DOE SAFETY EVALUATION REPORT (SER)

BROOKHAVEN HIGH FLUX BEAM REACTOR STABILIZATION AND DECONTAMINATION AND DECOMMISSIONING PROJECT

September 26, 2000

Concurrence and Approval Page

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DOE SAFETY EVALUATION REPORT (SER)

BROOKHAVEN HIGH FLUX BEAM REACTOR STABILIZATION AND DECONTAMINATION AND DECOMMISSIONING PROJECT (HFBR-S/D&DP)

EXECUTIVE SUMMARY

This Safety Evaluation Report (SER) documents the basis for the U.S. Department of Energy (DOE) Chicago Operations Office (CH) approval for Brookhaven Science Associates to reclassify the Brookhaven High Flux Beam Reactor from a Category 1 nonreactor nuclear facility to a radiological facility. The SER also documents the method of review and conclusions of the Safety Evaluation Review Team for the hazard classification for the Brookhaven High Flux Beam Reactor.

The SER contains a summary of the request for reduction in HFBR hazard category, which provides the approval authority sufficient knowledge and understanding of the basis for approving the reduction. It also 1) documents that an appropriate review of the request was conducted, 2) provides an independent assessment of the adequacy of the request, (BNL Nuclear Safety Committee reviewed and recommended approval without comment), and 3) defines the conditions of DOE approval.

The SER was prepared to address the required content elements for the preparation of an SER in DOE-STD-1104-96, *Review and Approval of Nonreactor Nuclear Facility Safety Analysis Reports* [1]. The approach for determining the final hazard classification was derived from guidance in DOE-EM-STD-5502-94, *Hazard Baseline Documentation* [2] and DOE-STD-1027-92, *Hazard Categorization And Accident Analysis Techniques For Compliance With DOE Order 5480.23, Nuclear Safety Analysis Reports* [3]. All documentation related to the management of the SER Team is contained in Appendix A.

The objective of the reduction request is to identify the facility conditions, and analyze accident and natural phenomena events for the activities authorized by the HFBR Project Program Baseline and HFBR Management Plan, determine the facility hazard classification, and identify the safety management programs and controls necessary to protect the workers, the public and the environment for the High Flux Beam Reactor Stabilization and Decontamination and Decommissioning Project (HFBR-S/D&DP).

A Safety Evaluation Review (SER) team composed of selected subject matter expert's conducted an in depth review of the reduction request. The SER team consisted of the DOE-HFBR Project Manager, one nuclear specialist, and one facility representative. Each Safety Evaluation Review team member reviewed the entire document. The resolutions of team member comments have been incorporated into the SER. The Review Comment Record (RCR) [5] resolutions are an integral element of the SER documentation.

The SER team concludes that the HFBR facility should be classified as RADIOLOGICAL and that the Safety Evaluation Report provides an adequate safety basis for the specific work scope identified in the HFBR management plan. This conclusion is based on the following premises:

1. The radiological material stored in the Special Nuclear Materials Storage Vault has been removed from the facility;

2. The form and distribution of the estimated Balance-of-Plant (BOP) radiological inventory contains gross radionuclide inventories in excess of unadjusted Category 3 threshold levels. An assessment of the form, location, and vulnerability to energy sources that could lead to release of these materials concludes that the quantity of dispersible radionuclides is below Category 3 thresholds;

3. The form and distribution of the Reactor Pressure Vessel internal components are fabricated from stainless steel, which have become highly activated from reactor operations. The principal isotopes of concern are Cobalt 60, a gamma emitter, Nickel 63, a beta emitter, and Fe-55, an auger electron and X-ray emitter;

4. There are minimal quantities of hazardous material located within the HFBR facility;

5. The hazards analysis for the work scope authorized in the HFBR Project Program Baseline and HFBR Management Plan does not yield any credible events that could result in hazard severity higher than “negligible” or risk category higher than “routine”;

6. The HFBR radiological inventory is not releasable for airborne dispersion based on the hazards analysis and structural integrity of the confinement systems in place;

