Journal of Al-Nahrain University Vol.11(2), August, 2008, pp.99-103 Science

EFFECT OF REFLECTOR MATERIAL ON NEUTRON CALCULATION OF MEU RESEARCH REACTOR

Qasid Abdel Sattar

Physics Department, College of Science, Al- Nahrain University, Jadiriah, Baghdad, Iraq.

Abstract

Effect of different reflector material like graphite, beryllium on core excess reactivity and multigroup neutron fluxes have been studied using standard computer codes Wims –D4 & Daixy. Four energy groups, x-y calculation have reflected on two opposite faces by single row of the graphite / beryllium reflector. The core reflected by single row of graphite and beryllium has a percentage excess reactivity of (14.6) and (16.8) respectively.

Introduction

Most of the research reactor presently utilizing HEU (highenriched Uranium) are being converted to MEU(medium enriched uranium) fuel, provided keeping its performance, power level and availability unchanged. This conversion process demands an increasing in U^{235} content to compensate for the loss of reactivity due to the increased absorption of neutrons by U^{238} percent[1]. To increase the amount of uranium in each fuel one can either increase the volume of the part of fuel element occupied by a uranium or one of can increase the amount of uranium packed into the available volume.

The effect of reflector material such as graphite, beryllium on two dimensions flux distribution and excess reactivity of the core has been studied using standard computer codes Wims-D4 and Daixy.

Basic Reactor Description

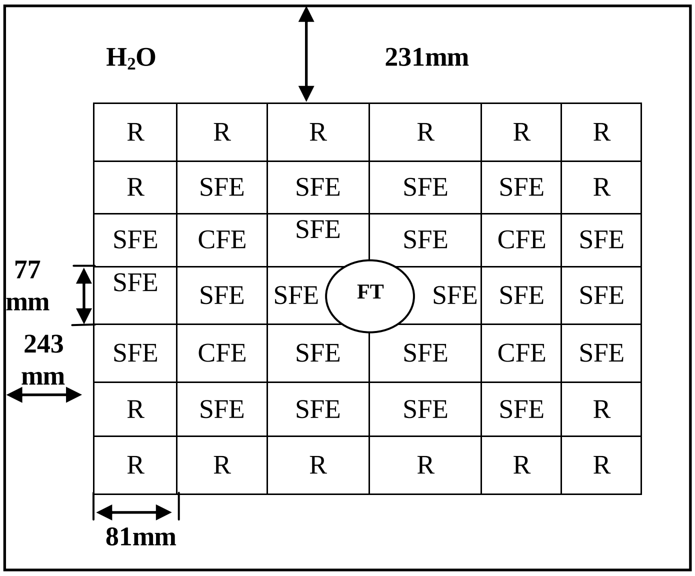
The Material Test Reactor is a pressurized, reflected, heterogeneous, open pool type, which is light water moderated and cooled. The reactor designed to operate at maximum thermal power level of (10MW). The design parameters were listed in Table (1).

Table (1)
Description of Design Parameter of the Core.

Reactor type		10MW MTR
Fuel		U – AL
Fuel Enrichment		30%
Grid Plate		6x5
Irradiation channel		One at core center
No. of shape of control rods		4
Lattice Pitch (mm)		81.0x77.1
Fuel Element Dimensions (mm)		80 x76 x 600
No. of Fuel Elements in the core		25
a- Standard Fuel Element		21
b- Constant Fuel Element		4
No. of plates in:	a-SFE	23
	b-CFE	17
Shape of plates: plates thickness (mm)	a-Inner plates	1.27
	b-Outer plates	1.50
Total width of the plate (mm)		67.1
Total length of the plate (mm)		600
Fuel meat Dimensions (mm)		63 x 0.51 x 600
Thickness of the clad (mm)	a- Inner plates	0.38
	b-Outer plates	0.495
Thickness of plates side (mm)		4.5
U^{235} Loading in:	a-SFE	260g
	b-CFE	194g
Coolant Flow Rate (m^2/h)		1000

The core

The core is assumed to contain (21) standard fuel element (SFE) and (4) control fuel element arranged in a symmetrical configuration on (6×5) grid. A flux trap has been arranged at center of the core as in Fig.(1).



**FT = Flux Trap*

Fig.(1): Reactor core assembly–2D.

Each fuel element type (U-AL) alloy contains 260g U^{235} in 23 fuel plates, which have a fuel meat dimensions (63×0.51 ×600) mm. While each control fuel element contains 194gm U^{235} in (17) fuel plates plus (6) aluminum plates forming with light water inside it the control zone as shown in Fig. (2).

