Analysis of a neutronic computational model for the core of material testing reactor MTR by using SQUID code

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Abstract:

It is a conventional practice in the design of nuclear reactor to introduce calculation of hot points to determine spatial variation for energy generated and then determine power distribution .The study had been carried out for core of a reactor type (MTR) by the neutronic code SQUID. In this study, we replace the reflector of the reactor by H_2O instead of D_2O as originally the reactor designed .

From the study we conclude that the reactor can operates safely ,to make sure of that we calculate the multiplication factor where their values ranged from (1.0854) when all control rods are up to (1.001)when three control rods are up . Also the values of hot points were calculated and compared with French documents results with D_2O as a reflector where the difference is (0.19%),and with light water as reflector instead of heavy water was calculated . For different cases according to control rod position , the values of hot point ranged between (0.46) to (1.64) in case all control rods are up also the values of the average power distributed on different fuel cells were calculated in case of light water as reflector firstly with three control rods are down and the maximum value $(2.13*10^{-2} Mw)$ .Secondly in case of four control rods are down, the maximum value $(1.925*10^{-2} Mw)$ we notice almost coincidence between the neutron flux distribution through the core of reactor and in different positions of control rods.

Key word: Hot points, Power distribution, Multiplication factor

تحليل نموذج حسابي نيوتروني لقلب مفاعل اختبار المواد MTR باستخدام البرنامج SQUID

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الخلاصة :

أن من المناسب عند تصميم أي مفاعل نووي الأخذ بحسابات النقاط الحارة لتحديد تغيرات الطاقة المتولدة ومن ثم تحديد توزيع القدرة ، أجريت الدراسة لقلب مفاعل نوع MTR باستخدام البرنامج النيوتروني $SQUID$ ، في هذه الدراسة تم استبدال العاكس للمفاعل النووي بالماء الخفيف بدلا من الماء الثقيل الذي هو مصمم لقلب المفاعل النووي أصلا حيث تم الاستنتاج بإمكانية عمل المفاعل النووي بصورة آمنة وذلك من خلال حساب عامل التكاثر النيوتروني الذي تتراوح قيمته بين 1.0854 في حالة أعمدة السيطرة جميعها مرفوعة إلى الأعلى و 1.001 في حالة ثلاثة أعمدة سيطرة مرفوعة إلى الاعلى كذلك فان قيم النقاط الحارة قد حسبت بوجود الماء الثقيل كعاكس وقورنت مع النتائج المنشورة في الوثائق الفرنسية وكان الفرق بينهما (0.19%) ، كذلك حسبت النقاط الحارة في حالة الماء الخفيف كعاكس ولعدة حالات حسب موضع أعمدة السيطرة وكانت القيم تتراوح بين (0.46) إلى (1.64) في حالة جميع أعمدة السيطرة مرفوعة إلى الاعلى كذلك فان قيم معدل القدرة موزعة على خلايا الوقود المختلفة قد حسبت في حالة وجود الماء الخفيف كعاكس أولا في حالة أعمدة السيطرة ثلاثة منها منزلة إلى الأسفل وكانت أعظم قيمة للقدرة في $(2.13*10^{-2} Mw)$ وثانيا في حالة أعمدة السيطرة أربعة منها منزلة إلى الأسفل فان أعظم قيمة لمعدل القدرة هو $(1.925*10^{-2} Mw)$.كذلك يوجد تطابق متقارب بين توزيع الفيض النيوتروني خلال قلب المفاعل في حالتي الماء الخفيف والماء الثقيل ولعدة حالات من أعمدة السيطرة .

الكلمات المفتاحية: تصمم قلب المفاعل النووي، عامل التكاثر النيوتروني، حسابات النقاط الحارة

1. Introduction:

A great deal of effort is devoted to ensure the nuclear reactors operators safety [1] , the core thermal design is usually based on the introduction of safety factors such a hot channel and hot spot factors The fuel assembly having the maximum power output is defined as the hot assembly. The hot spot in the core in the point of maximum heat flux or linear power density, while the hot channel is defined as the coolant channel in which the hot spot occurs or along which the maximum coolant enthalpy increase occurs.

The nuclear hot channel is defined to take into account the variation of flux and fuel distribution within the core.

The radial nuclear hot channel factor is

$$F_R^N = \frac{averageheat..flux.of.hot.channel}{averageheat..flux..of.channelin..core} = \frac{\frac{1}{H}\int_{\frac{-H}{2}}^{\frac{H}{2}} q^{=}(r_{HC})dz}{\frac{1}{NC}\sum_{i=1}^{NC}\frac{1}{H}\int_{\frac{-H}{2}}^{\frac{H}{2}} q^{=}(r_i)dz}$$

defined as the following:

The Nc here is the total number of channels in core , H is channels height and $q^{=}(r)$ is the heat flux distribution.

In similar manner , the axial nuclear hot channel factor is defined as the following

$$F_Z^N = \frac{\max imum..heat.flux..of.hot..channel}{average.heat.flux.of.the.hot.channel} = \frac{\max_Z [q^{=}(r_{HC})]}{\frac{1}{H}\int_{\frac{-H}{2}}^{\frac{H}{2}} q^{=}(r_{HC})dz}$$

The total nuclear hot channel factor or nuclear heat flux is then

$$F_q^N = \frac{\max imum..heat.flux.in.the..core}{average.heat.flux..in..the.core} = F_R^N . F_Z^N$$

The nuclear hot channel must not exceeds 2.6 Such factors are in general the result of local deviations in behavior from strictly adherence to that predicted by theoretical predictions of the fuel and coolant temperatures , fuel dimensions , coolant flow , local fuel and core heat generation etc. Such deviations are due to many factors, such as flux distribution and mechanical factors. Local deviations are caused by so many factors such as non-homogeneity of fuel , the presence of structural materials , control rod position in core , non-homogeneity of moderator [2].

Our main goal in this study is to calculate the hot points power distribution, the multiplication factor and flux distribution when we replace light water instead of heavy water as reflector. The neutron flux, multiplication factor and power distribution in principle can be obtained as a solution of linear Blotzmann equation [4].

2. Description of Reactor [7]:

The MTR reactor is a research reactor for material testing with a maximum power of 0.5 MW. The maximum fast and thermal neutron fluxes are on the order of 10^{13} and $10^{14} N/cm^2.\sec$ respectively outside the core tank , one of the reactor sides accommodates light water instead of heavy water as in the design of osiris reactor as a reflector tank .

The core tank is made of zircoloy 2. The 1st load of the core contains four types of fuel elements each with enrichment 90% normally

Besides these fuel elements the core contains six control an safety elements, which consist of fuel part and a neutron – absorbing part.

The fuel part of the control elements contains 13.21 gm U235/plate and B^{10} contain 605 $\mu.gm/cm^2$. The number of fuel plates in the fuel elements is 24 and in the control elements are 20. in additions to the standard fuel elements and control elements the core tank is designed to contain such other components as Beryllium reflector elements , aluminum element and in-core water chambers as shown in fig(1).

