EUR 498.e

EUROPEAN ATOMIC ENERGY COMMUNITY - EURATOM

THE CRITICAL FACILITY KRITO

by

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(Reactor Centrum Nederland)

1964

Report prepared by the Reactor Centrum Nederland
Institute for the Development of Peaceful Applications of Nuclear Sciences

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This design foresees in a power reactor of PWR type, with a two zone core of UO_2 fuel, canned in zircaloy with enrichments of 3.1 % and 3.8 % and 12 uniformly distributed control rods of a cadmium silver indium alloy.

However, for economical reasons, in KRITO use is made of aluminium as canning material and B_4C as poison material and the experiments will be done with a constant moderator to fuel ratio.

A short description of the facility and the experimental program will be given.

First criticality was attained on March 29, 1963.

The results obtained up till September 1963 will be summarised.

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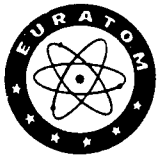

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THE CRITICAL FACILITY KRITO

1. Introduction.

1.1. The KRITO project.

The KRITO project is part of a joint undertaking of EURATOM and REACTOR CENTRUM NEDERLAND for the development of a nuclear reactor for ship propulstion, known as the NERO programme.

The primary objective of the KRITO project is to measure the reactor physics parameters of the designed NERO core.

The KRITO project makes use of two experimental facilities at Petten : the zero power reactor KRITO and the subcritical facility PUK. Both are designed by RCN and will also be operated by RCN.

The experimental work is performed by the physics department at Petten, the calculations are mainly done by the design and evaluation department at the Hague.

The first critical experiment in KRITO is a mock up or zero energy version of the proposed NERO design.

The NERO design foresees a reactor of PWR type, with two enrichments of the UO_2 fuel, canned in zircaloy tubes of 1.2 cm outer diameter, 120 of which will be bundled together in a hexagonal box of zircaloy. The fuel core will consists of 30 of such fuel assemblies of full size and 12 of subsize containing about 50 fuel rods.
Control is achieved by 12 uniformly distributed Y shaped rods of a cadmium silver indium alloy fitting between the hexagonal fuel boxes. Burnable poison will be incorporated in the UO_2 pellets for control of the excess reactivity needed for burn up.
The poisoned rods will only be placed in the peripheral fuel rods of each box, serving a second purpose namely to decrease the flux in these rods, which are most susceptible to flux peaking caused by the water gap around the fuel elements.
Further details about dimensions and parameters are given in table I.

The KRITO core has the same dimensions as the NERO core, however for reasons of economy use is made of aluminium as canning and fuel box material, control rods are made of B_4C. Furthermore the poison is applied in the form of thin B_4C foils (thickness 0.6 mm) between the UO_2 pellets. This leaves the possibility of changing the concentration in the course of the experimental programme.

The subcritical facility PUK will serve as a complement to the critical facility KRITO. See (1).

1.2. The experimental programme of the KRITO project.

This compromises :

a. Measurements of criticality, reactivity effects and neutron flux or power distributions in order to determine the worth of fuel rods, control rods, void- and temperature coefficients, and material bucklings, etc. (To be performed in KRITO).

b. Measurements of microscopic flux and power distributions in and around fuel rods near the water gaps and of parameters such as p, f and ε and related quantities (To be performed in PUK).

c. The same as a and b but with nuclear poisons in the fuel.

d. Kinetic measurements, including neutronic noise, to determine the reactor transfer function, mean neutron generation time and the effective β.

In both facilities substitution measurements will be made with zircaloy instead of aluminium both as canning material and as fuel element box, to be able to predict the effect of the use of zircaloy instead of aluminium on the reactivity and microscopic flux distribution.
The same will be done with control members of different materials.

2. Description of KRITO.

The KRITO facility at Petten consists of an aluminium tank (2.5 m diameter and 4.25 m height), in which the experimental core can be built up, pumps, piping, dump tank and control member drive mechanisms.
(see figures 1 and 2).
There is no shielding around the core tank itself. All shielding is provided by the walls of the reactor bay, which is 7.5 m wide, 11 m long, 12.5 m high with a wall thickness of 1 meter, except of the wall facing the control room, which has a thickness of 1.50 m.
Normal concrete has been used.
The control room is situated outside the bay in the adjacent two storey building. Nobody is permitted to be inside the bay during reactor operation.
The reactor is normally operated by control members but control by water level adjustment is also possible.
For this reason special care is taken to enable accurate measurements of the water height in the reactor vessel.
All control members serve also as safety devices.
In case of scram the members are dropped into the core.
In addition the water will be dumped when a scram occurs, thus reducing the effective multiplication factor of the reactor well below unity.

The valves, including the dump valve, in the water system are pneumatically operated. A 115 kW electrical heater is installed for heating the water, for temperature coefficient measurements. The maximum temperature is about 90° C.

The semigas - tight reactor bay is ventilated during operation and the gas activity at the outlet continuously monitored. In case of an abnormal increase of the activity, ventilation is stopped and valves in the in - and outlet are instanteneously closed by spring action.

A Po - Be neutron source, normally stored in a paraffine cylinder, adjacent to the reactor vessel, can remotely be inserted into the core via an aluminium tube to a position in the core centre at height zero. (see figure 5).
When the entrance door to the bay is opened the source is automatically withdrawn.

The nuclear instrumentation of the reactor consists of:

- Two channels in the counter range with time constant meters, connected to BF_3 counters.
  During initial approach to criticality another two BF_3 channels were used with scalers in the control room.

- A linear D.C. channel with deviation meter connected to a gamma compensated ionisation chamber.

- A log D.C. channel with time constant meter connected to a gamma - compensated ionisation chamber.

- Two safety channels connected to uncompensated ionisation chambers.

All neutron detectors are placed in vertical tubes around the core. Their position can easily be changed in vertical and radial directions as can be seen from figures 1 to 5.

Recorders are connected to one of the count rate channels, the linear and log channel.
Four gamma monitors are installed, three in the reactor enclosure and one in the control room.

The count rate meters of the counter channels have high and low level trips. The low level trips prevent the addition of reactivity by pumping moderator to the reactor tank or by withdrawing the control members, if the count rate is below a given level, i.e. if the neutron source is withdrawn. The high level trips give scram unless the log D.C. channel meter is on scale. These trips are then automatically by-passed but only when the first decade on the log D.C. meter is passed in a time longer then 12 seconds. The time constant meters in the counting channels give no scram but only an alarm above a time constant of about 8 decades/min.

The linear D.C. channel recorder has only low and full scale alarms. The log D.C. and two safety channels have high level trips. The time constant meter of the log channel gives an alarm above 0.4 decade/min. and scram above 0.8 decade/min. All trips cause a release of the control members as well as dumping of the water to a level below the fuel.

For accurate reactivity measurements a precise time constant meter is developed and used in connection with a gamma compensated ionisation chamber.
With this instrument the doubling time is measured and printed on paper each one third of the measured doubling time. For detailed information see (2).

Normal operating power is 1 - 20 Watt.
The doserates in the bay above the core are of the order of 200 mrem/hr at 10 Watt.

3. Outline of measurements ; KRITO cores I - IV.

The final full core of the proposed reactor in the cold clean condition will have a high excess reactivity.
Since in the critical experiment no compensating action of the high temperature, the lower water density, Xe and Sm poisoning, etc. is operative, it would be unsafe to build up this core immediately.
Instead the final core will be approached in four steps by starting from the smallest just critical core by adding fuel together with a neutron poison in order to keep down the reactivity and to simulate the power conditions in the final core.

In each step an extensive number of measurements will be made of neutron flux distributions, poison effects, influence of fuel addition and reactivity effects of control members.

The experimental programme will be in accordance with the following scheme :

KRITO core type I.

3.1 % enriched fuel, without B_4C poison, core diameter : about 40 cm, height 40 cm.
Experiments : determination of critical mass, control member worth and measurements of neutron flux distribution and flux peaking, determination of the effect of fuel rods with burnable poison, in between the UO_2 pellets.

KRITO core type II.

3.8 % enriched fuel, without B_4C poison.
core diameter : about 36 cm height 40 cm.
Experiments : as in KRITO core I.

KRITO core type III.

3.1 % and 3.8 % enriched fuel in two zones, with B_4C poison in boundary rods of each fuel assembly, core diameter : 123 cm, height 40 cm.
Experiments : determination of critical mass, poison concentration needed for fluxflattening, control member worth, measurements of detailed neutron flux distributions and water height coefficients.

KRITO core type IV.

As core III but with the full height of about 130 cm.
Experiments : determination of excess reactivity and measurement of detailed power distributions.

The microscopic parameters will mainly be determined in PUK and these measurements are only repeated in KRITO for reference.

The first two core configurations which will be investigated will serve to provide basic information about the criticality of the fuel, control member worth, and as first check of the reactor calculations.
The active fuel height is 40 cm. The water level is such that no change in reactivity can be caused by further water addition.

The third core will be the main object of the experimental programme, as the composition will be quite similar to the NERO design. Power distributions, fine structure measurements and temperature coefficients as influenced by the poison- concentration and - distribution are the subjects on which the programme will be concentrated.
The core will be built up stepwise, when a diameter of 123 cm is obtained, the core will be investigated thoroughly, as the power distribution in radial direction is assumed to be representative for the NERO core.