7. An analysis of the material present in the HFBR consists of activated structural materials associated with the reactor vessel and its internal components. These components are well protected by a massive steel and concrete shield structure. There are no credible energy sources with the potential to disperse these activated materials from the facility;

8. An adequate margin of safety can be maintained without relying on safety structures, systems and components for the work scope defined in the reduction request;

9. Adequate administrative controls (in lieu of the Safety Analysis Report and Technical Safety Requirements) are being developed using a graded approach to insure an acceptable operating envelope;

10. All controls and commitments defined in the HFBR Project Program Baseline and HFBR Management Plan will be enforced, and;

11. Each HFBR-S/D&DP sub-project will be analyzed through an Unreviewed Safety Issue Determination (USID) [6] screening process, which will be supported by detailed characterization information; detailed engineering and work packages; radiological work procedures; and a task specific Health and Safety Plan.

1.0 INTRODUCTION

1.1 Purpose

The purpose of the recategorization request is to establish an acceptable safety envelope for stabilization and decontamination and decommissioning activities in the HFBR facility. The HFBR Management Plan and hazard categorization reduction request defines the work scope or operations that will be associated with the project, analyzes the radiological Material-At-Risk (MAR), examines postulated accidents and hazards relating to the execution of the project, documents the final hazard classification (FHC), and identifies appropriate controls and commitments necessary to insure the protection of the workers, public and the environment. During the course of completing the planning and execution of the HFBR Project Baseline, the USID process may require additional safety and hazard analysis. The results of the USID process will be documented and become a part of the project documentation after review and approval by DOE.

The purpose of the Safety Evaluation Report is to document the results of an independent review of the hazard categorization reduction request for the Brookhaven High Flux Beam Reactor Stabilization, Decommissioning and Decontamination Project by a selected group of subject matter experts (SMEs). Each SME was selected based on their knowledge and experience with nuclear decommissioning operations, nuclear safety, occupational safety and health, hazardous materials operations, and radiological facility operations.

1.2 Review Process

This Safety Evaluation Report (SER) presents the results of the DOE-directed Safety Evaluation Review Team review and approval of the hazard categorization reduction request dated September 8, 2000 [7]. The review was conducted by a Safety Evaluation Review Team composed of staff of the DOE-Brookhaven Group and DOE-Chicago Safety and Technical Services Division.

1.3 Background and Operating History of the HFBR Facility

A summary of the HFBR background and operating history is included in the SER to aid the approval authority's review.

Initial criticality at the HFBR was achieved on October 31, 1965 and operation at the designed power level of 40 MW began in December of 1966. In 1982, after the completion of several modifications including replacement of the primary heat exchangers, operating power of the HFBR was increased to 60 MW in order to enhance

the reactor's research capabilities. In 1988, in part due to the accident at Chernobyl, the National Academy of Science and the National Research Council study of DOE reactors raised several questions, including some concerning the HFBR. In 1989, in response to these questions, the HFBR was shutdown to perform additional analysis and necessary corrective actions. The HFBR was returned to service in 1991 at an operating power level of 30 MW.

In December 1996, the HFBR was shutdown for refueling and maintenance, a routine activity which normally occurred every month. Before the reactor returned to scientific operations, a pair of newly installed monitoring wells indicated that a plume of tritiated water was contaminating the groundwater south and down-gradient of the reactor in excess of drinking water standards. Subsequent testing, data collection and analysis identified the HFBR spent fuel canal (pool) as the likely source of the tritium plume. The results of two pool leakage tests indicated a leakage rate of 6-9 gallon per day. This leak rate is consistent with the results from several hydrogeologic models of the plume.

In response to the tritium groundwater contamination, DOE and BNL initiated the Tritium Remediation Project (TRP). The purpose of this project was to identify and isolate the source of the HFBR tritium plume to ensure that tritium levels above the drinking water standard did not leave the site boundary. During 1997, all spent fuel elements stored in the fuel pool were shipped off site in four separate shipping campaigns. To accommodate final pool draining, 14 reactor control rod blades and other highly activated vessel internals stored in the pool were placed into on-site dry storage containers. On January 7, 1998, approximately 68,000 gallons of spent fuel pool water was pumped into on-site storage tanks, marking the end of the TRP ahead of schedule and without incident.