Type of fuel element	weight of U235 per plate in gm	Boron -10 contents in $\mu.gm/cm^2$
A	16.27	580
B	13.18	440
C	11.56	440
D	9.2	0

3.Methodology:

The core under consideration is cold and clean (fresh fuel , no xenon) one .In order to perform neutronic calculation, homogenization and group constants for homogenized regions for all reactor material were made using cell computer code WIMS_D4 by Askew eta'l [8] .unit cell calculation based on wigner _seitz cell modeling i.e. lattice structure of the core were represented in form of a cylindrical super _cell . As seen in the following table ,group energy structure based on energy limits for inelastic scattering ,un-resolved resonance and neutron up-scattering was chosen as 10MeV , 0.821MeV ,5.530Kev and 0.625ev(upper energy boundaries). The 69 group library was collapsed to obtain a four – group self -shielded cross-section data set.

Group no.	Region	Upper energy level	Lower energy level
1	Fast	10Mev	0.821Mev
2	1/E	0.821Mev	5.53Mev
3	Resonance	5.53Kev	0.625ev
4	Thermal	0.625ev	0.0

Group energy structure and limits

Core calculation was made using detailed two-dimension (x, y) neutronic model for reactor has been built using the neutronic computer code SQUID [6] .

The two dimensional diffusion code SQUID is an Italian computer program which is used to calculate the neutron flux , power distribution and multiplication factor for the MTR reactor . to carry out 2-D neutronic calculation the reactor (core , tank , reflector) is represented in coordinates , each in core components fig (1) represented with the necessary detail by a zone pattern distinguishing different types of compositions .

The MTR reactor to be calculated by two dimensional diffusion code SQUID is divided into (26) homogenized regions .

These regions are given numbers for each composition , then macroscopic cross sections for the (26) composition for diffusion calculation for neutron flux and power distribution addition to multiplication factor , these factors are our goal in this study.

4.Results and Discussion :

All required group constants were generated and made available , the calculation of hot points , flux distribution, power distribution and multiplication factor were made using the neutronic 2-D diffusion SQUID code.

Table (1) and (2) represent a comparison of hot points as calculated by SQUID code and French documents result [5] with tank of reactor filled with D_2O as reflector and the difference is (0.19%) between our results and French documents which means that the 2-D diffusion SQUID code is a good computational model for the core of MTR reactor.

Table (3) represent a comparison for average power between French document and the calculated average power by SQUID code , it's ranged from (0.57) to (1.55) .

Table (4) , (5) ,(6) and (7) represent the values of hot points with the tank of the reactor filled with H_2O we can notice that the values of hot points are less than that when the reflector is D_2O ,it is more safe.

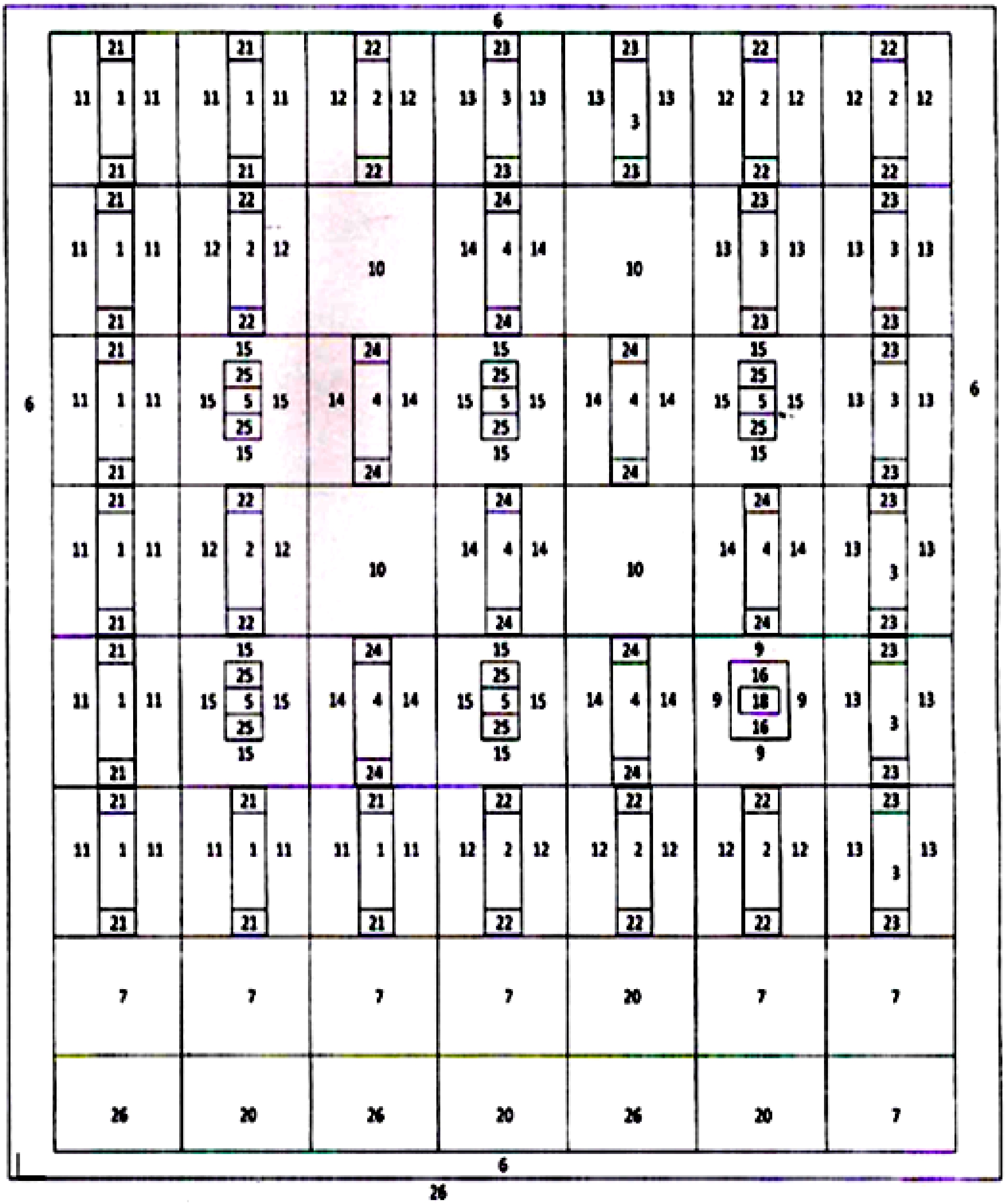

Fig (1) : Composition distribution for MTR reactor core for the computation model of SQUID code .