The last phase of the experimental programme for the NERO design will be a study of the reactor core at full size. The diameter will remain 123 cm, but the height will be increased to 131 cm. To control the excess reactivity boric acid will be added to the water. With this fourth core the main measurements will be the determination of control member worth.

In the third and fourth core some additional measurements have to be done to allow for the remaining deviation between the KRITO and NERO cores, such as the use of aluminium and boron carbide instead of zircaloy and a cadmium silver indium alloy.
These effects will be determined in so called substitution measurements in which one or more fuel assemblies similar to the NERO design will be placed at different positions in the core. The same will be done for the control members.

Finally, the low temperature in all cores is a disadvantage which cannot be avoided. To obtain some indication of the water temperature influence, criticality measurements will be done at about 90° C. If the results are in accordance with the calculation an extrapolation can be made to the operating temperature of 314° C.

4. Results of measurements in KRITO core I.

4.1. General.

KRITO core I has been built up by stepwise loading of UO_2 rods in hexagonal rings around a 10 Curie Po - Be neutron source. The minimum critical mass was determined by extrapolation to zero of the reciprocal countrate curves as measured with four BF_3 countertubes. By further addition of fuel rods, different core loadings were obtained. The excess reactivity was compensated, either by a decrease in the waterheight or by the insertion of one or more control members of B_4C.

Time constant measurements were used to determine the water height coefficient. Delayed neutron data were used as given in (3).
The effective β was taken as 0.72 %.

The differential reactivity worth for each member setting was also determined by positive time constant measurements. Integration of the obtained curves gave the worth of the control members and thus the excess reactivity of each of the core loadings.

Reactivity effects of core perturbations were determined from changes in the control member settings.

Flux density distributions of thermal neutrons in different loadings were determined by the activation technique.

4.2. Critical mass ; core loadings.

From the "criticality approach curves" the unperturbed minimum critical loading of the KRITO core I proved to be : 1009 ± 2 UO_2 rods, i.e. 330.7 kg UO_2 or 9.14 kg U-235.

For the measurements of core perturbation effects the core was further enlarged by adding more UO_2 fuel rods. The maximum built in excess reactivity was limited to the total worth of one control member in ring 1.
Important data on core loadings which are used as reference in later measurements are compiled in table IV.

Table IV. Typical fuel loadings of KRITO core I.

core loading no	number of fuel rods	mass UO_2 (kg)	mass U-235 (kg)	number of UO_2 rods above the critical number	water-height (cm)	excess reactivity compensated by control members (pcm)
critical core	1009	330.7	9.14	0	60	0
11	1077	353.0	9.76	+ 68	60	+ 860
14	1119	366.8	10.14	+110	60	+1350
16	1191	390.4	10.79	+182	60	+1990
18	1230	403.2	11.14	+221	60	+2725
24	1296	424.8	11.74	+287	60	+3460

The measured excess reactivity of the different core loadings has also been compared with the results of calculations. Results are shown in fig. 6a.

4.3. Water height coefficient

The change in reactivity with changes in moderator level $d\rho/dh$, was derived from the reactor time constant following a 0.5 cm increase in moderator level, using the relation between time constant and reactivity as calculated for this lattice. The critical height was varied by adding or removing peripheral fuel rods. Absolute moderator levels and level changes were measured with an accuracy of $\pm$ 0.5 cm and $\pm$0.05 cm, respectively. Fig. 6 shows $d\rho/dh$ and k_{eff} vs moderator height. The latter quantity was obtained by integrating the $d\rho/dh$ curve for the core loading 25, with critical waterlevel at 39.2 cm. No correction was made for the different core masses used.

Table V. Water height coefficients.

core loading no	number of fuel rods	critical water height h_w (cm)	control member settings (cm)	$\frac{d\rho}{dh_w}$ (pcm/cm)
24	1296	38.00	50	500
25	1230	39.25	50	400
26	1191	40.65	50	350
27	1119	42.95	50	220

4.4. Control member calibration.

The reactivity worth of each of the B_4C control members has been measured by positive time constant measurements. First this was done for different core loadings. Later these measurements were repeated in core loading 24 where the excess reactivity was compensated, either by one, or more of the other control members.

From these measurments the dependence on core size could be estimated, which is shown in fig. 7a. If there was any mutual influence of the control members this would have been observed in the measurements in core loading 24, but from the result no significant effect could be deduced.

The reactivity effect of each of the total inserted B_4C members in the central ring (r=18 cm, see fig 4) is -3400 pcm.
In the second ring (r=37 cm) this is about -300 pcm. Both results are valid for core loading 24. The total control member worth in other loadings can be estimated from the insert in fig. 7a.

In later experiments one of the B_4C control members in the inner ring was replaced by stainless steel and further by aluminium to investigate the effect of control member followers. The total reactivity of these Y shaped rods are respectively 41 % and 14 % of the B_4C value.
Results are shown in figures 7a and 7b.

4.5. Reactivity of fuel rods.

From the differences in excess reactivity of the various core loadings, the average increase in reactivity by addition of one fuel rod to the core periphery is estimated as 12.4 pcm.

As can be expected in this undermoderated core the effect of fuel rod addition is strongly dependent on the position in each fuel assembly. Pheripheral rods placed in the centre of an outer fuel assembly gave 10 pcm as compared to 18 pcm of the rods placed adjacent to the water gap between the aluminium fuel boxes.

4.6. Reactivity effects of gaps and clusters.

To investigate the effect of disturbances in the clean lattice, e.g. as caused by the use of fuel boxes and the gaps for the control members, water gaps have been simulated by removing a single row of UO_2 rods and secondly by removing two adjacent rows through the whole core. In this way a gap width of about 1.6 cm respectively 2.9 cm was obtained (see figure 2).

The reactivity effects were determined from the control member settings and the measured excess reactivity of the undisturbed core. No correction was made for a possible change in control member worth due to these disturbances. Results are shown in table VI.

In addition clusters of 7 rods were removed from different positions in the core and the reactivety changes determined.

Finally the H_2O/UO_2 volume ratio in one or more fuel assemblies was changed from 1.07 to 1.92 ; 6.09 and 8.64 by uniform removal of UO_2 rods. These measurements have merely been done as a guide for the safe operation of the subcritical facility PUK. see (1).

Table VI. Reactivity effects gaps and clusters.

core loading no	number of fuel rods	disturbance removal of fuel rods	reactivity effect of disturbance (pcm)
27(=14)	1119	reference core (excess reactivety = 1350 pcm)	-
28	1093	-26 rods of one row E-W	+ 750
30	1112	- 7 rods of cluster from D4	+ 280
31	1083	-26 rods of one row and two clusters of 5 rods each	+ 580
32	1055	-64 rods of double row E-W	+ 390
33	1045	-64 rods of double row and two clusters of 5 rods each	$\pm$ 0
34	1089	-30 rods from E4 H_2O/UO_2 vol. ratio = 1.9	+ 850
35	1080	-39 rods from E4 H_2O/UO_2 vol. ratio = 1.9	+ 920
36	1098	-21 rods from D3, D4 and E4 H_2O/UO_2 vol. ratio = 1.9	+1020
18	1230	reference core (excess reactivity =2725pcm)	-
42	1150	-80 rods from E4 H_2O/UO_2 vol ratio = 6.09	- 450
43	1143	-87 rods from E4 H_2O/UO_2 vol ratio = 8.64	-1675

4.7. Reactivity effects of B_4C poisoned fuel rods.

The effect of fuel rods poisoned with B_4C foils have been determined both on reactivity and flux density distribution..
In successive experiments these specially made fuel rods were placed at the boundary of one fuel assembly E4, at adjacent boundaries in the three control fuel assemblies D3, D4 and E4, at the core periphery and in different other places. The total effect on the reactivity is summarised in table VII. The influence on the flux distribution is reported in chapter 5 and shown in figure 11.

Table VII. Reactivity effects B_4C poisoned fuel rods.

core loading no	number of fuel rods	disturbance : replacement by B_4C poisoned fuel rods	reactivity effect of disturbance (pcm)	(pcm/ rod)
48(=18)	1230	reference core (excess reactivety = 2725 pcm)	----	----
49	1230	35 boundary rods in E4	-1725	-49.3
41	1230	36 boundary rods in D3,D4 and E4	-2265	-60
44	1230	35 rods in C3, D5 and F3 at the core periphery	-395	-11
45	1230	12 rods one from each fuel assembly	-265	-22
46	1230	24 rods two from each fuel assembly	-495	-20.6
47	1230	36 rods three from each fuel assembly	-725	-20.1

4.8. Neutron flux density measurements.

Measurements of the flux density distributions of thermal neutrons in the KRITO fuel core have been performed with activation detectors in the form of copper wires and manganese foils. The wires had a diameter of 1.5 mm and were inserted in water tight aluminium tubes with an inside diameter of 2.3 mm, thickness 0.8 mm and a length of 160 cm. The manganese foils had a diameter of 0.55 cm, mass about 20 mg, thickness 0.1 mm and contained 12 % Ni. The wires were placed adjacent to the fuel rods in the moderator. The foils were attached to fuel rods.

