

FINAL REPORT OF TIC

VOLUME 3

**EXPERIMENTAL
INVESTIGATIONS OF
THE PHYSICAL
PROPERTIES OF
WWER-TYPE
URANIUM-WATER
LATTICES**

AKADÉMIAI KIADÓ, BUDAPEST

TEMPORARY INTERNATIONAL COLLECTIVE (TIC)
FOR JOINT RESEARCH INTO
THE PHYSICS OF WWER-TYPE REACTORS

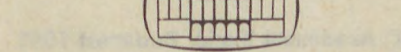
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TIC

EXPERIMENTAL INVESTIGATIONS

Dr. H. —

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The material for the present publication was prepared by an editorial team consisting of:

C. Alvarez	(Cuba)
J. Bárdos ^U	(Czechoslovakia)
R. Becker	(GDR)
L. Gácsi	(Hungary)
J. Gadó	(Hungary)
Iu.Ia. Kravchenko	(USSR)
Z. Szatmáry	(Hungary)
I. Vidovszky	(Hungary)

The English version was prepared by

J. Gadó, Z. Szatmáry, I. Vidovszky

For the compilation of the present publication, reports by the following specialists were used:

Cuba

O. Aguilar
C. Alvarez
A. Combarro

A. Elie
E. Orozco

Czechoslovakia

J. Broulik
J. Mikus
F. Hudec

C. Svoboda
J. Vacek

Finland

H. Rätty

GDR

R. Becker

Hungary

K. Almási
T. Czibók
J. Gadó
L. Gácsi
A. Gizella
Gy. Hegyi
E. Kondor

K. Krinisz
G. Pór
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Z. Szatmáry
J. Valkó
I. Vidovszky

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C. Dabrowski

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USSR

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К.В. Барболин (K.V. Barbolin)

Ю.Я. Кравченко (Yu.Ia.Kravchenko)

В.К. Калинин (V.K. Kalinin)

В.К. Обухов (V.K.Obuhov)

Viet-nam

Vu hai Long

Ha van Thong

АННОТАЦИЯ

В томе III Сборника трудов Временного международного коллектива (ВМК) описывается цикл экспериментов по физике уран-водных топливных решеток типа ВВЭР, проводившихся в рамках ВМК на критической сборке ZR-6M в Центральном институте физических исследований ВАН (г.Будапешт). Исследования, описанные в томе I настоящего Сборника, были продолжены при различных температурах и на других решетках. Эксперименты проводились с целью проверки и уточнения расчетных программ, используемых для вариантных расчетов реакторов ВВЭР-1000.

Приводятся условия проведения экспериментов, методика измерений и экспериментальные результаты по коэффициентам реактивности $\partial\rho/\partial N$, $\partial\rho/\partial T$, $\partial\rho/\partial C_B$, макро- и микрополям, лапласианам, спектральным характеристикам. В приложениях к тому дается добавочная информация об экспериментах, включающая картограммы исследованных конфигураций, оцененные радиальные макрополя, матрицы корреляции относительных активаций различных детекторов.

ABSTRACT

Volume 3 of the final report of the Temporary International Collective (TIC) contains a description of a series of experiments concerning the physics of WWER-type uranium fuelled water moderated lattices. The experiments in the frame of TIC were performed on the ZR-6M critical assembly established in the Central Research Institute for Physics of the Hungarian Academy of Sciences, Budapest. The series of experiments, described in Volume 1, has been extended to different temperatures and other lattices. The experiments were carried out with the aim of validating computer programs to be used for calculating the performance of WWER-1000 type power reactors.

The experimental conditions, the methods of measurements and the results of reactivity coefficients, reaction rate distribution and reaction rate ratio measurements are presented. In the Appendices volume supplementary information is given on the experiments, including core maps of the investigated configurations, evaluated radial reaction rate distributions and correlation matrices of the spectral ratios measured by different detectors.