	7	6	5	4	3	2	1
80	0.70* 0.80 0.91 0.8532** 0.8663 0.9903 0.81 0.74 0.87 0.8809 0.803 0.9445 0.97 0.98 1.00 1.058 1.006 1.082	0.92 0.96 0.93 1.0 1.032 0.9976 0.88 0.89 0.88 0.9525 0.9603 0.9464 0.99 0.96 0.91 1.079 1.038 0.975	1.08 0.97 0.96 1.156 1.024 1.006 1.05 0.94 0.92 1.121 0.9919 0.9686 1.07 0.94 0.91 1.142 0.9993 0.9535	1.07 0.99 1.00 1.114 1.022 1.009 1.02 0.92 0.94 1.068 0.952 0.9508 1.00 0.91 0.92 1.049 0.932 0.9337	0.99 0.93 0.94 1.002 0.9202 0.9043 0.94 0.87 0.90 0.9463 0.861 0.8733 0.92 0.89 0.91 0.9014 0.8767 0.8799	0.84 0.78 0.74 0.8047 0.7262 0.6707 0.81 0.77 0.74 0.7847 0.7178 0.6715 0.82 0.77 0.76 0.7858 0.7212 0.6854	0.73 0.65 0.73 0.6589 0.5569 0.5807 0.74 0.64 0.76 0.6633 0.5449 0.6123 0.75 0.67 0.80 0.674 0.5764 0.6629
70	1.01 0.96 1.01 1.101 1.04 1.096 1.05 0.96 1.04 1.141 1.043 1.127 1.15 1.08 1.08 1.257 1.177 1.174	1.21 1.12 1.07 1.309 1.213 1.143 1.07 1.00 0.94 1.351 1.25 1.147 1.11 0.91 0.95 1.38 1.184 1.125	0 0 0 0	1.16 1.05 1.07 1.213 1.078 1.077 1.19 1.09 1.09 1.243 1.121 1.094 1.19 1.13 1.10 1.244 1.164 1.109	0 0 0 0	0.91 0.86 0.86 0.8732 0.808 0.775 0.94 0.94 0.94 0.9078 0.8759 0.8488 0.95 0.97 0.95 0.911 0.9032 0.8561	0.85 0.76 0.92 0.7663 0.6531 0.7612 0.94 0.84 1.01 0.8456 0.7293 0.8437 0.94 0.85 1.05 0.8424 0.729 0.8796
60	1.16 1.09 1.08 1.27 1.184 1.171 1.12 1.01 1.04 1.219 1.27 1.27 1.15 1.06 1.04 1.251 1.153 1.153	1.55 1.32 1.35 1.685 1.421 1.452 5 1.54 1.28 1.36 1.673 1.383 1.462 1.51 1.27 1.31 1.637 1.374 1.407	1.36 1.18 1.23 1.453 1.255 1.28 1.38 1.20 1.29 1.475 1.275 1.351 1.31 1.14 1.20 1.398 1.211 1.252	3	1.14 1.02 1.13 1.142 1.006 1.089 1.22 1.06 1.22 1.223 1.043 1.132 1.47 1.07 1.19 1.166 1.049 1.138	1	0.98 0.86 1.07 0.8729 0.7372 0.901 1.07 0.94 1.16 0.9574 0.8017 0.9763 1.05 0.95 1.18 0.9441 0.8207 1.004
50	1.13 1.05 1.04 1.235 1.139 1.123 1.02 0.91 0.96 1.116 0.9871 1.035 1.00 0.90 0.90 1.085 0.9778 0.9733	1.22 1.04 1.00 1.318 1.126 1.069 1.15 1.05 0.98 1.242 1.133 1.045 1.06 0.95 0.91 1.144 1.025 0.9631	0 0 0 0	1.16 1.13 1.14 1.206 1.154 1.135 1.13 1.08 1.14 1.179 1.105 1.141 1.12 1.12 1.17 1.16 1.145 1.161	0 0 0 0	1.17 1.18 1.22 1.121 1.099 1.999 1.22 1.22 1.32 1.167 1.134 1.189 1.16 1.24 1.33 1.206 1.259 1.21	1.04 0.97 1.20 0.9294 0.8371 1.019 1.13 1.07 1.27 1.032 0.922 1.089 1.14 1.05 1.25 1.025 0.918 1.084
40	0.97 0.88 0.88 1.053 0.9505 0.9556 0.84 0.73 0.80 0.919 0.7960 0.8661 0.80 0.74 0.80 0.8746 0.8 0.867	6	1.17 1.05 1.15 1.248 1.102 1.193 1.17 1.04 1.21 1.243 1.09 1.254 1.24 1.14 1.25 1.316 1.195 1.297	4	1.21 1.16 1.23 1.207 1.128 1.238 1.30 1.21 1.39 1.293 1.187 1.328 1.27 1.2 1.37 1.268 1.173 1.31	1.30 1.22 1.34 1.287 1.128 1.238 1.51 1.32 1.40 1.298 1.187 1.328 1.50 1.35 1.39 1.29 187.1 1.238	1.16 1.06 1.25 1.052 0.9216 1.086 1.23 1.09 1.26 1.116 0.9554 1.094 1.16 1.01 1.18 1.114 0.8839 1.024
30	0.78 0.72 0.80 0.8425 0.7832 0.8023 0.67 0.62 0.74 0.7243 0.6602 0.8023 0.67 0.74 0.89 0.7287 0.7975 0.9509	0.80 0.82 0.84 0.861 0.9716 0.8979 0.75 0.80 0.89 0.8107 0.8508 0.9445 0.90 0.99 1.1 0.9685 1.057 1.16	0.84 0.81 0.83 0.8921 0.8461 0.8598 0.9 0.9 0.9 0.9492 0.9397 0.931 1.1 1.13 1.08 1.166 1.182 1.114	0.99 0.96 0.98 1.023 0.975 0.9826 1.06 0.97 1.04 1.102 0.9932 1.037 1.25 1.11 1.10 1.288 1.13 1.183	0.97 0.95 1.06 0.9711 0.9701 1.018 1.04 1.04 1.13 1.04 1.017 1.085 1.18 1.20 1.23 1.172 1.179 1.181	1.08 1.04 1.04 1.03 0.9787 0.953 1.13 1.09 1.06 1.084 1.026 0.9661 1.24 1.17 1.14 1.191 1.093 1.038	1.15 0.99 1.16 1.045 0.8692 0.999 1.17 0.96 1.12 1.062 0.8455 0.9503 1.25 1.08 1.13 1.134 0.9353 0.9438
	Be	Be	Be	Be	HYD	Be	Be

Table (1): A comparison of hot points between our results and ref.results in case of control rods (2) and (5) are up ,with D_2O as reflector .

* Ref.results [5] .

