Characterization of the High Flux Beam Reactor

This summary of the characterization of the Brookhaven National Laboratory (BNL) High Flux Beam Reactor (HFBR) is an excerpt from the HFBR Feasibility Study.

Site Characteristics

Due to past operations, the HFBR complex contains approximately 65,000 **curies** (Ci) of **radioactive** material (as of January 1, 2007), primarily nuclear **activation products** such as iron-55 (Fe-55), cobalt-60 (Co-60), nickel-63 (Ni-63), europium-154 (Eu-154), and europium-155 (Eu-155). Most (more than 99 percent) of this radioactive material is in the form of activation products, contained within the metal and concrete of the activated components (reactor internals, control rod blades, reactor vessel, thermal shield biological shield and beam plugs) (Figures 1 and 2). The radiation dose rates associated with these activated components are very high. For example, the calculated radiation dose rate at a distance of one foot from the reactor internals is more than 35,000 rem per hour. At a distance of one foot, the dose rate is as high as 13,000 rem per hour from a single control rod blade.

In addition, much smaller amounts of radioactivity, about 45 curies, are also contained inside the HFBR confinement building. Almost all of this radioactive material is contained within closed piping systems and components, and consists primarily of **tritium**, Co-60, and Fe-55. Most of the areas inside the confinement building are essentially free of contamination. Smaller amounts of radioactivity, totaling less than 1 curie, are in ancillary buildings/facilities such as the stack and the fan house, which also served the Brookhaven Graphite Research Reactor (BGRR) during its operating life. The contamination in these shared facilities consists mostly of cesium-137 (Cs-137), strontium-90 (Sr-90), and tritium.

The soil surrounding the HFBR is generally free of contamination. Tritium contamination is detected in soil directly below the confinement building, and there are indications of tritium in groundwater **downgradient** of the HFBR. The groundwater is now being monitored under the **Operable Unit (OU)** III Record of Decision. Limited areas of soil contamination are in the basement of and near the fan house and the stack, and in small areas around the HFBR confinement building. This localized contamination consists of tritium, Cs-137, Sr-90, and Co-60.

Short-lived radionuclides (with half-lives below 10 years) dominate the radiological inventory at the HFBR complex. There is a significant and relatively rapid reduction in the

curie: named for the radiation pioneers Pierre and Marie Curie, this is a unit of measure for materials based on the number of nuclear disintegrations per second. One curie (Ci) = 37 billion disintegrations per second. One thousandth of a curie is a millicurie.

radioactive: describes a material with an unstable nucleus that decays by emitting ionizing radiation, usually in the form of alpha particles, beta particles, or gamma rays. The resultant material may or may not be radioactive also. The time required for half the nuclei of a radioactive sample to decay is called the half-life period. The shorter the half-life period, the sooner the material will lose most of its instability. Half-life periods for the dominant radioisotopes (see below) associated with the HFBR are as follows:

radioisotope	*half-life, years*	*radioisotope*	*half-life, years*
cesium-137 (Cs-137)	30.2	iron-55 (Fe-55)	2.7
cobalt-60 (Co-60)	5.3	nickel-63 (Ni-63)	100
europium-154 (Eu-154)	8.8	strontium-90 (Sr-90)	28.1
europium-155 (Eu-155)	5	tritium (H-3)	12.3

Source:
Half-life periods from the DOE Office of Environmental Management Web site

activation products: materials whose nuclei have become unstable through exposure to neutrons. They have a different number of neutrons than the common form of the material, and they are radioactive because the balance between the protons and neutrons is unstable and will lead to the emission of radiation.

radioisotope: an unstable "isotope" (a variant of an element that has a different number of neutrons than usual). The number in the suffix indicates the mass of that element and the total number of particles in the nucleus.

tritium is a radioisotope of hydrogen (H) with one proton and two neutrons. The standard chemical abbreviation is therefore H-3.

Downgradient: "downstream" in terms of groundwater flow.

radiological inventory as a result of natural radioactive decay, even if no remedial actions are taken (Figure 3). There is also a corresponding reduction in the high present-day radiation dose rates associated with the activated components (Figures 4 and 5).

A summary of the quantities of radioactive material in the activated components, contaminated structures, components and underground ducts/pipelines, and contaminated soils (based on activation analyses, characterization and other investigations) is presented in Table 1.

