experimental Level of the HFBR Confinement Building (Figure 2-5). Each beam radiated out from the reactor core through a cylindrical penetration (referred to as a beam port) in the biological shield, and then through a beam tube. There were nine beam tubes.

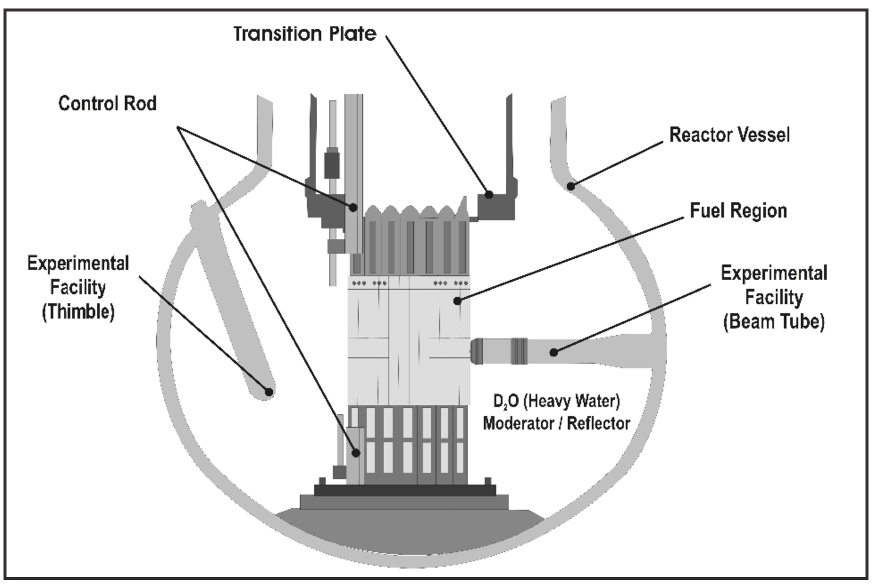



Figure 2-5. Cutaway view of the reactor.

BPs (Figure 2-6) were installed in the beam ports during HFBR operations to provide shielding and collimation of the neutron beams for conducting various experiments. The BPs were of a right cylindrical-stepped shape constructed of steel, concrete, and lead. The materials comprising the BPs became activated as result of exposure to neutrons.

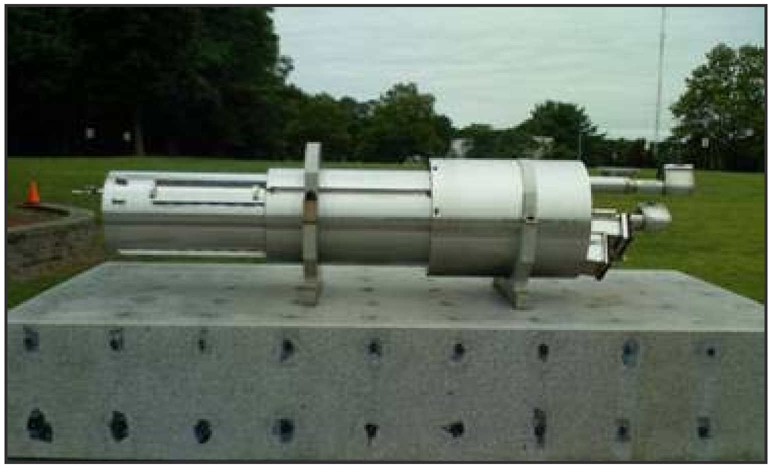


Figure 2-6. H-9 beam plug (spare).

For some experiments, a collimator was used in the neutron stream or beam to guide or otherwise modify the neutron beam going into an experiment. Collimators could be used to modify the speed (energy), number, density, path, or direction of the neutrons, as well. As with the BPs, the materials comprising the collimators became activated.

When they were not in use, seven of the BPs, which were 48 to 61 in. long (H-1, H-2, H-4, H-5, H-6, H-7, and H-8) were stored in the Beam Plug Storage Facility , a large, shielded cube with an array of various sized cylindrical holes, also called the "Cheese Box" (so-named because of all the holes in the structure). The remaining two BPs, which were 116 in. and 80 in. long (H-3 and H-9) were stored in transfer casks when all nine BPs were removed from the reactor beam ports.

An elaborate handling system was devised to safely move the highly radioactive, heavy BPs and collimators between the storage array and the beam ports. This handling system consisted of heavy shielded casks with shutter closures that were placed on a leveling fixture aligned with either the beam tube or the storage location. A reach rod system was then threaded into the BP or collimator to push it out of or pull it into the shielded cask.

## 2.5 Stakeholder Participation

### 2.5.1 BNL Community Relations

The BNL Community Involvement Plan was published April 15, 1999. It is supplemented by project-specific plans. In the case of the HFBR, a Communications Plan for the Regulatory Decision-Making Process for Decommissioning the High Flux Beam Reactor was developed. In accordance with these two plans and CERCLA Sections 113 (k)(2)(B)(i-v) and 117, the Community Relations Program focuses on informing and involving the public in the decision-making process to ensure that the views of the internal and external stakeholder communities are considered. A variety of activities are used to provide information and to seek public participation, including distribution of materials to a stakeholders' mailing list; holding community meetings, information sessions, tours, and workshops; and preparing and distributing fact sheets. The Administrative Record, which documents the basis for removal and remedial actions, was established and is maintained at the libraries listed below:

Brookhaven National Laboratory
Research Library
Bldg. 477A
Upton, NY 11973
631-344-3483 or 631-344-3489

Stony Brook University
Melville Library
Special Collections and University Archives
Room E-2320
Stony Brook, NY 11794
Phone: (631) 632-7119

U.S. EPA - Region II
Records Room
290 Broadway, 18th Floor
New York, New York 10007
212-637-4308

### 2.5.2 Community Involvement In Removal of CRBs and BPs

The community involvement activities conducted for the HFBR remedy selection process included a formal public review of the HFBR Proposed Remedial Action Plan (PRAP). The public comment period began January 10 and ended on March 17, 2008. Two information sessions and a public meeting were held during the public comment period. Public comments indicated that there was considerable community support for DOE's preferred remedial alternative identified in the PRAP (Alternative C, Phased Decontamination and Dismantlement with Near-Term CRB Removal). DOE's responses to public comments and concerns were included in the HFBR ROD Responsiveness Summary.

# 3.0 REMOVAL ACTIVITY

## 3.1 Objectives

The objective was the removal and disposal of the CRBs and BPs, as described in the HFBR ROD. It was to specifically control, minimize, or eliminate all routes of future human and/or environmental exposure to radiologically contaminated facilities or materials.

### 3.1.1 Proposed Action

The Action Memorandum addressed the removal and disposal of the HFBR CRBs and BPs. These activities were performed in accordance with DOE O 425.1C, *Startup and Restart of Nuclear Facilities*, dated 3-13-03, and resulting Documented Safety Analysis (DSA) and Technical Safety Requirements (TSR) documents.

The proposed action included the removal of the 16 CRBs from the reactor vessel, transfer to the spent fuel canal, loading into two disposable shielded transportation shipping casks, and shipment by truck to DOE's Nevada Test Site (NTS) for disposal. Removal of the CRBs would require flooding of the reactor vessel, interconnecting piping, and spent fuel canal. Following CRB removal, approximately 75,000 gallons of water used to flood the reactor and spent fuel canal would be processed and disposed. The reactor would be reassembled, and the spent fuel canal would be decontaminated.

The proposed action also included removal of the nine BPs (including three collimators), located on the experimental level of the Confinement Building; transferring them from the Beam Plug Storage Facility; loading them into disposable casks/containers, and shipping them for disposal at NTS or Energy Solutions (ES) of Utah.

The removal and disposal activities also included:

- Detailed planning
- Preparation of the Confinement Building for CRB and BP removal
- Procurement of shipping casks/containers
- Secondary waste processing, shipment, and disposal

### 3.1.2 Contribution to the Remedial Performance

This removal activity contributed to a one third overall reduction in the radioactive material inventory at the HFBR complex and is consistent with the final remedy documented in the HFBR ROD.

## 3.2 Detailed Planning

### 3.2.1 Selection of Performing Entity

Brookhaven Science Associates' Environmental Restoration Projects (ERP) management determined that the scope and complexity of the CRB and BP removal was within the capabilities of the HFBR staff and decommissioning field workforce.

**Facility Safety Basis Document – Effect on Removing the CRBs and BPs**

The DOE classification of HFBR at the start of CRB and BP removal was that of a Hazard Category 3 (HC3) Non Reactor Nuclear Facility. In accordance with Nuclear Safety Management (10 Code of Federal Regulations [CFR] 830), it was being managed for nuclear safety under a DSA with hazard controls identified through TSRs.

This meant that any activity performed at the HFBR required an Unreviewed Safety Question review in order to determine that the contemplated activity was authorized under the DSA. Additionally, implementing procedures were developed to ensure that TSR requirements were captured in executing work.

### 3.2.2 Radiological Preparations and Characterization for Removal Activities

Historical and current radiological surveys were used to support removal activities. In 2007 an activation analysis was performed to determine expected curie content and dose rates for all activated HFBR components including the CRBs. Based on the analysis CRBs were expected to read as high as 13,000 R/hr, and the transition plate greater than 35,000 R/hr, at 1 ft in air. These results were then decay corrected to February 15, 2009 to provide more accurate values for comparison. This made it possible to have a better understanding of what to expect when actual handling and transfer of CRBs began.

#### 3.2.2.1 CRB Characterization

The extensive characterization of the CRB components was necessary as much for waste management and disposal requirements as for worker safety. The transfer system, with extensive shielding and remote handling features, made it possible to handle even the most radioactive CRB with minimal exposure to a D&D worker or Radiological Control Technician (RCT).

Following their removal from the reactor, underwater radiation levels were taken and the activity in curies (Ci) was estimated for each CRB. The maximum dose rate for a single CRB was 6,774 R/hr at one foot in water. The actual activity for the 16 CRBs was 16, 075 Ci and compares reasonably well with the estimated total of 16,624 Ci.