** Our results .

	7	6	5	4	3	2	1
80	0.65* 0.66 0.76 0.6901** 0.6993 0.8006 0.68 0.62 0.73 0.7154 0.6504 0.7677 0.82 0.78 0.84 0.8656 0.8233 0.8881	0.77 0.80 0.78 0.8089 0.8381 0.8142 0.73 0.75 0.75 0.7744 0.7851 0.7804 0.84 0.82 0.78 0.8860 0.8590 0.8164	0.90 0.81 0.81 0.8089 0.8381 0.8381 0.88 0.79 0.79 0.7744 0.7851 0.7804 0.916 0.81 0.79 0.886 0.886 0.8164	0.898 0.84 0.84 0.9214 0.8491 0.8413 0.87 0.79 0.80 0.8937 0.7996 0.803 0.87 0.78 0.80 0.8929 0.7968 0.804	0.84 0.78 0.78 0.8363 0.7691 0.7564 0.79 0.74 0.76 0.7996 0.7285 0.7386 0.80 0.77 0.78 0.8032 0.7594 0.7593	0.70 0.65 0.62 0.6729 0.6606 0.5596 0.69 0.74 0.62 0.6638 0.6047 0.5647 0.70 0.77 0.64 0.6769 0.617 0.5836	0.61 0.55 0.61 0.5499 0.4648 0.4865 0.62 0.53 0.64 0.5577 0.4576 0.5168 0.63 0.57 0.68 0.5737 0.49 0.5654
70	0.85 0.81 0.86 0.9043 0.8537 0.9035 0.89 0.81 0.99 0.9472 0.8667 0.9427 1.00 0.94 0.95 1.06 0.9962 1.001	1.02 0.96 0.92 1.079 1.007 .9633 1.07 1.00 0.94 1.131 1.057 0.9055 1.11 0.91 0.95 1.176 1.024 0.9887	0 0 0 0	1.01 0.91 0.93 1.04 0.9273 0.9352 1.06 0.97 0.98 1.091 0.9916 .9767 1.10 1.05 1.02 1.132 1.074 1.028	0 0 0 0	0.78 0.74 0.73 0.7582 0.6949 0.6636 0.83 0.82 0.81 0.8078 0.7701 0.7404 0.87 0.81 0.84 0.836 0.8151 0.7687	0.72 0.64 0.78 0.6557 0.5575 0.6525 0.81 0.72 0.88 0.7379 0.6247 0.735 0.83 0.75 0.92 0.7555 0.6488 0.7818
60	1.01 0.95 0.95 1.076 1.007 1.006 0.99 0.89 0.94 1.005 0.9505 0.9699 1.04 0.96 0.91 1.1 1.023 1.021	1.38 1.18 1.23 1.455 1.241 1.292 1.39 1.72 1.473 1.239 1.342 1.39 1.21 1.43 1.475 1.27 1.337	1.23 1.08 1.15 1.209 1.132 1.186 1.29 1.16 1.28 1.36 1.208 1.317 1.29 1.17 1.27 1.356 1.226 1.318	3	1.07 1.05 1.05 1.074 0.9404 1.012 1.021 1.12 1.17 1.223 1.034 1.134 1.42 1.05 1.21 1.249 1.113 1.173	1	0.87 0.76 0.95 0.7899 0.6611 0.8069 0.98 0.84 1.04 0.8961 0.7382 0.8935 0.99 0.88 1.08 0.9114 0.7776 0.9399
50	1.03 0.96 0.96 1.093 1.017 1.021 0.95 0.85 0.92 1.007 0.9023 0.9699 0.94 0.87 0.89 1.003 0.9196 0.9393	1.13 1.00 1.00 1.199 1.056 1.05 1.09 1.04 1.03 1.163 1.103 1.08 1.05 0.98 1.00 1.108 1.042 1.043	0 0 0 0	1.25 1.23 1.23 1.289 1.259 1.244 1.03 1.28 1.32 1.348 1.315 1.333 1.36 1.34 1.41 1.401 1.372 1.42	0 0 0 0	1.19 1.16 1.16 1.168 1.101 1.073 1.29 1.24 1.28 1.267 1.173 1.189 1.37 1.29 1.33 1.343 1.231 1.239	0.98 0.90 1.10 0.9047 0.7987 0.9617 1.10 1.00 1.12 1.017 0.8987 1.046 1.13 1.02 1.19 1.046 0.9136 1.060
40	0.92 0.85 0.88 0.981 0.9008 0.9331 0.82 0.73 0.82 0.8746 0.7739 0.8726 0.80 0.75 0.85 0.8519 0.7995 0.8985	6	1.31 1.24 1.40 1.371 1.291 1.444 1.36 1.30 1.52 1.422 1.358 1.576 1.48 1.44 1.62 1.549 1.509 1.676+	1.40 1.33 1.45 1.448 1.361 1.475 1.51 4 1.57 1.56 1.455 1.594 1.55 1.45 1.57 1.604 1.495 1.598	1.46 1.35 1.42 1.474 1.345 1.397 1.60 1.47 1.55 1.62 1.469 1.525 1.60 1.46 1.55 1.627 1.46 1.523	1.41 1.29 1.34 1.378 1.218 1.265 1.51 2 1.42 1.489 1.286 1.338 1.50 1.35 1.39 1.474 1.211 1.311	1.16 1.02 1.19 1.081 0.9215 1.068 1.24 1.07 1.22 1.161 0.9668 1.087 1.19 1.0 1.15 1.114 0.9055 1.03
30	0.78 0.74 0.70 0.8266 0.7876 0.8972 0.68 0.64 0.80 0.7224 0.6848 0.8498 0.70 0.76 0.97 0.7415 0.8399 1.025	0.85 0.92 1.00 0.9015 0.9716 1.052 0.81 0.89 1.05 0.8619 0.9402 1.111 0.91 1.13 1.29 1.049 1.19 1.364	1.00 1.31 1.01 1.054 1.067 1.129 1.31 1.13 1.17 1.122 1.175 1.218 1.02 1.37 1.36 1.378 1.456 1.417	1.30 1.21 1.26 1.345 1.245 1.282 1.39 1.29 1.33 1.446 1.324 1.351 1.59 1.41 1.47 1.642 1.452 1.495	1.25 1.15 1.20 1.265 1.155 1.185 1.33 1.25 1.27 1.349 1.251 1.258 1.46 1.34 1.39 1.479 1.433 1.375	1.21 1.11 1.07 1.191 1.075 1.009 1.27 1.16 1.08 1.252 1.128 1.026 1.39 1.25 1.19 1.374 1.211 1.114	1.18 0.98 1.13 1.102 0.8926 1.008 1.20 0.96 1.10 1.124 0.8728 0.9649 1.29 1.11 1.12 1.212 0.9771 0.969
	Be	Be	Be	Be	HYD	Be	Be

Table (2) : Comparison of hot points between our results and ref.results in case of three control rods up , with D_2O as reflector .

* Ref.results [5] .

** Our results

7	6	5	4	3	2	1
1.96%* 1.88%** 0.69	2.24% 2.28% 0.76	2.30% 2.53% 0.81	2.37% 2.59% 0.81	2.23% 2.40% 0.81	1.90% 2.08% 0.65	1.66% 1.67% 0.57
2.50% 2.42% 0.88	2.92% 3.01% 0.69	0 0 0 0 10	2.89% 3.18% 0.99	0 0 0 0 10	2.38% 2.61% 0.81	2.20% 2.51% 0.75
2.73% 2.6% 0.98	2.51% 2.54% 1.22	3.47% 3.63% 1.18	3 19 ABS	3.16% 3.38% 1.07	1 ABS	2.59% 2.51% 0.88
2.61% 2.46% 0.95	3.04% 3.05% 1.04	0 0 0 0 10	3.79% 3.94% 1.29	0 0 0 0 10	3.63% 3.66% 1.24	3.03% 2.84% 1.03
2.27% 2.11% 0.85	6 ABS11	3.95% 3.97% 1.55	2.96% 2.90% 4 1.44	4.33% 4.47% 1.48	2.79% 2.74% 2 1.36	3.22% 2.97% 1.10
2.07% 1.92% 0.81	2.77% 2.60% 0.95	3.37% 3.32% 1.15	3.86% 3.78% 1.32	3.74% 3.58% 1.27	3.45% 3.92% 1.18	3.04% 2.77% 1.04

Table (3) : Comparison for the average power between ref.results and our results in case of of control rods (3) and (6) are down with D_2O as reflector .

* Ref.results [5] .

