THE CURRENT STATUS OF DALAT NUCLEAR RESEARCH REACTOR AND PROPOSED CORE CONVERSION STUDIES

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ABSTRACT:

The Dalat Nuclear Research Reactor (DNRR) with nominal power of 500 kW accumulated eighteen years of operation in March 2002 since its renovation from the previous 250 kW TRIGA-MARK II reactor. It totaled 22703 hrs at nominal power. The total energy released was 473 MWd. The DNRR uses WWR-SM fuel assembly with 36% enrichment. Weight of uranium 235 in assembly is about 40.2 g.

In April 1994, after more than 10 years of operation with 89 fuel assemblies, the first fuel reloading was executed. The 11 new fuel assemblies were added in the core periphery, at previous beryllium element locations. After reloading the working configuration of reactor core consisted of 100 fuel assemblies. The reloading operation increased the reactor excess reactivity from 3.8 $ to 6.5 $. This ensured exploitation of the DNRR for 8 years with 1200-1300 hrs per year at nominal power before second refueling.

The second fuel reloading was executed in March 2002. The 4 new fuel assemblies were added in the core periphery, at previous beryllium element locations. After reloading the working configuration of reactor core consisted of 104 fuel assemblies. The reloading operation increased the reactor excess reactivity from 2.7 $ to 3.8 $. This fuel reloading will ensure efficient exploitation of the DNRR for 3 years with 1200-1300 hrs per year at nominal power. The DNRR has been operated safely. It is used for isotope production, neutron activation analyses, research and training. This paper presents current status and proposed core conversion studies of the DNRR.

1. INTRODUCTION

The Dalat Nuclear Research Reactor was reconstructed in 1982 from the old 250 kW TRIGA-MARK II reactor. The latter was built in early 1960's. First criticality was reached 1963. At the beginning of April 1975, all fuel elements of the reactor were unloaded and shipped back to USA.

During 1982-1983, the reactor was reconstructed. Some structures of the former reactor such as the reactor aluminum tank, the graphite reflector, the thermal column, the horizontal beam tubes and the radiation concrete shielding were retained [1]. The reactor core, the control and instrumentation system, the primary and secondary cooling systems as well as other associated systems were newly designed and installed. The natural convection mechanism of light water for reactor core cooling was kept unchanged. The core is loaded with WWR-SM fuel elements with 36% enrichment. The renovated reactor reached initial criticality in November 1983 and attained its nominal power of 500 kW in February 1984. The maximum thermal neutron flux was 2.1E13 n/cm^2/sec. Since then DNRR has been operated safely.

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2. REACTOR DESCRIPTION

The DNRR is a pool type reactor, moderated and cooled by light water [2]. It was upgraded from the TRIGA Mark-II reactor built in early 1960’s. First criticality of the renovated reactor was in November 1983 and since March 1984, its regular operation has been done. Main specifications of the DNRR are shown in Table 1.

Table 1. Reactor Specifications

Reactor type	Swimming pool
Nominal thermal power	500 kW
Neutron flux (thermal, max.)	2.2×10^{13} neutrons/cm^2.s
Coolant and moderator	Light water
Reflector	Graphite, beryllium and water
Fuel type	WWR-SM, U-Al alloy, 36% enrichment
Number of control rods	7 (2 safety rods, 4 shim rods, 1 regulating rod)
Control rod material	B_4C for safety and shim rods, Stainless steel for automatic regulating rod
Neutron measuring channels	9 (6 CFC, 3 CIC)
Vertical irradiation channels	4 (neutron trap, 1 wet channel, 2 dry channels)
Horizontal beam-ports	4 (1 tangential, 3 radial)
Thermal column	1
Spent fuel storage (temporary)	inside reactor building, next to the reactor shielding

The DNRR consists of a cylindrical aluminum tank 6.26 m high and 1.98 m in diameter of the original TRIGA reactor. The reactor core, positioned inside the graphite reflector, is suspended from above by an inner cylindrical extracting well in order to increase the cooling efficiency for copping with higher thermal power of the reactor. The vertical section of the reactor is shown in Figure 1 and the cross-section view of the reactor core in shown in Figure 2.