The Conference Report accompanying Public Law 105-62, the Energy and Water Development Appropriation Act of 1998, directed that an EIS be prepared for the HFBR. In November 1997, a Notice of Intent to prepare an EIS for the HFBR pursuant to the National Environmental Policy Act (NEPA) was published in the Federal Register. Public meetings were held in December 1997 and January 1998 to receive comments regarding the scope of issues that should be in the EIS. In the spring of 1999, a draft EIS was prepared to evaluate the full range of reasonable alternatives regarding the future of the HFBR, as required by NEPA, including: (1) no action (maintaining the HFBR in a shutdown and defueled condition); (2) resume operation at a power level of 30 MW or up to 60 MW; (3) resume operation and enhance the facility; and (4) permanent shutdown with eventual decontamination and decommissioning. During the fall of 1999, the draft EIS was used by the Secretary of Energy to decide the future of the HFBR, along with public input from the Long Island community; input from the HFBR scientific user community and the DOE Basic Energy Science Advisory Committee; and the value of the scientific information produced by the HFBR.

On November 16, 1999 the Secretary of Energy announced that the High Flux Beam Reactor would be permanently shutdown. In order to effectively manage the transition of the HFBR from an operating reactor to a safe shutdown facility, a DOE steering

committee was formed in late December 1999. The committee comprised of representatives from the Office of Science (SC), the Office of Environmental Management (EM), the Office of Nuclear Energy, Science, and Technology (NE), the DOE Chicago Operations Office, the DOE Brookhaven Group, and Brookhaven National Laboratory. The steering committee has set forth the high level strategy that was used to develop the HFBR Management Plan.

As a result of a Memorandum of Understanding (MOU) between SC, EM, and NE, the HFBR was transferred, in April 2000, to EM for stabilization and eventual decommissioning.

The HFBR has been in a safe-shutdown mode since 1997 and during this period, routine surveillance and maintenance activities have been conducted to maintain the facility thereby ensuring there has not been any spread of radioactive contamination.

The Removal Action Objectives for the HFBR-S/D&DP are to: protect human health and the environment; achieve future land-use options for the Brookhaven National Laboratory; remove or permanently isolate contaminants of potential concern; minimize the impacts of transporting and disposing large volumes of contaminated media; and meet all applicable or relevant and appropriate standards, requirements, criteria, or limitations promulgated under federal or state environmental laws.

1.4 Scope and Duration of the Final Hazard Classification Applicability

The hazard classification reduction request and HFBR Management Plan will serve as the authorization basis for the HFBR Facility and sub-systems during the entire stabilization, decontamination and decommissioning project life cycle. USI determinations for each phase of the project scope will be added to the HFBR Management Plan required documentation as they are developed and approved. The HFBR Management Plan will be modified or updated at the conclusion of the project for any post-closure groundwater monitoring or surveillance and maintenance, or will be cancelled.

2.0 HAZARDOUS SUBSTANCES INVENTORY AND HAZARD CLASSIFICATION

2.1 HFBR Inventory

The radiological inventory considered for the HFBR Facility hazard classification was based on the principal constituents of the Reactor Pressure Vessel, Control Rod Blades, Transition Plate, Thermal Shield, and Biological Shield.

These components, fabricated from stainless steel, have become highly activated from reactor operations. The principal isotopes of concern are Cobalt 60, a gamma emitter, Nickel 63, a beta emitter, and Fe-55, an auger electron and X-ray emitter. Some other steel components, such as the anti-critical grid, are also made of stainless steel but since they were subjected to a much lower neutron flux, they are not nearly as activated as the

control rods or transition plate. The control rods are made of neutron poisons matrixed within and clad by stainless steel. The principal poison material in both the main and auxiliary control rod blades is Europium 153. The main blades also contain smaller amounts of dysprosium, another neutron poison. In addition to the activation products attributed to the steel, the control rods contain isotopes formed from neutron absorption reactions with the europium.

