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# Computing the Neutron Flux in VVRS-2 Reactor using MCNP-4C

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## Abstract

The MCNP-4C Monte Carlo code was used to model a 2 MW thermal VVR-S research reactor. The neutron with continuous energy cross sections of the ENDF/B-VI library was applied to MCNP-4C to calculate the thermal and fast neutron fluxes. The computed neutron flux showed that the MCNP-4C can be used in the reactors similar to VVR-S reactor.

**Keywords:** MCNP, Multiplication Factor, Neutron Flux, VVR-S

## 1. Introduction

MCNP Code[1] is a general-purpose Monte Carlo code that can be used for the transport of electron, photon, neutron or a coupled of them. This code has the capability to calculate eigen values for critical systems. The neutron cross sections can be read from ENDF/B-VI library. Important features of the MCNP code which is versatility and ease to use. A powerful definition of the source, geometry and tally, collection of variance reduction techniques, and different library of cross section data.

In 2009[2], the MCNP-4C code used to simulate the thermal and fast neutron fluxes in the Syrian Miniature Neutron Source Reactor (MNSR). The computed results and the measured results from the foil activation analysis have a good agreement. In 2014[3], the MCNP-4C was evaluated to determine the neutron flux in Greek Research Reactor (GRR-1) in comparison of different neutronic codes. Comparison of the thermal and fast neutron fluency rates obtained by the CITATION and TRIPOLI codes with corresponding MCNP results also showed a very good agreement.

In this study, the Monte Carlo technique which implemented in the MCNP-4C code can efficiently model fairly complicated geometries, such as the VVR-S core.

## 2. Reactor Description

The VVR-S is a tank-in-pool type research reactor, which uses enriched uranium as fuel, light water as coolant and moderator. The reactor block is mainly composed of reactor vessels, experimental channels, reactor core, mobile thermal column, upper rotating lids, in-core fuelling mechanism and biological shield. All these parts are made of four types of materials, aluminum, cast iron, concrete and graphite. Figure 1 shows VVR-S reactor block cross section. Since this reactor is a research reactor, it has different irradiation sites vertically and horizontally[4].