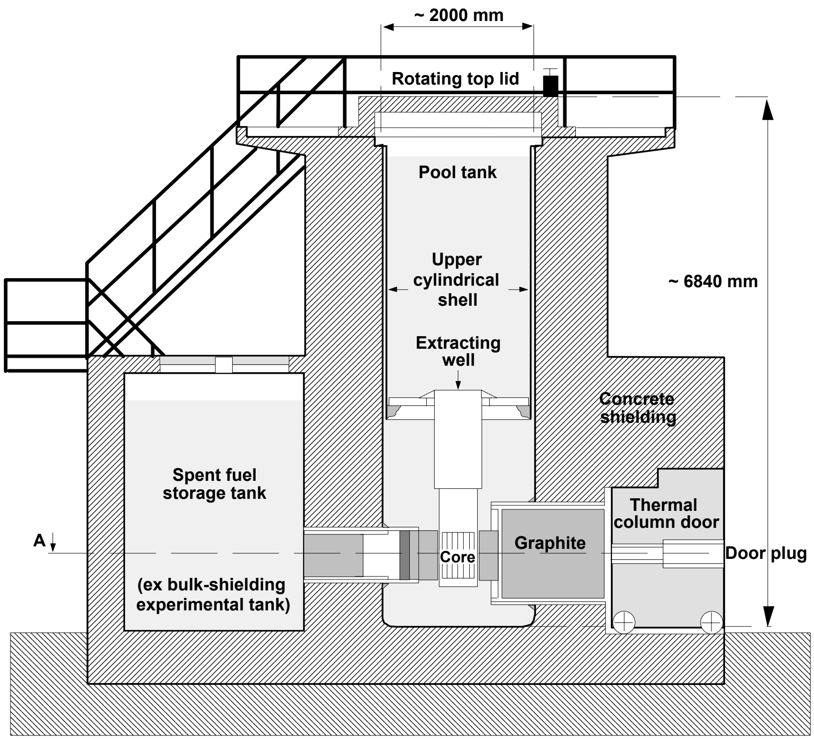

Figure 1. Vertical section view of the reactor

The core of the reactor utilizes fuel of aluminum-uranium alloy of Soviet-designed standard type WWR-SM, enriched to 36%, clad in aluminum. Each fuel assembly contains about 40.2 g of U-235 distributed on three coaxial fuel tubes (fuel elements), of which the outermost one is hexagonal shaped and the two inner ones are circular. The fuel layer with a thickness of 0.7 mm is wrapped between two aluminum alloy cladding layers of 0.9 mm thickness (Figure 3). At present, the reactor has been working with 104-fuel assemblies configuration.

The core cooling is maintained by natural convection. A circular shell, called extracting well, is installed right above the core to intensify water flow through the core by providing a 'chimney' effect. Pool water enters the bottom of the core, is heated by thermal energy released in the core and exits the top of the core. Heated water enters the extracting well, then exits the well and mixes with pool water. To keep the temperature of pool water at the core inlet below the operational limit, hot pool water is withdrawn from the upper pool part and circulated through a closed-loop heat removal system (primary cooling loop). Heat rejection is achieved through a secondary cooling loop. The heat exchanger removes primary coolant heat to secondary coolant, from which heat is discharged into the outside atmosphere through a fan-forced air cooling tower.