The aluminum portions of the reactor vessel and its internals are also activated. The principal isotopes are Fe-55, an auger electron and X-ray emitter, and the gamma emitter Zn-65. The largest aluminum structure, the reactor vessel, is located away from high flux areas. The combined contribution from activated aluminum components represents only ten percent of the total radionuclide inventory.

In the proposed lay-up configuration, the reactor vessel will be drained and dried once the light water is no longer needed for shielding, and the activated internals will remain installed until decommissioning is undertaken. Current plans call for maintaining the system dry in an inert atmosphere to eliminate the hazard of a coolant loss from a vessel or piping failure and to provide a stable environment that minimizes corrosion. This configuration is advantageous from an ALARA point of view because it makes use of the original reactor shielding to maintain surrounding dose rates very low. The shielding, nominally six feet of heavy concrete, also protects the vessel from natural phenomena (tornado, hurricane, earthquake) and fire. The decay heat from the control rods and transition plate is low, approximately 300 watts, so that elevated temperatures during layup of the system are not expected.

The thermal shield is a carbon steel and lead structure, of which only the activation of steel is significant. The principal activation products are Fe-55 and Fe-59 of which only Fe-55 is of concern since Fe-59 is relatively short lived. The activity of the thermal shield was estimated to be no greater than 7.2×10^5 Ci. The thermal shield surrounds the spherical and the lower cylindrical portions of the reactor vessel. Like the vessel, it is located in the biological shield cavity, so it too is protected by the heavy concrete from environmental effects that might have sufficient energy to initiate a radiological release. Details of the proposed operations within the facility and the credible energy sources are developed later in this document and will show that although the radionuclide inventory exceeds the unadjusted Category 3 thresholds, there is no credible mechanism that would lead to a radioactive release from the facility (no Material-at-Risk).

The biological shield is a heavy concrete structure that contains 60% by weight of steel punchings. Fe-55 again is the nuclide of concern and amounts to about 360 Ci., insignificant when compared to the activity of the thermal shield.

Other activated waste materials are stored in the HFBR and are awaiting disposal. The most active waste component is the H-6 beam plug stored in a shielded storage structure on the Equipment Level. Based upon previous beam plugs that have been disposed of, it is estimated that this beam plug contains approximately 21 curies of Cobalt 60. This storage structure, called the “cheese box”, also contains other activated components that

were associated with the experimental beam lines but are not nearly as activated. Material stored in the cheese box is well protected in that it is stored in deep holes within a large steel and concrete structure. Dispersal of the stored material is not credible since the material is comprised mostly of stainless steel and the large, stable structure protects its contents from fire and other energy sources. There are no postulated accidents that lead to dispersal of the materials stored in the cheese box.

Other wastes are stored in shielded pigs or barrels on the Equipment Level that contain miscellaneous small components removed from the vessel that were stored in the canal before it was drained and emptied. Based on characterizations of similar wastes previously disposed of, it is estimated that these containers contain less than a curie of activity from cobalt, nickel, and iron.

HFBR spent fuel had been disposed of as part of the tritium remediation project undertaken in 1997. With the recent removal and off-site transfer of tritiated heavy water from the reactor vessel, the existing radionuclide inventory consists mainly of activated metals from the reactor vessel and its internal components, the thermal shield, and the biological shield. Smaller amounts of activity are associated with radioactive auxiliary systems such as the heavy water purification and storage systems and some radioactive waste stored in the building.

The SER Team has reviewed the analysis that supports the radiological MAR inventory and concludes that the form and distribution of the material is contained and not dispersable in the reactor vessel and biological shield material, and that the inventory estimates are realistic.