** Our results .

	7	6	5	4	3	2	1
80	0.462 0.48 0.578 0.493 0.47 0.58 0.618 0.608 0.694	0.588 0.636 0.65 0.588 0.629 0.662 0.695 0.715 0.727	0.757 0.715 0.738 0.778 0.742 0.766 0.85 0.806 0.812	0.814 0.784 0.803 0.847 0.793 0.823 0.897 0.842 0.882	0.8 0.753 0.75 0.82 0.768 0.784 0.885 0.857 0.860	0.67 0.609 0.562 0.707 0.646 0.598 0.769 0.699 0.651	0.55 0.46 0.47 0.589 0.478 0.51 0.639 0.531 0.576
70	0.65 0.64 0.714 0.698 0.66 0.771 0.813 0.792 0.849	0.84 0.835 0.862 0.91 0.915 0.924 0.984 0.92 0.95	MOCK-UP	1.06 0.997 1.05 1.166 1.14 1.16 1.25 1.22 1.25	MOCK-UP	0.877 0.799 0.750 0.982 0.938 0.88 1.086 0.974 0.931	0.735 0.75 0.84 0.869 0.708 0.756 0.91 0.753 0.819
60	0.834 0.81 0.866 0.842 0.796 0.888 0.925 0.901 0.961	1.25 1.13 1.246 C.R.5 1.31 1.095 1.33 1.37 1.24 1.37	1.257 1.194 1.3 1.36 1.32 1.65 1.41 1.35 1.46	1.37 1.31 1.22 C_R3 1.43 1.33 1.43 1.43 1.34 1.43	1.3 1.19 1.24 1.45 1.32 1.36 1.45 1.33 1.35	1.23 1.175 1.096 C_R1 1.32 1.18 1.21 1.31 1.15 1.175	0.996 0.769 0.841 1.02 0.846 0.904 1.008 0.85 0.925
50	0.936 0.908 0.976 0.898 0.857 0.986 0.94 0.924 0.99	1.42 1.3 1.44 1.396 1.274 1.47 1.43 1.36 1.59	MOCK-UP	1.45 1.398 1.53 1.49 1.46 1.47 1.49 1.44 1.47	MOCK-UP	1.34 1.203 1.19 1.37 1.248 1.23 1.35 1.21 1.19	0.998 0.851 0.932 1.05 0.89 0.951 0.996 0.846 0.923
40	0.935 0.92 0.99 0.854 0.83 0.95 0.847 0.856 0.986	1.42 1.3 1.44 CR6 1.396 1.274 1.47 1.43 1.36 1.59	1.48 1.41 1.52 1.51 1.46 1.59 1.63 1.56 1.64	1.51 1.398 1.44 CR4 1.57 1.43 1.52 1.56 1.41 1.47	1.49 1.35 1.27 1.54 1.37 1.39 1.48 1.30 1.323	1.33 1.16 1.05 CR 1.35 1.16 0.84 1.29 1.12 0.91	1.006 0.96 1.05 1.02 0.832 0.881 0.933 0.749 0.881
30	0.825 0.84 0.99 0.71 0.72 0.93 0.72 0.842 1.065	0.99 1.03 1.13 0.94 1.03 1.17 1.09 1.23 1.38	1.13 1.1 1.11 1.175 1.172 1.164 1.39 1.41 1.33	1.3 1.164 1.16 1.194 1.202 1.199 1.54 1.34 1.42	1.143 1.02 1.022 1.194 1.08 1.058 1.39 1.36 1.23	1.022 0.911 0.842 1.05 0.922 .827 1.22 0.999 .89	0.912 0.732 0.789 0.901 0.697 0.735 0.97 0.77 0.744

Table (4) : Represent values of hot points in case of all control rods are up with H_2O as reflector

	7	6	5	4	3	2	1
80	0.48 0.51 0.62 0.51 0.49 0.61 0.63 0.62 0.72	0.63 0.68 0.71 0.62 0.67 0.71 0.72 075 0.77	082 0.79 0.82 0.84 0.81 0.85 0.90 0.86 0.89	0.92 0.885 0.92 0.94 0.89 0.94 0.98 0.94 0.996	0.92 0.87 0.88 0.94 0.89 0.92 1.0 0. 0.997 98	0.79 0.72 0.67 0.83 0.76 0.71 0.89 0.82 0.77	0.66 0.55 0.57 0.70 0.57 0.61 0.76 0.63 0.69
70	0.65 0.65 0.73 0.68 0.66 0.77 0.77 0.76 0.83	0.87 0.87 0.91 0.92 0.93 0.95 0.96 0.91 0.96	MOCK-UP	1.15 1.10 1.18 1.25 1.25 1.3 1.32 1.31 1.38	MOCK-UP	1.02 0.94 0.89 1.13 1.09 1.04 1.19 1.13 1.09	1.02 0.75 0.84 1.13 0.88 0.95 1.19 1.31 1.09
60	0.78 0.77 0.83 0.75 0.72 0.82 0.789 0.77 0.835	1.19 1.097 1.22 C_R 5 1.305 1.2 1.27 1.202 1.109 1.25	1.26 1.22 1.36 1.31 1.308 1.48 1.29 1.28 1.44	1.37 .43 1.31 C_R3 1.47 1.4 1.54 1.44 1.38 1.52	1.48 1.33 1.42 1.57 1.46 1.53 1.55 1.45 1.51	1.41 1.3 1.26 C_R1 1.496 1.32 1.38 1.47 1.31 1.36	1.098 0.91 0.99 1.19 0.99 1.06 1.17 0.98 1.08
50	0.784 0.765 0.83 0.709 0.67 0.77 0.703 0.673 0.739	0.96 0.92 0.915 0.918 0.946 1.004 0.862 0.832 0.938	MOCK-UP	1.424 1.432 1.53 1.42 1.47 1.54 1.39 1.41 1.51	MOCK-UP	1.49 1.36 1.326 1.51 1.47 1.325 1.47 1.34 1.35	1.15 0.99 1.09 1.28 1.028 1.104 1.13 0.97 1.06
40	0.684 0.657 0.73 0.597 0.556 0.679 0.577 0.567 0.676	C_R 6	1.22 1.21 1.36 1.26 1.208 1.43 1.26 1.27 1.46	1.4 1.36 1.499 C_R 4 1.48 1.37 1.524 1.41 1.34 1.46	1.53 1.45 1.49 1.55 1.44 1.50 1.48 1.35 1.42	1.46 1.29 1.426 C_R 2 1.466 1.28 1.325 1.39 1.23 1.244	1.14 0.96 1.05 1.44 0.95 1.06 1.05 0.85 0.93
30	0.559 0.556 0.669 0.478 0.48 0.624 0.490 0.578 0.746	0.672 0.769 0.856 0.634 0.73 0.881 0.767 0.897 1.063	0.863 0.9 0.985 0.89 0.96 1.025 1.08 1.17 1.17	1.16 1.18 1.24 1.21 1.24 1.31 1.36 1.38 1.54	1.14 1.06 1.095 1.18 1.12 1.127 1.37 1.395 1.296	1.08 0.998 0.94 1.097 1.007 0.92 1.24 1.076 0.98	1.02 0.83 0.898 1.001 0.78 0.83 1.06 0.86 0.84

Table (5) : Represent values of hot points in case of control rod (6) is down with H_2O as reflector .

