TÜRKİYE ATOM ENERJİSİ KURUMU

ÇEKMECE NÜKLEER ARAŞTIRMA VE EĞİTİM MERKEZİ

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CALIBRATION CALCULATIONS FOR THE TR-2 REACTOR

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ÖZET

TR-2 REAKTÖRÜ İÇİN HESAPLARIN KALİBRASYONU

TR-2 reaktörünün ilk yükleme durumu ve o anda yapılan deneyler esas alınarak, iki boyutlu hesaplar eksenel yöndeki akıbüküm terimi değiştirilmek suretiyle kalibre edildi. Bu yeni akıbüküm değeri kullanılarak yapılan reaktivite hesaplarının deneylerle çok iyi uyum içerisinde olduğu gözlendi.

ABSTRACT

CALIBRATION CALCULATIONS FOR THE TR-2 REACTOR

The 2D X-Y calculations have been calibrated by adjustments in the axial buckling term. The initial loading of the TR-2 reactor and the reactivity experiments done at that time are used as the bases of these calculations. The agreement between the experimental results and the reactivity calculations is very good, after this calibration procedure.

CONTENTS

TABLES

FIGURES

I. INTRODUCTION

It is usually not possible to obtain exactly the same the k-effective value of the experiments with the calculations. So generally, some modifications in the group structure, in modelling of the reactor or adjustments in the buckling terms are made in order to meet the same excess reactivity value.

In this study initial loading of the TR-2 reactor is taken as the basis of these calculations. It is known that the TR-2 reactor was slightly above critical with 7 fuel elements. This configuration is calculated in X-Y geometry for 5 groups and the axial buckling is adjusted according to the experimental value. All successive loadings and the reactivity worths of each element are calculated with this adjusted buckling value and the results agreed very well with the experimental values.

II. CALCULATIONS

The 5 group cross-sections generated by EPRI-CELL[1] at ANL are used in the calculations. GEREBUS[2] code is used for the 2D diffusion calculations. 48x50 meshes are used in X-Y geometry. Side plates are treated as seperate regions in the core modelling. The TR-2 initial core loading is shown in Figure-1. The U-235 content differs slightly from one element to another. They are given for the 4 control and 10 fuel elements in Table-1.

First, the criticality experiment is simulated. The TR-2 reactor was slightly above critical with 4 Be blocks on one side, 2 Al blocks on the other 2 corners, 4 control elements inserted to core positions 34, 43, 55, 63 and 7 fuel elements inserted to core positions 33, 35, 44, 45, 53, 54, 64. The excess reactivity is measured to be 695 pcm. The axial buckling term is adjusted until the calculated excess reactivity matches to this value. The variation of excess reactivity versus the axial buckling is given in Figure-2. This adjusted axial buckling is used in all diffusion calculations.

Approach to criticality experiment is simulated by the X-Y calculations. The results of calculations and the experiments are given in Table-2. As can be seen the maximum difference is less then 3%.

The effect of Be reflectors on the excess reactivity is investigated. Be blocks are replaced by water and the experimental reactivity worths are compared with the results of calculations on Table-3. The worths of Al blocks are also calculated, but there is no experimental value at that time for comparison. One experiment has been made in the 3rd cycle, that means after some depletion of the fuels, and the reactivity value of the 2 Al blocks is found to be around 90 pcm. The maximum error in the reactivity values of Be blocks is 6.8% and the average error is less then 3%.

The reactivity worth of each fuel element is calculated. The results are given in Figure-3. The average error between the experiments and the calculations is found to be less then 2%, and the maximum error is 4.13%.

The anti-reactivity effects of Xe+Sm during 50 hours of operation of the reactor at 3 and 5 MWs power levels, and afterwards 100 hours of shutdown are given in Figure-4. The equilibrium Xe+Sm values are 2888 pcm and 3297 pcm, the peak values after shutdown are 4358 pcm and 6397 pcm for 3 and 5 MW power levels respectively, which are very close to the results of previous calculations (2872, 3270, 4278 and 6412 pcm, in the same order) /3/.

III. DISCUSSION OF THE RESULTS

The agreement between the experimental values and the calculational results after the calibration is very good. The average error is about 2% and the maximum error is about 7%. The maximum error (6.8%) occurs for Be block at position 32, but in reality it is not very serious, since the difference in reactivity is 50 pcm which is quite small (less then 1% of the total excess reactivity).

Errors in experiments may come from the uncertainities in calibration curves of the 4 control rods, and some small contribution of fission product accumulation on the anti-reactivity during operation of the reactor. The errors in the calculations may come from the modelling and the group structure. Also, all the control rods assumed to be out for all calculations which does not reflect the reality. The partial or total insertion of one or two control rods effect the flux distribution and so the reactivity worths. But, since we are always loking for the reactivity differences the real error becomes quite small.

The calibration calculations will continue for the control rods. After the development of a simple modelling, it will be possible to simulate the control rod insertions for the TR-2 reactor. The fuel shuffling after each loading and the corresponding fuel depletion during each cycle can be calculated more precisely by using this new modelling.