NOMENCLATURE

Below some notations and expressions are explained which are used throughout this book but which are not standard.

a_k	fitted parameter
C_B	concentration of boric acid (H_3BO_3) dissolved in the moderator given in units of g/kg; sometimes, when this cannot lead to misunderstanding, it is abbreviated as "boron concentration"
$f(x, a)$	fitting function (see Volume 1 for more detail)
H	moderator height measured from the bottom end of the fuel rods
K_m	type of perturbed lattice consisting of fuel assemblies containing m lattice positions; sometimes it is used for the corresponding macrocell
λ_z	axial reflector saving
λ_r	radial reflector saving
ψ_I	value of an intra-macrocell distribution for macrocell position I
X_n	core obtained by replacing every nth fuel rod by a perturbation of type X; sometimes it is used for the corresponding macrocell
X_∞	core obtained by replacing the central fuel rod by a perturbation of type X
absorber rod	rod containing absorber material used only in the experiments (see Volume 1 for more detail)
configuration	reactor core characterized by the core map, boron concentration, absorber composition, lattice pitch, and temperature
control rod	rod used only for control purposes (to be distinguished from the "absorber rod")
core map	layout of fuel rods and absorber rods indicating fuel enrichment but not the absorber rod type and other parameters characterizing the "configuration"
enrichment	always expressed as atomic percentage of ^{235}U

fuel assembly	imitator of the fuel assemblies of WWER-type reactors
intracell	expression related to the dependence on the position inside the elementary cell
intra-macrocell	expression related to the dependence on the position inside the macrocell
macrocell	part of perturbed lattices by translation of which the whole core can be obtained
schematic core map	core map which is common to several cores (see Volume 1 for more detail)
spectral ratio	ratio of activities measured for the reactor and for the thermal column (see Volume 1 for more detail)
water gap	lattice perturbation obtained by pulling out a row of fuel rods from the lattice
water hole	lattice perturbation obtained by pulling out a fuel rod from the lattice
WWER	water moderated and water cooled power reactor of Novovoronezh type

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1. INTRODUCTION TO VOLUME 3 OF THE FINAL REPORT OF THE TIC

The experimental results presented here are based on measurements carried out on the ZR-6M critical assembly between 1979 and 1984.

The experiments described in Volume 1 of the Final Report of the TIC [Szatmáry et al. 1985] were continued for further cases, i.e. for different temperatures (in the range of 20 - 130°C) and in other lattices (e.g. for other lattice pitches, 15.0mm and 19.05mm), hereby enabling us to study the lattice parameters in wider ranges than earlier. Some new parameters such as the reactivity coefficient of temperature and boron concentration ($\partial\rho/\partial T$ and $\partial\rho/\partial C_B$) were introduced.

The present publication, similarly to Volume 1, is restricted to the presentation of the measured results (together with the methods used) but the problems of comparing experimental and calculated results are not considered here. In this sense, analysis of the experimental results is postponed to a later volume.

The experimental facility, i.e. critical assembly ZR-6M, is described in Chapter 2. From the neutron-physical point of view this critical assembly corresponds to critical assembly ZR-6, described in Chapter 2 of Volume 1. The critical assembly was reconstructed and modified so that it became suitable for measurements above room temperature (up to 135°C). In Chapter 2 only the modifications and the experiments performed to establish the nuclear safety of the critical assembly are described. Together with this description, data are given on the influence of uncertainties of technical data on the neutron physics parameters of the investigated lattices.

Only the experimental methods of the new parameters ($\partial\rho/\partial T$ and $\partial\rho/\partial C_B$) are described in Chapter 3, most of the experimental

methods are described in Chapter 3 of Volume 1, so it was unnecessary to repeat them here.

Chapter 4 is devoted to the results of measurements. Quantities such as criticality data, bucklings, spectral ratios, etc. are presented there fully but those involving of large tables such as reaction rate distributions are only described in Chapter 4 and the distributions themselves are presented fully in Appendix B. The experimental errors given in this work are always simple σ values. It should be noted, that the errors caused by the uncertainties of the technical parameters are not included in the experimental errors.