	7	6	5	4	3	2	1
80	0.478 0.498 0.595 0.50 0.48 0.59 0.622 0.61 0.695	0.604 0.65 0.66 0.599 0.634 0.66 0.69 0.70 0.7	0.769 0.725 0.752 0.77 0.733 0.758 0.82 0.77 0.77	0.836 0.813 0.851 0.84 0.799 0.852 0.85 0.82 0.88	0.851 0.925 0.849 0.853 0.828 0.88 0.80 0.898 0.945	0.764 0.714 0.677 0.796 0.757 0.72 0.85 0.81 0.78	0.67 0.57 0.59 0.715 0.59 0.64 0.77 0.66 0.72
70	0.65 0.64 0.708 0.68 0.65 0.75 0.77 0.75 0.796	0.835 0.816 0.822 0.88 0.87 0.85 0.919 0.845 0.85		0.99 0.95 1.04 1.05 1.03 0.99 1.096 1.14 1.18		0.96 0.92 0.90 1.06 1.08 1.06 1.12 1.112 1.113	0.888 0.75 0.84 1.05 0.88 0.95 1.09 0.93 1.03
60	0.78 0.76 0.802 0.76 0.72 0.79 0.803 0.77 0.818	1.02 1.15 C_R 1.01 5 1.16 1.07 1.15 1.17 1.05 1.15	1.11 1.03 1.14 1.17 1.11 1.29 1.18 1.12 1.26	C_R 3	1.23 1.18 1.33 1.4 1.3 1.46 1.39 1.34 1.46	1.34 1.25 1.33 C_R 1 1.44 1.3 1.42 1.44 1.33 1.41	1.12 0.95 1.06 1.23 1.05 1.14 1.22 1.05 1.17
50	0.799 0.769 0.817 0.734 0.686 0.778 0.737 0.699 0.755	0.945 0.879 0.915 0.921 0.924 0.95 0.879 0.884 0.917		1.24 1.3 1.37 1.29 1.33 1.44 1.33 1.43 1.48		1.46 1.39 1.44 1.51 1.47 1.51 1.52 1.44 1.47	1.21 1.06 1.18 1.28 1.12 1.22 1.24 1.07 1.109
40	0.72 0.686 0.753 0.64 0.59 0.716 0.627 0.615 0.728	C_R 6	1.2 1.18 1.36 1.26 1.24 1.47 1.34 1.35 1.54	1.38 1.34 1.499 C_R 4 1.46 1.41 1.578 1.49 1.42 1.55	1.52 1.45 1.559 1.6 1.54 1.62 1.59 1.528 1.57	1.532 1.39 1.45 C_R 2 1.58 1.41 1.47 1.51 1.37 1.4	1.25 1.067 1.18 1.28 1.07 1.15 1.18 0.967 1.06
30	0.6099 0.606 0.87 0.529 0.533 0.828 0.546 0.644 0.953	0.729 0.83 0.92 0.699 0.8 0.96 0.85 0.99 1.17	0.92 0.966 1.05 0.975 1.05 1.12 1.190 1.29 1.29	1.24 1.18 1.34 1.32 1.34 1.38 1.5 1.38 1.54	1.23 1.16 1.21 1.31 1.24 1.27 1.53 1.57 1.48	1.22 1.12 1.07 1.27 1.15 1.05 1.47 1.24 1.13	1.16 0.95 1.03 1.15 0.907 0.964 1.23 0.99 0.97

Table (6) : Represent values of hot points in case of control rods (3) and (6) are down , with H_2O as reflector .

	7	6	5	4	3	2	1
80	0.57 0.58 0.69 0.599 0.57 0.69 0.74 0.73 0.811	0.699 0.74 0.73 0.698 0.72 0.735 0.81 0.806 0.78	0.85 0.78 0.78 0.86 0.79 0.78 0.91 0.824 0.799	0.859 0.799 0.799 0.865 0.78 0.79 0.878 0.796 0.808	0.79 0.74 0.72 0.78 0.725 0.733 0.807 0.758 0.768	0.65 0.58 0.76 0.66 0.604 0.78 0.687 0.627 0.59	0.53 0.45 0.46 0.55 0.454 0.485 0.581 0.49 0.538
70	0.777 0.75 0.83 0.816 0.77 0.88 0.923 0.89 0.93	0.975 0.935 0.916 1.03 1.00 0.95 1.08 0.974 0.958	MOCK-UP	1.025 0.928 0.94 1.08 1.001 0.99 1.13 1.10 1.05	MOCK-UP	0.769 0.707 0.671 0.827 0.791 0.754 0.86 0.85 0.788	0.659 0.56 0.62 0.746 0.628 0.694 0.77 0.655 0.748
60	0.937 0.902 0.942 0.915 0.857 0.934 0.967 0.926 0.966	1.35 1.18 1.25 C_R5 1.37 [illegible] 1.31 1.38 1.22 1.31	1.249 1.12 1.18 1.33 1.21 1.34 1.33 1.23 1.33	C_R 3	1.20 1.16 1.33 1.34 1.27 1.45 1.34 1.29 1.45	C_R 1	0.803 0.669 0.77 0.93 0.75 0.85 0.937 0.79 0.905
50	0.964 0.921 0.966 0.887 0.823 0.924 0.892 0.84 0.898	1.12 1.02 1.04 1.09 1.077 1.078 0.87 1.033 1.047	MOCK-UP	1.32 1.31 1.29 1.38 1.367 1.39 1.44 1.43 1.48	MOCK-UP	1.22 1.16 1.11 1.327 1.23 1.237 1.407 1.29 1.29	0.933 0.815 0.928 1.05 0.919 1.004 1.085 0.937 1.03
40	0.873 0.83 0.895 0.777 0.717 0.856 0.763 0.744 0.872	C_R 6	1.37 1.32 1.485 1.452 1.402 1.62 1.56 1.54 1.72	1.408 1.42 1.42 C_R 1.609 1.519 1.658 1.653 1.55 1.60	1.535 1.412 1.459 1.684 1.54 1.589 1.69 1.528 1.585	1.443 1.278 1.32 C_R 1.548 1.348 1.39 1.535 1.354 1.38	1.12 0.945 1.36 1.199 0.994 1.05 1.15 1.05 1.005
30	0.742 0.734 0.87 0.645 0.647 0.828 0.664 0.778 0.993	0.874 0.982 1.07 0.841 0.951 1.13 1.019 1.179 1.377	1.076 1.107 1.182 1.142 1.211 1.289 1.392 1.486 1.471	1.39 1.287 1.337 1.49 1.378 1.42 1.708 1.545 1.696	1.32 1.213 1.239 1.42 1.323 1.323 1.68 1.686 1.558	1.242 1.122 1.05 1.317 1.174 1.064 1.55 1.288 1.16	1.138 0.920 0.998 1.159 0.904 0.946 1.259 1.008 0.971

Table (7) : Represent values of hot points in case of control rods (1) , (3) and (6) are down , with H_2O as reflector .

Table (8) gives the values of multiplication factor for four cases and these values ranged from (1.0854) when all control rods are up to (1.001) when control rods (1,3,6) are down , these values gives an indication that the reactor operates safely with (H_2O) as reflector .

Control rod situation	Multiplication factor
All control rods are up	1.0854
Control rod (6) down	1.059636
Control rods (3) and (6) down	1.02487
Control rods (1) , (3) and (6) down	1.001

Table (8) : Represent values of multiplication factor vs control rod situation .

table (9) represent the power distribution and it's percent on fuel rods ranged from (1.81%) to (4.58%) and the power ranged from ($0.7 * 10^{-2} Mw$) to ($2.29 * 10^{-2} Mw$) when control rod (1) , (3) and (6) down .