Operable Units (OUs): within a site, groups of areas containing the same or similar contamination. The areas within one OU are not necessarily adjacent. Six OUs have been designated at BNL. The plans for remediating an OU are developed in accordance with an Interagency Agreement (IAG) among EPA, NYSDEC, and DOE (in the case of BNL), and are detailed in a Record of Decision (ROD).

decommissioning: safe removal of a facility from service and reduction of residual radioactivity to an acceptable level, usually through decontamination and dismantlement of the facility structures, systems and components.

In addition to radioactive contamination, there are also non-radioactive hazardous materials in the HFBR complex. Certain chemicals and hazardous materials were used during the construction and operation of the HFBR. They include PCBs, asbestos and lead in materials of construction, organic solvents for degreasing equipment, and elemental mercury in certain instruments used in facility operations. Non-radioactive hazardous materials found in the HFBR complex include the following:

- Asbestos-containing material (ACM) intrinsic to older floor and ceiling tiles, in gaskets, pipe and wiring insulation, switchgear spark arrestors, and roofing material
- PCBs intrinsic to original paint, and hydraulic fluids
- Lead intrinsic to paint, lead blocks and dust, shielding, and batteries
- Other heavy metals of concern including zinc that was frequently detected, and cadmium and beryllium that were found sporadically
- Sampling for mercury revealed negative results but mercury is intrinsic to capacitors, light ballasts, gearboxes, and in motor-operated valve lubricating oils
- Solvents, degreasers, lubricants, oils and petrochemicals intrinsic to equipment such as motors and compressors
- Sodium Hydroxide (NaOH) and Sulfuric Acid (H_2SO_4) were used for water treatment
- Lithium arsenite used in the confinement building air conditioning system
- Suspected trace amounts of cadmium nitrate and gadolinium nitrate on the operations level due to spills

Table 1. Location of HFBR Radiological Inventory

Component	Description	Radioactivity (curies)
Activated Components		
Reactor Vessel	Aluminum reactor vessel, which contains the reactor internals and control rod blades.	380
Reactor Internals	Several small components within the reactor vessel were constructed of aluminum and/or stainless steel.	16,387
Control Rod Blades	Control rod blades (CRBs) are located inside the reactor vessel. They are constructed of stainless steel and contain europium oxide, and dysprosium oxide.	21,900
Thermal Shield	The thermal shield surrounds the lower reactor vessel and is inside the biological shield. It is	24, 876

	made of carbon steel and lead.	
Biological Shield	The biological shield is constructed of special high density concrete. The shield is 8 feet thick and shields personnel in the HFBR confinement building from the radiation from activated components. The inner portions of the biological shield contain most of the radioactivity.	125
Beam Plugs	Cylindrical steel plugs that provided shielding from the activated components. They are stored inside special shielded containers in the confinement building.	847
Contaminated Structures, Components and Underground Ducts/Pipelines		
HFBR Systems and Components	The primary coolant system and connecting piping systems contain most of the remaining activity; the major radionuclides are tritium, Co-60, Fe-55, and Ni-63.	45
Structures inside the HFBR Confinement Building	The structures and components inside the confinement building include those on the operations level, experimental level, and equipment level. The floors and walls are generally not contaminated, and there are few radiation areas. The radiologically controlled areas are posted with signs and there is limited access.	Tritium: <0.1
Stack Building	The stack served both the HFBR and the BGRR. There is contamination on the inner surface of the stack. Most of the radioactivity is CS-137 and Sr-90 from the BGRR.	0.03
Fan House (Building 704)	The fan house has been in use supporting both the HFBR and BGRR. Portions of the fan house are contaminated with Cs-137, Sr-90, and tritium, including sections of a concrete below-grade duct and the soil in the basement. Most radioactivity is related to BGRR operations.	0.1
Fan House (Building 802)/Tritium Evaporation Facility	The Building 802 fan house directs air discharges from several facilities to the stack. The tritium evaporation facility is no longer in service. Surveys show low levels of contamination.	<0.01
Stack underground ventilation ducts and lines	The ducts from Building 750, Building 801, and Building 802 are contaminated. Short sections of the ducts from Building 901 and Building 701 are also contaminated where they are connected to the stack or to other interconnecting ductwork.	<0.1
D/F Waste Line	This double-walled underground pipeline that runs between Building 750 and Building 801 is contaminated with Co-60 and tritium.	<0.1