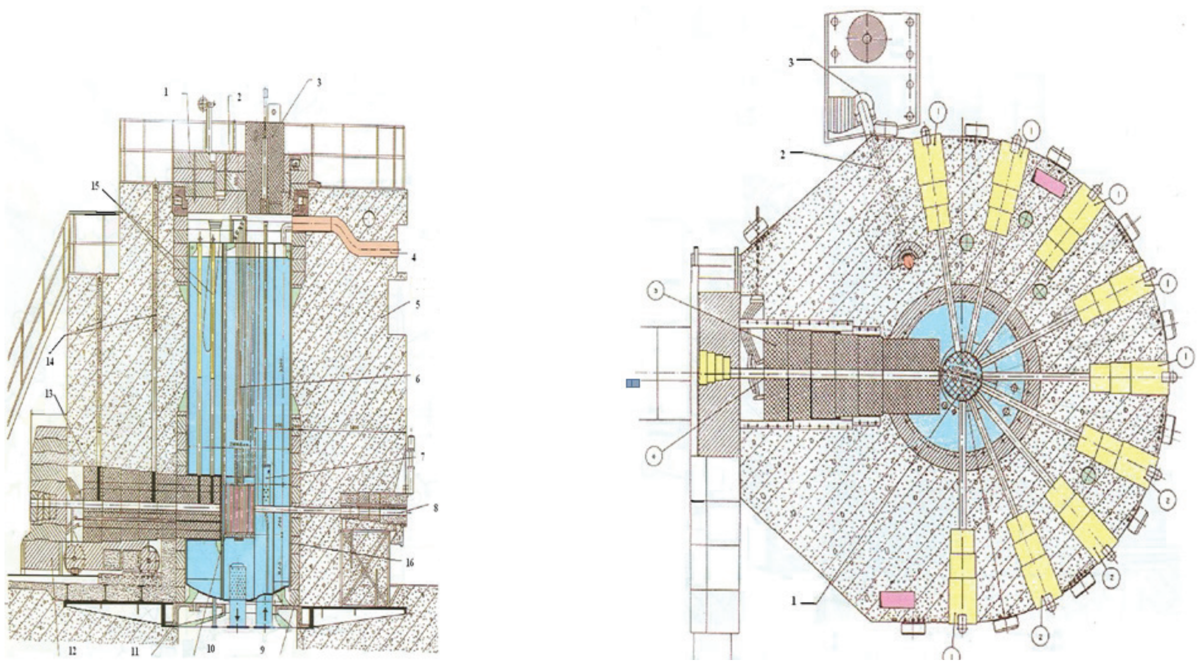
## 3. Methodology

The reactor geometry and characteristics are carried out in MCNP code. The VVR-S reactor assumed in a critical state, then by KCODE deck and proper tally power and neutron flux can be computed[5]. The following states for VVR-S Reactor have modeled by MCNP Code

- When all control rods are withdrawn
- When 10% of the length of the protection rods are at the core

Table 1 shows the density of the VVR-S reactor main components used in the MCNP material card.

**Author for correspondence*



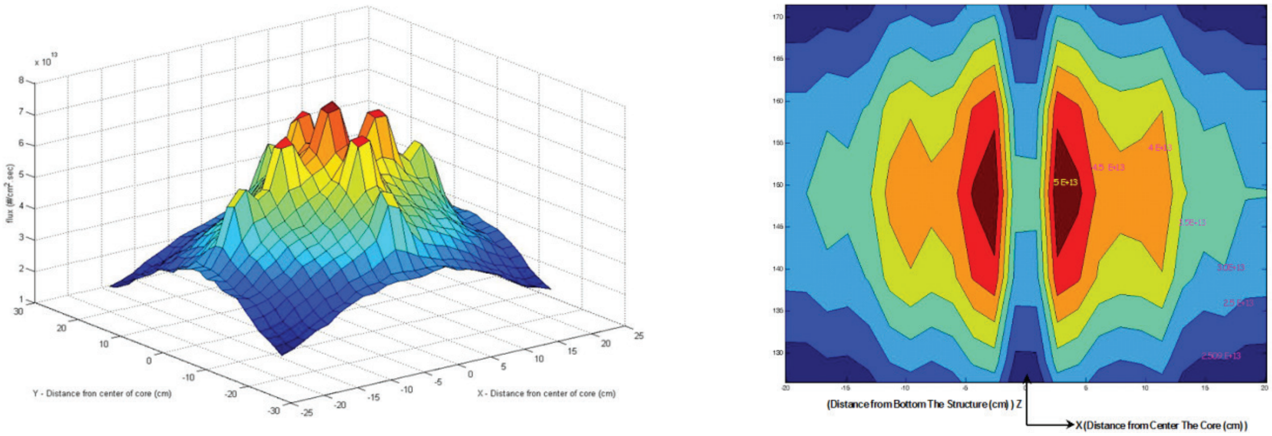
(a) (b)