Table (10) represent the values of power distribution and it's percent on fuel rods when control rods (1),(3),(4) and (6) are down, the values ranged from ($1.02*10^{-2} Mw$) to ($1.955*10^{-2} Mw$) and the power percent from (1.76%) to (3.91%) and from these values we conclude that reactor operates safely if we replace the reflector of the reactor by H_2O instead of D_2O as reflector .

Fig (2) represent the flux distribution in case all control rods are up .

Fig (3) represent the flux distribution in case control rods (3) and (6) are down .

Fig (4) represent the flux distribution in case control rods (1) , (3) and (6) are down

5.Conclusion:

From the above tables (4,5,6)were H_2O is a reflector we notice clearly that values of hot points are less than the hot points of and figures for the hot points in case of D_2O as reflector and the multiplication factor is in critical state in different situation of control rods also we can say that the reactor can operate safely if we replace the reflector of the reactor by H_2O instead of D_2O. Also the computational model for the core carried out by the SQUID code is efficient .

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Lattice No.	P%	Power(MW)*10^{-2}
87	1.81	0.905
77	2.36	1.8
67	2.61	1.305
57	2.53	1.265
47	2.25	1.125
37	2.09	1.045
86	2.14	1.07
76	2.87	1.435
66	2.52	1.26
56	3.11	1.555
46	-	-
36	2.96	1.48
85	2.34	1.17
65	3.6	1.8
55	-	-
45	4.26	2.13
35	3.66	1.83
84	2.33	1.165
74	2.96	1.48
54	4.03	2.015
44	3.18	1.59
34	4.13	2.065
83	2.17	000
63	3.26	000
54	-	-
43	4.58	2.29
33	3.84	1.92
82	1.77	0.885
72	2.29	1.145
62	-	-
52	3.65	1.825
42	2.84	1.42
32	3.5	1.72
81	1.4	0.7
71	1.91	0.955
61	2.31	1.155
51	2.78	1.39
41	3.03	1.515
31	2.91	1.455

Table (9) : Represent power distribution and its percent on fuel rods when control rod (1) , (3) and (6) are down , with H_2O as reflector .

Lattice No.	P%	Power(MW)*10^{-2}
87	2.26	1.13
77	2.87	1.435
67	3.03	1.515
57	2.77	1.385
47	2.31	1.155
37	2.31	1.02
86	2.67	1.335
76	3.44	1.72
66	2.84	1.42
56	3.20	1. 6
36	2.66	1.33
85	2.88	1.44
65	3.85	1.925
55	-	-
45	3.53	1.765
35	2.99	1.495
84	2.86	1.43
74	3.43	1.715
64	-	-
54	3.54	1.77
34	3.26	1.63
83	2.67	1.335
63	3.41	1.705
53	-	-
43	3.91	1.955
33	3.25	1.625
82	2.2	1.1
72	2.72	1.36
52	3.68	1.84
42	2.73	1.365
32	3.3	1.65
81	1.76	0.88
71	2.31	1.155
61	2.63	1.314
51	2.98	1.49
41	3.12	1.56
31	2.93	1.465

Table (10) : Represent power distribution and its percent on fuel rods when control rod (1) , (3) , (4) and (6) are down , with H_2O as reflector .

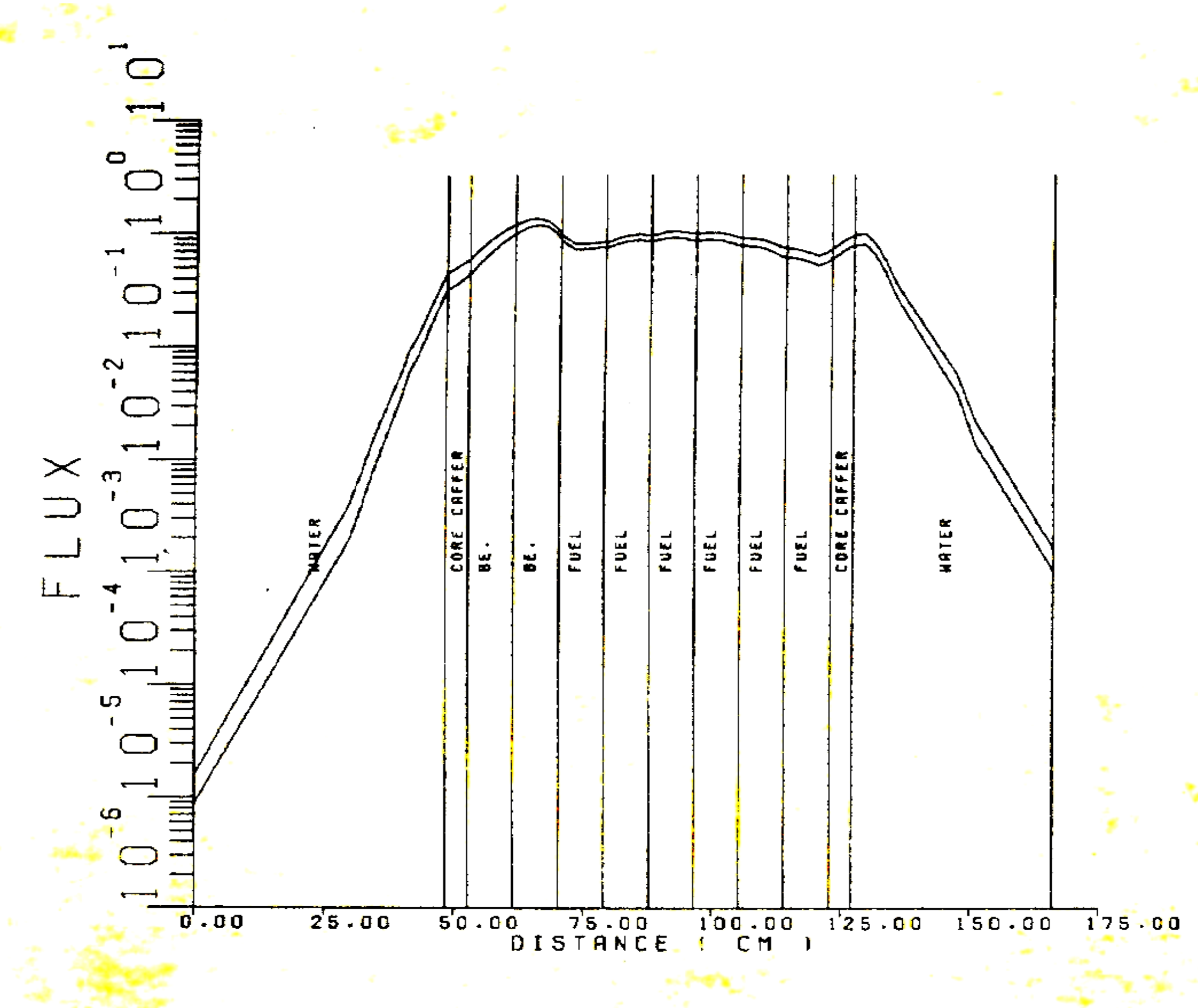

Fig (2) : Relation between thermal flux and distance in case of D_2O or H_2O as reflector in case all control rods are up .

