The Experiment Research of Ghana MNSR With LEU Core

Li-Yiguo Peng-Dan Wu- Xiaobo Hong-Jingyan, Lu-Jin, Wang-Mengjiao
Hao-Qian, Pan-Lin.

China Institute of Atomic Energy, Beijing,102413,P.O.Box 275-75,China

Abstract: Ghana Miniature Neutron Source Reactor(MNSR) with thermal power of 30kW is designed and manufactured by China Institute of Atomic Energy (CIAE) in 1995, it'S mainly used for NAA, training and teaching, testing of nuclear instrumentation. Ghana MNSR has the fuel （UAl4）with 235U of 90.3% enrichment，Al alloy as cladding, metal Be as reflectors and light water as moderator and coolant.

Since 2014, Ghana MNSR was converted from HEU to LEU, the core dimensions of the Ghana MNSR is not changed，the HEU fuel and Al cladding are replaced with LEU fuel and Zircaloy respectively, the critical mass, the control rod worth and top Be reflector worth are measured, the final loading of fuel elements are determined. The experiment was done on the Zero Power Experiment equipment of MNSR.

1 Description of equipment

The reactor with thermal power 30kW is an under-moderated reactor of pool-tank type, and UO^2 with enrichment of 13% as fuel, light water as coolant and moderator, and metallic beryllium as reflector. The fission heat produced by the reactor is removed by the natural convection. Fig. 1 shows the diagram of the experimental equipment.

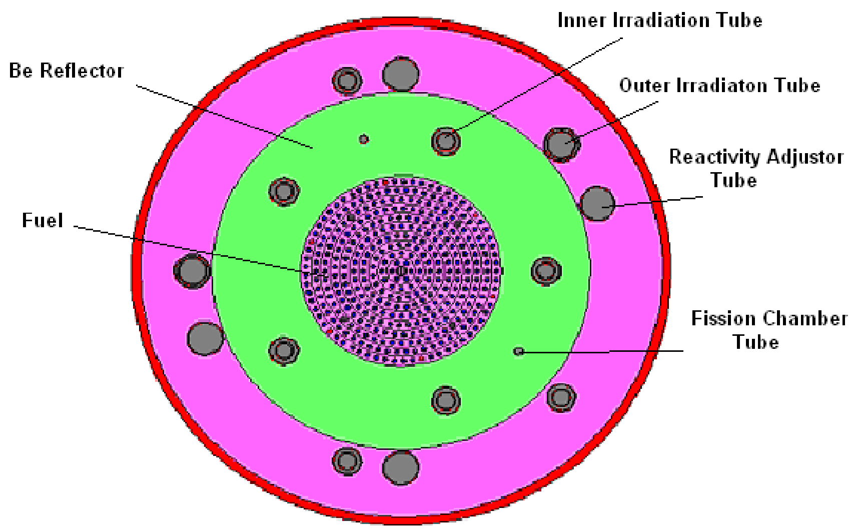

Fig.1 The diagram of the experimental equipment

One central control rod is in the center of reactor core.

1.1 Reactor

The upper and lower grid plates are linked by four tie rods, ten rows of 355 lattices are concentrically arranged, the central lattice is reserved for central control rod. While the four tie rods are uniformly arranged at the eighth row. The rest lattices are for fuel element and dummy elements (see Fig.2).

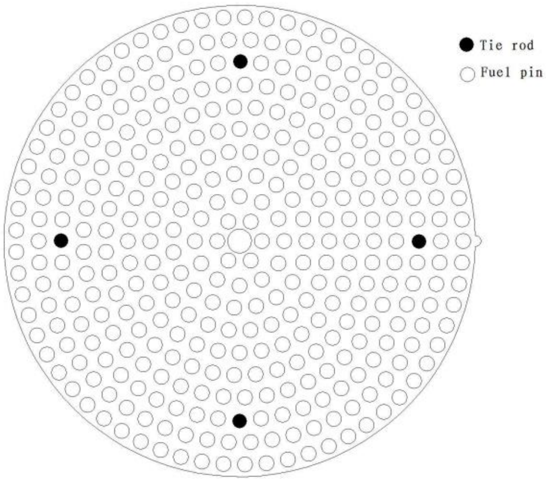

Fig. 2 The diagram of fuel arrangement

The UO_2 is used as the fuel meat with density 10.6g/cm3, ^{235}U enrichment is 13%, the dimension is Ø4.3×230 mm. The cladding material is Zr-4 alloy with wall thickness of 0.55 mm and 248 mm in length（8 mm end plug at up end, 9 mm end plug at lower end, 1 mm Helium gas between the upper end and fuel meat）