**Figure 1.** The VVR-S reactor blocks a) vertical cross section, b) horizontal cross section.

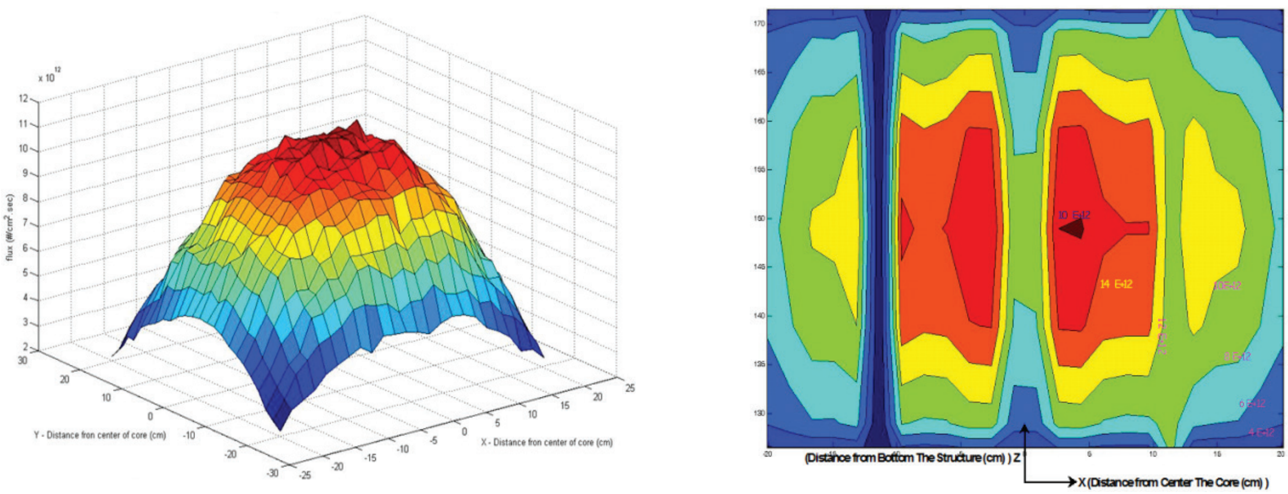
**Table 1.** The density of the main components in VVR-S[6]

| Component | Materials | Overall density (g/cm³) | Component | Materials | Overall density (g/cm³) |
|---|---|---|---|---|---|
| Heavy Concrete | ***Fe, H, O,*** *Mg,* ***Ca****, Si, Al,* ***Mn****, S* | 3.2 | Water | *H, O* | 0.994081 |
| Light Concrete | *H, C,* ***O****, Na, Mg, Al,* ***Si****, S, Ca, Fe, Zn, Zr, Ag, In, Sm, Eu, Hf, Co, K* | 2.3 | Fuel | *U, O, Mg* | 5.6 |
| Air | ***N, O****, Ar* | 0.001205 | Graphite | *Al, As, Ag, Au, Br, Cr, Co, Cs, Mg, N, Ni,* ***C*** | 1.7 |
| Aluminium | ***Al****, Si, Cu, Mn, Mg, Cr, Fe, Zn* | 2.7 | Stainless Steel | ***Fe,*** *Cr, Ni,* ***Mn****, Si, S, P, Mo, W, Nb, Al, Ta, Cu, Co, C* | 7.8 |
| Control rod (B4C) | ***B****, C* | 1.69 | | | |

* Highlighted materials are the dense material in related card.