#### 3.2.2.2 BP and Collimator Characterization

Because at the start of the removal project only limited historical data was available for the BPs and collimators, radiation measurements, to the extent possible without moving the components, were taken. These measurements of accessible components, coupled with the knowledge of the sizes, exposure history, and historical data, provided a fairly detailed knowledge of what to expect when the actual handling and transfer of components began.

The extensive shielding and "hands-off" features of the transfer system made it possible to handle even the most radioactive BP with minimal D&D worker or RCT radiation exposure. It was necessary, however, to have detailed Curie content and radiation readings to meet the packaging, shipping, and then disposal requirements (Table 3-1).

Table 3-1. Beam Plug Activity and Dose Rate Information.

| BP or Collimator | Co-60 Activity (Ci) | Dose Rate (R/hr) | Transport Container |
|---|---|---|---|
| H-1 | 4.07 | 4.67 @ 18" | 10-142 cask |
| H-2 | 2.01 | 2.3 @ 18" | 10-142 cask |
| H-3 | 0.46 | 4 @ 9.5" | Small transfer cask |
| H-4 | 5.94 | 30.8 @ 10" | Large transfer cask |
| H-5 | 1.5 | 5.5 @ 9.5" | 10-142 cask |
| H-6 | 7.37 | 44 @ 9" | shielded box |
| H-7 | 1.28 | 4.6 @ 9.5" | 10-142 cask |
| H-8 | 3.11 | 11.2 @ 9.5" | 10-142 cask |
| H-9 | 32.8 | 70 @ 12" | 3-55 cask |
| C-1 (H-3 collimator) | 0.004 | 0.01 @ 12" | steel box |
| C-2 (H-2 collimator) | 0.044 | 0.12 @ 12" | steel box |
| C-3 (H-3 collimator) | 0.004 | 0.01 @ 12" | steel box |
| "Candlestick" | 0.132 | 0.3 @ 12" | steel box |
| TOTAL | 58.7 | -- | -- |

### 3.2.3 Procedure Prep, Field Crew Management, and Worker Training

Detailed procedures were developed for these tasks. Training was conducted for the field work team on the procedures, including procedure walk-through by the workforce, followed by dry-run evolutions to note and correct procedural deficiencies or improvements. The procedures were practiced until the field work team was considered proficient and the procedures were adequate. Then the CRB uncoupling process was practiced in mockups, and dry runs were conducted of the entire evolution.

#### 3.2.3.1 Mock Up of Reactor Vessel Control Rod Blade Removal

The process for removal of CRBs from the reactor vessel involved the use of very long, specialized tools that had been developed during construction of the reactor plant. Those tools served to manage the fuel elements, remove and install fixtures, and remove and replace control rod drive components, including the CRBs. Over time, improvements were made as lessons-learned were incorporated into their design.

Approximately a dozen specialty purpose reactor servicing tools, used during reactor refueling and maintenance activities, were available for use in the CRB removal operations.

#### 3.2.3.2 Mock-Up for CRB Uncoupling and Training on Tools

Two spare control rod drive units were available at the HFBR in long-term vertical storage on a crane column. Being on open display enabled their use in training and troubleshooting the process for CRB removal. One of the spares was taken down and used in the uncoupling set-up, training, and practice dry-runs/mock-ups to qualify the D&D workers to perform the uncoupling tasks. The mock-up training took place on the Operations Level adjacent to the tool storage area.

Although the spare control rod drive mechanism was radiologically uncontaminated, some of the handling tools (especially the more complex ones) were contaminated from previous use, so the mock-up training was accomplished in full protective clothing for contamination control. That had the added benefit of giving the workers experience in working in the conditions they would encounter in the reactor pit.

Figure 3-1 shows workers practicing with the tools, and Figure 3-2 shows a close-up view of CRB tools.

Figure 3-1. D&D workers using the uncoupling tools in mockup training. All training was done with full protective clothing to simulate actual conditions.

Figure 3-2. Close-up view of CRB tools (left to right): auxiliary blade guide bushing tool, main and auxiliary blade (un)coupling tool, main blade handling tool.

### 3.2.4 Readiness Preparations for CRB and BP Removal

For HC3 non-nuclear facilities DOE Order 425.1C requires implementation of a three-step readiness process before approval is granted to commence such activities in nuclear facilities. They include a Management Self Assessment (MSA) by the contractor, a Contractor Operational Readiness Review (ORR), and then a separate ORR conducted by DOE.

- ERP Contractor Management Self-Assessment. During May of 2008, ERP developed an MSA Plan and then conducted the MSA during July of 2008. Findings and observations were identified and corrected.
- ERP Contractor Operational Readiness Review. The contractor ORR was conducted during July and August of 2008. Deficiencies were identified and corrected.
- DOE Operational Readiness Review. DOE, in consultation with an outside organization, conducted its ORR during early September of 2008. Deficiencies identified during this review concerning management's standards and approach required significant changes to be made in the ERP management of the process.
- DOE Operational Readiness Review Followup and Confirmation. In December, 2008, when these changes were in place, DOE reviewed/confirmed the readiness for startup of the CRB removal process.
- DOE Operations Readiness Review Check and Dates. From January 13 to 15, 2009, DOE HQ performed an Independent Verification of Closure of DOE ORR findings. This review concluded that, pending the closure of some minor open issues, that the startup activities at the HFBR could be authorized.

## 3.3 Procurement of Shipping Casks

The HFBR control rod blades and beam plugs consisted of approximately 20,000 Ci of activated metals and exhibited extremely high dose rates—greater than 10,000 Rem per hour. In accordance with ALARA principles, one objective of the HFBR Decommissioning Project was to identify and use Type B packages that had an expiring Certificate of Conformance (COC), in order to enable use of the package not only for transportation, but for final disposal of these activated reactor components. Several packages certified by the NRC had COCs that were due to expire on October 1, 2008, as mandated by 10 CFR Part 71, in order to align U.S. shipping cask requirements with those of the International Atomic Energy Agency (IAEA). Although these packages were designed and analyzed to withstand normal and accident conditions, they did not undergo the rigorous testing required by the current regulations.

BSA was fortunate to locate and procure four such Type B packages. The Brookhaven Site Office (BHSO) worked with DOE headquarters to request authorization for limited use of these packages under DOE authority. BHSO requested approval for one final shipment of three Type B packages, specifically the CNS 1-13 C, the CNS 1-13 G and the CNS 3-55. The request established that it was prudent for DOE to allow one last shipment of these packages which have demonstrated a proven safety record.

DOE first issued a COC for the three Type B packages based on the NRC approved safety basis. A revised COC was issued to extend the expiration date and require additional compensatory safety measures, such as satellite tracking. The DOE also required the shipments to be conducted as federal government shipments and required transport by federal government employees, in accordance with the provisions in Title 49, Code of Federal Regulations, Part 171.1(d)(5). The waste was managed, packaged, and transported in accordance with, or with equivalent safety to, all relevant regulations, including those of DOE and the Department of Transportation (DOT).

Allowing one final use of these very dependable packages simplified handling and limited the radiation exposures to workers from these high dose rate components by eliminating the need to unload the contents at the disposal facility. It provided for final disposition of these packages that could no longer be used for Type B shipments and minimized waste disposal volumes. Use of these packages facilitate project success and enabled compliance with commitments made in the HFBR Record of Decision.

## 3.4 Preparations for the Removal of the CRBs and BPs

### 3.4.1 Preparing the Facility

#### 3.4.1.1 Facility Status

After HFBR shutdown in December 1996 and the removal of fuel from the reactor vessel in 1998, the experimental equipment, instrumentation, and shielding were dismantled and either moved to other locations or excessed.

The configuration of the reactor after the fuel had been removed and the vessel drained was:

- The reactor vessel head was installed.
- All reactor vessel penetrations used for vessel access, lighting, and re-fueling were closed.
- The reactor vessel dewatering tubes remained in place.
- The reactor pit was closed and locked.

To meet Suffolk County Article 12 requirements, the spent fuel canal was modified in the 1990s with a new, freestanding double-walled stainless steel liner with an instrumented low-point sump to eliminate the potential for leakage to the environment. It has never been placed in service.

The BPs and the collimators that were used to modify or manage the stream of neutrons to the experiment were transferred to the Beam Plug Storage Facility (the “Cheesebox”) in 2001.

To provide the necessary shielding, the reactor vessel and spent fuel canal required filling with water. It was determined that the reactor vessel water levels required for shielding (Figure 3-3) needed to range from 150 in. to 162 in. (measured depth from bottom of vessel).

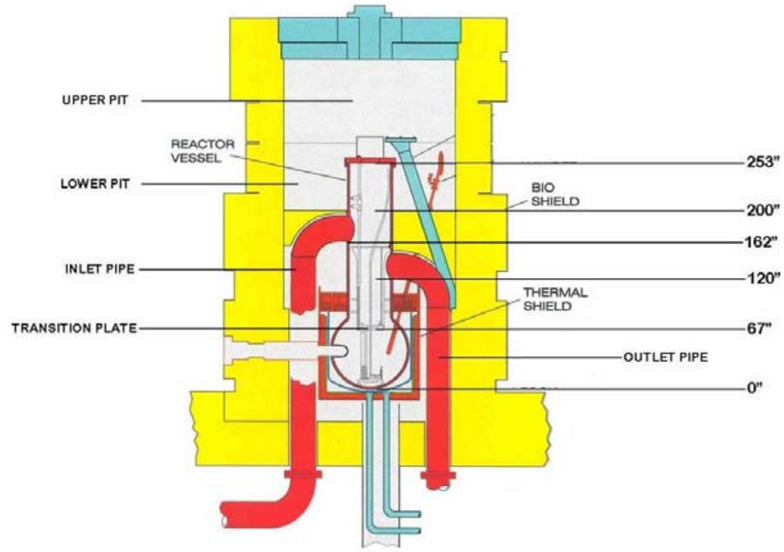



Figure 3-3. Reactor vessel water level.

