OPERATION AND UTILIZATIONS OF DALAT NUCLEAR RESEARCH REACTOR

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Abstract

The reconstructed Dalat nuclear research reactor was commissioned in March 1984 and up to September 1988 more than 6200 hours of operation at nominal power have been recorded. The major utilizations of the reactor include radioisotope production, activation analysis, nuclear data research and training.

A brief review of the utilizations of the reactor is presented. Some aspects of reactor safety are also discussed.

Introduction.

In Dalat (South Vietnam) the 250 Kw TRIGA MARK II reactor, which was in operation from 1962 to 1968 was completely out of action after the removal of the fuel elements just before the end of the war in 1975. The newly reconstructed 500 Kw reactor of Dalat Nuclear Research Institute is unique of its kind in the world: Soviet - designed core and control system installed in the undismountable infrastructure of the former TRIGA reactor, which includes the reactor tank and shielding, graphite reflector, horizontal beam tubes, thermal column etc ... [1]. The new reactor reached initial criticality in November 1983 and regular operation commenced in March 1984. Up to September 1988 more than 6200 hours of reactor operation at nominal power have been recorded.

Reactor structure and characteristics.

The fuel elements are of Soviet standard type VVR-M2 with an enrichment of 36% U-235 and are clad with Al. The fuel assembly which are 60 cm long consists of a hexagonal shaped outer tube and two cylindrical inner tubes. Inside the core are inserted 7 control rods (2 safety rods, 4 shim rods and 1 regulating rod). Outside and around the reflector are positioned 9 ion chambers for reactor control purpose. All shim and safety rods are made of boron carbide, while the regulating rod is made of stainless - steel. The total reactivity worth of shim rods is $12.8\beta_{eff}$.