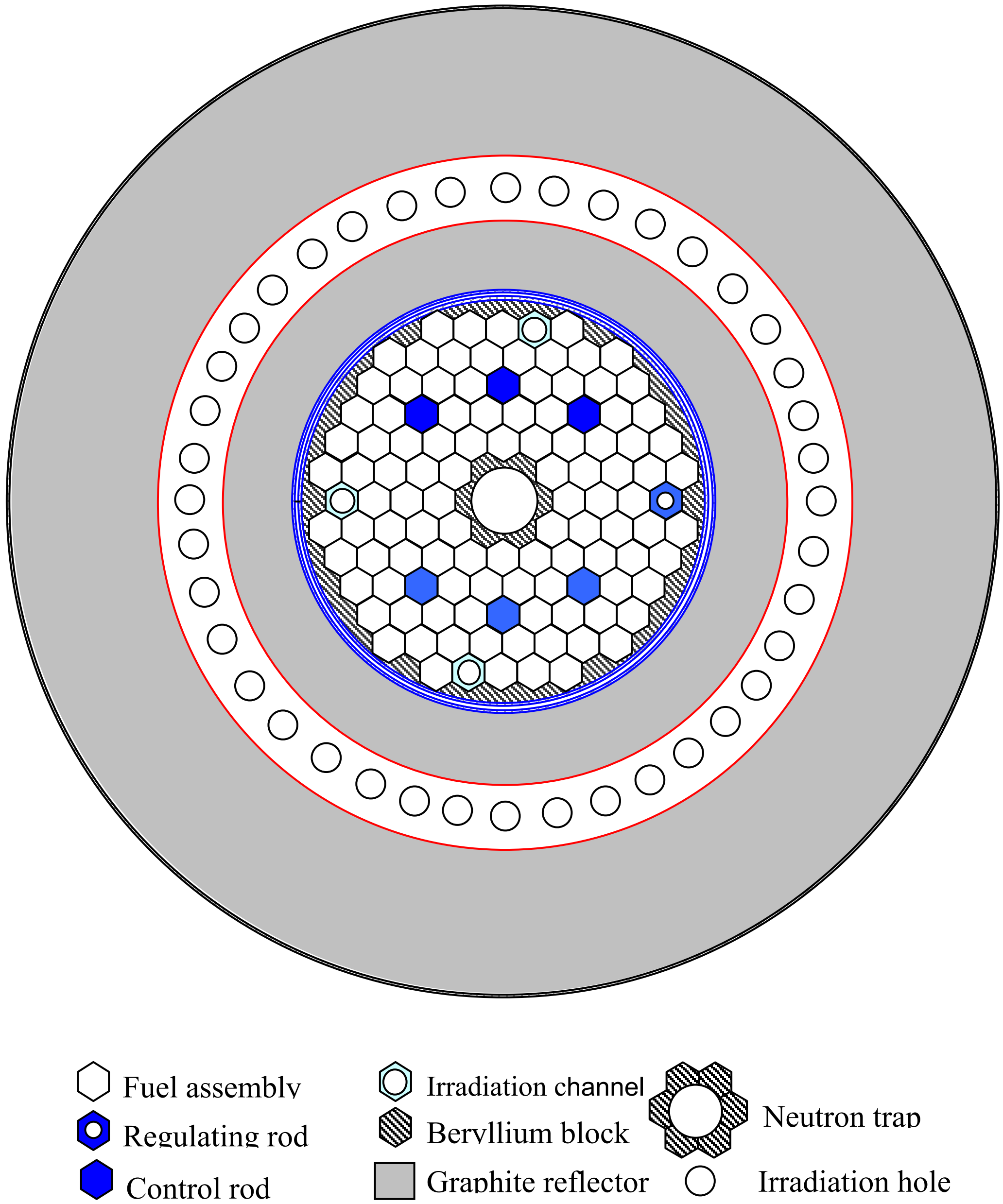

Figure 2. Cross-section view of the reactor core

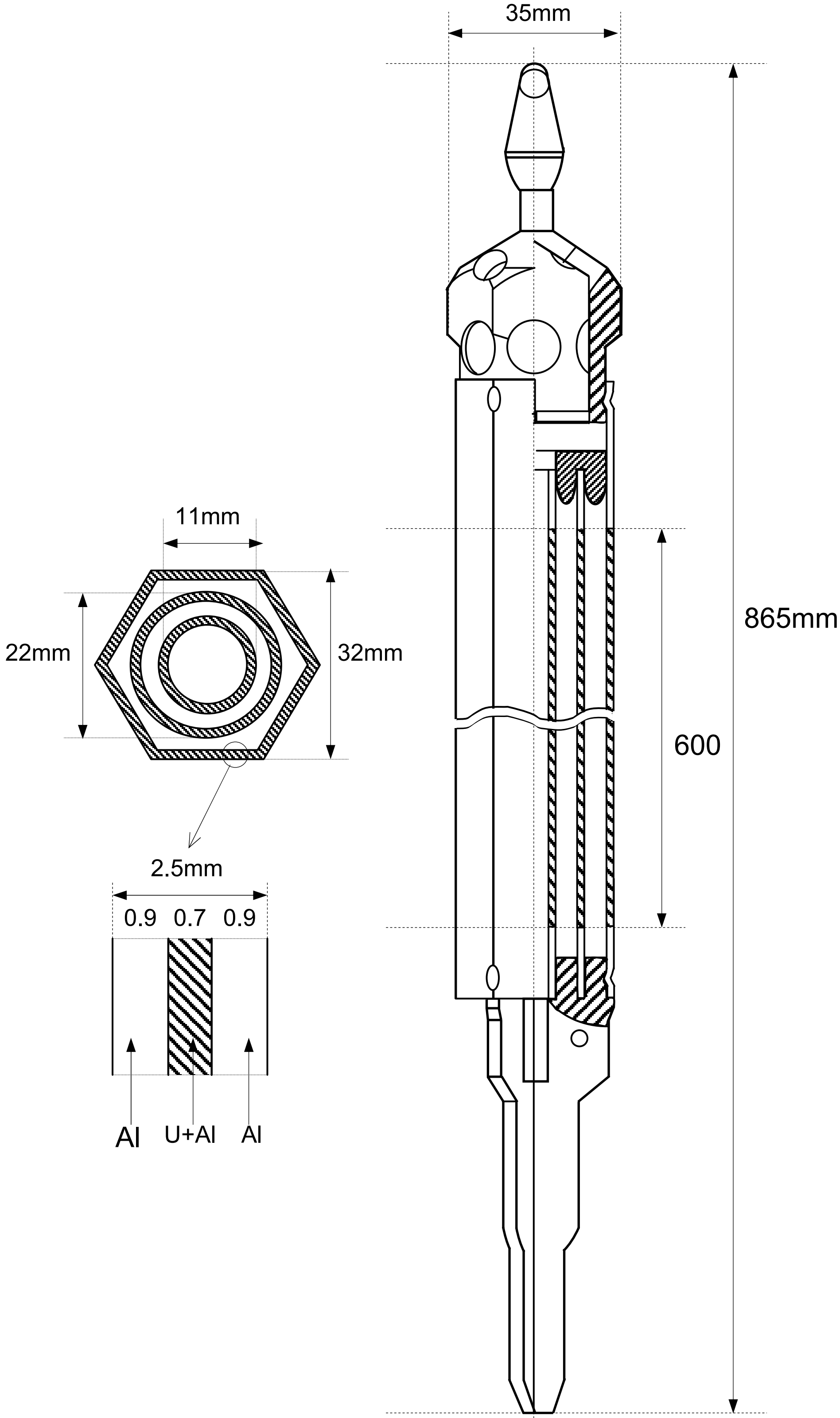

Figure 3. Fuel assembly type WWR-SM of the DNRR

Reactor control and protection are effected by six control rods composed of boron carbide in stainless steel sheath (two of which are safety rods and the other four are shim rods), and an additional control rod, called automatic regulating rod, composed only of stainless steel. Each rod hangs from a flexible cable connected to its own electric motor drive. The rods move vertically within aluminum tubes penetrating through the core. The safety and shim rods (if the latter are partly withdrawn) can be fully inserted into the core within less than one second by free drop under the influence of gravity in order to stop the chain reaction. The absorption length of the control rods is of 650mm that is sufficient to completely cover the active height of the reactor core.

The former bulk shielding has been modified into a storage tank for spent fuel elements. Depth of the tank is 3.7 m. The tank has covers and is filled with distilled water. It has 300 holes to contain spent fuel assemblies.

The first working configuration of the core was obtained on February 1984 with the 72 hr successful test operation of the reactor. The configuration consisted of 88 fuel elements with neutron trap in the center of the core.