Tables 1.1 to 1.4 below summarize and roughly classify the lattices investigated and give references to the relevant internal reports. A detailed description of the lattices is given in reports [814,817 and 819]. Report [816] describes the methodological experiments performed on ZR-6M.

In the experiments described, both regular and perturbed lattices were investigated. The influence of the main lattice parameters (fuel enrichment, lattice pitch, boric acid concentration in the moderator, temperature) on the neutron physics characteristics were mainly studied for the regular lattices.

In choosing the lattice perturbations to be studied, the characteristic perturbations of WWER-1000 reactor were taken as a measure of orientation. The same types of perturbations (absorber rods, water holes) were used as in the perturbed lattices described in Volume 1. In the early experiments (described in Volume 1) the perturbations were investigated as irregularities introduced into the reference lattice (lattice pitch - 12.7mm, fuel enrichment - 3.6%, temperature - 20°C, no boron in moderator). In further experiments, described here, other perturbed lattices (e.g. lattice pitch - 11.0mm), were

investigated too.

The following lattice characteristics were measured:

- criticality parameters H_{cr} and $\partial\rho/\partial H$,
- reactivity coefficients $\partial\rho/\partial T$ and $\partial\rho/\partial C_B$,
- radial and axial distributions of reaction rates (by activating foils and measuring fuel activity) referred to as Φ_{MA} ,
- spectral ratios for different detector materials and lattice positions (referred to as A_{ml}),
- intra-macrocell distributions of reaction rates referred to as Φ_{MI} .

For completeness, some results from Volume 1 are presented here as well. The summarizing tables always contain the averages of all the measured values.

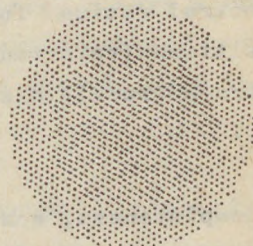
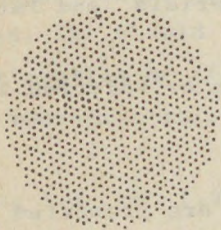
A mixed referencing system is used throughout this book: TIC reports are referred to simply by their numbers; other papers, articles or books are referred to by author(s) and year of appearance.

This Volume, similarly to Volume 1, is published both in Russian and in English.

Table 1.1 Regular one- and two-region lattices

Most of the cases studied consisted of one-region cylindrical cores but the quantity of available fuel elements of 1.6 and 4.4% enrichment made it necessary to use 3.6% driver zones for lattices of these enrichments.

Typical core maps



Notation for

one-region lattices

· - fuel rods of 3.6
or 4.4% enrichment

two-region lattices

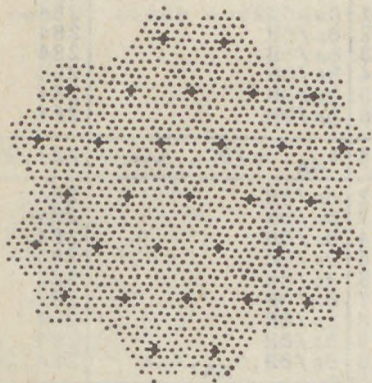
x - fuel rods of 1.6
or 4.4% enrichment
· - fuel rods of 3.6
enrichment