A comparison has been made between results of wire activation and the results obtained by scanning the gross gamma activity of fuel rods. The average to maximum ratio for the vertical distribution for the copper wires was about 6 % higher than for the fuel rod measurements. This effect is partly caused by the applied counting procedure and presumably partly by the difference between the power density distribution in the fuel rods and thermal neutron flux density distribution in the moderator.

Fig. 9 gives a representative vertical distribution measured with a copper wire and with a fuel rod.

From the counting results of irradiated copper wires positioned along two radial directions in the fuel core, radial distributions of the thermal neutron flux density were obtained. One representative distribution for a distance of 26 cm above zero level is shown in fig. 8.

To obtain the flux density distribution in a fuel assembly, in each of the equivalent fuel assemblies D3, D4 and E4 33 copper wires have been irradiated. The irradiation positions in these assemblies were chosen in such a way that by combination of the results a complete mapping of the flux density in a central fuel assembly was obtained. The results for h=20 are shown in fig. 10.

Some flux measurements have also been performed to obtain data on the flux density distribution of thermal neutrons across the normal water gap between two fuel assemblies and across the water gaps which were introduced by removing a row of fuel rods. Activation detectors in the form of manganese foils were attached on fuel rods, while in the water gap itself the foils were fixed on thin aluminium foil holders.
These measurements were repeated with poisoned fuel rods along the watergaps to investigate the flux flattening as caused by the B_4C poison.

Some of the results are shown in figure 11.

5. Comparison of calculations and experiments.

Physics calculations have been performed making use of four group diffusion theory. The clean lattice in a fuel box has a H_2O/UO_2 volume ratio 1.07 but the average ratio in the complete core is 1.42.
The difference has been acounted for in the calculations by dividing each fuel assembly into two regions : a central region with a H_2O/UO_2 volume ratio of 1.07 and an outer region containing the fuel rods at the pheriphery of the assembly, the Al wall and the water in the water gap. This region has a H_2O/UO_2 volume ratio of 2.0.
This method has the advantage above homogenizing of the core, that an indication of the fluxpeaking near the water gaps is obtained.

PDQ calculations to determine the flux pattern have been performed on an IBM 7090 computer.
In figure 8 a comparison has been made between the measured flux distribution at various points in the core and the results of the calculations.

Further have been calculated :
k_{eff} as a function of the total mass UO_2 in the core (fig 6a),
k_{eff} as a function of waterheight, and the watercoefficient (fig 6b)
These calculations were performed with the use of desk calculators . In table II some characteristics of the cores I and II are given.

Table I. NERO parameters.

Reactor system.

Thermal reactor power	60	MW
Pressure primary system	140	Atm
Inlet temp reactor vessel	283	°C
Outlet temp reactor vessel	314	°C

Reactor core

Enrichment, inner zone	4.4	atom %-U235
Enrichment, outer zone	4.8	atom %-U235
Volume inner zone	0.4137	m^3
Volume outer zone	0.7249	m^3
Volume core	1.138	m^3
Core height	1139	mm
Average core diameter	1128	mm
Number of fuel assemblies full size 120 rods	30	
Number of fuel assemblies sub size, 57/50 rods	12	
Total number of rods	4242	
Weight UO_2	3977.4	kg
Weight U-235	159	kg
Diameter UO_2 pellets	10.03 ± 0.01	mm
Cladding diameter	10.2/11.9	mm
Cladding thickness	0.85 ± 0.08	mm
Lattice pitch, hexagonal	15.1	
Number of Y shaped control rods	12	

Volume fractions in core :	cold	hot
UO_2	0.3352	0.3459
H_2O	0.4402	0.4404
Cladding	0.1252	0.1257
Fuel element boxes	0.0473	0.0473
Control rods	0.0407	0.0407
Helium	0.0115	-
Volume ratio H_2O/UO_2:		
Control rods in	1.3130	1.2732
Control rods out	1.4344	1.3909
Infinite multiplication factor		1.337
Effective multiplication factor (clean core, full power)		1.201
Average thermal neutron flux density clean core	0.93×10^{13}	n/cm^2 sec

Table II. KRITO core I and II parameters.

	Core I	Core II	
Enrichment	3.12	3.81	weight %
	3.16	3.86	atomic %
Diameter UO_2 pellets	10		
Diameter inside-, Al cladding	10.1		
Diameter outside-, Al cladding	12.0		
Lattice pitch hexagonal	15.1		
Number of rods per element	120		
Number of rods, critical	1009	~820	
Fuel height	40.25	40.25	cm
Average core diameter	54.70	49.2	cm
Weight UO_2	330.81	269.0	kg
U-235	9.14	9.04	kg
Aluminium	45.67	37.31	kg
H_2O	44.79	36.59	kg
Vol fraction UO_2	0.3359		
H_2O	0.4496		
Al cladding	0.1410		
Al boxes	0.0390		
Control rods	0.0278		
He	0.0067		
Density UO_2	10.42		g/cm^3
H_2O	0.9982		
Al	2.699		
Moderator temperature	20	20	°C
Extrapolation length	8.05	8.05	cm
Infinite multiplication factor	1.363	-	
ν	2.43	2.43	
Migration length τ	46.10	46.00	cm^2
Diffusion length L^2	2.43	2.19	cm^2

Table III. Fuel parameters.

	Core I	Core II	
Fuel rod weight UO_2	327.8	327.9	g
U-235	9.08	11.02	g
Number of pellets per rod	32	41	
Height fuel pellet	12.40	9.65	mm
Number of pellets in B_4C poisoned fuel rod	30	-	
Number B_4C foils in B_4C poisoned fuel rod	29	-	
Average B_4C weight per foil	13.6	13.6	mg
Average B-10 weight per foil	2.0	2.0	mg

References.

(1) Ir. A. Tas and Drs. M. Bustraan ;
The subcritical facility PUK, SM 42/59 or
RCN-Int-63-058.

(2) Ir. P.C. van den Berg ;
A precise period meter, to be published.

(3) G.R. Keepin, T.F. Wimett and R.K. Ziegler ;
Delayed neutrons from fissionable isotopes
of U, Pu and Th :
Journal of Nuclear Energy 6. No 1/2,1 (1957).