Based on plant worker knowledge, the volume of water required to fill the reactor vessel and associated primary system piping to the level of 162 in. was 6,500 gallons. It was decided that domestic water would provide the required shielding benefit for removal activities.

The reactor vessel filling systems and reactor head vent valve were accessible and available for operation before reactor pit entry was necessary. The spent fuel canal was also empty and required filling to support removal of the CRBs. Handrails were installed around the spent fuel canal as a safety measure for workers.

The activated BPs and collimators had high radiation dose rates—in the R/hr level. This would necessitate the use of shielded transfer casks and an adjustable leveling table when transferring them from the reactor biological shield beam ports to the Beam Plug Storage Facility. The transfer cask had a shutter arrangement that closed off the open end and provided complete shielding for the component. The transfer casks, which can be seen in the center and right of Figure 3-4, protected workers from radiation and enabled safe handling of these heavy components.


Figure 3-4 Beam plugs, transfer casks, and BP storage area at start of BP and collimator removal.

Two large, shuttered, shielded transfer casks were staged at the HFBR. One held the H-3 BP, which had been stored in the cask and was slated to remain there during transfer to the Waste Management Facility, where it would be disposed of with the cask. The other transfer cask held the H-9 BP, which was too long for the container and protruded through the open shutter. The exposed part was activated, so had been shielded with lead blankets, to protect workers.

#### 3.4.1.2 Filling the Systems with Water

The reactor vessel, the associated legs of the primary coolant system, and the spent fuel canal were filled with domestic water. After the reactor vessel was filled, an entry was made to the reactor servicing pit. Reactor pit entries were carefully monitored for radiation levels, airborne radiological contamination levels, and air quality for confined space entry. The reactor pit was also treated as a confined space, even though it is ventilated.

A modified reactor-vessel water-level monitoring system with digital indication was installed. This was necessary to provide a reliable monitor for water level during the CRB removal activities, because water was needed in the reactor vessel to shield workers.

The reactor vessel closure flange was removed and set aside. Several of the reactor vessel light-port flanges were removed to allow the placement of lights and cameras down into the core area. The pumping systems and the tubing that was used to remove water from the reactor vessel were later removed and stored.

Workers had to access reactor internals through the vessel head opening and through access openings near the top of the vessel. When the reactor fuel had been removed, the control rods were positioned for future work by driving them to the end of their travel using the rod drive motors and then disconnecting electrical power. When the reactor was accessed for this work, the workers had to operate the Control Rod Drive Assemblies manually.

Figure3-5 shows the view inside the vessel prior to removal of the CRBs.

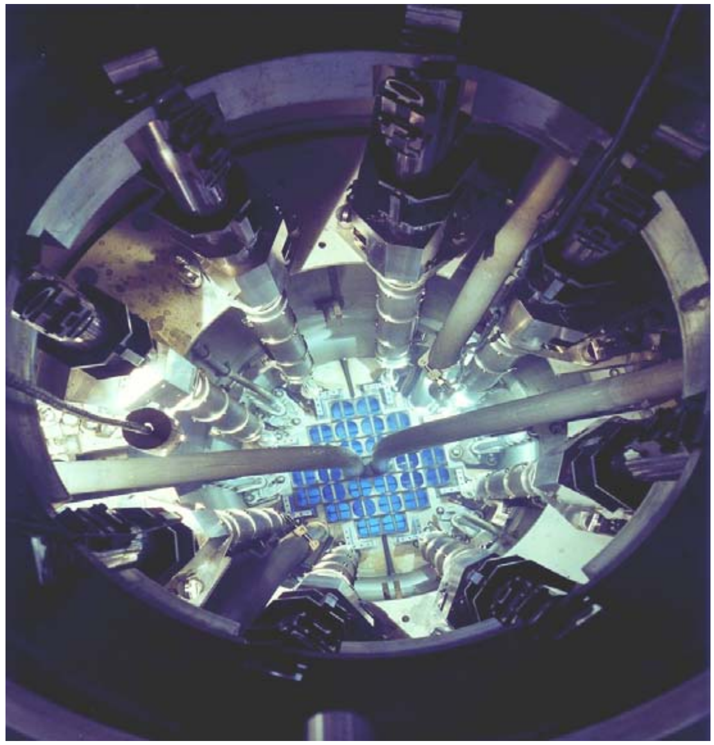


Figure 3-5. Reactor vessel with closure flange removed and CRBs in place.

The spent fuel canal was also filled to capacity using domestic water. This water level provided a minimum of 9 ft of shielding above the bottom of the discharge chute, which is a tube coming down from immediately beside the reactor vessel flange. This plant design feature provided a path for moving highly radioactive components from the reactor vessel to the spent fuel canal. Fuel elements and other radioactive components were lifted above the reactor vessel head flange and then guided by a slide consisting of a curved panel that aligned a component—such as the CRBs—with the discharge chute for lowering to the spent fuel canal.

#### 3.4.1.3 Preparing the Reactor Vessel for CRB Removal

When the reactor vessel was filled, entry was possible into the reactor servicing pit. It was necessary to remove the reactor vessel head and several of the top access ports to provide access to reactor internals for workers using long-handled tools. In the original plant configuration, before remote camera technology was developed, the reactor was equipped with periscopes for monitoring and viewing reactor internals, monitoring refueling and maintenance operations, and reading identification markings on fuel elements. In some cases, binoculars were used from the top of the vessel to view such details.

Worker safety was of primary importance, considering the radiation fields of the reactor's irradiated components. It is also important to understand the process for managing how close to the surface of the reactor vessel water an irradiated component could be brought and continue to provide the required shielding for workers. The procedures for CRB removal provided administrative controls for managing reactor component movements, personnel entry into the reactor pit, the use of special handling tools (especially those associated with radioactive components), and the removal of items from the reactor. One limiting condition was that no component being handled would yield a reading above 100 millirem per hour (mr/hr) at the reactor vessel flange while personnel were present.

#### 3.4.1.4 Preparing the Spent Fuel Canal for CRB Removal and Transfer

The disposal plan for the CRBs required that the auxiliary CRB follower rods be separated from the auxiliary CRBs. The auxiliary CRBs were attached to follower rods to extend the CRB section below the reactor core during operation. Reduction in length was necessary because the casks procured for shipping and disposal of the CRBS would not accommodate the longer length of the auxiliary CRB with its follower.

A strike plate was installed to protect the spent fuel canal liner in the possible event of a cask-drop accident.

Storage racks were fabricated and installed in the spent fuel canal to stage the eight Main CRBs and the eight Auxiliary CRBs with their follower extensions.

An underwater system was installed to shear the 1-inch diameter aluminum auxiliary CRB follower rod just above the CRB. Detailed procedures were developed to perform the shearing operation and then stage the two parts in the storage racks until they could be loaded into the shipping/disposal casks.

Walk-through and practice shearing were accomplished through a progressive series of more and more realistic dry runs. After a practice session, feedback lessons-learned were incorporated into the procedures. Practice included the insertion into the reactor vessel of a spare non-irradiated training CRB of each type. Each CRB had the adapter piece referred to as the "transfer tool" screwed onto the upper end. The procedures were then practiced by grappling, lifting, transferring, shearing, and storing a practice CRB until the process was routine. Post-work radiological and hazardous substance surveys were performed, in accordance with BNL radiological control procedures.

## 3.5 Removal, Packaging, Shipment, and Disposal of CRBs and BPs

With a) an integrity test completed on the CNS 1-13G cask, b) the spent fuel canal equipped with racks to hold the CRBs, c) a "strike plate" installed in the bottom of the spent fuel canal, and d) the canal filled with domestic water, preparations were complete for moving the shipping casks into the HFBR, placing them into the spent fuel canal, and beginning to load the CRBs.

### 3.5.1 Radiological Controls During Removal Activities

The radiological control department provided full coverage, with RCTs being an integral part of the D&D worker crew, both inside the work areas at the reactor top and with the workers at the spent fuel canal.

The Radiological Control Manager and the Facility Support Supervisor participated in daily briefings on the aspects of radiological controls and provided total coverage of all parts of the work. In most cases they routinely participated with the crew to ensure that coverage, surveying, and monitoring were effective.

The Radiological Work Permits (RWP) that were developed hand-in-hand with the Work Procedures were designed and prepared to provide worker protection through the continuous monitoring and management of components. Further, the RWP provided for full-time coverage from the Radiological Control Technicians for this work, to monitor and assist in controls for radiation and the "transferable" radioactive contamination that was in corrosion products and deposits on the surfaces of all reactor vessel internals, the surface of the reactor vessel, and in the domestic water after it had picked up some of that transferable contamination.

Radiological Instrumentation was utilized to monitor radiation levels and air particulate activity in all areas where the workers were located. The combination of installed instrumentation and monitoring by the radiological staff ensured that all types of radiation exposure were maintained As Low As Reasonably Achievable (ALARA). A Radiation Detection and Alarm System (RDAS) (Figure 3-6) was installed to protect workers. It was designed and located to detect radiation levels exceeding the TSR-required 100 mr/hr and as an additional precaution, 80 mr/hr. The RDAS provides both visual and audible alarms and used the Ludlum 375 area monitor with an internal Geiger Muller Detector.


Figure 3-6. Radiation Detection and Alarm System (RDAS) instrument Ludlum 375/4.

The effectiveness of radiological controls was evident in that the project experienced no radioactive contamination of workers, no spread of radioactive material, and the radiation dose received was consistently well below conservative dose estimates for each part of the job. The entire CRB job was accomplished with a total dose of less than 129 millirem to workers as compared to the 527 millirem estimated.

An extensive Radiological Protection plan with customized procedures was used, along with continuous RCT and Radiological Control Management presence during the transfer of BPs and collimators. Worker and RCT radiation exposures were very low—see Section 3.8, ALARA.