The irradiation facilities in this core comprised of 2 vertical pneumatic irradiation channels together with the central neutron trap and the wet irradiation channel. Surrounding the reactor core, a rotating tray containing 40 irradiation holes was arranged at the same position as the former “Lazy Suzan”. The 4 horizontal neutron beam ports and the thermal column were retained from the old reactor.

The DNRR is operated mainly in continuous runs of 100 hrs, once every 4 weeks, for radioisotope production, neutron activation analyses, training and research purposes. The remaining time between two consecutive runs is devoted to maintenance activities and also to physics experiments.

3. FUEL RELOADING

In April 1994, after more than 10 years of operation with 89 fuel assemblies, the first fuel reloading was executed. The 11 new fuel assemblies were added in the core periphery, at previous beryllium element locations. After reloading the working configuration of reactor core consisted of 100 fuel assemblies. The reloading operation increased the reactor excess reactivity from 3.8 \$ to 6.5 \$. This ensured exploitation of the DNRR for 8 years with 1200-1300 hrs per year at nominal power before second refueling.

Research on core management of DNRR with the purpose of maintaining safety operation and effective utilization of reserve fuel assemblies is carrying out in the frame work of research theme in the years 2000-2001 [3]. Optimum second refueling pattern for DNRR and strategy utilization of fuel assemblies based on fuel burnup distribution gained from calculation and experimental measurement.

Calculation of fuel burnup and burnup distribution for Dalat Nuclear Reactor are carried out based on cell calculation program WIMS and two diffusion calculation programs HEXAGA and HEXNOD in two dimensional geometry. Experimental measurement of fuel burnup for Dalat Nuclear Reactor was realized by measurement method of long live isotopes from fission products. Fuel burnup distribution in November, 2000 is show in Figure 4. Fuel burnup distribution in March, 2002 is show in Figure 5.