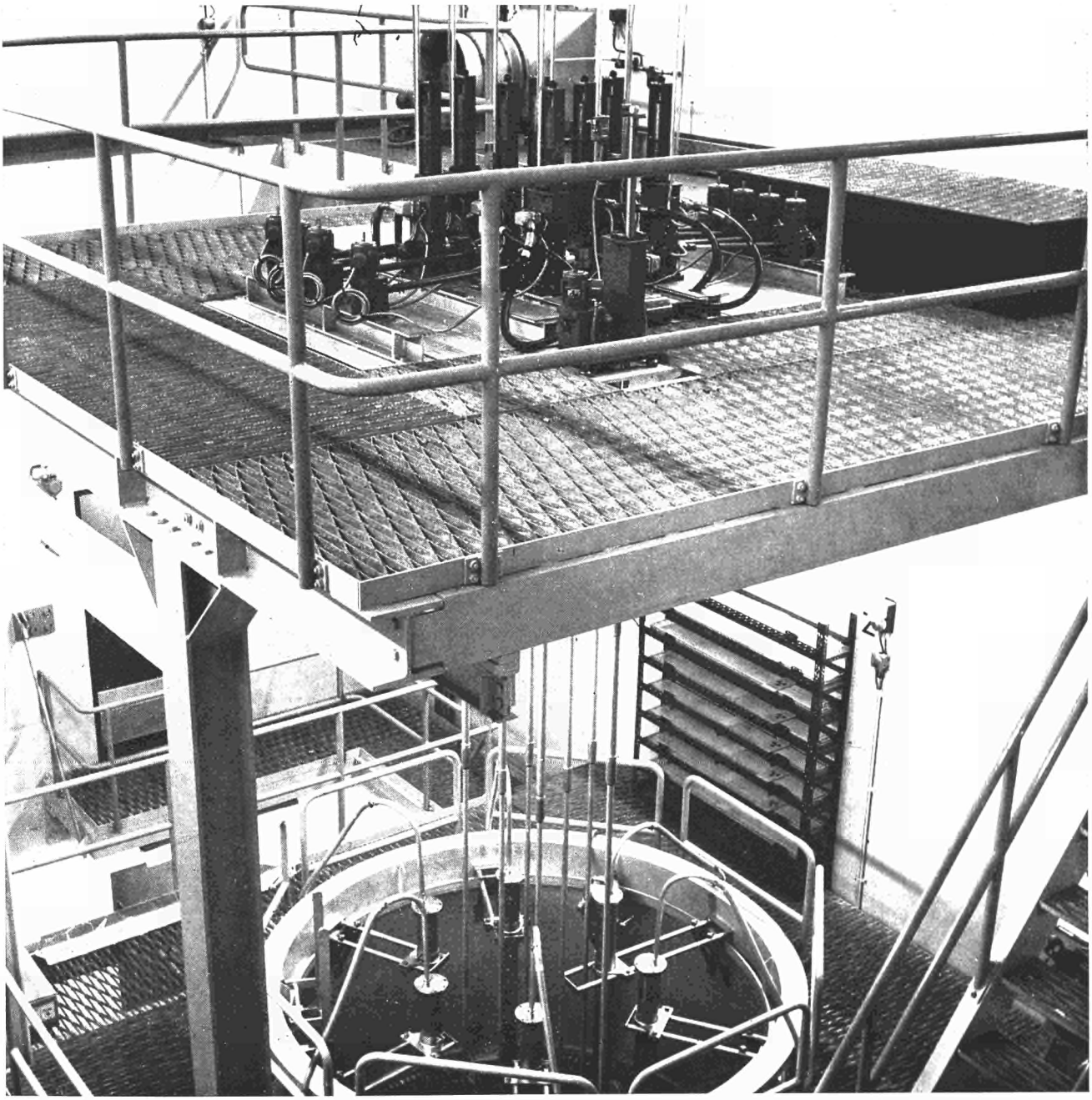


Figure 1 - KRITO installation

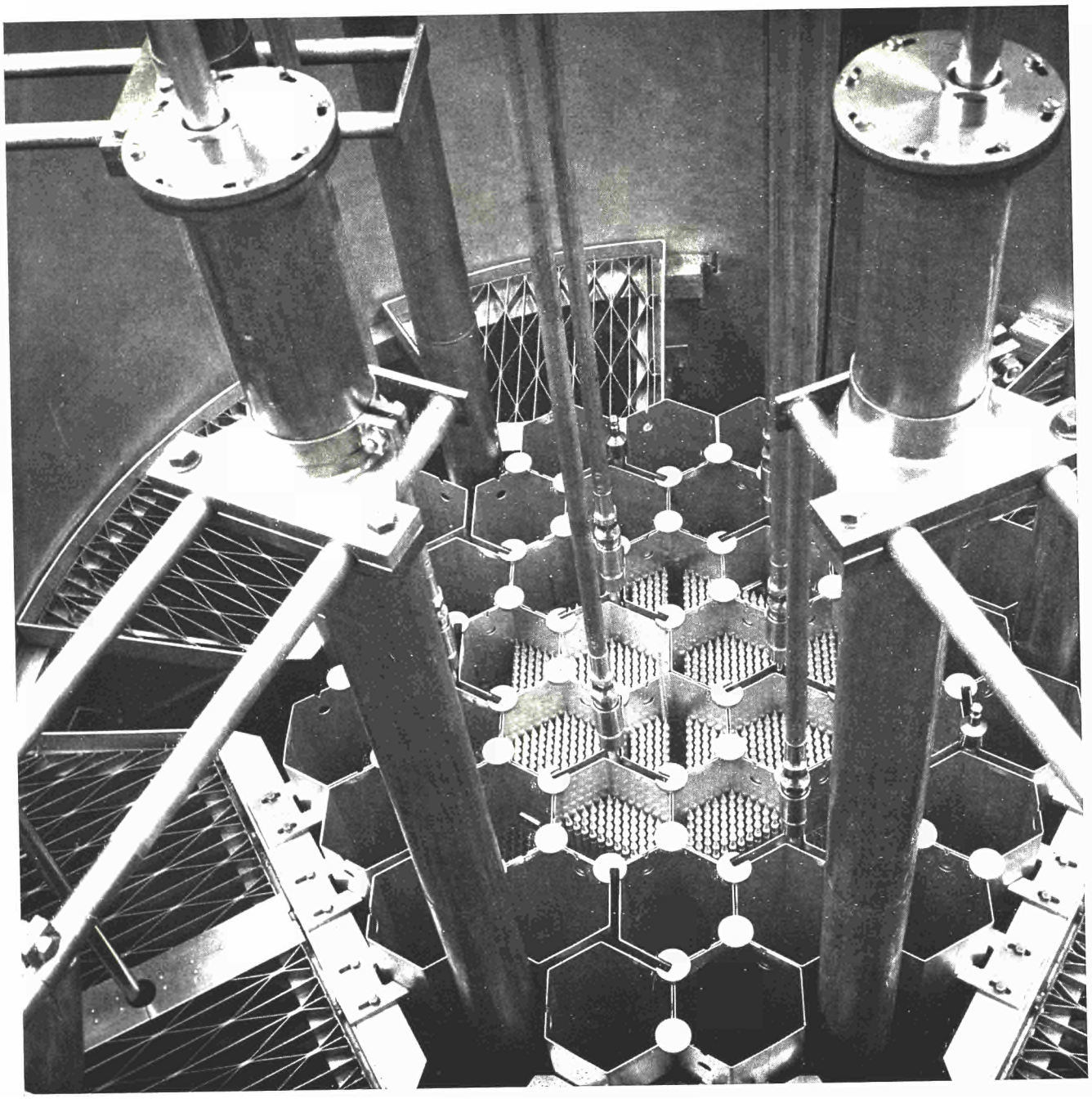


Figure 2 - KRITO core I

water gap introduced by removal of a double row of UO_2 rods.

Figure 3. Three dimensional view of critical facility.

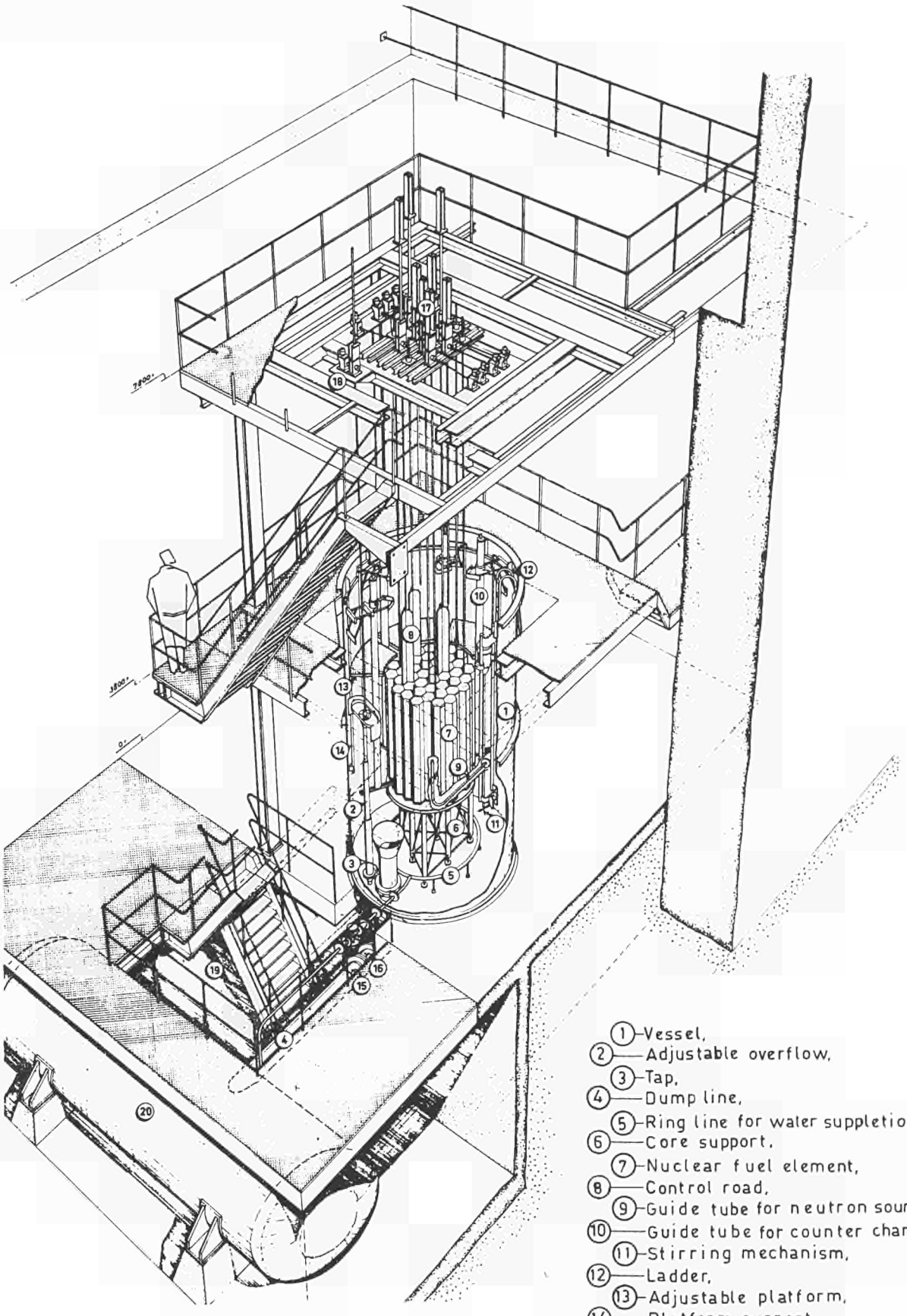
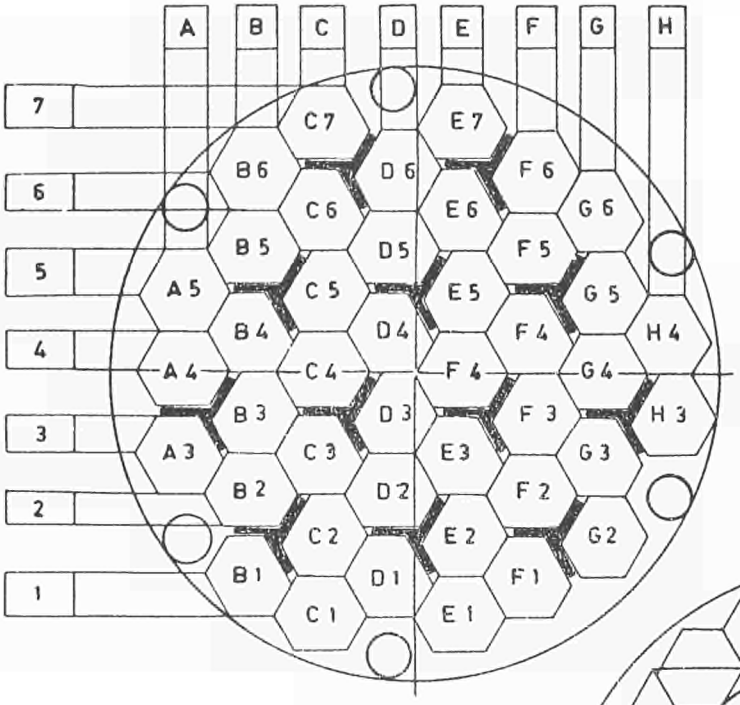
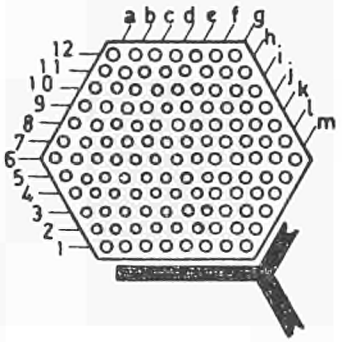