2.2 Special Nuclear Material (SNM) Storage Vault Inventory

All of the SNM stored in the vault has been removed to an appropriate storage facility outside of the HFBR facility. In addition to the SNM, there are twelve low enriched uranium (LEU) fission plates stored on the Equipment Level. These plates were originally intended for use in a new beam shutter to be installed at the Brookhaven Medical Research Reactor (BMRR). The shutter project has been cancelled and the LEU plates are being stored at the HFBR until they can be properly disposed of. These plates each contain about 5 kilograms of uranium enriched to about 20% U-235. Each plate is stored in a separate, DOT approved 6M shipping container, so consistent with DOE 1027-92 guidance, the nuclear material contained in the plates is excluded from the facility's hazard category radionuclide inventory. Plans are being developed to remove the LEU from the HFBR facility.

2.3 Hazardous Material Inventory

Many of the hazardous chemicals associated with the operating facility, such as 2000 gallons of sulfuric acid, several thousand gallons of chemicals used for secondary water treatment, and the five drums of gadolinium nitrate used as a neutron poison have also

been disposed of. Efforts to reduce or eliminate the remaining chemical hazards such as the 350 gallons of cadmium nitrate/light water solution are in progress.

2.4 Hazard Classification Summary

In determining the hazard category of a facility, DOE -STD–1027-92 provides guidance to consider the potential energy sources and initiating events that could lead to dispersal of radionuclides. When the physical form, location and interaction with potential energy sources are considered, categorization of the HFBR as a radiological facility can be justified even though the gross radionuclide inventory at the HFBR exceeds the unadjusted Category 3 thresholds. These gross inventories were then compared to the threshold quantities (TQ's) in DOE-STD-1027-92 (DOE 1992b) to determine the preliminary hazard classification (PHC). The PHC for the HFBR facility was determined to be a non-reactor nuclear facility Hazard Category 3. A supporting hazard analysis was subsequently prepared and provided the basis for the final hazard classification (FHC) of RADIOLOGICAL. The SER Team concludes that the PHC was accurately determined based on the estimated radiological and hazardous materials inventories and agrees with the FHC.

3.0 HAZARDS ANALYSIS

3.1 Hazards Analysis

A hazard analysis [7] was performed for the HFBR facility, which considered the entire HFBR facility. The hazard analysis identified hazards (postulated accidents and natural phenomena) and evaluated the possible causes and effects of potential scenarios involving these hazards. Consistent with the hazard analysis approach, the analysis did not attempt to develop an exhaustive list of causes; rather, the analysis listed a sufficient number of causes to judge the credibility of the hazards. The hazard analysis then evaluated the effects of each scenario. The effects identified were limited to realistic but conservative impacts associated with the scenario. As a result, a credible list of scenarios were developed for the HFBR facility. These scenarios are considered bounding based on the overall risk associated with each scenario.

3.2 Risk Assessment

The risk assessment of the HFBR is based on a methodical review of each of the initiating events and corresponding hazards associated with the facility, as originally defined by the hazard analysis. Each initiating event and associated hazards were examined for severity, probability and risk category. Only one accident-initiating event is postulated to occur at any one time. All the hazard analysis accident scenarios were listed and analyzed by a working group (BNL Nuclear Safety Committee) consisting of independent reactor systems and ES&H subject matter experts.

Considering the administrative controls and other mitigating factors, only routine industrial risks exist for the work scope identified in the HFBR Management Plan.

3.3 Final Hazard Classification.

The HFBR facility final hazard classification is RADIOLOGICAL based on: a) the dose consequences of an unmitigated accident is less than 10 Rem at 30-meters over a 24-hour period to the maximally exposed individual, and b) applying the methodology described in DOE-EM-STD-5502-94, Table 1.

The SER Team concludes that the hazard analysis adequately considered an appropriate range of accidents and natural phenomena events, and determined that there are no credible release mechanisms (energy sources) that could result in a release in any quantities of the radiological inventory material-at-risk (not releasable). Using Table 1 of DOE-EM-STD-5502-94, a classification of RADIOLOGICAL is appropriate. The SER Team recommends classification of the HFBR Facility as RADIOLOGICAL.