**(a)**

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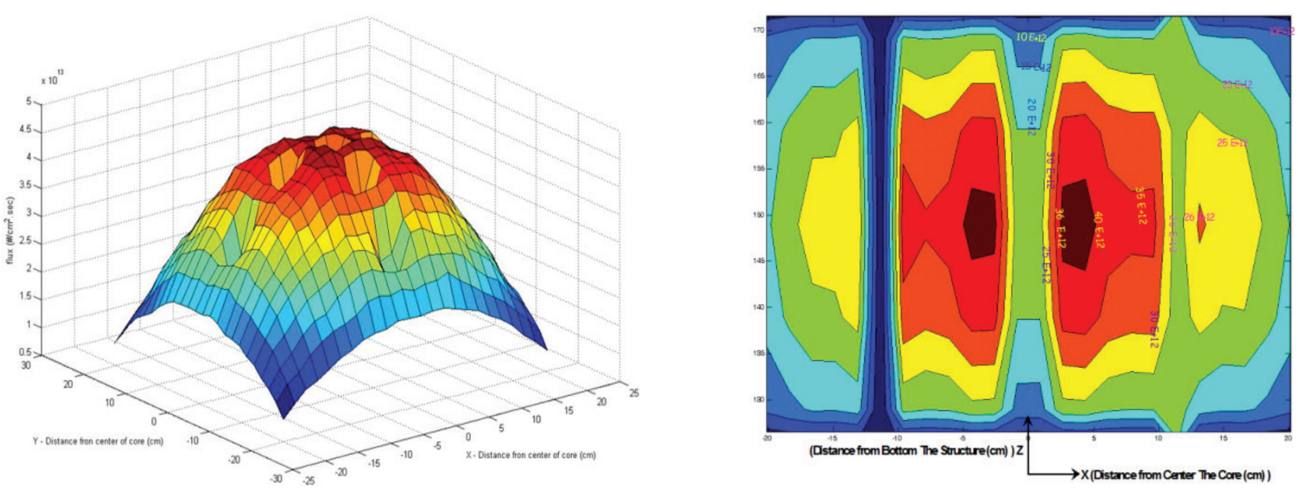
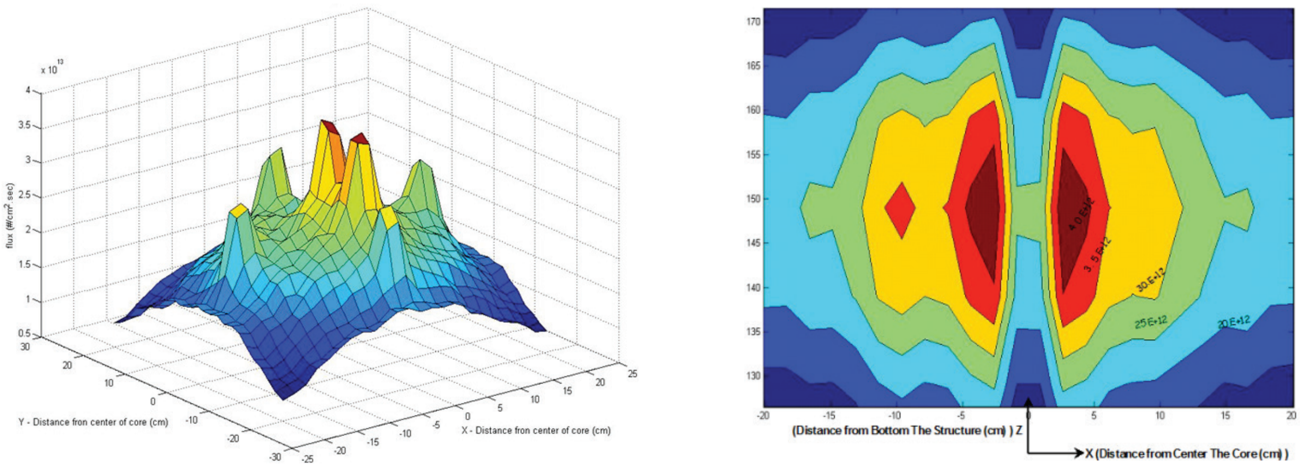
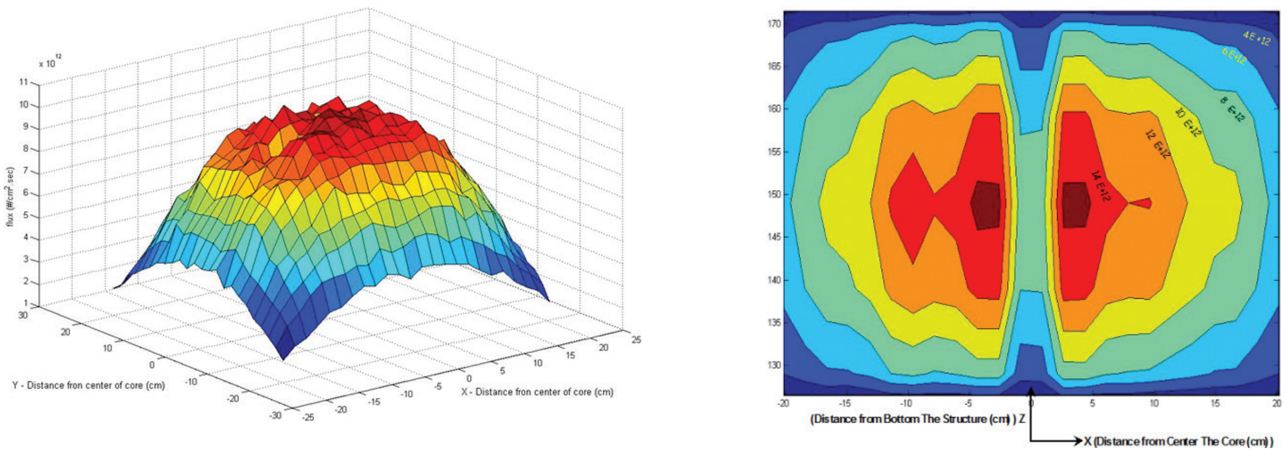