### 3.5.2 Removing, Packaging, and Shipping of CRBs

After approval of the HFBR Decommissioning Project Startup Plan, the long-handled tools were installed, and removal of the CRBs was begun on January 30, 2009.

A section of the HFBR Startup Plan included the placement of long-handled tools into the reactor vessel using the bridge crane. In previous (routine) operations at HFBR, the upper end of the tool was attached to the crane hook and the bottom end was guided up to and into the reactor vessel while the tool was mostly lifted and positioned by the crane operator. Current safety standards relating to crane hoisting and rigging operations prevented this method from even being considered because of the potential for the tools to contact the exposed 480-Volt buss bars on the crane.

After several purely manual movements of tools and critiques of the process, the crane was brought over the reactor vessel with a man located on the crane bridge over the reactor vessel itself. This process was planned and implemented utilizing all required fall protection practices and procedures. That person then stabilized the upper end of the tools that were being rotated to vertical and lowered into the vessel by one or two other team members. This process worked well and enhanced team safety.

In the partial view of the Reactor Pit (Figure 3-7), the reactor vessel opening is on the right and the fuel discharge chute opening, leading to the spent fuel canal, is on the left. The curved slide to the far right is used to push the CRB over so it can be guided into the fuel discharge chute and lowered into the spent fuel canal.

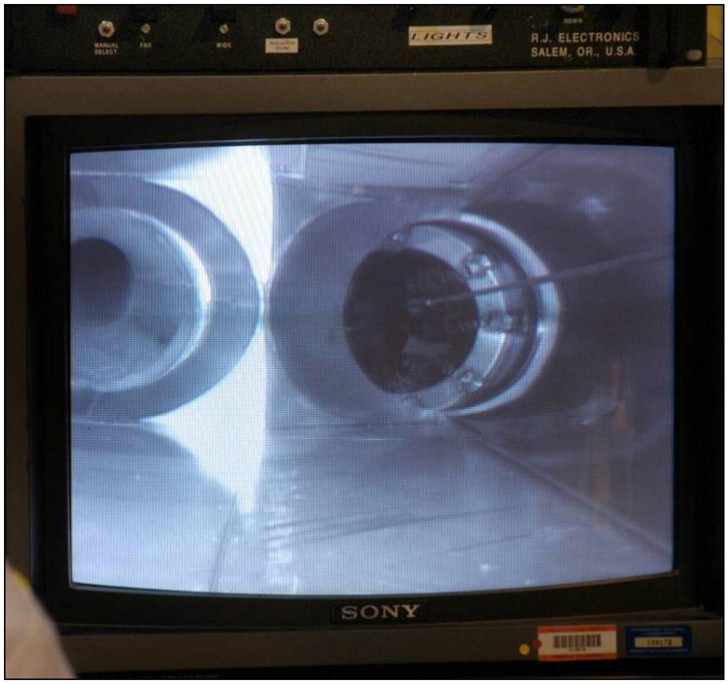



Figure 3-7. Reactor pit.

In auxiliary CRB removal shown on a monitor (Figure 3.8), an auxiliary CRB is connected to its follower rod, which is attached to the hoisting cable and being guided by the slide over to the fuel discharge chute opening for it to be lowered into the spent fuel canal.

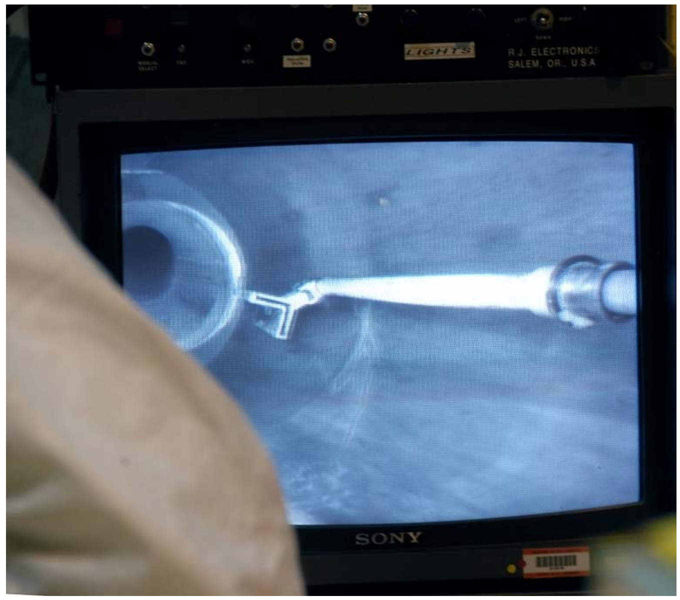



Figure 3.8. Auxiliary CRB removal.

The last CRB was transferred to the spent fuel canal February 24, 2009. All 16 CRBs stored in the spent fuel canal can be seen in Figure 3-9.

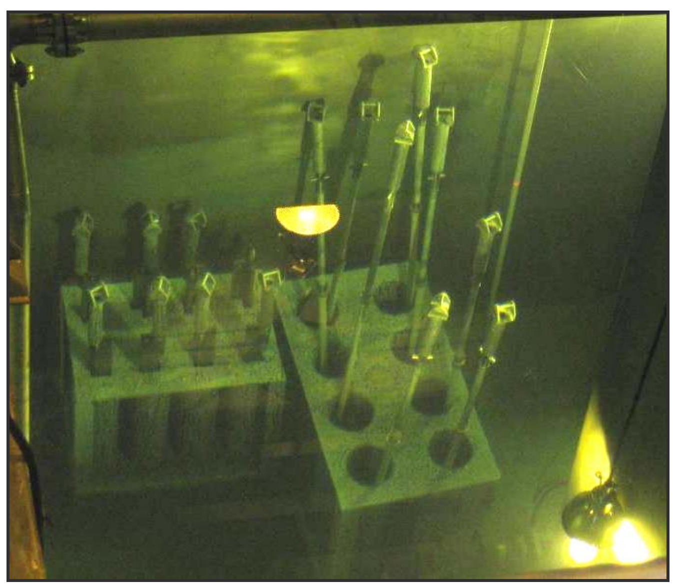


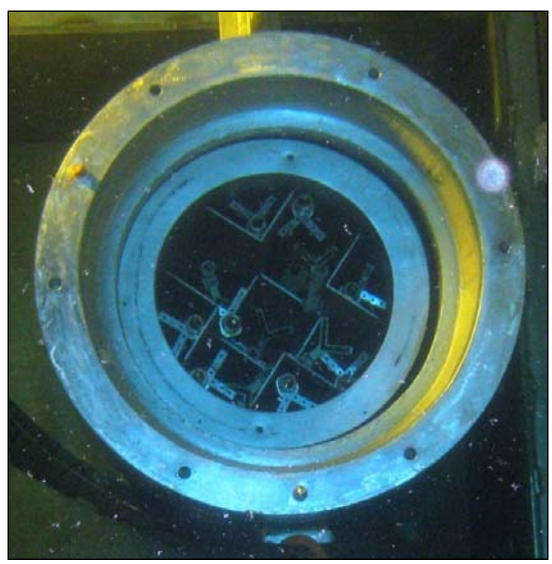
Figure 3-9. Main and auxiliary CRBs stored in fuel pool.

While the CRB removal was taking place, preparations were being made for loading them into the shipping casks. A complete walk-through and procedure dry run were performed to prepare for cask handling. Then the first cask was placed in the spent fuel canal (Figure 3-10) to receive the CRBs.

Figure 3-10. Shipping cask being lowered into the fuel pool.

The first cask was loaded with the eight main CRBs and one auxiliary CRB (Figure 3-11), closed up with the shielded covers, and then removed from the spent fuel canal on February 26, 2009. It was drained of water, leak-tested satisfactorily, and removed from the building. This cask was then placed on the shipping trailer and the over-pack shielding was installed for shipping.

Figure 3-11. Main and auxiliary CRBs loaded into the CNS 1-13G cask.



The process for shearing the Auxiliary CRB followers was proven during dry runs for the CRB removal. Because the aluminum followers were embrittled from radiation exposure, some shards of the aluminum tubes broke off during the shearing process. Following the loading of the CRBs, these shards had to be retrieved from the spent fuel canal floor and placed in the casks separately.

The installation of additional shielding for the CNS 1-13G cask, loaded on its trailer, is shown in Figure 3-12, and the complete package ready for shipment to NTS is shown in Figure 3-13.

Figure 3-12. Shielded overpack being placed over CNS 1-13G cask.

Figure 3-13. CNS 1-13G shipping cask with CRBs ready for the road.

The second shipping cask, the CNS 1-13C, was brought into the building, checked, and then installed in the spent fuel canal on February 27, 2009. It was loaded with the seven remaining auxiliary CRBs, the followers, and the retrieved aluminum shards from the CRB follower shearing process. This cask was closed and removed from the spent fuel canal on March 4, 2009. It was then drained, leak-tested satisfactorily, and removed from the HFBR on March 6, 2009.

### 3.5.3 Removing, Packaging, and Shipping the BPs and Collimators

One beam plug, H-9, was longer than any of the others (to meet a special experimental need) and would not fit into a standard shipping cask without a reduction in size. Therefore, it was necessary to transfer H-9 to the Waste Management Facility (WMF), where the low-activity end could safely be cut from the rest of the assembly, which would enable BP H-9 to be transported in a CNS 3-55 Type B cask. Figures 3-14 and 3-15 show the transfer of BP H-9 to the shipping cask for transfer to the WMF, which occurred on January 27, 2009. Note that this operation pre-dated removal of the CRBs. By the time the CRBs had been removed, processing of BP H-9 was completed and it was possible to move right into removal of the remaining BPs and collimators.


Figure 3-14. Transfer of BP H-9 to shipping cask CNS 3-55.

Figure 3-15. BP H-9 being loaded into shipping cask CNS 3-55.

Figure 3-16 shows the packaged BP H-9 ready for the road.

Figure 3-16. H-9 in CNS 3-55 cask ready for shipment.