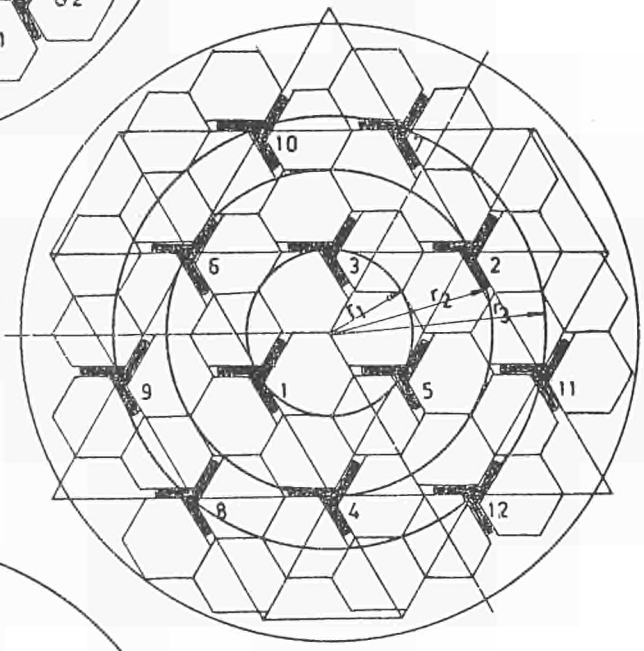
Figure 4. KRITO-core CODE-system.

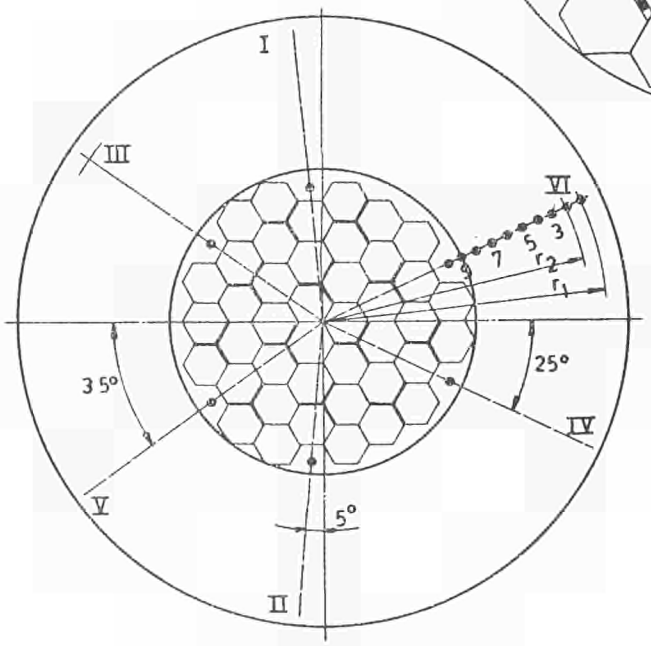




Control member positions.

r_1 = 18,3 cm	Posities	1, 3 en 5.
r_2 = 36,6 cm	Posities	2, 4 en 6.
r_3 = 48,4 cm	Posities	7, 8, 9, 10, 11 en 12.





r_1	= 105	cm
r_2	= 100	cm
r_3	= 95	cm
r_4	= 90	cm
r_5	= 85	cm
r_6	= 80	cm
r_7	= 75	cm
r_8	= 70	cm
r_9	= 65	cm
r_{10}	= 60	cm

neutron-Detector positions.

Figure 5. KRITO core vertical scale.

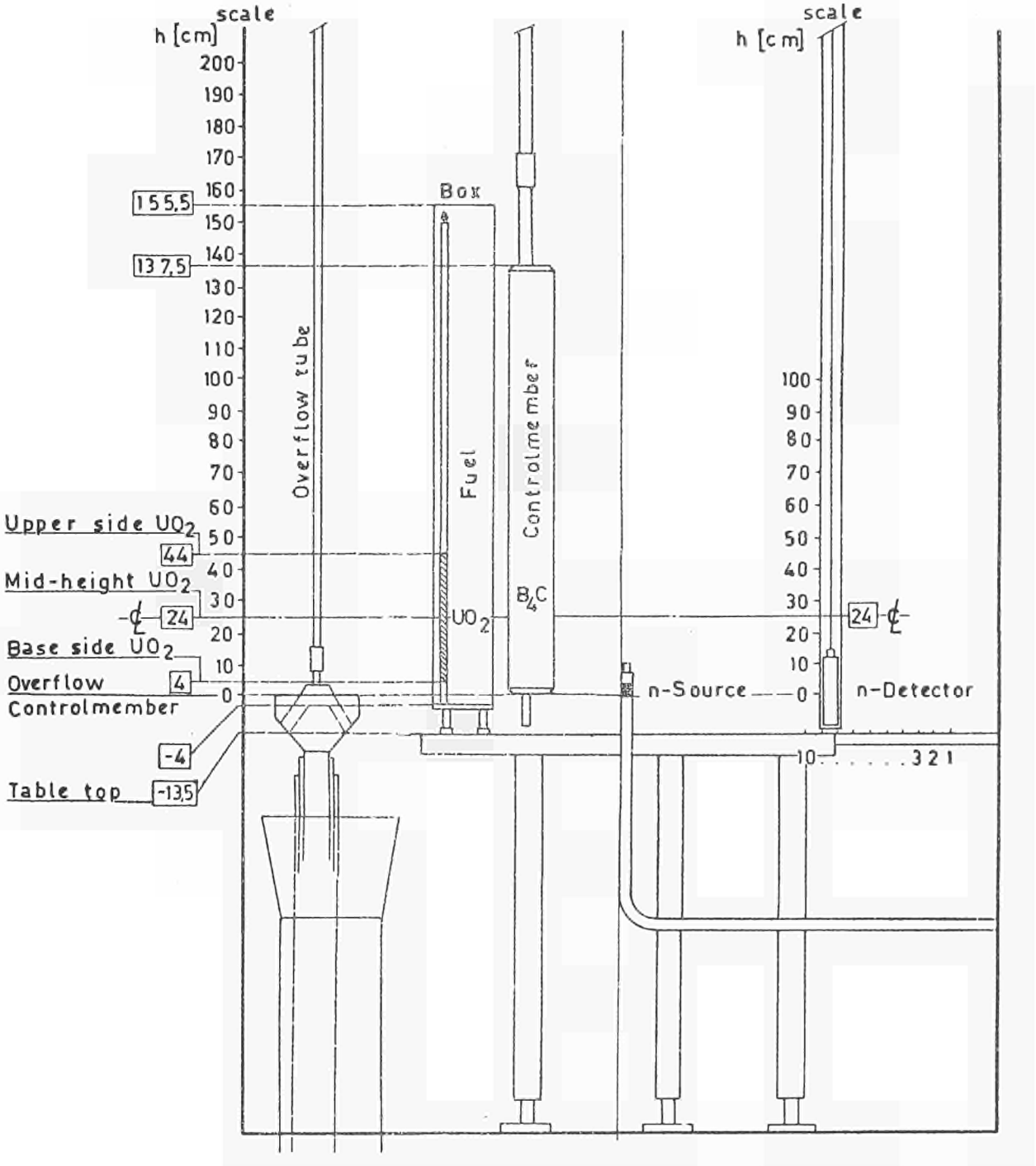


Figure 6a. Excess reactivity ρ_{ex} vs loading N. (number of UO_2 rods)

