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MASTER

MEASUREMENTS OF THE ADJOINT FLUX IN A COMPACT FAST REACTOR

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1. Measurements

Measurements of neutron importance distribution were performed inside the fast source reactor TAPIRO /1,2,3/.

The adjoint flux in the core and in the copper reflector was investigated by the use of a small Cf-252 source packed in a stainless steel container, 8 mm in diameter and 5 mm thick. The neutron source was positioned in the diametral channel in the core and in the reflector. Small cylinders of 93% enriched uranium metal and of copper were used, in the core and reflector regions respectively, to fill up the channels so as to avoid any flux perturbation around the source.

Relative measurements only were performed to obtain the neutron importance distribution with the aim to make an intercomparison between different techniques of measurement and to compare experimental and calculated results.

Pseudo-reactivity, source multiplication and linear power rise methods /4/ were used in our experiments. Other possible techniques such as pulsed source, source jerk and extrapolation techniques were not tested due to the experimental arrangement of the TAPIRO reactor or the low precision associated to such methods.

A block scheme of the experimental sequences used in our measurements are listed in Table 1.

Good precision can be obtained with all these methods, if the neutron source can be changed with its mock-up or from one position to the other without varying the reactor configuration. Unfortunately the TAPIRO experimental arrangement requires us to remove the whole diametral channel with a part of the core and of the copper reflector. The repositioning of the channel can sometimes introduce perturbations in the reactor configuration and modify the result of the measurement. The precision, in our case, associated to these techniques becomes of difficult evaluation.

To avoid such a kind of perturbations we have used a method based on a double series of countings at two different power levels: the choice of the counting rate can be different from one measurement to the other and, without the use of the source mock-up, we obtain a result proportional to the source importance.

The experimental sequence followed in this technique is shown in Table 1d); the product of the source stringth S by its importance S^* is given by

$$SS^* = \frac{\Delta \rho}{\frac{1}{N_1} - \frac{1}{N_2}}$$

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where $\Delta \rho$ is the difference between the reactivities of the control rod at the two counting rates N_1 and N_2.

The precision associated to the method covers the range between 2% (in the middle of the core) and 20% in the inner copper reflector depending on statistical errors in counting rate and in the reactivity of the control rod position.

Experimental results for the relative importance function in the core of the Cf-252 source are listed in Table 2. The agreement between the different techniques is satisfactory.

We have performed measurements of the energy dependence of the adjoint flux Φ^* (E) using a set of calibrated neutron sources with different spectra obtained from Karlsruhe; owing to the large dimension of these sources we could not perform importance measurements in the reactor core, but only in the reflector using tangential and radial 1 channels. The results obtained are of little meaning due to the large experimental errors and the uncertainties in the spectrum and strength of the sources.

By use of the Karam technique /5/ we have also performed a measurement of the Normalization Integral. Disagreament between calculated and experimental value is about 30%, but at least part of this may be due to uncertainties in the absolute calibration of the neutron source.

2. Calculations

The TAPIRO reactor was represented in the calculations either in one-dimensional or in two-dimensional geometry; the relative schematizations are given in Fig. 1. The equivalent radius of the core for the one-dimensional calculation was chosen so as to preserve the value of K-eff given by the two-dimensional calculations (which in turn well reproduce the experimental value).

One-dimensional calculations were performed by means of the ANISN code in S-8 approximation with isotropic scattering. The cross sections were derived from the ENDF/B-III files and collapsed to 27 groups by means of the ETOE-MC^2 code chain.

Two-dimensional calculations were performed by means of the DOT code, also in S-8 approximation and isotropic scattering. The derivation of the cross section was the same, but due to computer storage and time limitations, only 6 energy groups were used.

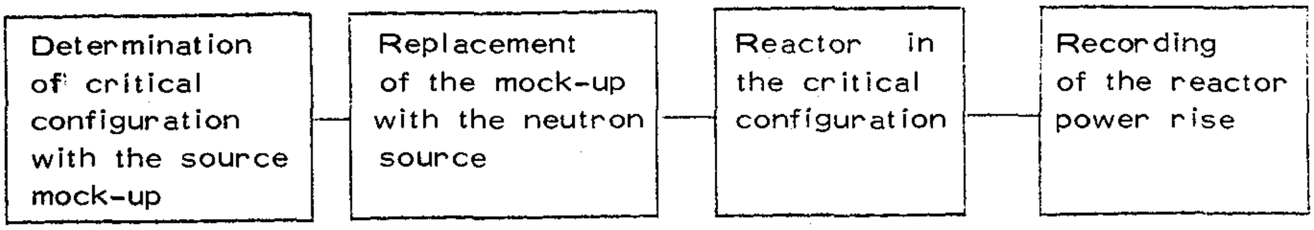
Experimental and calculated values normalized in the core center are compared in Fig. 2. The agreement is very good (maximum discrepancy about 2%) in the core zone; on the contrary in the copper zone the 1-D calculations underestimate the adjoint flux more and more up to a maximum discrepancy of about 50%.