After the CRBs and related materials had been shipped and while BP H-9 was still being processed, removal of the remaining BPs and collimators began. The use of the leveling table for loading a BP into the transfer cask can be seen in Figure 3-17. It was necessary to position the leveling table in front of the BP in its storage location and then place the transfer cask on the table. After aligning the BP, it was pulled with a rod screwed into the BP until it was inside the transfer cask. Then the shutter was closed and the transfer cask and leveling table were surveyed to ensure they were free of external radioactive contamination. After they surveyed clean, both the transfer cask and the leveling table were transferred to WMF on a flatbed truck where the operation was reversed to unload the cask.


Figure 3-17. Transfer cask and leveling table loading BP H-7.

When the transfer cask was returned to HFBR, it was loaded with the next BP to be removed. The beam plug loading configuration of partially loaded 10-142 cask can be seen in Figure 3-18.


Figure 3-18. BP loading configuration of partially loaded 10-142 cask.

Beam plug H-6 was expected to contain low levels of radioactivity. During removal of this plug from its storage location, high levels of radiation were detected and the item was placed back inside the storage location until radiological engineering could perform dose and curie calculations. It was then packaged in a shielded B-25 box within a Shielded Multi-Use Type A Container (SMAC) for shipment as a Low-Surface Activity (LSA) package. The work was accomplished without incident or spread of radioactive contamination, and exposure was ALARA.

Exposure to the workers for BP and collimator preparation and removal was 31 mRem, well below the 150 mRem predicted value.

#### 3.5.4 Completion of Activities

When all BPs were removed from the HFBR facility, the D&D crew and the RCTs cleaned the Cheesebox storage location and decontaminated all surfaces, including the storage locations for long-term storage.

## 3.6 Final Conditions

### 3.6.1 Reactor Vessel

- All CRBs (eight main and eight auxiliary blades) were removed from the reactor vessel.
- All dummy fuel elements were removed and disposed of as rad waste.
- The transition plate inserts, “A” bolts, and locking cups were left in the vessel. A bucket was used to store some parts; others are lying on the transition plate. Some

transition plate inserts are sitting in the slots where they were originally installed

- The reactor vessel and primary pump-out lines were installed. A larger tube was used to pump both vessel and primary down to 20 in., and a smaller tube reached to the bottom of the reactor vessel. These tubes enter through the reactor top access ports, pass through the pumps, and then are routed out to the west side of the pit through penetrations in the biological shield.
- The reactor vessel was sealed up; the reactor vessel head flange was installed and tightened. The access ports were installed and tightened.
- Note that for the pump-out of the last of the water from the reactor vessel, air pressure was applied—through the reactor vessel helium pressurization system piping—so the system was capable of pressurization.
- The reactor tools, potentially needed for future use, were inventoried, photographed, and store in the “dry box,” a radioactively contaminated storage box located on the operations level. Tools determined to be of no future use were disposed of as rad waste.
- The reactor vessel head vent was left open.
- The reactor vessel radiation survey was conducted following the removal of the CRBs, dummy assemblies, and tools prior to placing the closure flange in place. The radiations levels were:
    - 8,248 R/hr at the transition plate at the M-7 slot
    - 9,045 R/hr above the anti-critical grid

#### 3.6.2 Reactor Pit and Upper / Lower Tritium Containments on Operations Level

- The reactor pit was cleared of all extraneous parts, tools, and equipment.
- The pumps for draining the reactor vessel remain in the reactor pit and the discharge tubes run out to the west side of the reactor top hat.
- The temporary Radiological Monitoring Equipment was removed, specifically the radiation area monitors and the instrument used to monitor the pit and reactor vessel head radiation levels during and at the completion of reactor coolant draining and pump-down.
- The Lower Tritium Containment in the reactor pit was closed.
- The Upper Tritium Containment on top of the reactor top hat is closed and locked. Only one radiologically contaminated component remains in the Upper Tritium Containment, and that is the hose reel and hoist for fuel elements.
- The operating system for the fuel element hoist was disconnected to prevent operation.
- The reactor pit ladder was removed and stored along side the reactor top hat.
- The reactor pit shielding plug was installed (7,625-pounds) and double-locked with High-Radiation Area locks.

- When closed, the radiation levels inside the reactor pit at the top of the reactor vessel head were 7 R/hr.
- A full set of surveys were documented for the reactor pit and the tritium containments.
- The exteriors of all the reactor top hat area and upper tritium containment were radiologically decontaminated.

### 3.6.3 Spent Fuel Canal on the Equipment Level

- The spent fuel canal was drained and radiologically decontaminated to very low radiological contamination levels.
- The strike plate onto which the casks were landed was left sitting on the bottom of the spent fuel canal at the east end.
- The spent fuel canal ladder was reinstalled and the new handrails were modified to accommodate the ladder.
- Spent fuel canal leak detection will be maintained in service until facility isolation is complete.
- The spent fuel canal covers, which were fabricated of wood planking, were discarded for fire loading minimization considerations.

### 3.6.4 BP and Collimator Storage Area on Experimental Level

- All BPs and collimators are out of the facility.
- Both shielded and shuttered transfer casks have been transferred out of the facility and disposed.
- The Beam Plug Storage Facility (Cheesebox, Figure 3-19), is empty and radiologically clean.
- All storage location covers are off the Beam Plug Storage Ports.
- The transfer cask leveling table is in the facility on the Experimental Level and is radiologically clean for disposal.


Figure 3-19. Beam plug storage area, as-left condition.

## 3.7 Personnel Safety

Worker, public, and environmental safety were paramount in the planning and implementation of the removal work. During the performance of the removal activities, there were no instances of personnel radioactive contaminations, overexposures, internal radioactive material uptakes, or lost-time accidents.

## 3.8 ALARA—As Low As Reasonably Achievable—Radiation Dose

ALARA was of prime importance and practiced constantly during all planning and implementation of the removal work. During the performance of the removal activities, there were no instances of personnel radioactive contaminations, overexposures, internal radioactive material uptakes, or lost-time accidents.

Exposure estimates were made for each of the major tasks to be accomplished. In every case, the actual dose to individuals and the total dose to the work force, see Table 3-2, were lower than the estimated dose .

**Table 3-2.** HFBR Radiation Exposure by RWP.

| RWP No. | Title | Total Dose (mRem) | Dose Estimate (mRem) |
|---|---|---|---|
| 2008-ERP-058 | CRB Removal | 102.4 | 135 |
| 2008-ERP-059 | CRB Cask Loading | 26.4 | 392 |
| 2008-ERP-063 | BP Removal | 31 | 150 |
| 2008-ERP-064 | CRB Canal Work | 2.4 | 21 |
| TOTAL | | 162.2 | 698 |

## 3.9 Cost

The estimated cost presented in the Action Memorandum for removal and disposal of the CRBs, BPs, and collimators was $3,330,000.

The actual cost is shown in the table below:

**Table 3-3.** Costs for CRB and BP Removal and Disposal.

| Description | Project Cost, $ |
|---|---|
| BNL Labor | 441,425 |
| Subcontracts, including shipping casks | 1,815,000 |
| Materials | 632,730 |
| Plant Engineering Support | 177,640 |
| Other Distributed Costs | 48,510 |
| Facilities Site Services Support | 795,620 |
| Additional Cost for Waste Water Disposal | 400,000 |
| Total Cost | 4,310,925 |

# 4.0 WASTE MANAGEMENT

The waste management plan for the removal of the irradiated materials (CRBs, beam plugs, and collimators) from the HFBR was based on historical documentation as well as radiological engineering review and direct survey. More than a third of the HFBR radiological inventory was safely removed, packaged and transported from BNL to NTS and ES of Utah. Waste minimization was effected through burial of package and its contents.

## 4.1 Control Rod Blades

The CRBs were packaged within the CNS 1-13C and 1-13G Type B packages. The two packages had different shielding capabilities. To ensure the proper configuration within each cask, radiological engineering was used to estimate the curie content and dose rates of each blade. Because the auxiliary CRBs with their aluminum followers were too long for the cask cavity, they were segmented underwater. All eight of the main blades were loaded intact into a fitted liner within the CNS 1-13G cask along with one auxiliary blade. The remaining seven auxiliary blades and the cut follower sections were placed into the fitted liner within the CNS 1-13C cask. These casks were then sealed per the manufacturer specifications and shipped via flatbed truck to NTS. The packages were buried, along with the contents, as low level waste at NTS.

## 4.2 BPs/Collimators

The packages selected for the transportation and disposal of the nine BPs and three collimators included one Type B shipping casks, the CNS 3-55, which was used for BP H-9. All of the remaining BPs removed were placed intact within the selected package. All of the other BPs and collimator shipments met DOT LSA requirements and were able to be transported within shielded packages for disposal at ES of Utah.

The three collimators were relatively low in dose rate and were disposed of as mixed waste (due to inherent lead) at the ES of Utah disposal facility. The collimators were placed into a B-25 box along with an additional piece of irradiated metal that was found to be in the BP Storage Facility (Cheesebox). This box was shipped via flatbed truck to ES of Utah for treatment (macro-encapsulation) and disposal.

