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ARAB REPUBLIC OF EGYPT
ATOMIC ENERGY ESTABLISHMENT
REACTORS DEPARTMENT

STUDY AND COMPARISON OF DIFFERENT METHODS OF CONTROL IN LIGHT WATER CRITICAL FACILITY

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NUCLEAR INFORMATION DEPARTMENT
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ABSTRACT

The control of nuclear reactors, may be studied using several control methods, such as control by rod absorbers, by inserting or removing fuel rods (moderator cavities), or by changing reflector thickness. Every method has its advantage, the comparison between these differet methods and their effect on the reactivity of a reactor is the purpose of this work. A computer program is written by the authers to calculate the critical radius and worth in any case of the three precedent methods of control.

INTRODUCTION

During the design of a reactor, one of the important problems is the reactor control. For a zero power reactor, one can use it to examine the effect of the different methods of reactor control (using control rods, moderator cavities, reflector thickness variation,..... etc).

But for the design of this faility one has to make theoretical study calculating the effects of these different methods on reactivity.

1. Control using Absorbing Rods:

By the usual group method for computing the multiplication factor of a reflected reactor, the reduction in critieality factor caused by the presence of control rods can be caleulated. As a practical matter it is usually desirable to achieve the greatest reduction in criticality factor with the minimum number of control rods. [1] For this purpose, it appears advantage to place all the rods at the point near the center where the flux is maximum. On the other hand, rods placed closed will shadow each other. So, one can put one rod in the center and the others some what far to minimize the shadowing effect. In our comparison here we have used six configuration of control rods as follows:

1. One central rod
2. One eccentric rod
3. One central + one eccentric rods
4. Two eccentric rods
5. Four eccentric rods
6. One ecntral + four eccentric rods

The calculations are made using the two group diffusion theory, taking into cansideration the fictitious parameters for the control material. (2)

$$W_R \quad \frac{K-1}{K} \left[\left(\frac{R_o}{R_R} \right)^2 - 1 \right]$$ where,

The worth is calculated using the above relation

W_R control rod reactivity worth.,

K infinite multiplication factor.,

Ro critical radius for reflected core without control rods,

R_R " " " " " with " "

II. Control By Inserting Or Removing Fuel Rods.

The second method studied for reactor control is water cavities introduced by withdrawing or removal of fuel rods (baskets). Since the thermal nentron flux in a reactor core can be increased by the creation of a cavity filled with the moderting material inside the core and in the other hand some fissile material is withdrawn. As in the case of control rods, the criticality calculations are made using the two group diffusion theory for the six configurations mensioned above. In these calculations the boundary conditions ar taken as in a case between core and finite reflector, since the withdrawn baskets have thickness7.6 Cm, and the moderator is light water.

$$W_c \quad \frac{K-1}{K} \left[\left(\frac{R^o}{R_c} \right)^2 - 1 \right]$$

The reactivity worth is calculated using the above equation:

Table:2

critical radius and worth calculated for six cavities configurations

	Cavities configuration	critical core radius	worth
1.	One central	22.2562	-0.039047
2.	One eccentric	21.5949	-0.017910
3.	One central + one eccentric	22.7635	-0.053987
4.	Two symmetrical eccentric	22.1368	-0.035382
5.	Four identical	23.2304	-0.066882
6.	Four identical + one central.	24.4785	-0.097790

Table: 3

Critical radius ,worth and reflector saving For each reflector thickness

Reflector thickness	Critical core radius	Worth	Reflector
30	20.1950	-0.000057	7.29469
27	20.1999	-0.000241	7.28977
24	20.2093	-0.000593	7.28036
21	20.2316	-0.001421	7.25815
18	20.2845	-0.003384	7.20520
15	20.4098	-0.007971	7.07986
12	20.7019	-0.018336	7.78786
9	21.3558	-0.040025	6.13391
8	21.7072	-0.050878	5.78256
7	22.1469	-0.063739	5.34279
6	22.6848	-0.078466	4.80489
5	23.3241	-0.094661	4.16557
4	24.0574	-0.11167	3.43227
3	24.8663	-0.12872	2.62339
2.5	25.2910	-0.137016	2.19873
2.0	25.7242	-0.145064	1.76553
1.5	26.1628	-0.152809	1.32689
1.0	26.6045	-0.160223	0.885241
0.5	27.0475	-0.167299	0.442215
0.0	27.4897	-0.172958	0.0

Interpretation of results

The above given results for different control methods as taboleted in tables 1,2, and 3 can be interpreted as follows.