The bed evaluation of the adjoint flux in the interface zone, previously found by Karam /5/, does not seem sufficient to explain such a large discrepancy. The inadequacy of the monodimensional schematization in the reflector zone may be the most likely explanation; actually, the two-dimensional calculations yield much better agreement, although the small number of groups used makes the results less significant.

TABLE 1

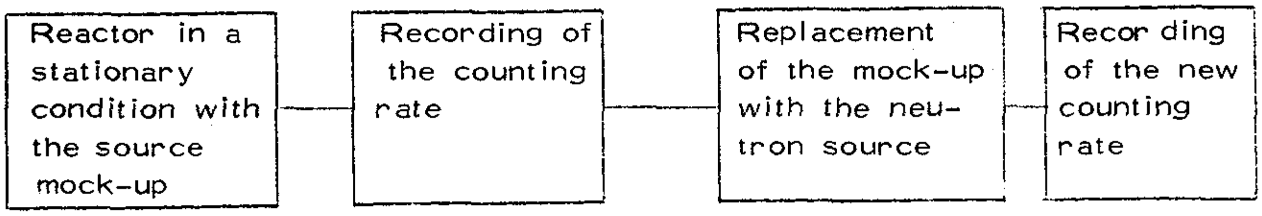
Experimental Sequences of the Different Techniques for Adjoint Flux Measurements.

1 - a Linear Power Rise



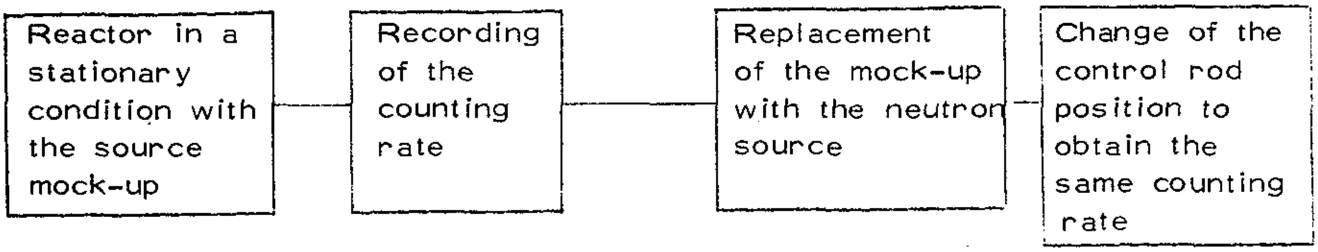
$S^* \propto$ reactor power rise

1 - b Source moltiplication



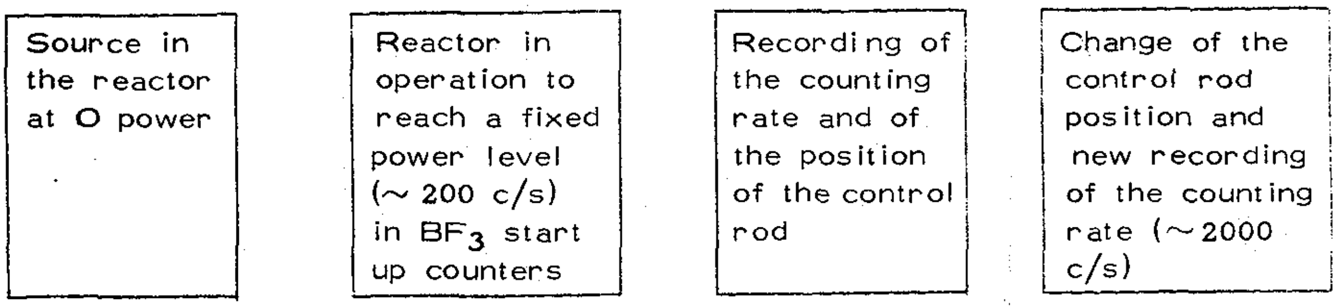
$$S^* \propto \frac{C - C\ \text{background}}{C\ \text{background}}$$

1 - c Pseudoreactivity



$S^* \propto \Delta\xi$ = *Changement in the control rod position*

1 - d Double counting technique



$$S^* \propto \frac{\Delta\xi}{\frac{1}{N_1} - \frac{1}{N_2}}$$

TABLE 2

Comparison of different techniques for relative measurements of the adjoint flux

X (cm)	Double counting	Linear rise	Pseudo-reactivity	Multiplication
0	1.	1	1	1
10	.97±.02	.96	.99	.96
20	.96±.02			
30	.91±.02	.90	.93	.91
40	.83±.02			
50	.72±.02	.71	.75	.70
60	.63±.02			