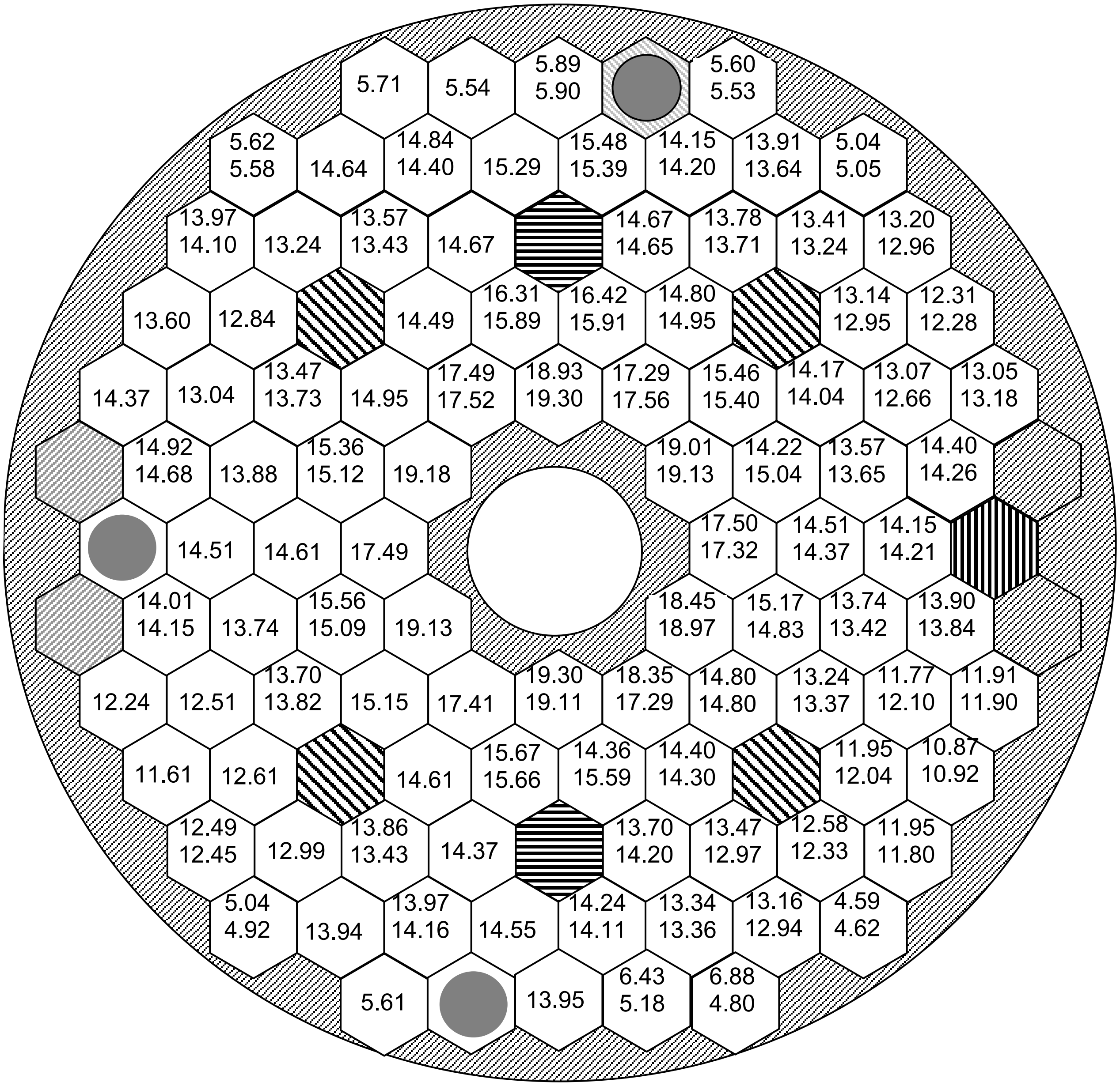

Figure 4. Fuel burnup distribution in November, 2000
- Upper values are experimental data
- Lower values are calculated data