Table 4-1, Waste Shipment Details, lists shipment specifics for the transportation of the CRBs, BPs, and collimators to their respective disposal sites. The federal shipments began in mid-February 2009, and were completed by the end April 2009. The low-level waste shipments, including shipments of the secondary waste and solidified water from the HFBR canal and reactor vessel, were completed by October 2009. The total volume of the waste disposed was 578.2 $yd^3$

Table 4.1. Waste Shipment Details.

| Cask/Package | Contents | Shipment Type | Disposal Volume | Burial Facility | Date of BNL Departure | NTS/ ES Arrival Date |
|---|---|---|---|---|---|---|
| 1-13G | 8 main CRBs and 1 auxiliary CRB | LLRW – Type "B" DOE Cert | 4.82 $yd^3$ | NTS | 3/5/09 | 3/9/09 |
| 1-13C | 7 auxiliary CRBs and all cut follower sections | LLRW – Type "B" DOE Cert | 1.75 $yd^3$ | NTS | 3/13/09 | 3/17/09 |
| 3-55 | Beam Plug H-9 (without cut section) | LLRW – Type "B" DOE Cert | 12.4 $yd^3$ | NTS | 2/19/09 | 2/23/09 |
| 10-142 not used as a Type B package | Beam Plugs H-1, H-2, H-5, H-7 and H-8 | LLRW - LSA | 27.5 $yd^3$ | NTS | 4/15/09 | 4/20/09 |
| B-25 box | Beam Plug H-6 | LLRW - LSA | 3.5 $yd^3$ | NTS | 7/20/09 | 7/27/09 |
| Large transfer cask | Beam Plug H-4 | LLRW - LSA | 2.29 $yd^3$ | NTS | 5/509 | 5/11/09 |
| Small transfer cask | Beam Plug H-3 | LLRW - LSA | 1.3 $yd^3$ | NTS | 4/16/09 | 4/21/09 |
| Tristan Pig | Beam Plug H-9 (cut section) | LLRW - LSA | 1.1 $yd^3$ | NTS | 4/16/09 | 4/21/09 |
| B-25 box | Collimators plus additional irradiated metal piece | Mixed -LLRW | 3.5 $yd^3$ | ES of Utah | 6/25/09 | 6/30/09 |
| 250-gallon IBC containers | Solidified water | LLRW - LSA | 450 $yd^3$ | NTS | 6/25/09 to 9/29/09 | 6/30/09 to 10/5/09 |
| 20' Sea-Land container | Secondary waste | LLRW - LSA | 70 $yd^3$ | ES of Utah | 8/13/09 | 8/18/09 |
| TOTAL WASTE VOLUME SHIPPED AND DISPOSED | | | 578.2 $yd^3$ | | | |

# 5.0 LESSONS LEARNED

1. The decision to fill the reactor vessel, primary system, and spent fuel pool with domestic water would have been entirely acceptable if the irradiated component removal had been performed expeditiously and not been delayed. Problems and shortcomings documented during the DOE readiness process of MSA and ORR took longer than expected when findings required changes in both process and equipment. Corrosion of plant components produced water clarity problems and hindered the uncoupling and dismantling process. The CRB uncoupling tool, left in the reactor water for a weekend, corroded and could not be used until removed and cleaned. A slide-hammer process had to be devised to remove the transition plate inserts from the transition plate. Water clarity in the spent fuel canal was affected, but not drastically.

2. The very comprehensive radiological characterization that was performed made it possible to manage the high risk components without exposure or harm to the workers. These tasks were performed with no personnel contamination, no spread of contamination, and very little radiation exposure.

3. Waste specialists were utilized to determine the optimum methods for packaging and shipping the waste generated from the project. Waste Management preparations and planning made it possible to transfer all components and materials to the Waste Management Complex with minimal delay and without incident. The excellent planning and preparation saved considerable time and money.

4. The latest technology and equipment should always be factored into high risk jobs such as this. Cameras, lighted cameras, lighting, and personal protective clothing and equipment are examples. During this job, continuous upgrading was necessary.

5. Training on the long-handled, in-vessel handling and uncoupling tools was performed in the horizontal position instead of vertically as they are oriented during actual use. This resulted in difficulties in CRB removal that could have been prevented. Also, the positioning of cameras and lighting could have been practiced as well.

6. Use was made many times of a small (1-in. diameter and 6-in. long) radiation detector referred to as an AMP-100 or AMP-200. This little tool made it possible to obtain radiation readings in air and in water of any of the components that were being handled. The detectors were used wisely to contribute much information for decision making.

7. Toward the end of the removal action, the D&D team and its management went through a period of excellence that was noteworthy. A combination of peer-checking and looking out for each other made it possible for the team to be “self-correcting.” They were able to perform their tasks safely and smoothly per the procedure without outsiders pointing out improvements or errors.

8. During the removal of the CRBs and BPs, changes were made to ERP procedures. This process enabled the work team to make procedure changes expeditiously and keep the work progressing without serious delay. In many cases, procedure changes were necessitated by changing field conditions or problems with the planned process.

9. Early in the CRB removal process, a practice was introduced to encourage work pause for discussions and lessons learned. This was coupled with the introduction of "Excellence Critiques for Lessons Learned." Excellence critiques were used at the end of evolutions and each morning. In these critiques, the activities were discussed for improvement and lessons learned. The team became self-critical while being proactive.

# 6.0 REFERENCES

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# APPENDIX A

# ACTION MEMORANDUM

ACTION MEMORANDUM

# HIGH FLUX BEAM REACTOR
# REMOVAL ACTION FOR
# CONTROL ROD BLADES AND BEAM PLUGS

**July 2008**

Prepared by:
Brookhaven National Laboratory
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Prepared for:
U.S. Department of Energy
Brookhaven Site Office
Upton, New York 11973

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## ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

| | |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| ARAR | Applicable or Relevant and Appropriate Requirements |
| BNL | Brookhaven National Laboratory |
| BP | Beam Plug |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act. |
| CFR | Code of Federal Regulations |
| CRB | Control Rod Blade |
| DOE | U.S. Department of Energy |
| EPA | U.S. Environmental Protection Agency |
| HWMF | Hazardous Waste Management Facility |
| NEPA | National Environmental Policy Act |
| NTS | Nevada Test Site |
| NYSDEC | New York State Department of Environmental Conservation |
| NYSDOH | New York State Department of Health |
| PRAP | Proposed Remedial Action Plan |
| RDIP | Remedial Design Implementation Plan |
| ROD | Record of Decision |
| SCDHS | Suffolk County Department of Health Services |
| S&M | Surveillance and Maintenance |
| WLA | Waste Loading Area |

# I. PURPOSE

The purpose of this Action Memorandum is to document the decision by the U.S. Department of Energy (DOE) to complete the removal and disposal of the High Flux Beam Reactor (HFBR) control rod blades (CRBs) and beam plugs (BPs).

In consultation with the U.S. Environmental Protection Agency (EPA), New York State Department of Environmental Conservation (NYSDEC), New York State Department of Health (NYSDOH), and Suffolk County Department of Health Services (SCDHS), DOE developed a Proposed Remedial Action Plan (PRAP) for the HFBR Complex that summarized the evaluation of four remedial alternatives. The public comment period for the PRAP began on January 10 and concluded on March 17, 2008. DOE addressed the comments received, and a draft Record of Decision (ROD) including a responsiveness summary is being prepared for review by the regulators.

Given the considerable regulatory and community support for DOE's preferred remedial alternative (Alternative C, Phased Decontamination and Dismantlement with Near-Term CRB Removal), DOE has decided to expedite the removal and disposal of the CRBs and BPs (containing 35 percent of the current HFBR radioactive material inventory) by exercising its removal action authority. Accordingly, the decision to proceed with the removal and disposal of the CRBs and BPs is being documented in this Action Memorandum.

Expediting this action will allow DOE to take advantage of the availability of shipping casks and disposal sites. Certified casks have been purchased at discounted prices because their licenses (Certificates of Compliance) are set to expire on October 1, 2008. As these casks are equipped with robust shielding, only two shipments of CRBs will be required. The shipping casks with the CRBs will be disposed of at DOE's Nevada Test Site (NTS), greatly simplifying cask handling and disposal operations at NTS.

# II. SITE CONDITIONS AND BACKGROUND

## A. Site Description and History

BNL is owned by the U.S. Department of Energy, one of the 17 DOE national laboratories. BNL conducts research in the physical, biomedical, and environmental sciences, as well as in energy technologies and national security. The Laboratory also builds and operates major scientific facilities available to university, industry, and government researchers.

BNL is located in Suffolk County on Long Island, about 60 miles east of New York City. Approximately 1.4 million people reside in Suffolk County and approximately 450,000 reside in Brookhaven Township, within which BNL is situated. The BNL site covers almost 5,300 acres, much of which is wooded. BNL has operated since 1947 as a research facility for national science and technology programs, and is expected to continue this mission for the foreseeable future.

Most BNL facilities are located near the center of the site in a developed portion that covers about 1,700 acres. The HFBR Complex is within this central portion of the BNL property. The complex covers about 13 acres, which is less than one-hundredth of the overall BNL site.