References

/1/ B. A. Zolotar, et. al., "EPRI-CELL Code Description", Advanced Recycle Methodology Program System Documentation, Part II, Chapter 5, Electric Power Research Institute (Sept. 1977)

/2/ M. Console, A. Danery, and E. Salina, "EREBUS : A Multi-Group Diffusion-Depletion Program in Two Dimensions", FN-E-88 (FIAT-1967)

/3/ M. H. Turgut, "Neutronics Calculations of the TR-2 Reactor Present Core", Technical Report No.: 30 (Sept. 1986)

Table-1 : The initial U-235 contents of control and standart fuel elements

Core position	Element Type	U-235 content [gr]
33	Standart fuel element	281.23
53	" " "	281.73
44	" " "	281.97
54	" " "	280.80
64	" " "	281.83
35	" " "	280.13
45	" " "	280.74
65	" " "	280.47
46	" " "	281.56
56	" " "	281.33
43	Control " "	207.77
63	" " "	208.21
34	" " "	208.38
55	" " "	207.68

Table-2 : Criticality experiment results

Core position	U-235 content [gr]	Total U-235 content [gr]	Calculated k-eff	Calculated excess reactivity [pcm]	Measured excess reactivity [pcm]	Difference %
Initial loading		1676.54	0.8556444	-	-	-
33	281.23	1957.77	0.9054114	-	-	-
64	281.83	2239.60	0.9462967	-	-	-
45	280.74	2520.34	0.9813906	-	-	-
35	280.13	2800.47	1.0070080	696	695	0.14
65	280.47	3080.94	1.0290724	2825	2749	2.76
56	281.33	3362.27	1.0510585	4858	4971	2.27
46	281.56	3643.83	1.0722899	6742	6652	1.35

Table-3 : The calculational and experimental reactivity values of the Be and Al blocks

Element	Core positions	Calculated k-eff	Calculated reactivity worth [pcm]	Experimental reactivity worth [pcm]	Difference %
Be	32	1.0644746	685	735	6.8
Be	42	1.0583603	1228	1228	0.0
Be	32+42	1.0519350	1805	1848	2.33
Be	32+42+62	1.0449724	2438	2424	-0.58
Be	32+42+52+62	1.0361876	3250	3191	-2.43
Al	36	1.0714130	77	-	-
Al	66	1.0713829	79	-	-
Al	36+66	1.0705128	155	-	-

32* Be	42 Be	52 Be	62 Be
33 1**	43 SR1 CE	53 FE	63 SR2 CE
34 CR1 CE	44 FE	54 FE	64 2
35 4	45 3	55 CR2 CE	65 5
36 Al	46 7	56 6	66 Al

CE : Control element
FE : Fuel element
Be : Be block
Al : Al block

SR1 : Safety rod No.1
SR2 : Safety rod No.2
CR1 : Control rod No.1
CR2 : Control rod No.2

*) Core position

**) Loading step No.

1st step : Reactor not critical
2nd step : Reactor not critical
3rd step : Reactor not critical
4th step : Reactor critical; SR1, SR2, CR1 out, CR2 at position 683
5th step : Reactor critical; SR1, SR2, CR1 out, CR2 at position 441
6th step : Reactor critical; SR1, SR2, CR1 out, CR2 at position 271
7th step : Reactor critical; SR1, SR2 out, CR1 at position 780, CR2 in

Figure-1 : The initial loading of the TR-2 reactor

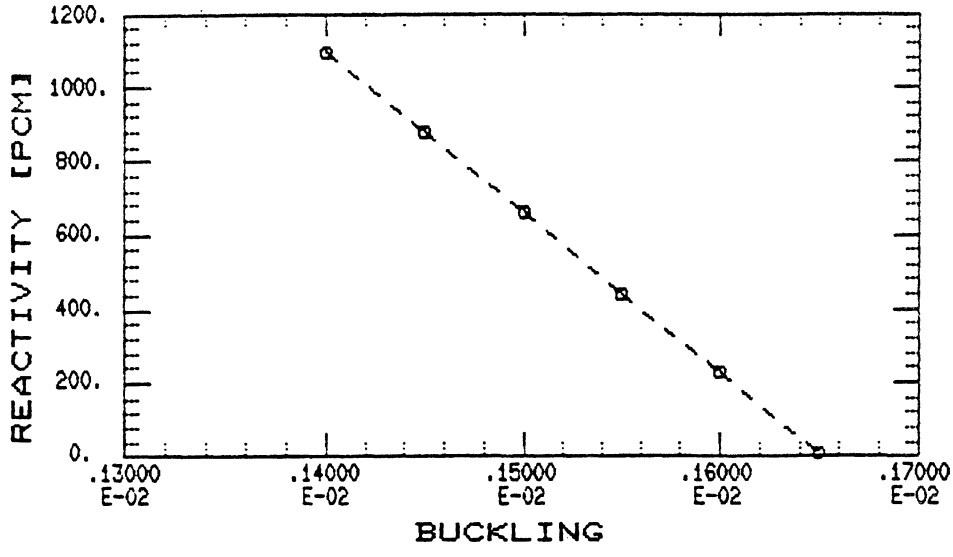

Figure-2 : The variation of excess reactivity versus axial buckling

Be	Be	Be	Be
2590* 2542+	SR1	3939 4031	SR2
CR1	4732 4781	4688 4674	2891 2833
2462 2522	3383 3294	CR2	2302 2397
Al	1899 1884	2136 2085	Al