1.From table1

a) The program set up for calculation of control rods has emphasiezed the fact that the worth using a central rod is greater than that of eccentric rod.

b) The worth of one central and one eccentric rod is smaller than the sum of worth of one central and worth of one eccentric. This is due to shadowing effect (the same can be found by adding cases1 + 5 and compare with 6)

c) The shadowing effect do not appear for the case of two eccentric rods compared with twic the worth of one eccentric because the distance betwen the two rods is large (28 cm).

2. From table 2

It can be seen that the effect of water cavities on control has the same fature as in the above case of control rods with regard to shadowing and to the order of magnitude of worth for this type of fuel.

3. From table 3

This method is to control by changing the water reflector thickness.
From table 3 one can devide it into three main Parts.

a) Decreasing the reflector thickness from 30 to 1[illegible] Cm, the reactivity rate of change is very small.

b) From 15 to 8 Cm the rate of change of reactivity is very prediominat and quite enough to be used for reactor control as the worth is in the same order of two control rods.

c) From 8 to zero cm the worth increases very rapodly, so part "a" can be compared with fine regulating control rod, part "b" is comparable to manual rods and part "c" gives the function of safety rods.

4) Comparing the results given above in 1,2 and 3 we have the following:

a) The effect of withdrawal of control fuel basket of thickness 7.6 cm is slightly greater than that of a control rod of BC4 of radius 1-o5 Cm.

b) The reduction of reflector thickness from 30 to 9 cm is equivalent to the presence of a central BC4 rod, while its reduction to 8 cm is equivalent to one central and one eccentric rod or water cavities (figure 1.).

where,

W_c cavities reactivity worth,

Ro critical core radius for reflected core without cavities, and

R_c " " " " " " with cavities.

III. Control By Changing Reflector Thickness.

Changing the reflector thickness has an inportant effect on reactor criticality specially in the case of finite reflectors. The number of neutrons reflected to the core decrease by decreasing the reflector thickness i.e the flux decreases and reactivity decreases. Thus it makes the same function as obsorbers,i.e decreasing the number of neutrons. The two group diffusion theory is also used for the calculations and the retlector thickness is changed from zero to 30 Cm (infinite water reflector). The reflector saving and the worth in each case are calculated by the relations:

$$S = R_b - R_t$$

$$W_t = \frac{K-1}{K} \left[\left(\frac{R_t}{R_t} \right)^2 - 1 \right]$$

where,

S reflector saving,

W_t reactivity worth of reflector of thickness t,

R_t critical core radius for reflected core with reflector thicknesst, and

R_b critical core radius for bare reactor,

R_T " " " " reflected reactor of thickness T.

Data used"

For all the calculations, the UARR 1 core and reflector materials are taken into consideration[4], the control rods are of Boron carbide of diameter 2.1 Cm the material in cavities and reflector is light water.

Results:

The calculated critical radius and reactivity worth for each configuration of control rods re presented in table 1.

Table 2 presents the critical radius and reactirity worth in case of using water cavities with different configurations.

The reflector savings, critical redii and reactivity worths for each reflector thichness are given in table 3

Table: 1

Critical radius and worth calculated for six control rods configurations

control rods configuration	critical core radius	worth
1. One central	22.164	- 0.036226
2. One eccentric	21.5599	- 0.016600
3. One central + one eccentric	22.6643	- 0.051143
4. Two symmetrical eccentric	22.0741	- 0.033431
5. Four identical	23.1014	- 0.063345
6. Four identical + one central	24.1705	- 0.090510

CONCLUSION

The present work demonstrated the different possible ways of controling the flux in a nuclear reactor, namely by absorbers, moderator cavities and changing the reflector thickness.

On discussing the results of the effect of these methods we can withdraw the conclusion that:

a) Any of these three methods of reactor control can be used with efficiencies approximatly equivalent but dipending on the technical facilities of using each one of them.

b) Although the control rod method has the advantage of rapid control that can shutdown the reactor very rapidly, it has the disadvantage that it makes perturbation inside the reactor core.

c) Moderator cavities have the advantage that they do not make perturbations and they can be used as channels for experiments It should be pointed out that the present work consider each method of control separitly. However this work can be extended to study the case of combination of two methods or more.