4.0 CONTROL AND COMMITMENTS

4.1 Special Controls

BSA, through their work planning and control procedures, will strictly enforce the administrative controls identified in the BNL Standards Based Management System (SBMS) that includes integrated safety management concepts within its work planning requirements. Administrative controls are an acceptable basis for maintaining an adequate margin of safety in lieu of the derivation of Technical Safety Requirements for a Radiological Facility.

4.2 Project-Specific Controls

The use of Safety Significant Structures, Systems and Components are not required to maintain an adequate safety envelope for the work scope defined and authorized by the HFBR Management Plan and are therefore not included as a commitment.

4.3 Programmatic Controls

BSA will enforce the programmatic controls identified in the HFBR Management Plan during the execution of the HFBR-S/D&DP. Any anticipated or implied waiver from any controls identified will require DOE approval.

4.4 Commitments

4.4.1 Classification. DOE approves the HFBR facility as RADIOLOGICAL based on the characterization information available to support a classification determination in accordance with DOE-STD-1027-92, Change 1.

4.4.2 Authorized Work Scope. Only that work scope identified by the HFBR Management Plan will be executed until, or unless, the activity identified as new work is specifically authorized through the USID review and approval process.

4.4.3 Special Controls. All special controls identified in the HFBR Management Plan will be adhered to.

4.4.4 Project-Specific Characterization. Any work scope that is determined to be outside the authority of the HFBR Management Plan will be preceded by a characterization activity to determine radiological and/or hazardous materials inventories and an USID screening will be completed in accordance with the approved procedure.

4.4.5 Unreviewed Safety Issue Determination Procedure. All work scope that is determined to be outside the authority of the HFBR Management Plan will be screened against a DOE approved HFBR-S/D&DP USID procedure. A task-specific hazard analysis will be completed and reviewed as a part of the USID procedure for all work scope determined to be outside the authority of the HFBR Management Plan and must be approved by DOE before the work activities may begin. USIDs will be approved in accordance with DOE-BHG Administrative Instruction BHG-OA-17. Approval authority for USIDs will be delegated to the Group Manager, DOE Brookhaven Group.

4.5 HFBR Authorization Basis Manual. The following documents will constitute the HFBR Authorization Basis Manual and will be placed under configuration control: a) Hazard Classification and HFBR Management Plan; b) Safety Evaluation Report and DOE Approval; c) HFBR Health and Safety Plan; d) HFBR Quality Assurance Project Plan; and, e) Unreviewed Safety Issue Determinations with DOE Approval(s).

4.6 Records and References. Appendix A provides a reference to essential records, documentation and information generated throughout the review process and are available to the HFBR Management Plan approval authority on request. All USIDs that are subsequently developed will become an essential HFBR Management Plan control document subject to configuration management.

5.0 CONCLUSION

The Safety Evaluation Review (SER) Team concludes that the hazards associated with the work scope authorized by the HFBR Management Plan for Brookhaven High Flux Beam Reactor Stabilization and Decontamination and Decommissioning Project have been adequately identified and evaluated. Further, the SER Team concludes that the HFBR Facility has been properly classified as RADIOLOGICAL based on characterization and analysis of radiological inventories. Adequate controls and commitments for the work scope activities identified in the HFBR Management Plan have been identified and will

be enforced to protect the workers, the public or the environment. The SER Team recommends that the HFBR recategorization request be approved.

Appendix A

Records and References:

1. Department of Energy, *Review and Approval of Nonreactor Nuclear Facility Safety Analysis Reports*, DOE-STD-1104-96.

2. Department of Energy, *Hazard Baseline Documentation*, DOE-EM-STD-5502-94.

3. DOE-STD-1027-92, *Hazard Categorization And Accident Analysis Techniques For Compliance With Doe Order 5480.23, Nuclear Safety Analysis Reports*

4. BHG Administrative Procedure, BHG-OA-17, *Review/Approval of Unreviewed Safety Issue Determinations*, July 21, 1999.

5. Safety Evaluation Review (SER) Review Comment Record (RCR).

6. HFBR Unreviewed Safety Issue Determination (USID) Procedure

7. HFBR Reduction in Hazard Category Request dated September 8, 2000