Sanitary sewage line from the HFBR	The sanitary sewage line is contaminated with tritium, Co-60, Ni-63, and Cs-137	<0.1
Contaminated Soils		
Soils under Building 704 – fan house	Soil contamination in the soil floor of the basement containing up to 33 pCi/g Sr-90 and 217 pCi/g Cs-137. The detection of these radionuclides indicates the source to be the BGRR.	<0.1
Soils around Building 705 – stack	Cs-137 concentrations slightly above background levels (the highest sample was 6.4 pCi/g).	<0.01
Soils under Building 750	Soil concentrations up to 47 pCi/g tritium and up to 7,130 p Ci/liter tritium (equivalent to about 7.1 pCi/g) in the groundwater	<1.0
Soils around the HFBR complex	Twenty-one isolated area of contamination were initially identified during site characterization. Because of their limited size, many of these areas were actually cleaned up during characterization. Remaining soil contamination areas are posted in accordance with BNL procedures.	<0.01

Figure 1. Reactor Vessel, Thermal Shield, and Biological Shield

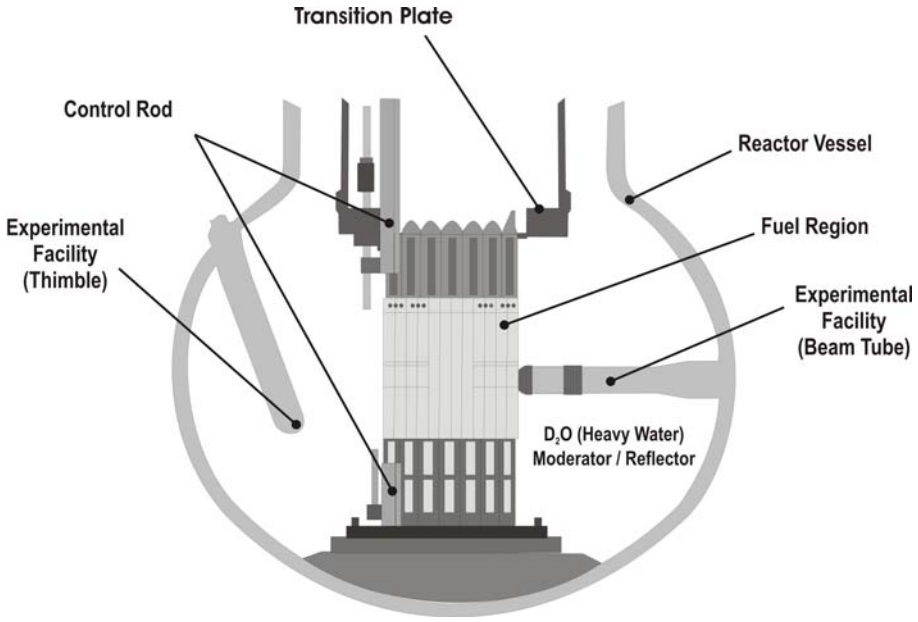

Figure 2. Reactor and Biological Shield

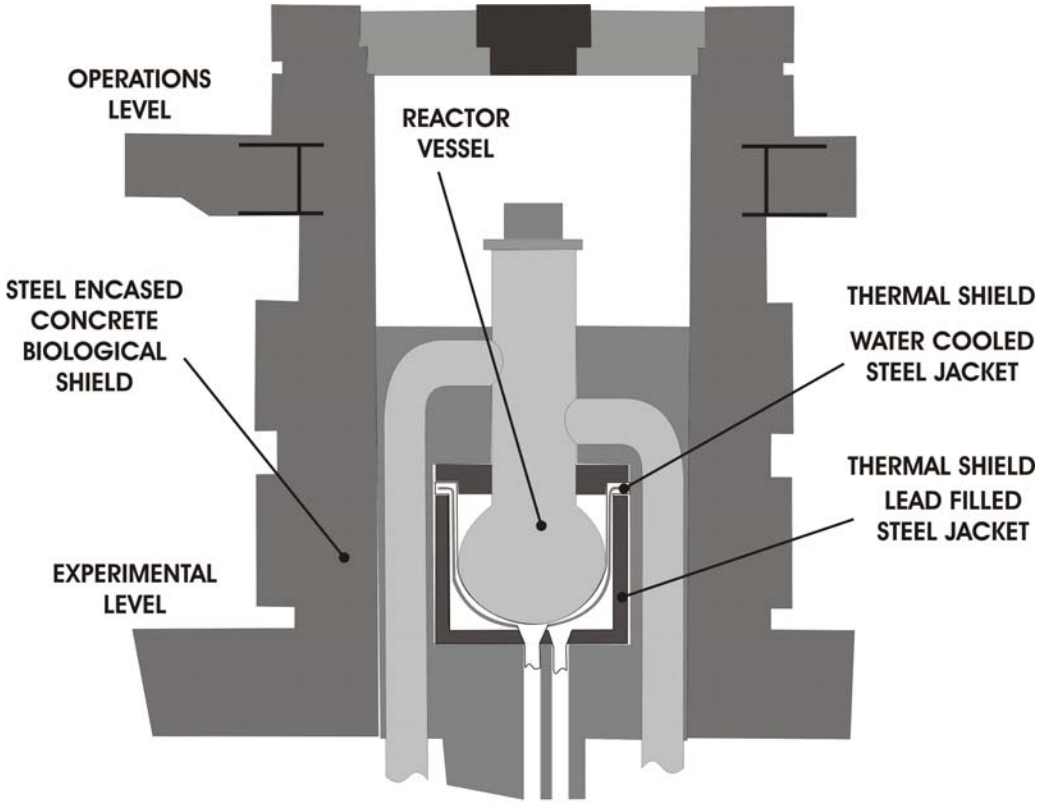

Figure 3. HFBR Radiological Inventory

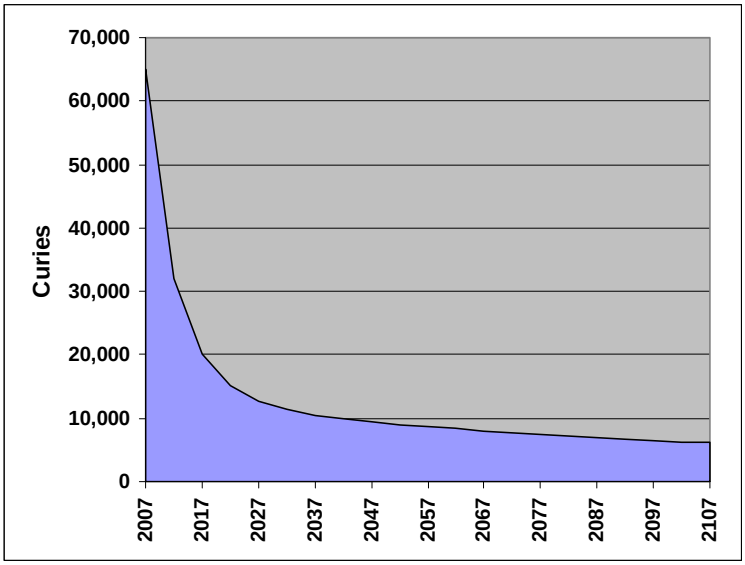

Figure 4. HFBR Dose Rate Reduction (2007-2107)

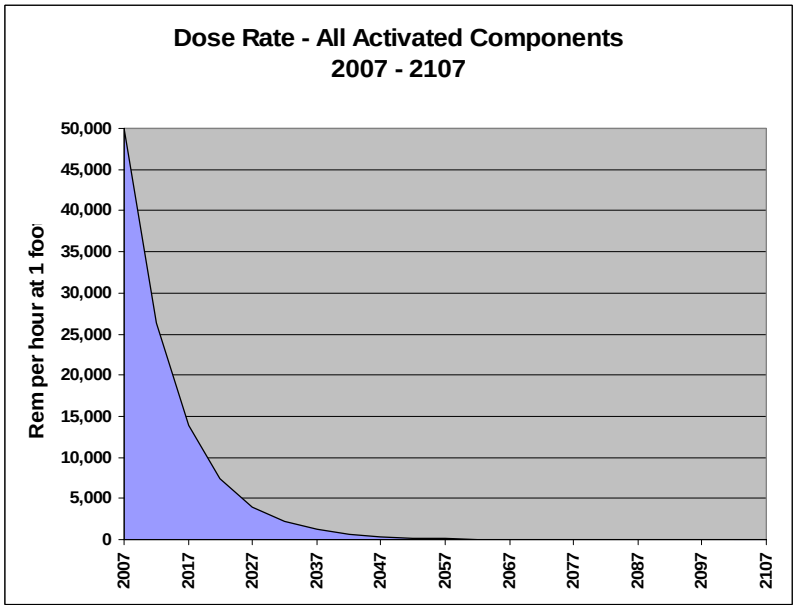

Figure 5. HFBR Dose Rate Reduction (2047-2107)