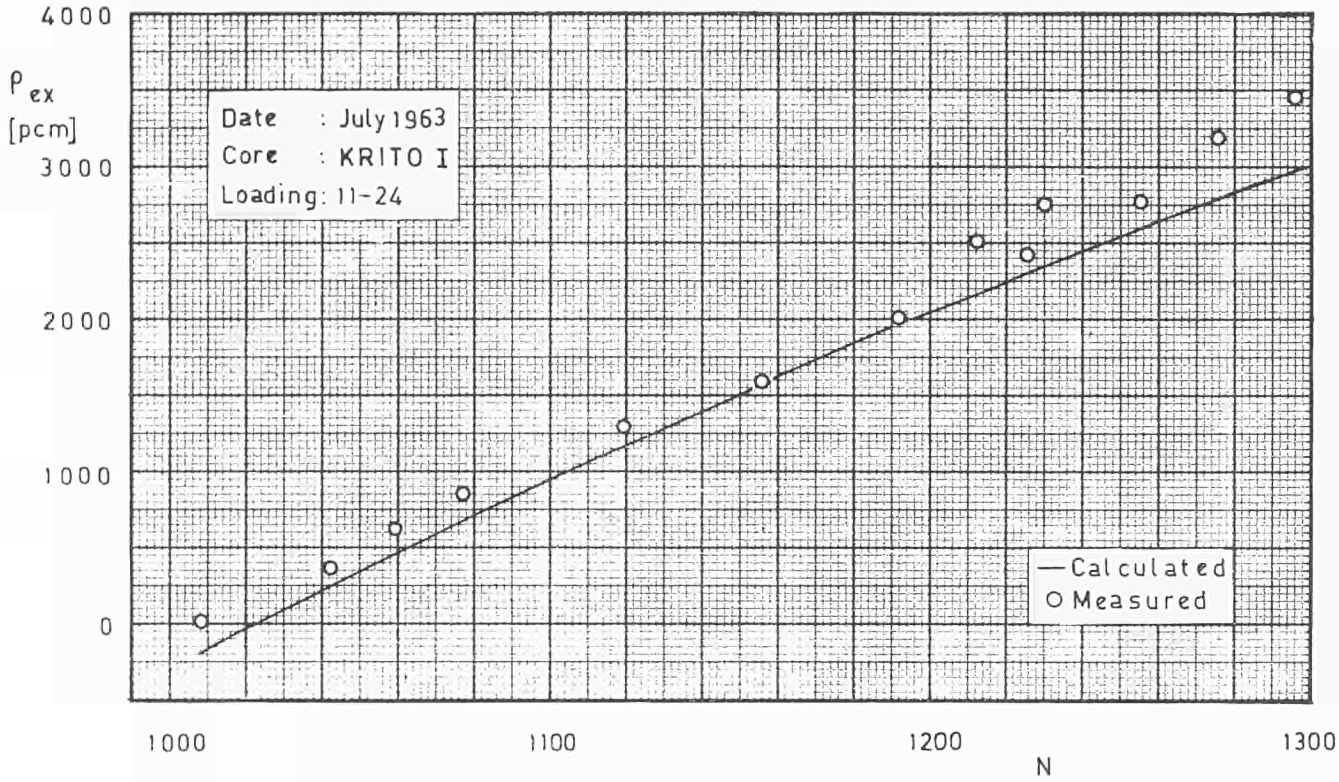


Figure 6b. Waterheight coeff. of reactivity $\frac{\partial \rho}{\partial h_w}$ vs waterheight h_w and k_{eff} of clean core vs waterheight. (loading 25)

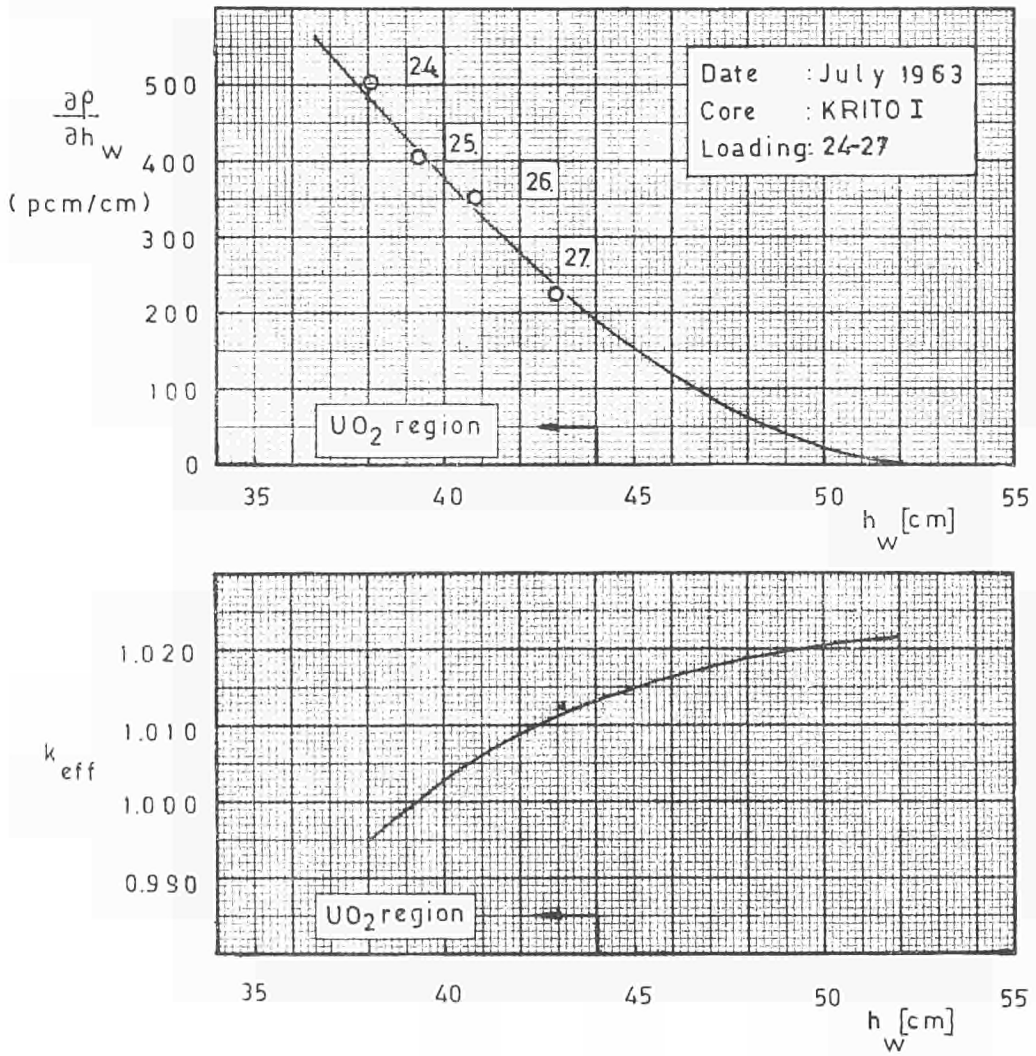


Figure 7a, Controlmemberworth ρ vs height h_r, position 1–3.

