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LEU Conversion Feasibility Studies for the BMRR and HFBR*

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INTRODUCTION

Feasibility studies have been performed to convert both the Brookhaven Medical Research Reactor (BMRR) and the High Flux Beam Reactor (HFBR) at the Brookhaven National Laboratory from the use of HEU (93%) fuel to the use of LEU (<20%) fuel. The studies are intended to determine suitable LEU fuels that will provide fuel lifetime and neutron flux performance similar to the current HEU fuels. Both reactors use MTR-type fuel assemblies: the BMRR has 18 fuel plates with 140g ^{235}U (0.43 gU/cm^3) and the HFBR has 20 plates, of which 18 are fuel with 351g ^{235}U (1.1 gU/cm^3).

REACTOR MODELS

The BMRR is a 3 MW light-water cooled, graphite reflected reactor used for medical and research purposes. A model of the BMRR is shown in Fig. 1. The reactor has two irradiation facilities that have tailored neutron spectra. A thermal neutron irradiation facility (TNIF) is used for animal research and an epi-thermal neutron irradiation facility (ENIF) is used for boron capture neutron therapy (BCNT).

The HFBR is a heavy-water cooled and moderated reactor with multiple beam tubes, and several in-core and ex-core experiment locations. A model of the HFBR is shown in Fig. 2. Very high thermal neutron fluxes are achieved in the D_2O reflector in the vicinity of the beam tubes and in the irradiation facilities.

COMPUTATIONAL METHODS

Both reactors were modeled using the three-dimensional (XYZ-geometry) DIF3D diffusion theory code[1] with cross section generated using the WIMS-D4M code[2], and using the MCNP Monte Carlo code[3]. Fuel cycle calculations were performed using the REBUS code[4].

FUEL CONVERSION STUDY RESULTS

The conversion of the BMRR appears to be feasible using an LEU core consisting initially of 17 fuel assemblies with a loading of 162g ^{235}U. The HEU and LEU assemblies both have 18 fueled plates, but the cladding thickness of the LEU plates is 0.38 mm instead of 0.51 mm. The uranium density in the U_3Si_2 - Al fuel meat is 2.5 g/cm^3 and this fuel is fully-qualified for routine use in the BMRR. Both cores use approximately the same number of fuel assemblies per year, and the neutron fluxes and the neutron spectra in the two irradiation facilities are nearly the same.

Initial studies indicate that it may not be possible to convert the HFBR to LEU fuel with its current core configuration. The HFBR core is under-moderated and has a hard neutron spectrum. Direct substitution of LEU fuel meat for HEU fuel meat further hardens the neutron spectrum and decreases excess reactivity available to achieve a reasonable fuel cycle length. A core configuration with better neutron thermalization appears to be necessary in order to utilize LEU fuel.

Alternative core configurations with better neutron thermalization are being investigated. For example, removing 10 of the 28 fuel assemblies from around the central six core locations, adds enough excess reactivity such that reasonable LEU fuel densities are possible. At a power level of 40 MW, an LEU assembly with 20 fuel plates would provide fuel cycle lengths of 16 days and 22 days with ^{235}U loadings of 450g ^{235}U (4.5 gU/cm^3) and 600g ^{235}U (6.0 gU/cm^3) per assembly. Fast and thermal neutron fluxes in the central irradiation positions and thermal fluxes in the beam tube positions are nearly the same in these LEU alternative configurations as in the HEU standard configuration. While the LEU alternative core configurations are neutronically possible, the thermal hydraulics, safety and operation of these HFBR configurations haye not yet been investigated.