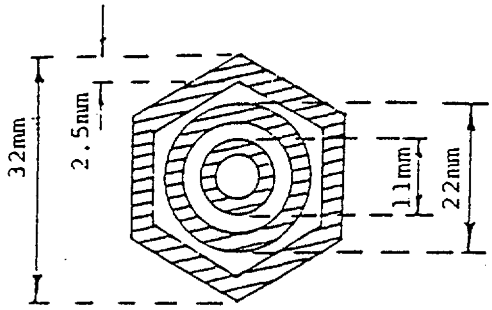

Fig. 1a
Cross-section of the fuel element
VVR-M2

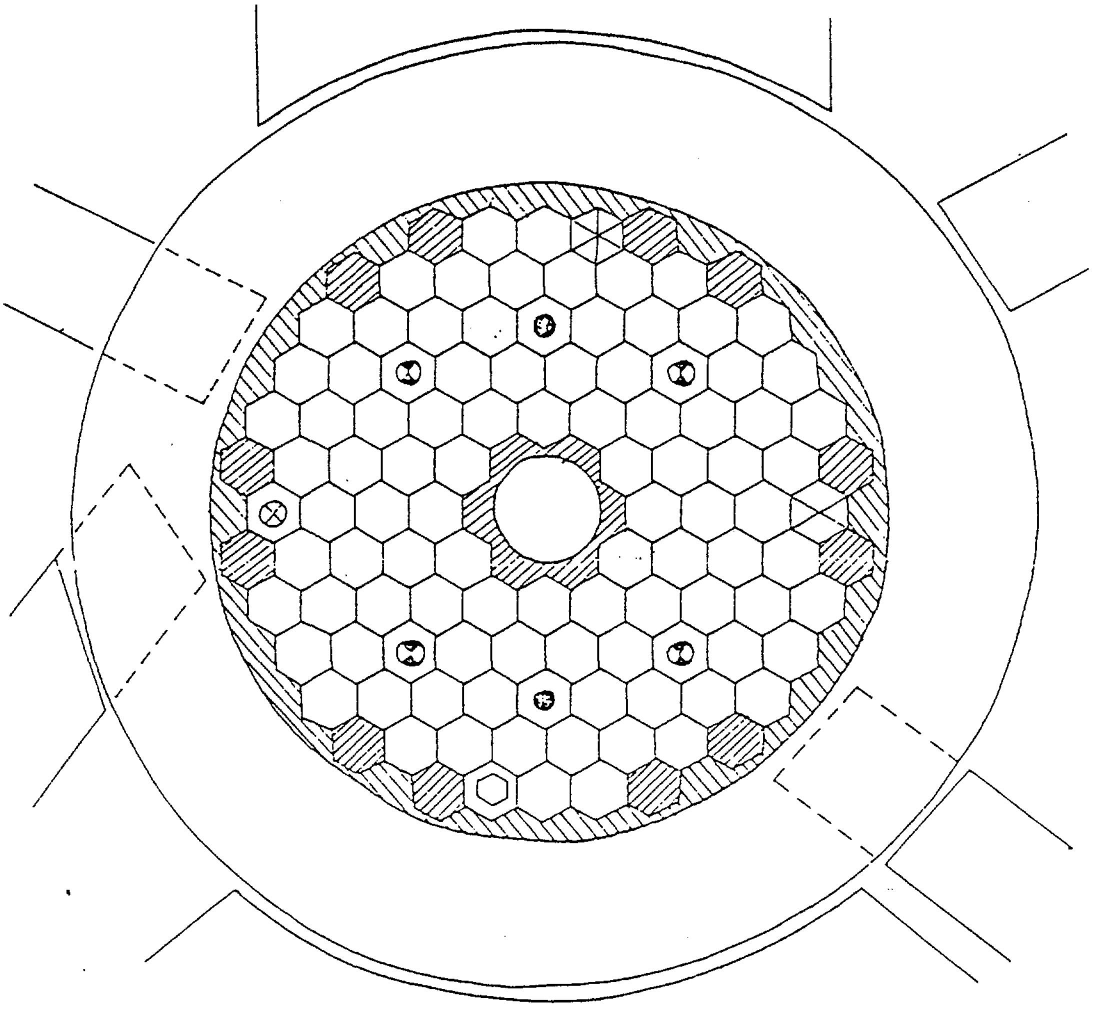

Fig. 1b Reactor Core Arrangement

⬡ Fuel element ▨ Beryllium ◉ Safety rod ⬡ Shim rod
⊘ Regulating rod ⊛ Pneumatic tube (13-2) ⊗ Pneumatic tube (7-1)
⬡ Wet irradiation channel ✲ Neutron trap

The reactor core is located in the tank structure of the former TRIGA reactor and surrounded with a thin layer of beryllium blocks together with the graphite reflector of the former TRIGA reactor. There are 89 fuel assemblies in the reactor core. Seven unit cells at the center of the core are occupied by a water - beryllium neutron trap, which has an inside diameter of 65 mm. (Fig. I)

The core cooling mechanism is basically natural convection as in the former TRIGA reactor, but the driving effect is enhanced by a 2 meter long chimney placed directly above the core. The whole core - chimney assembly is suspended from the top of the reactor tank. The driving effect of the chimney and the increase of the reactor power result in the increase of the dose rate above the water surface (mainly from N_16) as compared to the former TRIGA reactor. Thus a rotary platform made of steel with lead glass windows installed on the reactor tank significantly reduces the dose rate on the top floor of the reactor.

Experimental and Irradiation Facilities.

Experimental and irradiation facilities consist of the following :

- The water - beryllium neutron trap in the center of the core ($f_{th} = 2.1 \times 10^{13}$ n/cm^2 sec).
- The rotary specimen rack assembly with 40 irradiation holes located in the graphite reflector. ($f_{th} = 3.2 \times 10^{12}$ n/cm^2 sec)
- A pneumatic transfer system installed near the beryllium reflector. This system is used for sample irradiation in off-line activation analysis.
- Another pneumatic transfer system with dry irradiation channel installed in the core for simultaneous analysis of uranium and thorium by delayed neutron counting technique.
- A fast pneumatic transfer system installed in the thermal column ($f_{th} = 4.1 \times 10^{10}$ n/cm^2 sec) for short-lived activation analysis with pure thermal neutrons.
- The neutron beam facility at the tangential horizontal channel A thermal neutron flux $f_{th} = 5 \times 10^{6}$ n/cm^2 sec is available at the beam port for thermal neutron capture studies and transmission experiments.
- The radial horizontal channel, which pierces the graphite reflector and terminates adjacent to the fuel will be equiped with neutron filters (Si,S,V,Mn,Fe,Ni). Monochromatic epithermal neutrons will be used for neutron physics studies in cooperation with the Kiev Institute for Nuclear Research.

Reactor Operation and Utilizations.

At present the reactor is operated in two weeks cycle with 75 hours of continuous operation at nominal power.The accumulated operation time from 10/3/1984 to 10/9/1988 is 6219 hours. The reactor has been operated in good condition except for a two-months shut-down period in 1987 for maintenance of the control system and installation of the I-131 production line. The data presented in Table I show the trend to better utilization of the reactor operation. Three radioisotopes are regularly produced and supplied to hospitals : I-131, Tc-99m generator and P-32.

Table I.

Operation and Utilization Statistics of Dalat NRR.