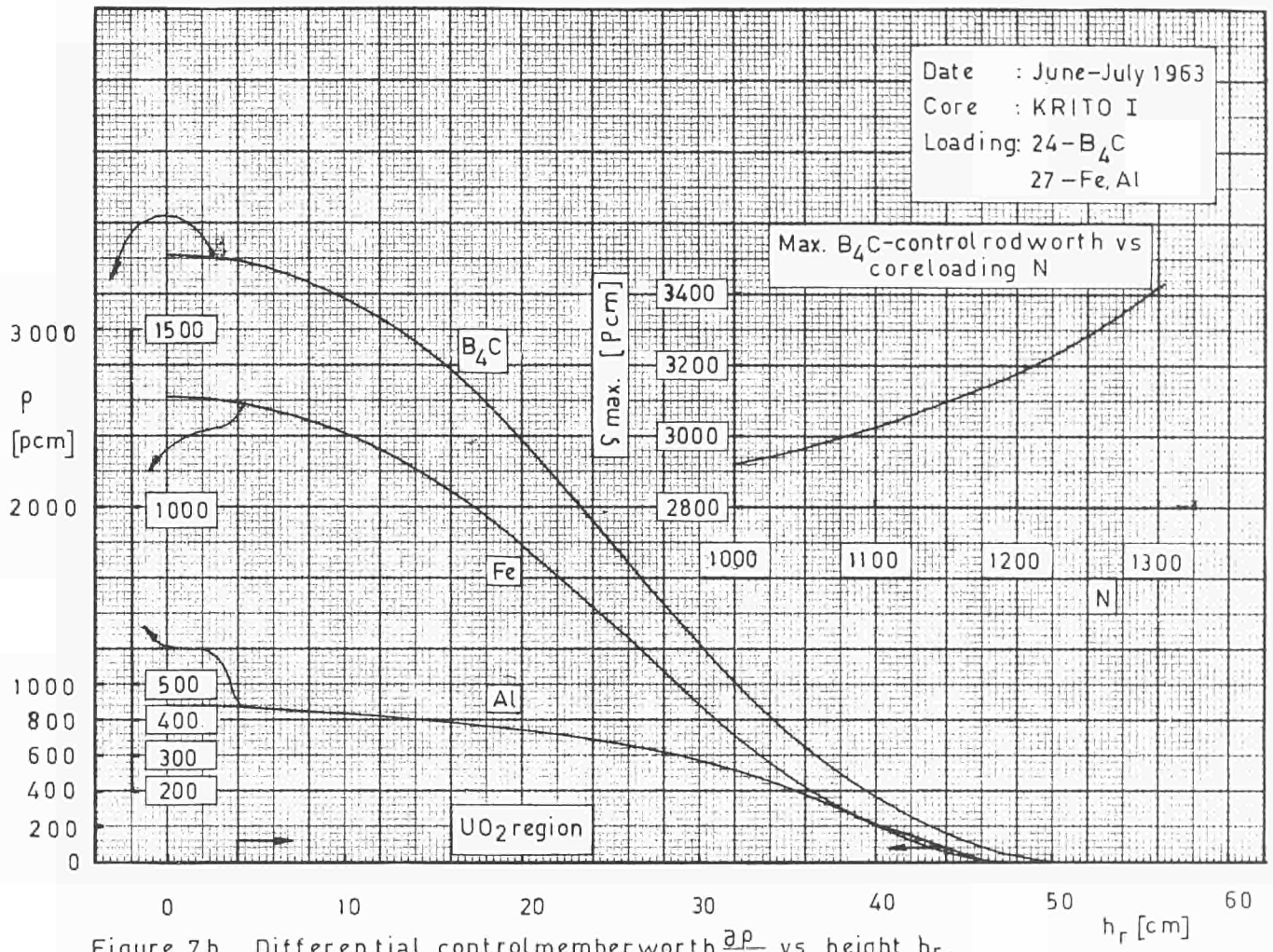


Figure 7b, Differential controlmemberworth $\frac{\partial \rho}{\partial h_r}$ vs height h_r.

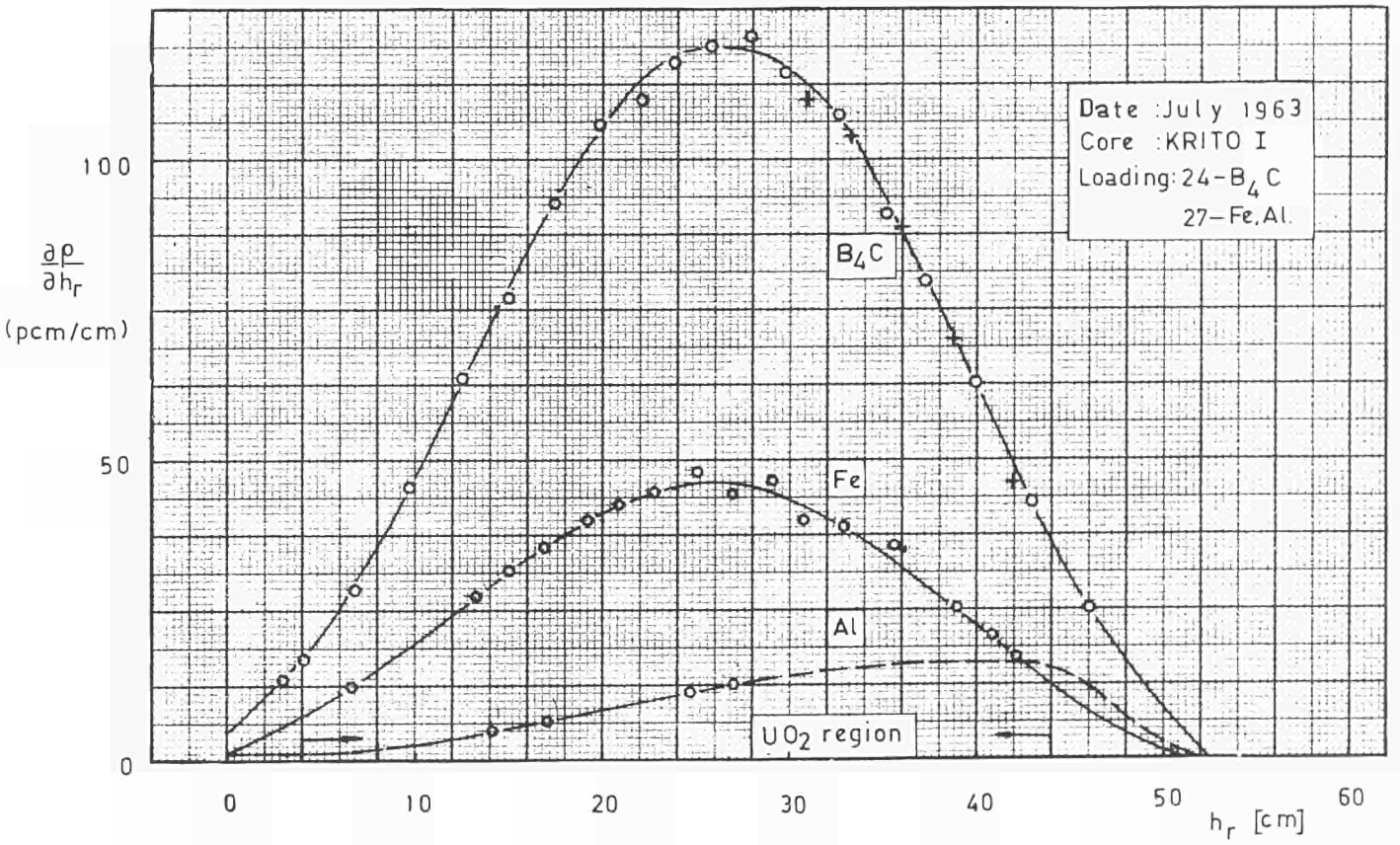


Figure 8, Radial thermal neutron flux density distribution, W.N.W.– E.S.E.

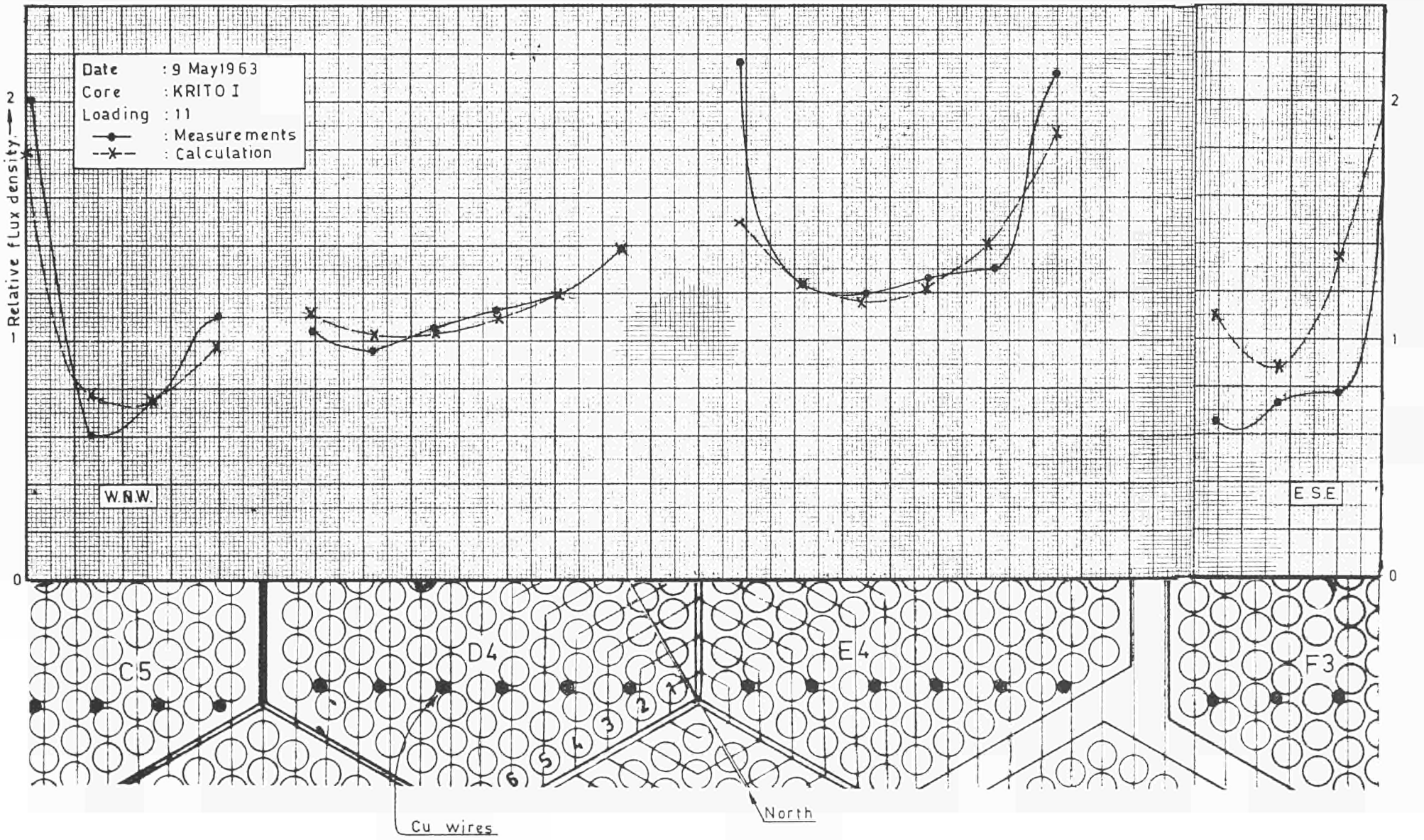
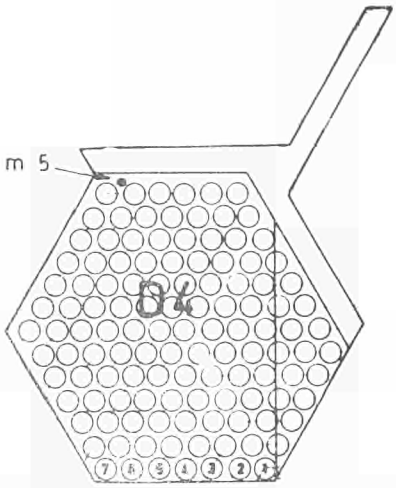


Figure 9. Typical vertical thermal neutron flux density distributions measured with a copper wire and with a fuel rod.