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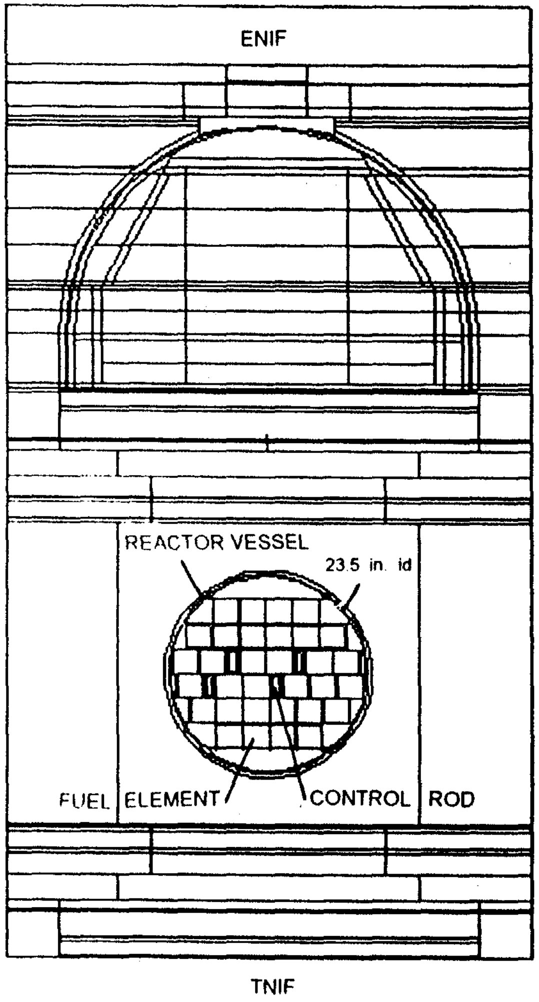

Figure 1. BMRR Model

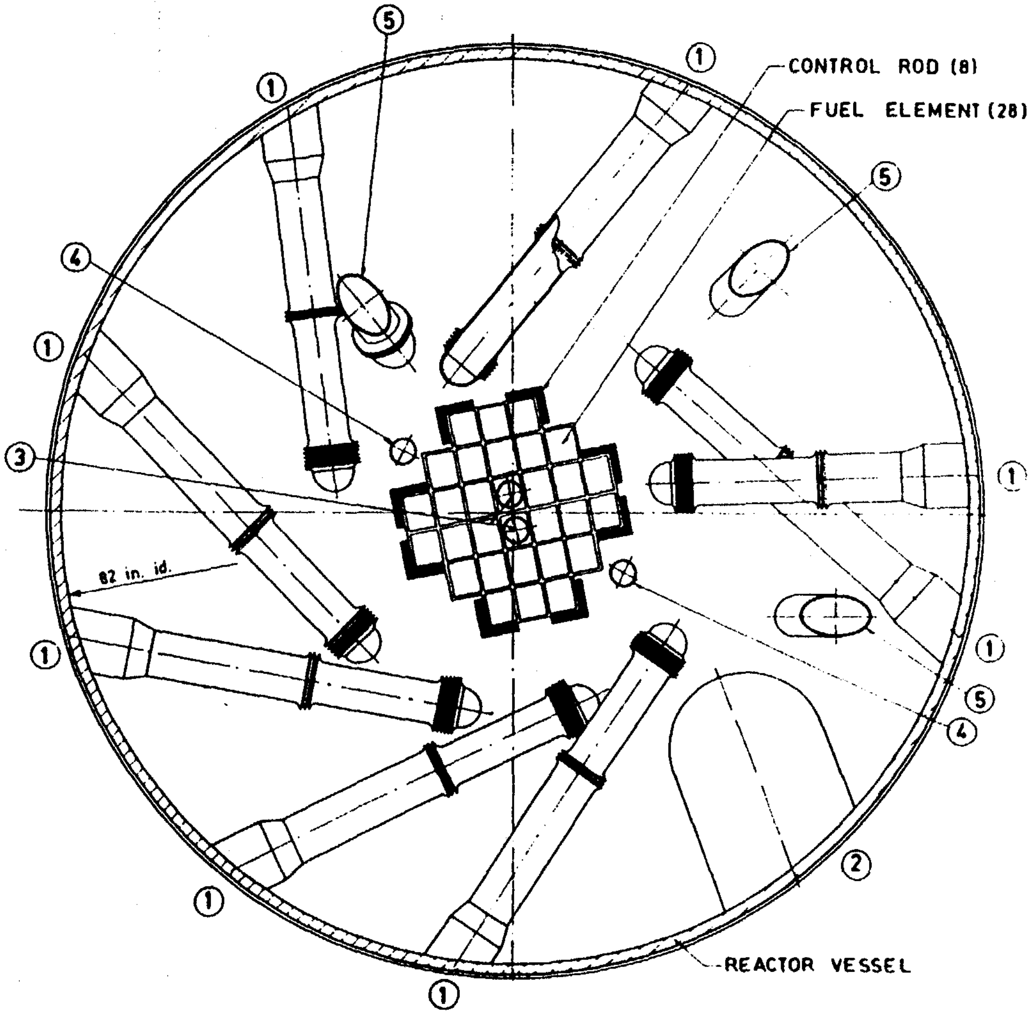

Figure 2. HFBR Model