	1984 (from 10-3-1984)	1985	1986	1987	1988 (to 10-9-1988)
Operation time (hours)	922	1722	1403	1022	1150
Isotope Production for medical uses (curies)	5.2	13.2	27.7	34.2	45
Irradiation Samples for NAA	1200	1700	~3000	~4000	~2000

At present and even in the near future the capability of radioisotope production is still higher than the domestic demand in in-vivo diagnosis. A variety of radioisotopes are being also produced for the applications of tracer technique in agriculture (mainly P-32 for the investigations of soil-plant relationship) hydrology and industries.

Apart from isotope production and routine activation analysis, other research activities involving the use of the reactor can be mentioned as following :

- Development of simple Tc-99m extraction generator by using inorganic ion-exchangers titanium and zirconium-molybdate as irradiated targets. This type of generator are being regularly and successfully used in hospitals [2].
- Investigation of the reactor-produced excitation sources for X-ray fluorescence analysis. Excitation source Ge-71 is routinely produced and successfully used [3].
- Determination of composite nuclear constant k_o (used in the standardization of multielement activation analysis). A simple method of k_o-factor determination had been proposed [4] and new data for short - lived isotopes are being currently

obtained by using fast pneumatic transfer system installed in the thermal column.

- Experimental neutron silicon doping in the neutron trap.
- Use of high gamma dose rate in the neutron trap after reactor shut-down for radiation chemistry investigations.
- Analysis of biological and enviromental materials. The concentration levels of trace elements in human hair (Cu, Mg, Mn, Zn, Co, Cr, As, Sb, I, Hg) were obtained for the population of HochiMinh city.
- Use of thermal neutron beam for elemental analysis by (n, gamma) and transmission techniques.

Some aspects of reactor safety.

The measured temperature coefficient of the reactivity is negative and equals to $2 \times 10^{-2} \beta_{eff}$ / C. This value is typical for the Soviet-designed water-cooled heterogeneous research reactor [5]. However this value is associated with the coolant - moderator, while in the case of the former TRIGA reactor the negative temperature coefficient is nearly prompt and associated with the homogeneous fuel - moderator elements. The prompt temperature coefficient of the reactivity is more lower and can be evaluated as $\sim 1 \times 10^{-3} \beta_{eff}$ / C [5]. The preliminary reactor safety analysis has been performed by the Soviet designers, and the attention was paid to the problem of the response of the reactor to the reactivity insertion. Some severe postulated events had been investigated :

- Spontaneous withdrawal of shim rod at nominal and zero (10^{-5} % P_o) power operation (v = 3.4 mm/sec).
- Spontaneous withdrawal of regulating rod at nominal power operation (v = 20 mm/sec).
- Downfall of fuel assembly leading to the reactivity insertion of 1.3 β_{eff} in 0.3 sec.

The calculations taking the action of the protection system into account confirmed the safety of the reactor in every cases.

Special attention is paid also to the problem of the quality of the tank structure of the former TRIGA reactor, which became operational more than 25 years ago, but it has been kept idle for many years before reconstruction. Although careful inspection for water-tighness performed before reconstruction works on the reactor tank,the graphite reflector and the horizontal channel showed their normal state, however, there is still concern about the possible failure of these components. Routine monitoring for the primary circuit water by low-background gamma spectrometry method shows rather low specific activity of such corrosion products, as ^{65}Zn, ^{60}Co, ^{51}G, ^{187}W ... Besides these radionuclides, fission products as 135Xe and 88Kr were also detected at more lower levels. However, no increase of the specific activity of these radionuclides was observed during 4.5 years of reactor operation. With the technical assistance of the IAEA in this year the tank structure and the beam tubes will be inspected with underwater telescope and endoscope.

The fuel cladding temperature will also be measured. A thermometric fuel element with 9 thermocouples is now prepared in Soviet Union and the experiments will be performed in early next year.

It is hopeful that the results of the above mentioned experiments and inspections will serve a basic for the future plan of operation of the reactor and the possibility of its power upgrading.

References

[1] Pham Duy Hien.
Proc. of first Asian Symposium on Research Reactor
Tokyo, Nov. 1986, p.124

[2] Le Van So.
IAEA Seminar on Radionuclide Generator Technology
Vienna 13 - 17 October, /1986/

[3] P.Z.Hien, N.T.Anh, D.D.Thao, T.Truong.
J. Radio and Nucl. Chem., Letters, 118 /3/,217, /1987/

[4] P.Z.Hien, T.K.Mai, T.X.Quang, T.N.Thuy.
J. Radio and Nucl. Chem., Letters, 105 /6/,351, /1986/

[5] Archengelski N.V., Dikarev V.C., Egorenko P.M.,
Rjazanchev E.P., Sov. Atom. Energy 64,/5/,331,/1988/