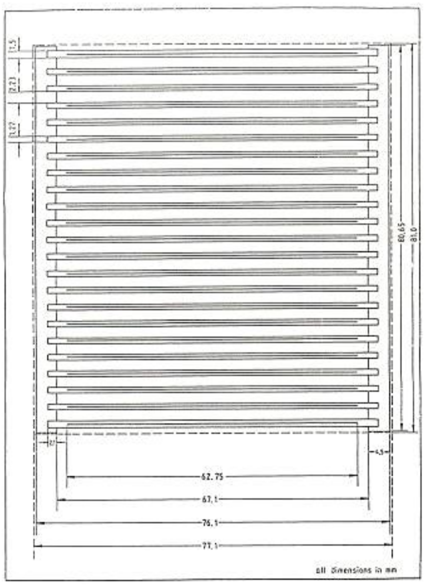


Fig. (2): A cross- section for standard fuel element (SFE).

Reflectors

The core was assumed to be reflected by single row of reflector material (graphite / Beryllium) on two opposite faces and surrounded by light water on all other sides. The advantages of using reflector are:

1- To reduce the critical volume of the core and reactor.
2- To reduce the critical mass of the fuel.
3- To flatten and improve the average neutron flux, thus increasing the excess reactivity of the core [2], Fig.(3) show imaginary cell.

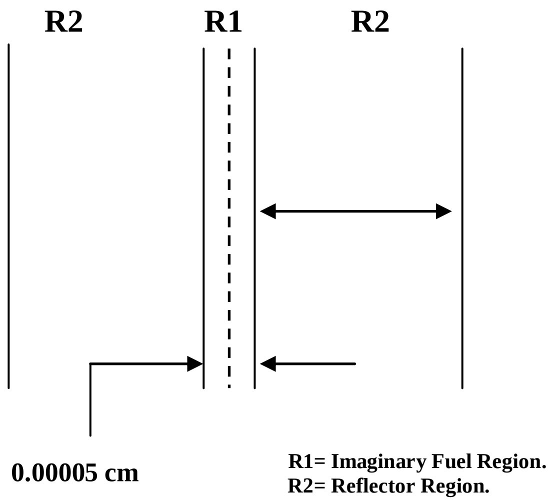


Fig.(3) : Imaginary cell for generation of reflector constants.

HEU to MEU fuel conversion

Some of the potential in this research concerns in performing a conversion include matching the performance capability of U^{235} content in fuel element having sufficient excess reactivity in order to decrease the loading in fuel plates with high peaking factors and maintaining or enhancing neutron flux in the flux trap, graphite and beryllium reflector [2].

The first technical task that required was a comparison of core excess reactivity between UAL_x dispersion HEU fuel 93% and the MEU fuel 30% as shown in Table (2). From this table we notice keff in both cases are nearly equal, i.e. keff in both cases is high enough to ensure sufficient excess reactivity with the core operating at 10MW.

Table (2)
30% and 90% fuel Enrichment comparison.

Fuel type	No. of plates	Fuel meat (cm)	U^{235} gm/cm^3	U^{235} enrich %	Keff [1]	Keff [2]
U-AL	23	0.051	2.6	30	1.170	1.005
U-AL	23	0.051	0.68	93	1.184	0.997

Keff [1]= **Fresh core.**
Keff[2] = **EOC (End Of Cycle)**

The Model Calculations

Group constants generation [3] :

Group constants for the fuel were generated by dividing reactor core into slab type unit cell with reflective boundaries. The cell was divided into three regions namely fuel meat type (U-AL) alloy, clad Al and moderators (H_2O).

Material of the side's plates and water on the either side of the side's plates were homogenized over the corresponding region.

Also we can introduce a thin imaginary fuel region in each control cell and reflector Fig.(3) to generate a group constants of each of them using Wims-D4 code which available several option for differential and integral solution of Boltzmann equation include either discrete ordinate (SN-method) or the collection probability techniques.

Two dimensional core model:

For studying the effect of different reflector material on multigroup neutron fluxes and core excess reactivities, the reactor core was reflected symmetrically on two opposite sides by one row of reflector element graphite / beryllium (followed by light water). Because of the symmetry of one core was analyzed, two dimensional four group calculations were carried out using Daixy code [4]; (Daixy compute multigroup neutron flux distribution in 2D by solving multigroup neutron diffusion equation); at x-axis = 48.6cm, y-axis = 50.5cm of the core besides to compute effective multiplication factor of the core after normalizing the flux to a power level of 10MW in the whole core.

Results and discussion

Group constant of reflector materials (graphite/beryllium) are summarized in Table (3), in addition to the distribution of four groups neutron fluxes within the core, graphite and beryllium reflector regions as shown in Fig.(4) and Fig.(5) Respectively.

Table (3)
Group constants of different reflector materials.