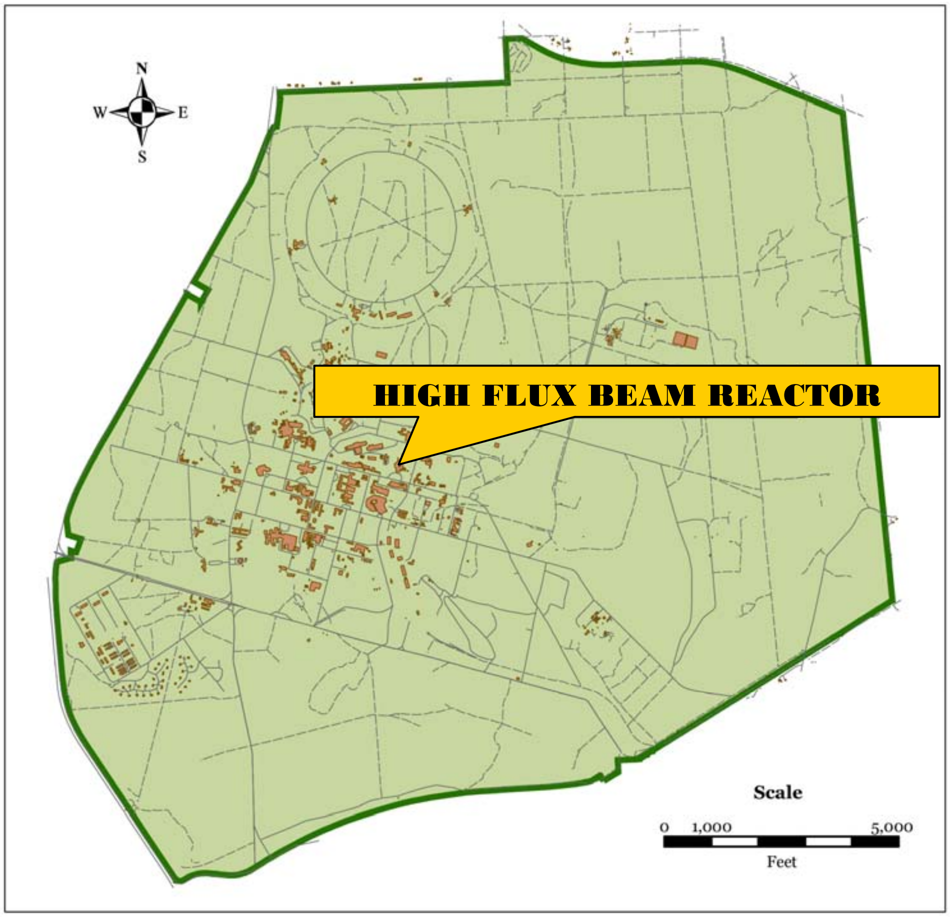


**Figure 1. Location of High Flux Beam Reactor on BNL Property**

The HFBR operated from 1965 to 1996 and was used solely for scientific research, providing neutrons for materials science, chemistry, biology, and physics experiments. During a routine maintenance shutdown in 1996, tritium from the spent fuel canal was found in groundwater south of the reactor. Investigations revealed that the source of the tritium was a small leak in the ceramic tile-lined concrete pool where spent nuclear fuel was stored. Operations at the HFBR were suspended and the DOE considered what to do. All of the spent fuel was removed and sent to DOE's Savannah River Site in 1998. The pool was drained and a freestanding, double-walled, stainless steel liner with an instrumented low-point sump was installed to eliminate the potential for leakage to the environment. In November 1999, DOE announced it was permanently closing the reactor. The HFBR has been continuously maintained under a surveillance and maintenance (S&M) program from its initial operation in 1965.

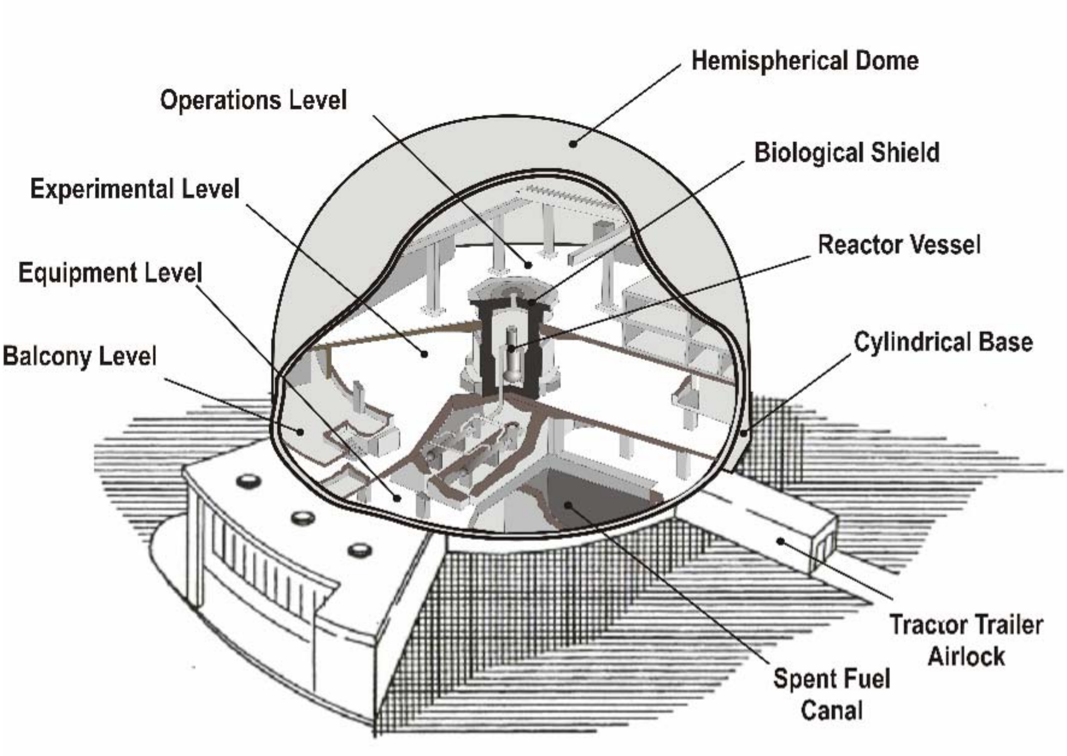


**Figure 2. -- Cutaway View of the HFBR Confinement Building**

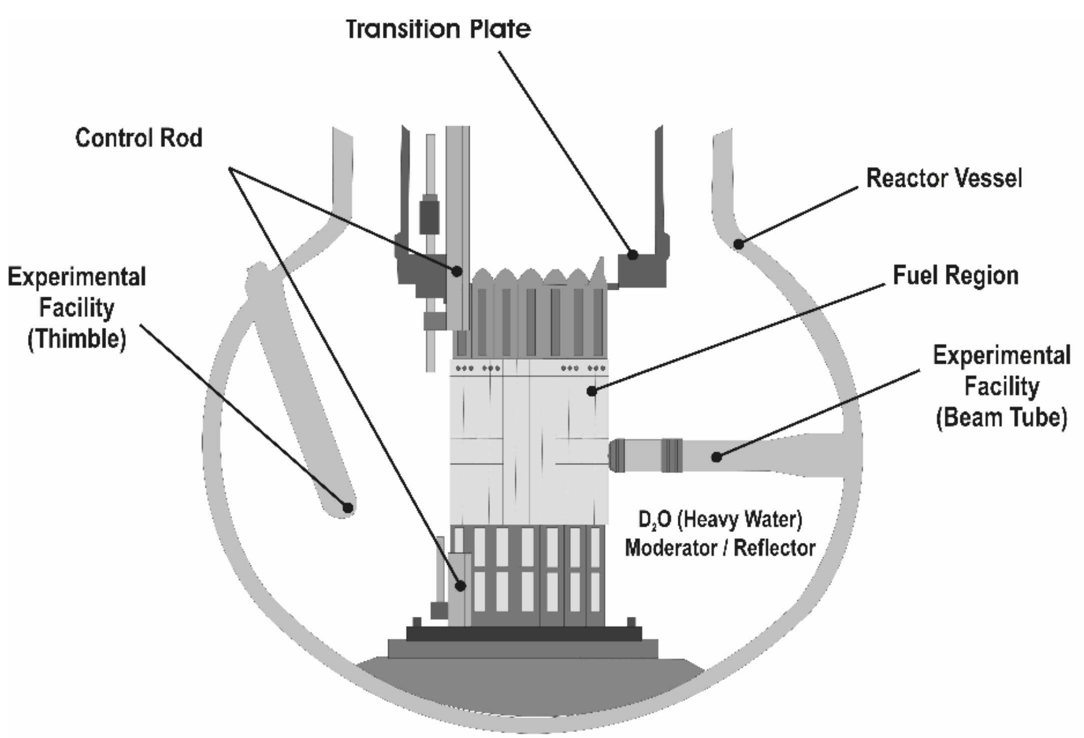


**Figure 3. – Cutaway View of the Reactor**

## B. Actions to Date

*1. Previous Actions*

A number of actions have been taken to remove contaminated structures, systems, and components from the HFBR Complex. The completed interim actions are summarized below:

- The HFBR fuel was removed and sent to an off-site facility.
- The primary coolant was drained and sent to an off-site facility.
- Scientific equipment was removed and is being reused.
- Shielding and chemicals were removed and are being reused at BNL and other facilities.
- The cooling tower superstructure was dismantled and disposed.
- The confinement structure and spent fuel canal were modified to meet Suffolk County Article 12 requirements.
- The Stack Monitoring Facility was dismantled and disposed.
- The Cooling Tower Basin and Pump/Switchgear House was dismantled and disposed.
- The Water Treatment House was dismantled and disposed.
- The Cold Neutron Facility contaminated systems were removed and the clean building has been transferred to another organization for re-use.
- The Guard House was dismantled and disposed.

*2. Current Actions*

The cleanup of the WLA is currently in progress, authorized by the *Action Memorandum, High Flux Beam Reactor, Removal Action for Waste Loading Area*. It is being performed as a non -time-critical removal action.

The Waste Loading Area (WLA) is an area (about 2 acres) along the eastern boundary of the Former Hazardous Waste Management Facility (HWMF). The cleanup of the WLA was transferred to the HFBR scope of work in September 2005 through a modification to the Remedial Design Implementation Plan (RDIP) for the Former HWMF.

*3. Planned Actions*

The public comment period for the HFBR PRAP concluded on March 17, 2008. DOE addressed the comments received, and a draft ROD including a responsiveness summary is being prepared for review by the regulators. This removal action is consistent with the selected remedy and will be documented in the HFBR ROD.

## C. National Priorities List Status

Brookhaven National Laboratory was added to the National Priorities List in 1989.

# III. THREATS TO PUBLIC HEALTH OR WELFARE AND THE ENVIRONMENT/ STATUTORY AND REGULATORY AUTHORITIES

This action is being undertaken as a removal action under the Interagency Agreement among the DOE, EPA, and NYSDEC.

The appropriateness of the removal action is based on the following:

- Factors listed in 40 Code of Federal Regulations (CFR) 300.415 (b) (2) of the regulations implementing the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), including:
    - Actual or potential exposure of human populations, animals, or the food chain to hazardous substances or pollutants or contaminants.
- Preferred alternative for the HFBR described in the HFBR PRAP

# IV. IDENTIFICATION OF REMOVAL ACTION OBJECTIVE

The removal action objective is consistent with the following remedial objective for the HFBR activated components stated in the HFBR Feasibility Study and PRAP:

- Control, minimize, or eliminate all routes of future human and/or environmental exposure to radiologically contaminated facilities or materials

# V. PROPOSED ACTION AND ESTIMATED COSTS

## A. Proposed Action

This Action Memorandum addresses the removal and disposal of the HFBR CRBs and BPs.