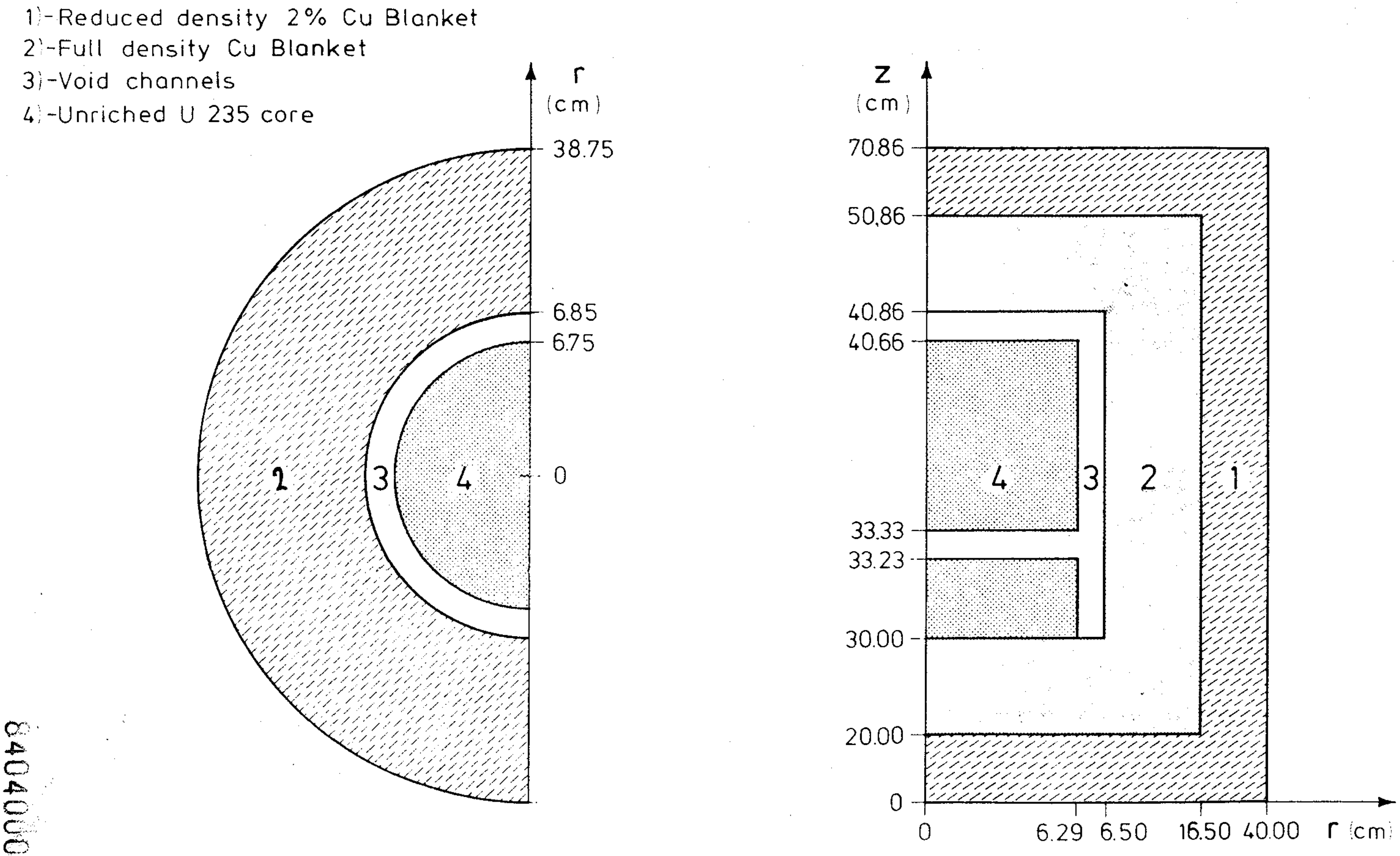


Fig. 1- Tapiro reactor models for transport calculations

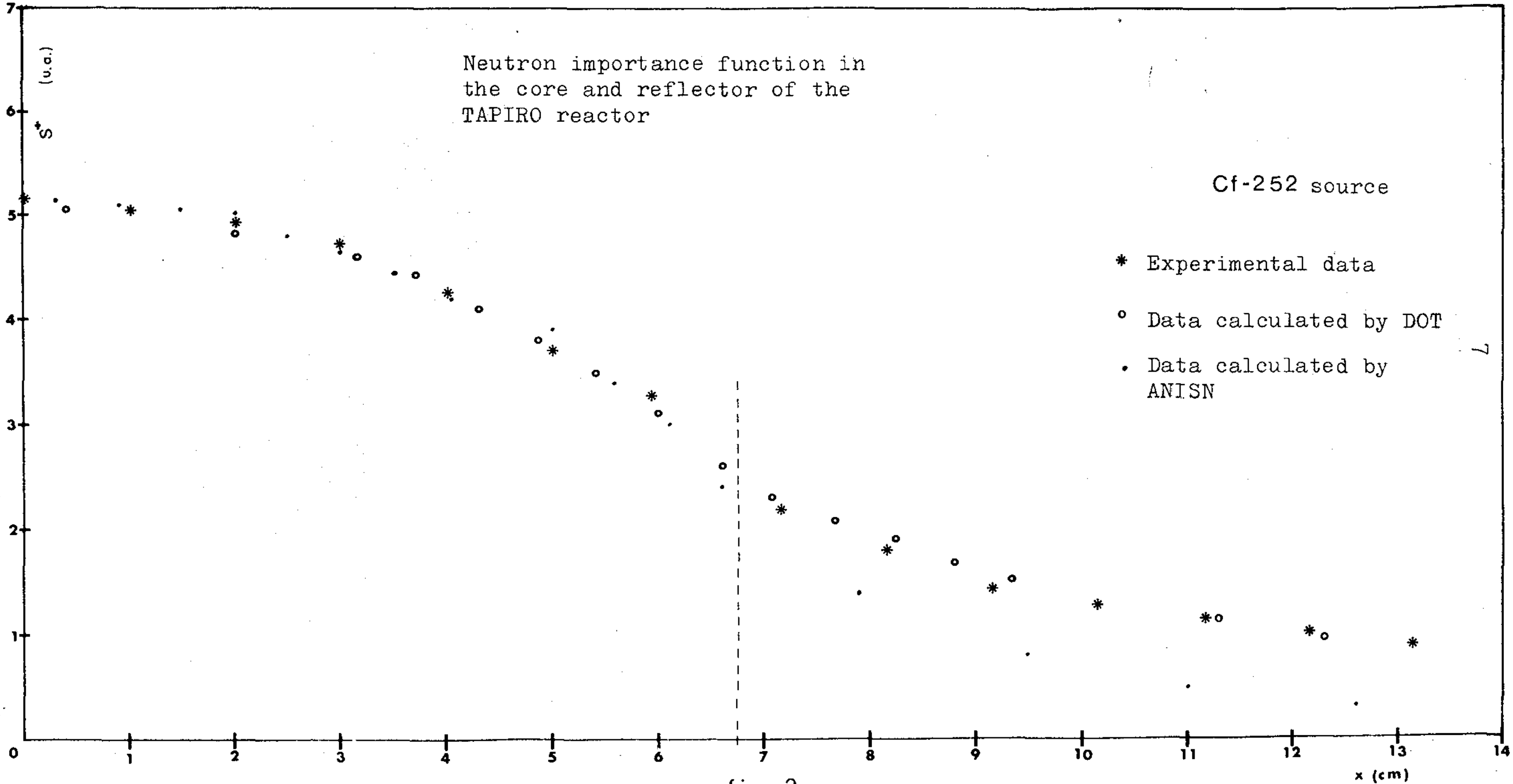

Neutron importance function in
the core and reflector of the
TAPIRO reactor
Cf-252 source
✱ Experimental data
○ Data calculated by DOT
• Data calculated by ANISN
S^+ (u.a.)
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
x (cm)

fig. 2

Reference

/1/ A. D'ANGELO, M. MARTINI and M. SALVATORES, "The TAPIRO Fast Source Reactor as a Benchmark for Nuclear Data Testing", Energia Nucleare (Milan) Vol. 20, n. 11, 614-621 (1973);
A. D'ANGELO, M. MARTINI and M. SALVATORES, "^{235}U Compact Cu-Reflected TAPIRO Reactor Integral Experiments Results and a Check of Some High-Energy ENDF/B-III Data", Trans. Am. Nucl. Soc. Vol. 17, p. 498-499 (1973)

/2/ U. FARINELLI, "Use of a Fast Source Reactor for Low Power Irradiation Experiments", in Research Reactor Experimental Techniques, Proceedings of a Study Group Meeting held by the International Atomic Energy Agency, p. 493-503, Ed. Acad. Rep. Soc. Rom., Bucharest (1965)

/3/ U. FARINELLI and M. MARTINI, "Facilities for Shielding Benchmark Experiments at C.N.E.N. - Casaccia", N.E.A. - Euratom Specialists' Meeting on Integral Shielding Experiments, Ispra 17-19 April 1974

/4/ E. GREENSPAN, "The Measurement of Neutron Importance Function", J. Nucl. Energy 27, 129-138 (1973)

/5/ R.A. KARAM, "Measurements of the Normalization Integral and the Spatial Distribution of the Importance of Fission Neutrons" NSE 37, 192 - 197 (1969)