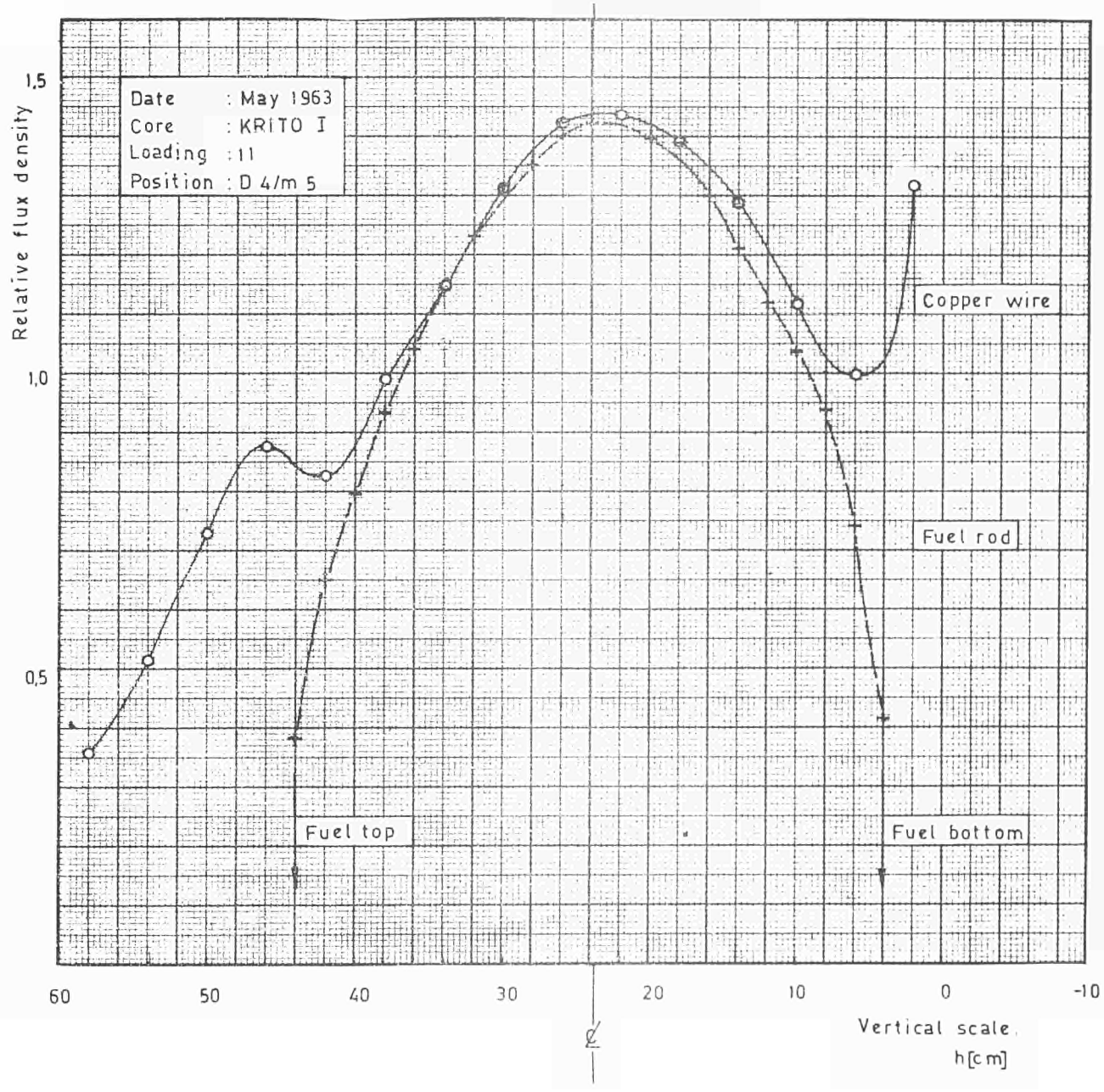


Figure 10. Thermal neutron flux density distribution in one fuel box.

Date	: 4 June 1963
Core	: KRITO I
Loading	: 24
h	: 20 cm.

N—normalization point,
=—measured in D 3,
Δ—measured in D 4,
o—measured in E 4,

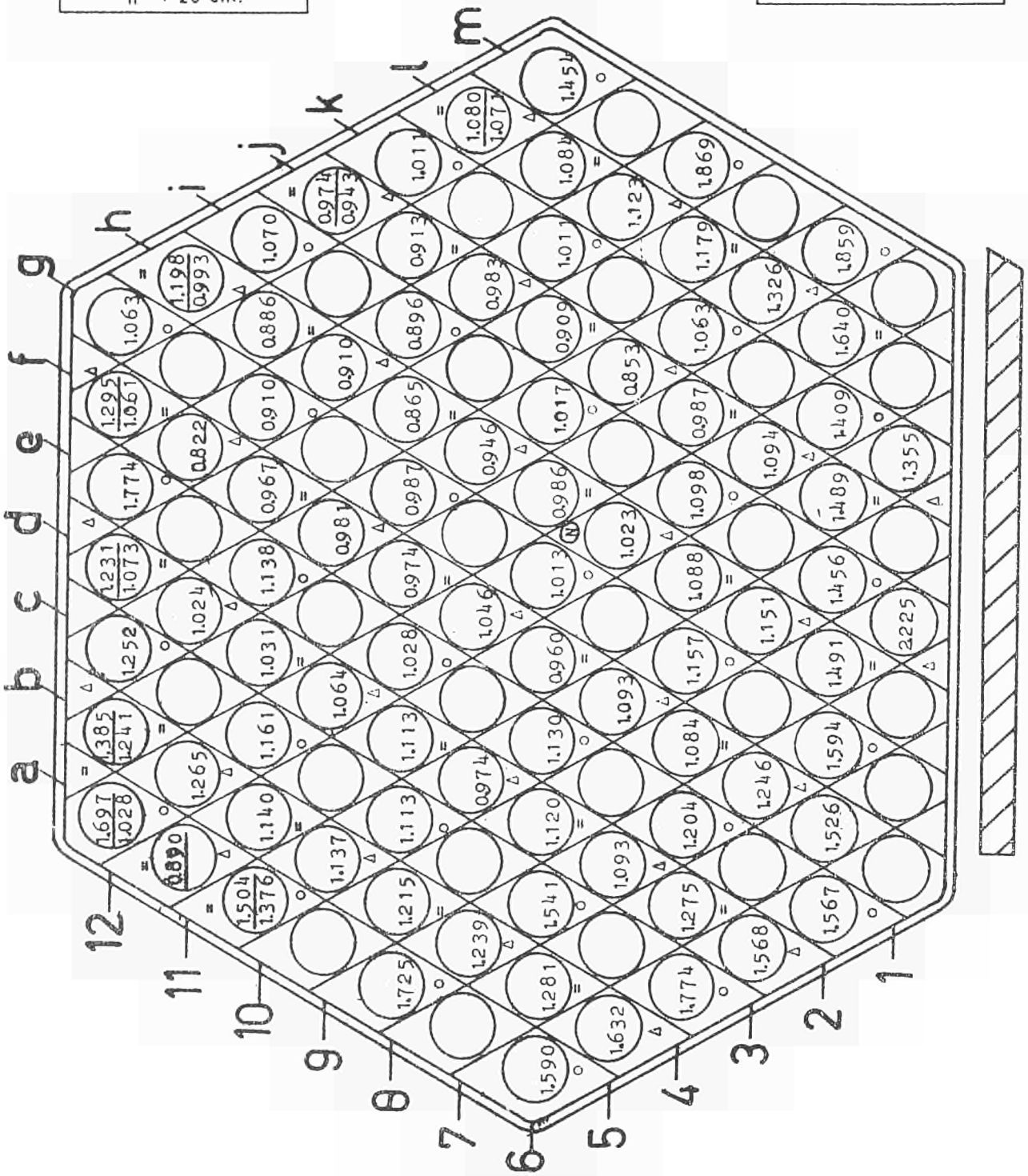


Figure 11. Neutron flux density distribution over gap between D_3 and D_4.