There are 16 CRBs in the reactor vessel, separated into main and auxiliary groups, each containing eight CRBs. The proposed action includes the removal of the CRBs from the reactor vessel, transfer to the fuel canal, loading into two disposable shipping casks, and shipment by truck to NTS for disposal.

Nine activated beam plugs are currently stored at the HFBR complex (on the experimental level of the Confinement Building). The proposed action includes the removal of the BPs (including three collimators), loading into disposable casks/containers, and shipment to DOE's Nevada Test Site and Energy Solutions' Clive Operations facility in Utah for disposal.

The removal and disposal activities also include:

- Detailed planning
- Preparation of the Confinement Building for CRB and BP removal
- Procurement of shipping casks/containers
- Secondary waste processing, shipment and disposal

## B. Contribution to the Remedial Performance

This removal action will contribute to the overall reduction in the radioactive material inventory at the HFBR complex. This action will be documented in the HFBR ROD.

## C. Description of Alternative Technologies

No new or alternative technologies are required for the implementation of this action.

## D. Applicable or Relevant and Appropriate Requirements

The *National Contingency Plan*, Section 40CFR300.430 (f)(1)(ii)(B), requires compliance with federal and state applicable or relevant and appropriate requirements (ARARs) unless a waiver is invoked. The ARARs are listed below:

1. *Chemical-Specific ARARs*

   a. *6 NYCRR Part 380, Rules and Regulations for Prevention and Control of Environmental Pollution by Radioactive Materials:* These regulations are the relevant and appropriate regulations for controlling radioactive emissions and liquid releases to the environment while completing the remedial action. Potential radioactive surface contamination release, airborne radioactivity generation and release, or radioactive liquid release will be controlled to eliminate emissions that would affect human health or the environment.

b. *U.S. Department of Transportation Requirements for the Transportation of Hazardous Materials (49CFR Parts 100 to 170):* These regulations will apply to any wastes that are transported off site.

*2. Location-Specific ARARs*

*None*

*3. Action-Specific ARARs*

*a. Occupational Radiation Protection (10CFR835):* These rules establish radiation protection standards for all DOE activities. Remedial actions and safe storage will be performed in accordance with the requirements of a DOE-approved radiation protection program and dosimetry program, and appropriate procedures will be established to ensure compliance with this regulation.

*b. Nuclear Safety Management (10CFR830):* These rules establish the minimum acceptable quality assurance and nuclear safety controls for all applicable DOE activities. All remedial action will be performed in accordance with the requirements of a DOE-approved quality assurance and nuclear safety control program and appropriate procedures will be established to ensure compliance with this regulation.

c. *49CFR Sections 173.4-173.471, Packaging and Transportation of Radioactive Material:* These rules apply to the proper packaging and transportation of hazardous material, specifically Class 7, radioactive material. Packaging and transportation of all DOE generated waste will be performed in accordance with this regulation.

*4. "To Be Considered" Guidance*

*a. DOE Order 451.1B, National Environmental Policy Act Compliance Program:* This order requires that CERCLA actions address National Environmental Policy Act (NEPA) values.

b. *DOE Order 5400.5, Radiation Protection of the Public and the Environment, including As Low As Reasonably Achievable (ALARA) Approach:* This order establishes the standards and requirements for protecting members of the public and the environment against undue risk from radiation. As with 10CFR835, remedial action will be performed in accordance with appropriate procedures that will be established to ensure continued protection of the public and the environment. ALARA is the practical approach to radiation protection used to manage and control exposures (both individual and collective of the work force and the general public) and keep releases of radioactive material to the environment as low as is reasonable, taking into account social, technical, economic, practical, and public policy considerations. Technologies and techniques will be incorporated into this remedy so that radioactive waste is minimized and direct exposure to radiation sources is reduced to as low as is reasonably achievable.

c. *DOE Order 435.1, Radioactive Waste Management:* This order provides guidance and requirements for managing and disposing of radioactive waste generated at DOE facilities.

d. *40CFR300.440, Off-Site Rule (52FR49200):* The purpose of this rule is to avoid having wastes generated from response actions that are authorized or funded under CERCLA contribute to present or future environmental problems. This is accomplished by directing the waste to management units that have been determined to be environmentally sound. The rule establishes compliance and release criteria, and establishes a process for determining whether facilities are acceptable based on those criteria. The rule also establishes procedures for notifying waste management units of their unacceptability, for reconsidering unacceptability determinations, and for re-evaluating unacceptability determinations. In accordance with this rule, HFBR wastes will only be sent to off-site facilities that meet EPA acceptability criteria.

e. *Suffolk County Sanitary Code – Article 12, Toxic and Hazardous Materials Storage and Handling Controls:* This code requires the use of all available practical methods of preventing and controlling water pollution from toxic and hazardous materials. For the Article 12 registered components remaining at the HFBR, detailed surveillance and maintenance actions will be included in the S&M program.

f. *DOE Order 460.1B, Packaging and Transportation Safety:* This order establishes safety requirements for the proper packaging, transfer, and transportation of hazardous materials.

g. *DOE Order 460.2A, Departmental Materials Transportation and Packaging Management:* This order establishes requirements for management to ensure safe, secure, efficient packaging and transportation of materials, both hazardous and non-hazardous.

## E. Project Schedule

Detailed planning for this action is currently in progress. This removal action is expected to be completed by October 2008.

## F. Estimated Cost

This removal action will cost approximately $3,330,000.

## VI. EXPECTED CHANGE IN THE SITUATION SHOULD ACTION BE DELAYED OR NOT TAKEN

The proposed action (near-term removal and disposal of the CRBs and BPs) offers many advantages. This is particularly so in the case of CRBs because of a combination of unique circumstances.

Certified casks have been purchased at discounted prices because their licenses (Certificates of Compliance) are set to expire on October 1, 2008. As these casks are equipped with robust shielding, only two shipments of CRBs will be required. The shipping casks with the CRBs will be disposed of at DOE's NTS, greatly simplifying cask handling and disposal operations at NTS.

If the action is delayed, it would be necessary to rent alternate casks. An assessment of the use of available alternate casks shows that it is likely to result in the following adverse impacts:

- Higher cost
- Increased number of shipments because of reduced shielding
- Unloading of the shipping casks at NTS (for reuse) resulting in increased complexity of operations at NTS
- Higher radiation exposure to operators at NTS

(Note: It may be possible to mitigate these impacts by DOE making arrangements to self certify these casks and give authorization for limited use for one final shipment to the disposal site following the current expiration date.)

In addition to the above, people with extensive knowledge and experience in handling the CRBs and BPs and disposal sites are currently available to implement the removal action. It is uncertain if such expertise and disposal sites will be available in the future.

## VII. PUBLIC PARTICIPATION

### A. BNL Community Relations

The BNL Community Involvement Plan was published April 15, 1999. It is supplemented by project-specific plans. In the case of the HFBR, a Communications Plan for the Regulatory Decision-Making Process for Decommissioning the High Flux Beam Reactor was developed. In accordance with these two plans and CERCLA Sections 113 (k)(2)(B)(i-v) and 117, the Community Relations Program focuses on informing and involving the public in the decision-making process to ensure that the views of the internal and external stakeholder communities are considered. A variety of activities are used to provide information and to seek public participation, including distribution of materials to a stakeholders' mailing list; holding community meetings, information sessions, tours, and workshops; and preparing and distributing fact sheets.

The Administrative Record, which documents the basis for removal and remedial actions, was established and is maintained at the libraries listed below:

Brookhaven National Laboratory
Research Library, Bldg. 477A
Upton, NY 11973
631-344-3483 or
631-344-3489

U.S. EPA - Region II
Records Room
290 Broadway, 18th Floor
New York, New York 10007-1866
212-637-4308

### B. Community Involvement Related to the Removal of Control Rod Blades and Beam Plugs

The community involvement activities conducted for the remedy selection process for the HFBR included a formal public review of the HFBR PRAP. The public comment period began January 10 and ended on March 17, 2008. Two information sessions and a public meeting were held during the public comment period. Public comments received indicate that here is considerable community support for DOE's preferred remedial alternative identified in the PRAP (Alternative C, Phased Decontamination and Dismantlement with Near-Term CRB Removal). DOE's responses to public comments and concerns will be included in the HFBR ROD Responsiveness Summary.

## VIII. OUTSTANDING POLICY ISSUES

There are no outstanding policy issues identified for this removal action.

## IX. ENFORCEMENT

DOE owns BNL and DOE will fund this removal action. The removal action will be conducted in accordance with CERCLA and National Contingency Plan requirements, the Interagency Agreement, and applicable New York State regulations.

## X. RECOMMENDATION

This Action Memorandum recommends a non-time-critical removal action for the removal and disposal of the HFBR CRBs and BPs. This decision document was developed in accordance with CERCLA, as amended, and is consistent with the National Contingency Plan.

## XI. REFERENCES

BNL, 2007a. *Feasibility Study, Brookhaven High Flux Beam Reactor, Decommissioning Project*, prepared by Brookhaven Science Associates for the U.S. Department of Energy, September 2007

BNL, 2007b. *Action Memorandum, High Flux Beam Reactor, Removal Action for Waste Loading Area*, prepared by Brookhaven Science Associates for the U.S. Department of Energy, October 26, 2007

BNL, 2008. *The Proposed Remedial Action Plan for the High Flux Beam Reactor at Brookhaven National Laboratory,* prepared by Brookhaven Science Associates for the U.S. Department of Energy, January 2008

CERCLA-FFA, 1992. *Federal Facility Agreement under CERCLA Section 120, Administrative Docket Number II-CERCLA-FFA-00201, IAG Agreement*, United States Environmental Protection Agency, Region II, United States Department of Energy, and the New York State Department of Environmental Conservation, In the matter of the U.S. Department of Energy's Brookhaven National Laboratory, 1992.

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