Material	Energy Range	Group	D(cm)	$\sum_t$ (cm^{-1})	$\nu\sum_f$	$\sum_r$ (cm^{-1})
Graphite	10MeV-821KeV	1	1.5663	2.885E-06	0.00	1.722E-02
	821KeV-5.53KeV	2	1.134	4.615E-05	0.00	3.236E-03
	5.53KeV-0.625eV	3	0.9841	6.305E-04	0.00	2.784E-04
	0.625eV - 0.00eV	4	0.9562	2.836E-04	0.00	2.294E-05
Beryllium	10MeV-821KeV	1	3.829E-01	4.733E-06	0.00	4.121E-01
	821KeV-5.53KeV	2	3.621E-01	5.535E-05	0.00	7.322E-02
	5.53KeV-0.625eV	3	5.734E-01	7.616E-04	0.00	3.675E-03
	0.625eV - 0.00eV	4	4.662E-01	4.322E-04	0.00	1.483E-04

When we make a comparison between both reflectors, we notice the following:

For graphite reflector, the excess reactivities added having slight advantage because of its higher slowing down power and moderation ratio. In other side, beryllium is best reflecting material due to higher slowing down power when compared with graphite, also average thermal neutron flux increases with slightly lower peak value in the reflector region[5]. In addition to the slowing down power for epithermal neutrons, beryllium is nearly (1.5) times better than graphite.

Conclusions

i. In the reflector region (graphite - beryllium) next to the fuel thermal flux recovers rapidly to the value in the HUE case and the flux is only the percent lower in a typical water-trap or irradiation position inside or outside the core.

ii. Reflector materials better than light water in the order of priority are beryllium and graphite. The later will need canning if it is to be used in pool-type research reactors such canning will reduce the core excess reactivity and affect the flux shape to some extent. Thus beryllium, which adds maximum excess reactivity and does not, required canning proves to be the best reflector material and could be the first choice.

iii. Although the problem associated with beryllium such as it's an availability and very high cost, which should be taken in consideration it is still the first choice.

iv. Graphite has good nuclear reflector characteristics and has been used in several researches and power reactors, as it's easily available and easy to fabricate.

v. Finally, we conclude from the above points that the beryllium is a best reflector material than graphite.