Be	Be	Be	Be
48** 1.85x	SR1	-92 -2.34	SR2
CR1	-49 -1.04	14 0.30	58 2.01
-60 -2.44	89 2.63	CR2	-95 -4.13
Al	15 0.79	51 2.39	Al

*) Experimental reactivity worth [pcm]

+) Calculational reactivity worth [pcm]

**) Difference (Experimental-Calculational) [pcm]

x) Difference in percent (Difference/Experimental*100)

Figure-3 : The calculated and experimental reactivity values of the fuel elements

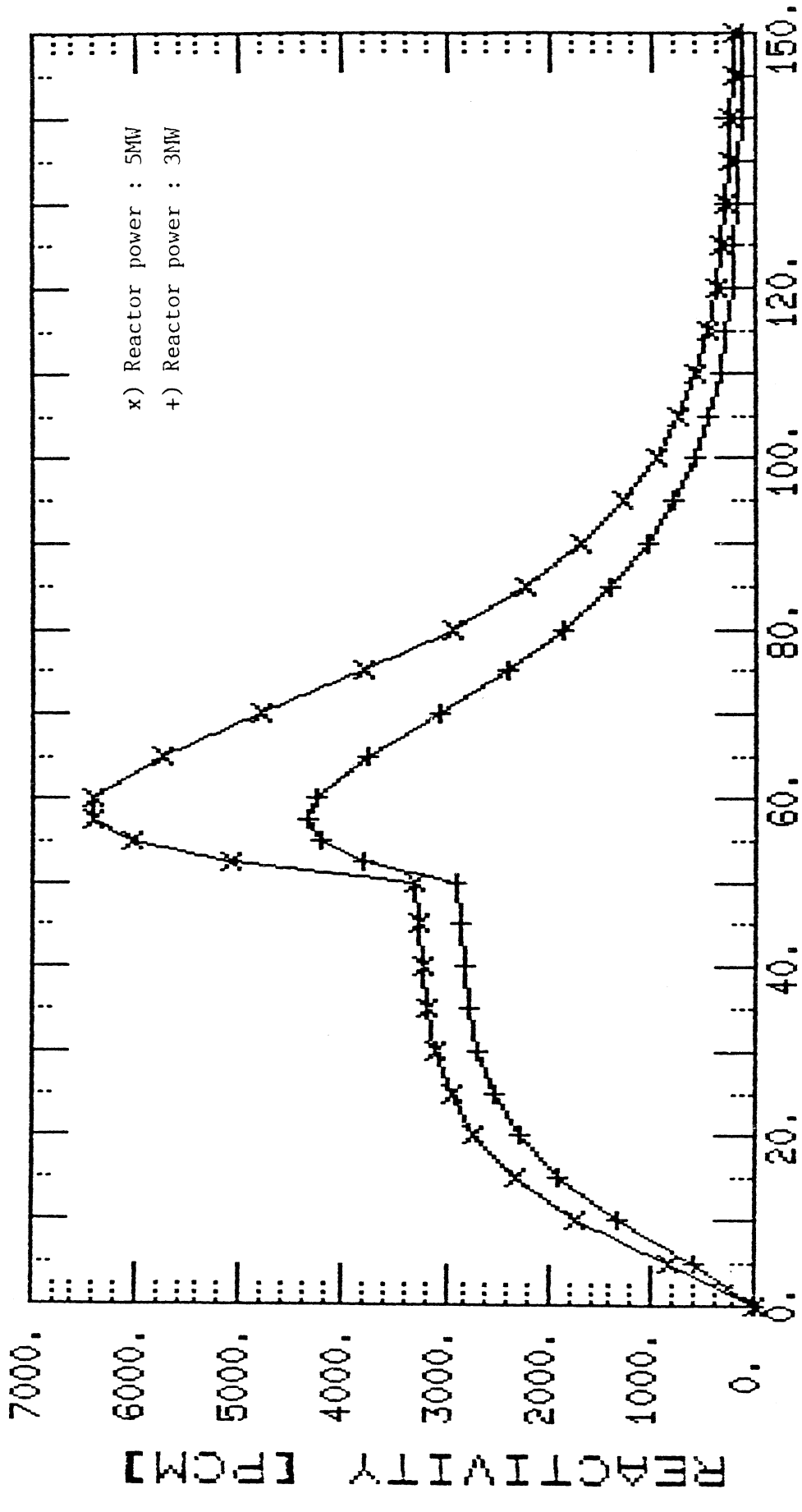

Figure-4 : The Xe+Sm anti-reactivity curves
(50 hours of reactor operation and 100 hours of shutdown)