The central control rod : 1）Guide tube：inner dia. 9mm，outer dia. 12mm，length：278mm；2）Meat：Cd tube outer dia. 4.5mm，inner dia. 2.5mm, length 290mm；inside Cd tube：Al rod Φ 2.5×290（mm）; 3) Outside Cd tube S.S tube outer dia. 6.0mm，wall thickness：0.5mm , total length：450mm。

The fuel Cage：1）Dia：230mm，height：258mm; 2）Top core plate：Zr-4 alloy thickness：3mm, lower core plate：Zr-4 alloy thickness：5mm.

1.2 Side Be reflector

The dimension：inner dia.: 231 mm，outer dia.: 435 mm, height：238.5 mm.

1.3 Bottom Be reflector

The dimension：dia.: 290 mm，thickness：50 mm，central hole diameter: 15 mm.

1.4 Top Be reflector

The Al alloy tray for Top Be reflector：inner dia.：246 mm, outer dia.：252 mm，height：170 mm，bottom thickness：2 mm.

The dimension of top Be reflectors：dia.: 243 mm, hole dia.: 25 mm，total thickness：109.5 mm. Several thicknesses of Be shim are available as follows: 1.5，3.0，6.0 and 12.0 mm.

1.5 Irradiation and guide Tubes

Inner irradiation sites：5 sites are uniformly and vertically arranged in the side Be reflector at the radius of 165 mm；the irradiation tube（rabbit tube）inserts into the irradiation site to the depth of 190.0 mm，Outer thimble of the irradiation tube：outer dia.: 32.0 mm，inner dia:. 29.0 mm；inner thimble：outer dia.: 22.0 mm，inner dia.: 19.0 mm.

Outer irradiation sites（outside the side Be）: 5 sites are uniformly and vertically arranged outside the side Be reflector at the radius of 232.5 mm，insertion depth is 190.0 mm. Outer thimble：outer dia.: 42.0 mm, inner dia.: 39.0 mm；inner thimble：outer dia.:34.0 mm, inner dia.: 31.0 mm

2 Zero power experimental results

The experiment was done in the MNSR zero power equipment, some parameters were measured.

2.1 Critical mass

Two ways of extrapolation and insertion were used for the measurement of critical mass. The results are 329.1 fuel elements while the fuel elements in the outermost circle are not uniformly arranged.

2.2 Worth of the central control rod

The worth was measured by the period method. Insert a part of the rod in the reactor, measured the worth by the same method again. Do it Alternately, the total worth of the rod was measured finally(see Fig.3). The total worths of the central control rod of the experiment are 7.65 mk.The measured worth of the control rod lower part is -0.725 mk.

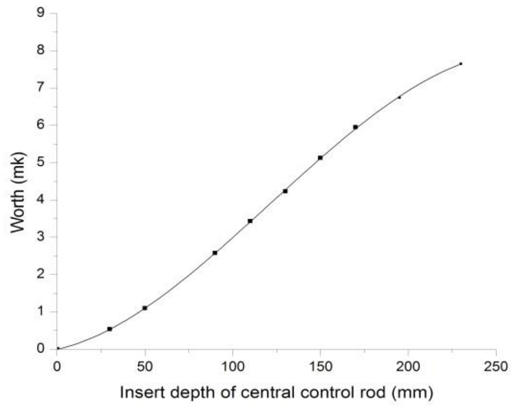

Fig.3 Central control rod worth

2.3 Worth of the top Beryllium reflectors

By the period method, the worth was also measured. Add the piece of top Be, measured the worth; and then, take out the fuel element from the reactor core, add the top Be, measured the worth again; Do it Alternately, the total worth of the rod was measured finally(see Fig.4). The total worth of the top Be reflectors by the experiment measurement is 18.7mk.