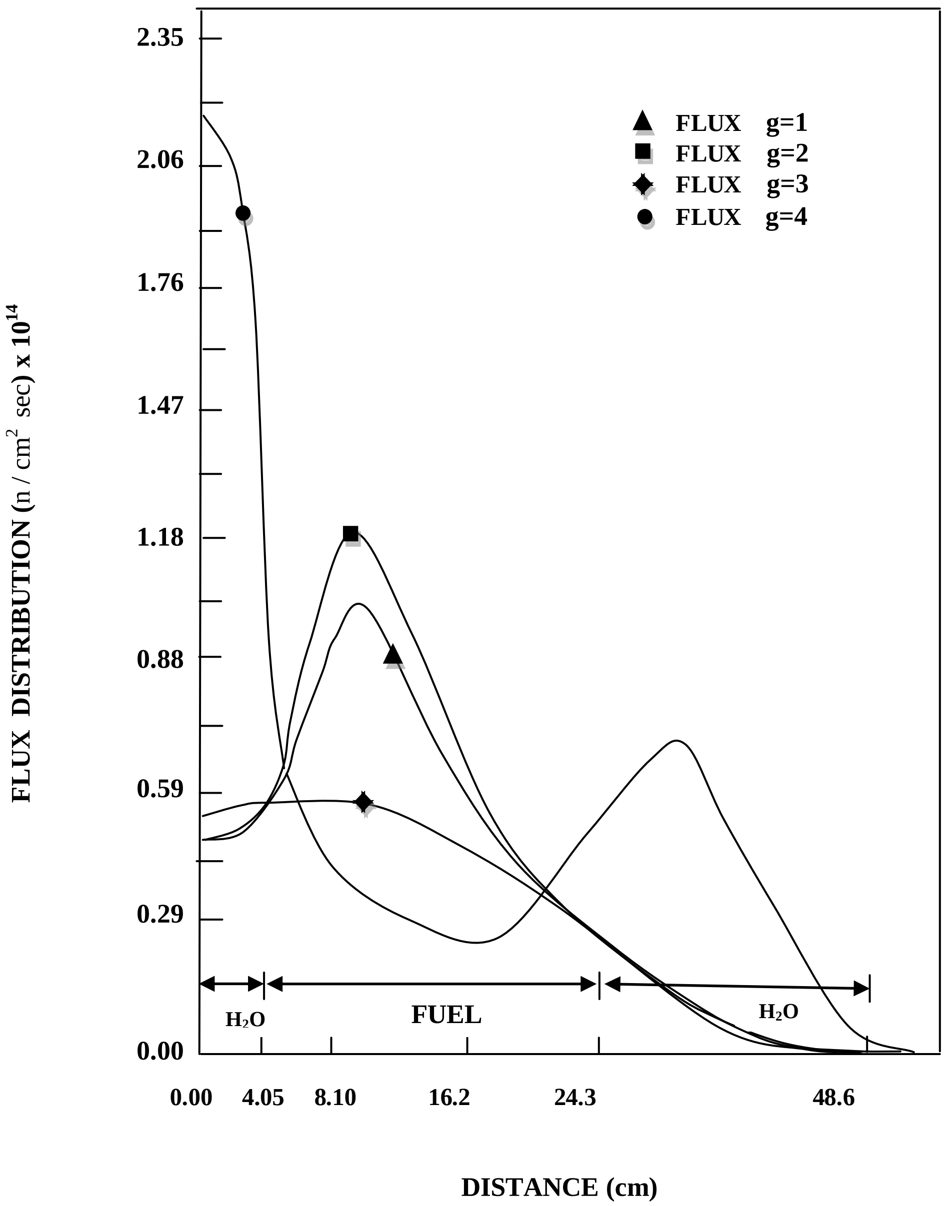


Fig. (4) : Core Reflected by Graphite.

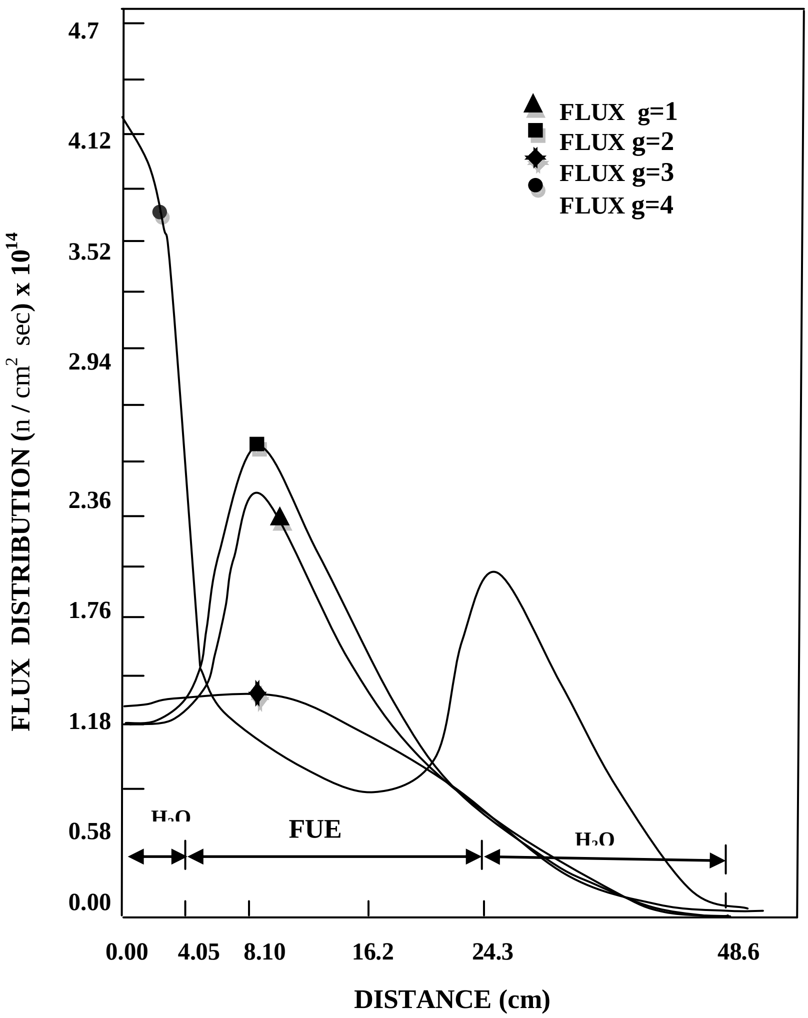


Fig. (5) : Core Reflected by Beryllium.

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الخلاصة

تم دراسة تأثير مادة العاكس (البريليوم / الكرافيت) على مفاعلية المفاعل ولمجاميع طاقية متعددة بأستخدام برامج برامج (Wims-D4و Daixy). شملت الدراسة الحسابات النيوترونية لتأثير مادة العاكس الموضوع على شكل صف واحد على جانبي المفاعل البحثي المفترض. وقد وجد ان مفاعلية المفاعل لكل من العاكسين (الكرافيتي والبريليوم) هي (14. 6%) و (16.8%) على التوالي.