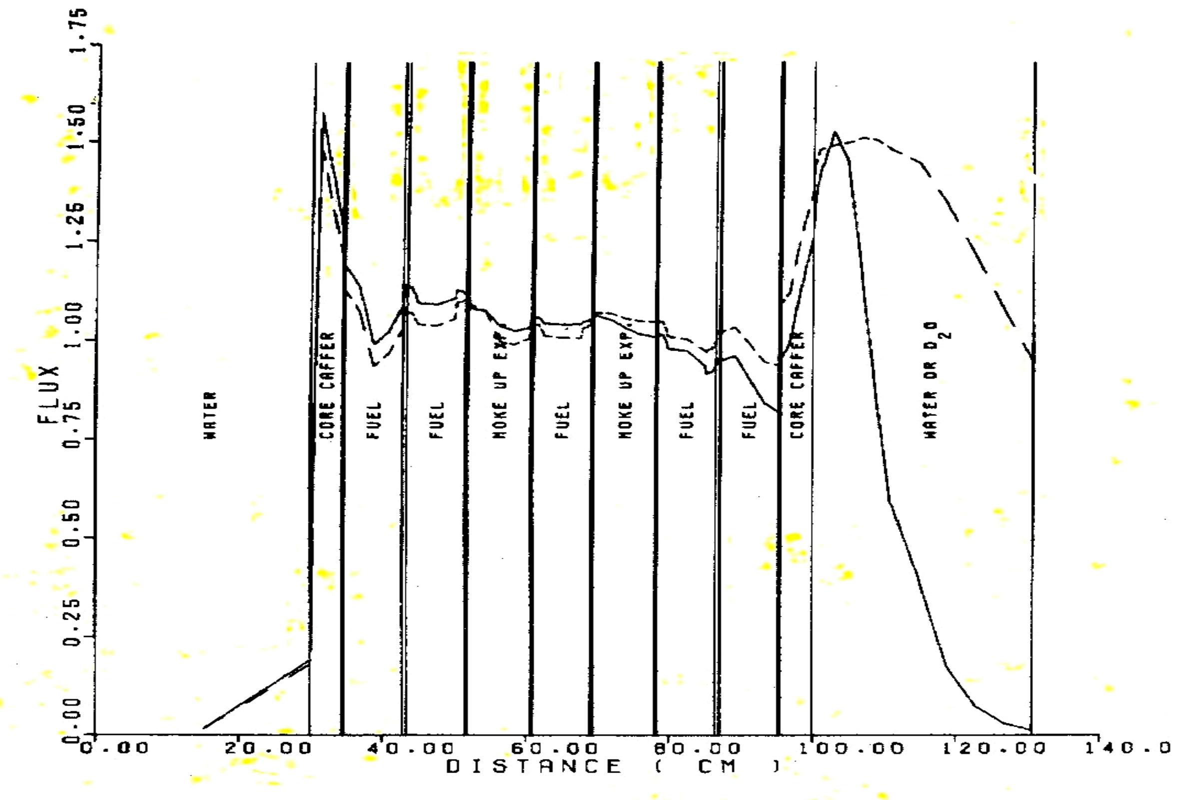

Fig (3) : Relation between thermal flux and distance in case of control rods (3) and (6) down , with D_2O or H_2O as reflector .

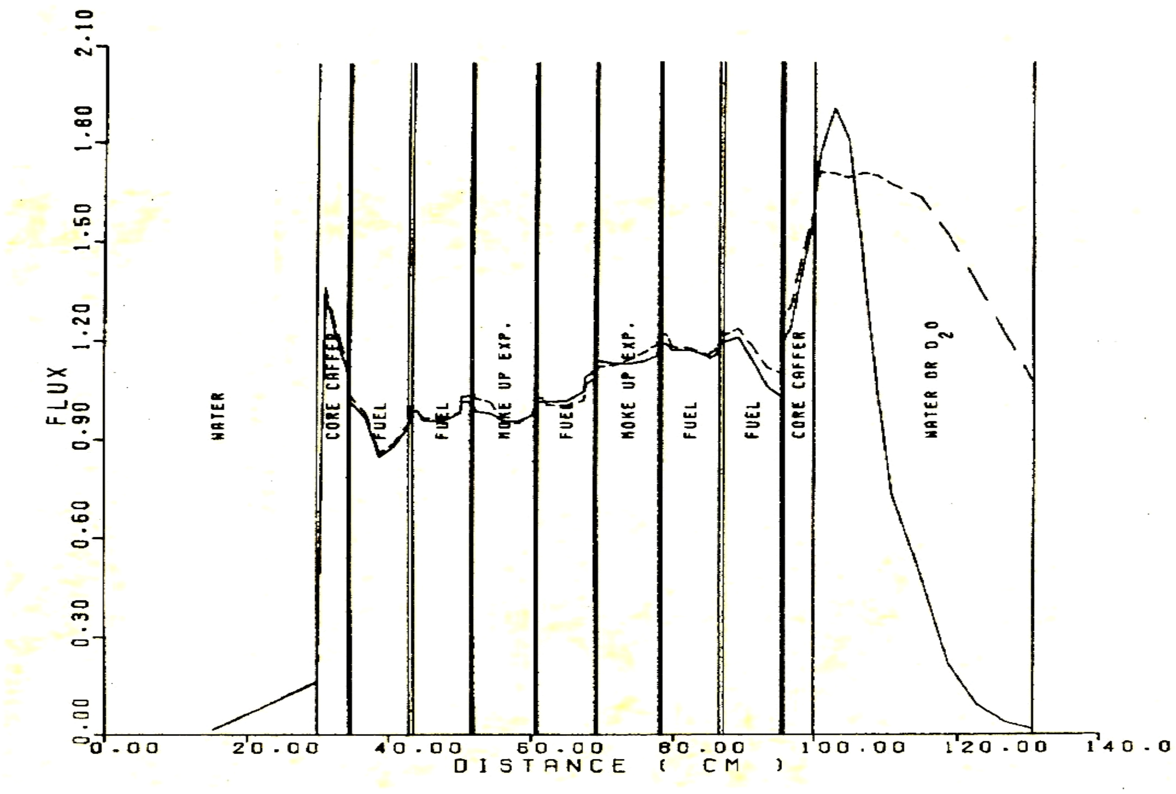

Fig (4) : Relation between thermal flux and distance in case of control rods (1) , (3) and (6) down , with D_2O or H_2O as reflector

No of composition	composition
1	9.2gm U253/fuel plate fuel type4
2	11.56gm U253/fuel plate fuel type3
3	13.18gm U253/fuel plate fuel type2
4	16.27gm U253/fuel plate fuel type1
5	13.21gm U253/fuel plate fuel of control role
6	Coffer of reactor core
7	Beryllium reflector
9	Outside region of control rod
10	Mock up experiment
11	Outside region –fuel type4
12	Outside region fuel type3
13	Outside region fuel type2
14	Outside region fuel type1
15	Outside region for control rod-up
16	Absorbing region for control rod-down
18	Water region- control rod-down
20	Aluminum Block
21	Boron region –fuel type4
22	Boron region fuel type3
23	Boron region fuel type2
24	Boron region fuel type1
25	Boron region for control rod- up
26	Light water

Appendix (1) : Represent the composition