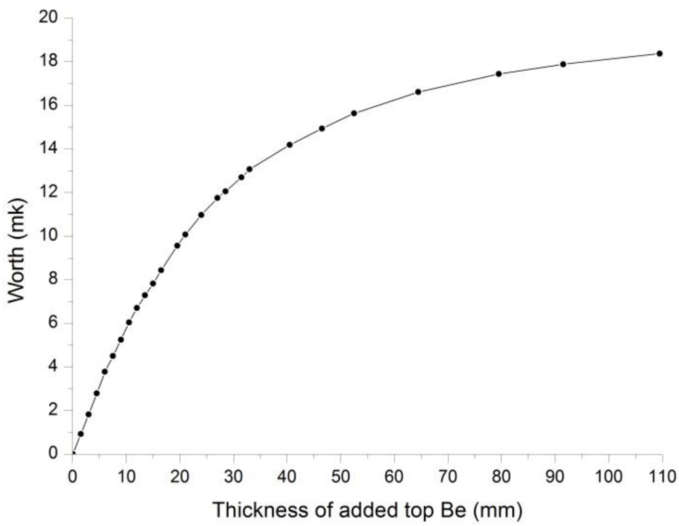

Fig.4 Top Be worth

2.4 Worth of fission chambers and their tubes

By the period method, first, the reactivity of the core was measured, and then, put the two fission chambers and their tubes into the holes of fission chamber in the side Be, the reactivity of the core was measured again. The worth of two fission chamber and their tubes was measured by the reactivity difference of two values. The measuring worth is -0.255 mk.

2.5 Worth of outer irradiation tubes and top Be tray

By the period method, first, the reactivity of the core was measured, and then, put the two outer irradiation tubes into the holes in the side Be, the reactivity of the core was measured again. The worth of two outer irradiation tubes was measured by the reactivity difference of two values. The measuring worth of two outer tubers is -0.396mk. By the same way, the measured worth of the top Be tray is -0.579 mk.

3 Final loading

At the initial state of the Ghana MNSR with LEU core, there are five inner tubes in the side reflector; five outer tubes installed; four reactivity regulator tubes; two fission chambers and their associated tubes; the lower part of control rod in the reactor core; and an empty top Be tray installed. The total worth of all these reactor components should be considered for the selection of the final fuel loading to establish approximately 4 mk of excess reactivity.

At the experimental state of the Ghana MNSR core with LEU , there are five inner irradiation tubes in the side reflector; no outer irradiation tubes; no reactivity regulator tubes; no fission chambers or their associated tubes; no control rod lower part in the core; and no top Be tray. The reactivity was measured as 1.53 mk when 326 fuel elements were loaded, with the fuel rods uniformly arranged in the outermost ring.

Based on the measurements described in section 2, the worth of five outer tubes in the reactor is -0.99 mk; the worth of four empty reactivity regulator tubes is -0.792 mk; the worth of two fission chambers and their associated tubes is -0.255 mk; the worth of the lower part of control rod is -0.725 mk; and the worth of empty top Be tray is - 0.579 mk. Thus, a total worth is -3.341 mk.

The initial excess reactivity of the Ghana MNSR should be approximately 4.0 mk. The average worth of one fuel element in the outermost ring is 0.798 mk, so the final loading at the initial state of reactor is 334 fuel elements, the rest lattices will be filled by dummy elements.Fig.5 shows the arrangement of the fuel elements.

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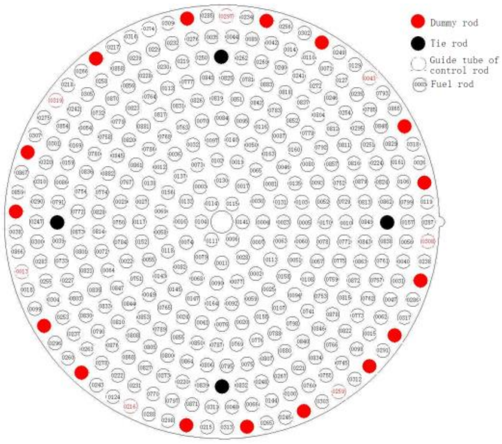

Fig. 5　The arrangement of the fuel elements.