**(c)**

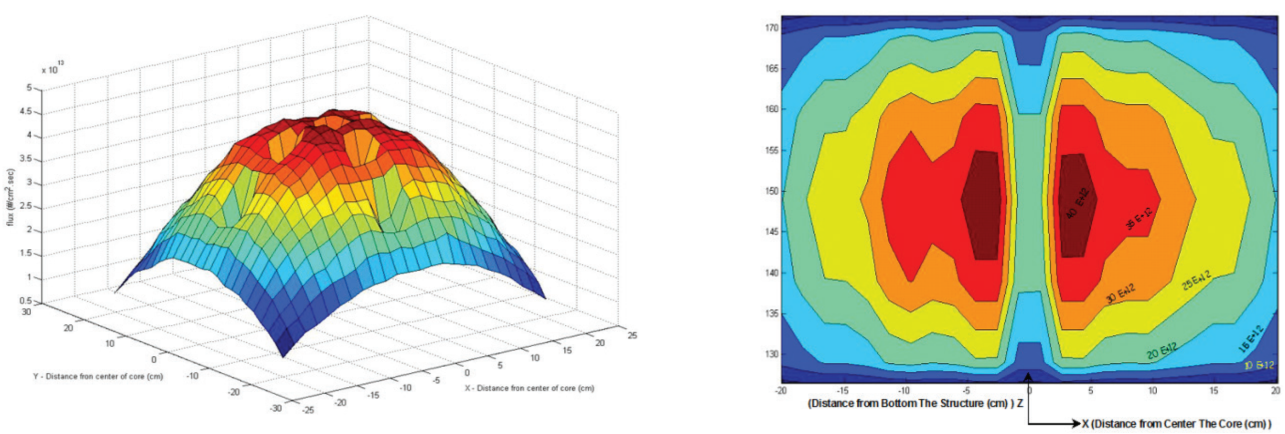
**Figure 2.** 3D and 2D distribution of a) Thermal b) Epithermal c) Fast neutron flux in VVR-S when all control rods are outside the core.




**(a)**




**(b)**




**(c)**

**Figure 3.** 3D and 2D distribution of a) Thermal b) Epithermal c) Fast neutron flux in VVR-S when 10% of protection control rods are outside the core.

## 4. Result and Conclusion

The core modeled in two states; when all control rods are outside the core, and when 10% of the height of the protection control rods is at the core. Figure 2 and Figure 3 shows the distribution of the thermal neutron flux, epithermal neutron flux, and fast neutron flux in two states.

It is obvious from the Figures that when all control rods are outside the core the water coolant passes through the position of the control rods. Thus the thermal neutron flux increases and the flux of the fast neutron is decreased. Although, when 10% of the lengths of the control rods are at the core, the peak of thermal flux shifted to the bottom of the core. In addition, when all control rods are withdrawn, the calculated multiplication factor by the MCNP code is 1.053221. The multiplication factor is about 1 when control rods moved into the core about 10 %. Since operators and scientists who work in reactor physics group and in the analytical laboratory need a complete map of the thermal and fast neutron fluxes, thus this technique can be used to obtain the distribution of neutron flux in the core of VVR-S reactor.

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