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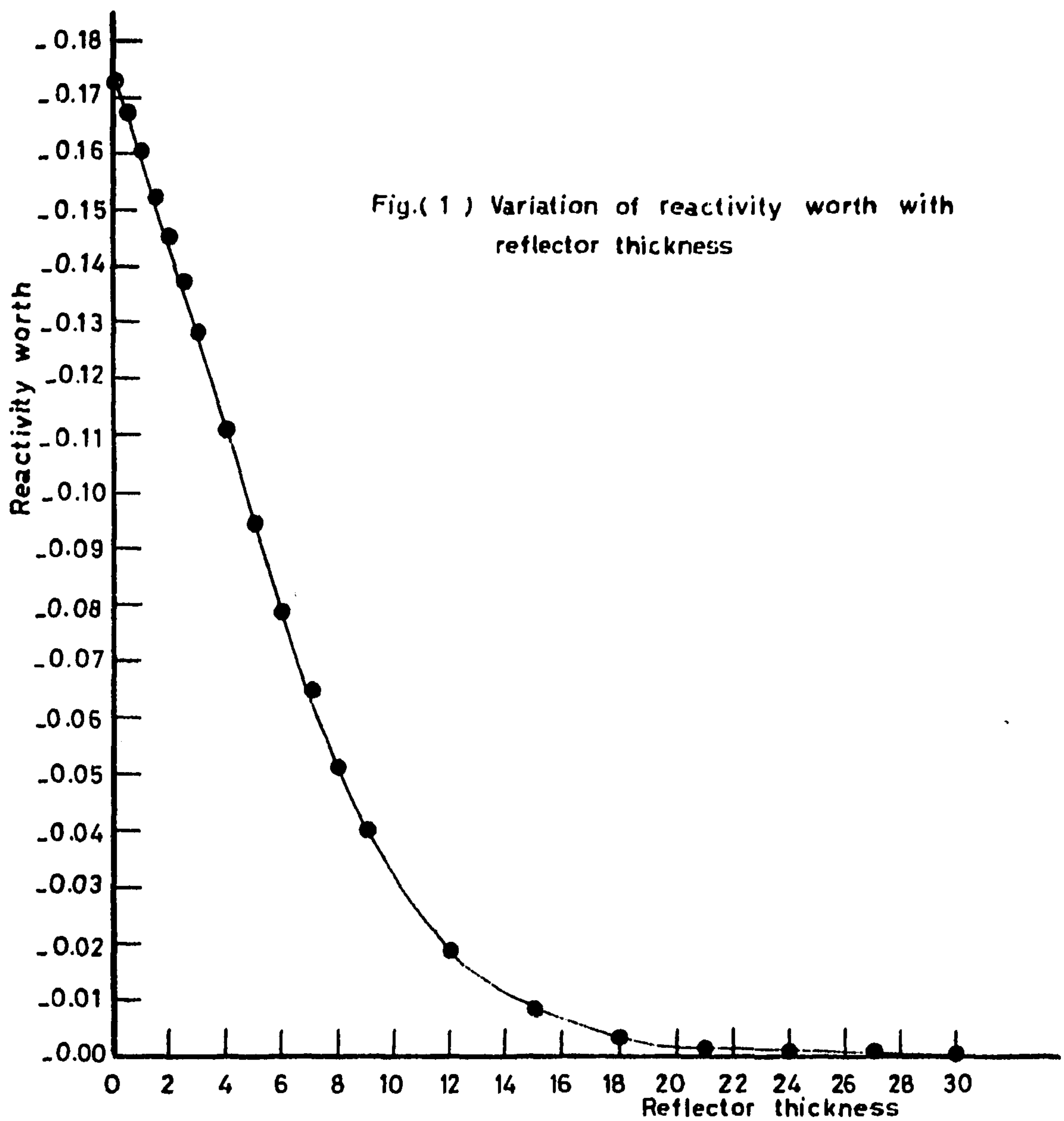

Fig.(1) Variation of reactivity worth with reflector thickness