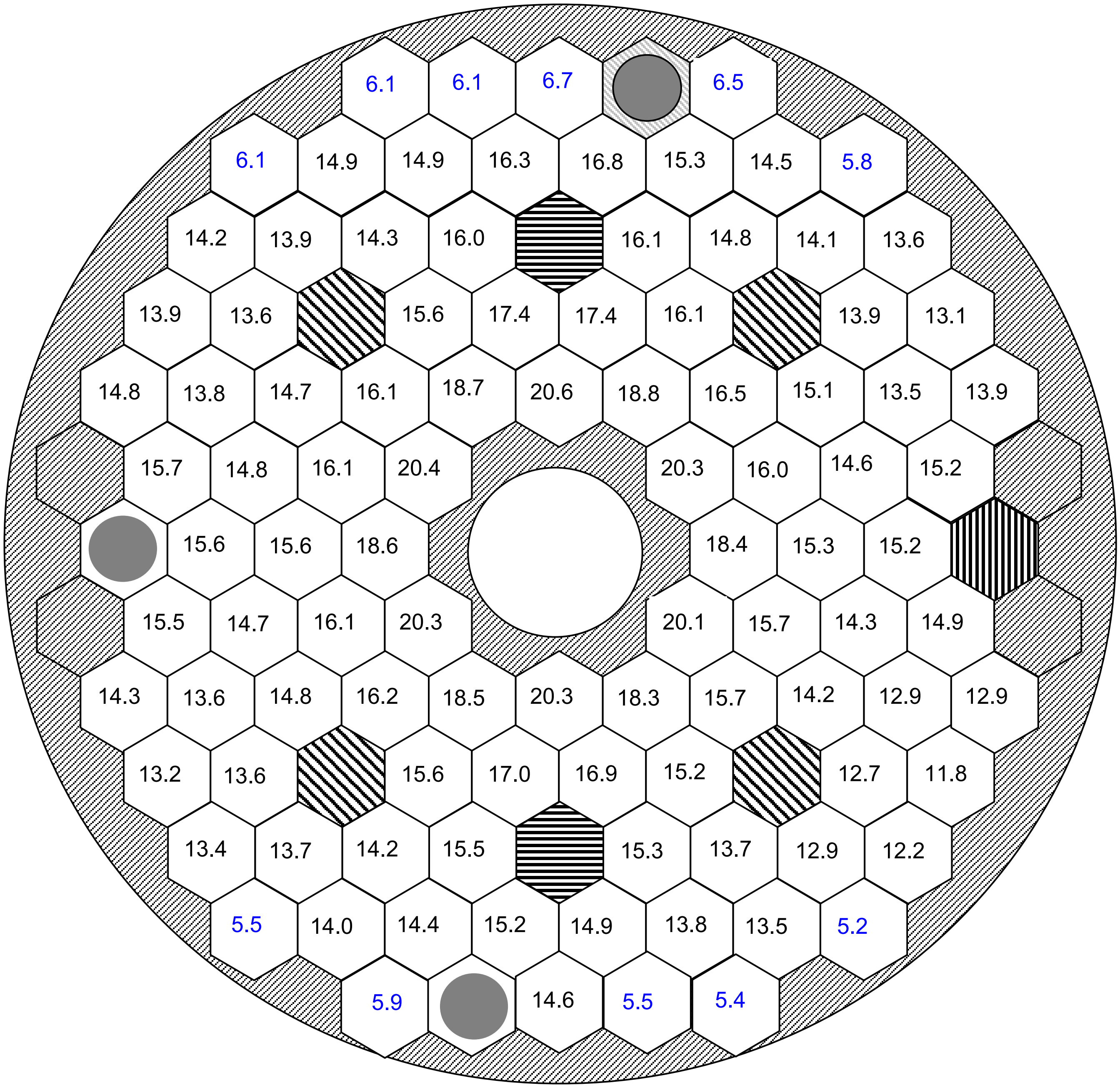

Figure 5. Fuel burnup distribution in March, 2002

Optimum second refueling pattern for Dalat Nuclear Reactor was approved by director of Nuclear Research Institute base on carried out researches. It is the pattern of replacement of 4 Beryllium rods at the core periphery by 4 new fuel assemblies. By realizing this pattern, fuel burnup of spent fuel assemblies taken out from reactor in the next refueling will be increased. After second fuel refueling, reserve reactivity of the reactor increased by 1,26$. The reactor will be operated for more than 3000 hrs at nominal power until next refueling. Measured parameters of reactor core after refueling show that reactor will be operated safely from nuclear and thermal safety point of view.

The second fuel reloading was executed in March 2002. The 4 new fuel assemblies were added in the core periphery, at previous beryllium element locations. After reloading the working configuration of reactor core consisted of 104 fuel assemblies as shown in Figure 2. The reloading operation increased the reactor excess reactivity from 2.7 $ to 3.8 $. This fuel reloading will ensure efficient exploitation of the DNRR for 3 years with 1200-1300 hrs per year at nominal power.

4. PROPOSED CORE CONVERSION STUDIES

We have in reserve 36 fuel assemblies. We propose study on conversion of our reactor core from the use of medium enriched uranium (MEU) fuel to the use of low enriched uranium (LEU) fuel. There are two type of core conversions considered [4] : (1) conversions where only the fuel and reactor core are changed and (2) conversions where other major modifications are made to accommodate the fuel change. We choose type 2 for our case. We would like to put more irradiation channel and reduce number of control rod in the core and major change in control system. We choose to convert to LEU fuel without changes in fuel element dimensions. We will operate our reactor with an interim core using both MEU and LEU fuel until an equilibrium core with LEU fuel is established.

By now we do not have experience in core conversion. We would like to have cooperation and help from other countries in this matter.

4. CONCLUSION

After renovation, the maximum power of DNRR was increased to 500 kW. Some structures of the former reactor were retained. The technological systems of the reactor were newly designed and installed. The natural convection mechanism of light water for reactor core cooling was kept unchanged. The core is loaded with WWR-SM fuel elements with 36% enrichment. The renovated reactor attained its planned nominal power in February 1984. After two refueling, now the working configuration of reactor core consisted of 104 fuel assemblies. DNRR has been operated safely. It is used for isotope production, neutron activation analyses, research and training.

Conversion of our reactor core from the use of medium enriched uranium (MEU) fuel to the use of low enriched uranium (LEU) fuel is proposed. Since we do not have experience in core conversion, We would like to have cooperation and help from other countries in this matter.

REFERENCE

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