Lat- tice pitch [mm]	En- rich- ment [%]	C _B [g/ kg]	T [°C]	Number of fuel rods	Core iden- tifica- tion	Measured quantities	TIC reports
12.7	3.6	0	20 80 130	805	154/154 246/154	$\partial\rho/\partial H, \Phi_{MA}, A_{mt}$ $\partial\rho/\partial H, \Phi_{MA}, \partial\rho/\partial T$ $\partial\rho/\partial H, \Phi_{MA}$	264, 266, 267 264, 265 264, 266, 267
12.7	3.6	1.1	20 130	1765	162/161	$\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$ $\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$	275 275
12.7	3.6	4.0	20 80 130	1765	161/161	$\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$ $\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$ $\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$	270, 275 270, 275 270, 275
12.7	3.6	5.8	20 80 130	1765	163/161 247/161	Φ_{MA}, A_{mt} $\Phi_{MA}, \partial\rho/\partial T, \partial\rho/\partial C_B$ Φ_{MA}, A_{mt}	272, 277, 278 272, 276 272, 277, 278
12.7	4.4	0	20 130	625	159/159 164/159	$\Phi_{MA}, A_{mt}, \partial\rho/\partial T$ Φ_{MA}, A_{mt}	268, 269, 274 285 274, 273, 278
12.7	4.4 3.6	0	20 80 130	625 186	166/166	Φ_{MA}, A_{mt} Φ_{MA}, A_{mt}	274, 273, 278 274, 273, 278 274, 273, 278

Lat- tice pitch [mm]	En- rich- ment [%]	C _B [g/ kg]	T [°C]	Number of fuel rods	Core iden- tifica- tion	Measured quantities	TIC reports
11.0	3.6	0	20	1855	188/188	$\Phi_{MA}, \partial\rho/\partial T, A_{mt.}$ $\partial\rho/\partial H$	280, 281, 282 283, 284
			80			$\Phi_{MA}, \partial\rho/\partial T$	281, 283
			130			$\Phi_{MA}, \partial\rho/\partial T, A_{mt.}$	280, 281, 282 283
			20	1891	191/191	$\partial\rho/\partial H$	284
			20	1801	192/192	$\partial\rho/\partial H$	284
			20	1747	193/193	$\partial\rho/\partial H$	284
			20	1711	194/194	$\partial\rho/\partial H$	284
			20	1675	195/195	$\partial\rho/\partial H$	284
			20	1638	196/196	$\partial\rho/\partial H$	284
11.0	3.6	1.0	20	1855	209/188	$\Phi_{MA}, \partial\rho/\partial C_B, A_{mt.}$	281, 282, 283
15.0	3.6	0	20	409	212/212	$\partial\rho/\partial H$	284
			20	487	213/213	$\partial\rho/\partial H$	284
			20	571	214/214	$\partial\rho/\partial H$	284
			20	661	215/215	$\partial\rho/\partial H$	284
			20	769	216/216	$\partial\rho/\partial H$	284
			20	811	217/217	$\partial\rho/\partial H$	284
			20	919	218/218	$\partial\rho/\partial H$	284
			20	1015	219/219	$\partial\rho/\partial H$	284
			20	637	220/220	$\partial\rho/\partial H, \Phi_{MA}, A_{mt.}$	284, 287, 291
15.0	3.6	4.0	20	1931	239/239	$\partial\rho/\partial H$	288
				1800	238/238	$\partial\rho/\partial H$	288
				1687	237/237	$\partial\rho/\partial H$	288
				1519	236/236	$\partial\rho/\partial H$	288
				1339	235/235	$\partial\rho/\partial H$	288
				1213	234/234	$\partial\rho/\partial H$	288
				1147	240/240	$\partial\rho/\partial H$	288
				1069	232/232	$\partial\rho/\partial H, \Phi_{MA}, A_{mt.}$	287, 288, 291 292, 293, 294
				985	233/233	$\partial\rho/\partial H$	288
15.0	4.4	0	20	583	221/221	$\partial\rho/\partial H, \Phi_{MA}, A_{mt.}$	286, 287, 288 291, 292
				691	223/223	$\partial\rho/\partial H$	288, 292
				637	224/224	$\partial\rho/\partial H$	288, 292
				547	225/225	$\partial\rho/\partial H$	288, 292
				500	226/226	$\partial\rho/\partial H$	288, 292
				437	227/227	$\partial\rho/\partial H$	288, 292
				396	228/228	$\partial\rho/\partial H$	288, 292
				361	229/229	$\partial\rho/\partial H$	288, 292
				349	230/230	$\partial\rho/\partial H$	288, 292
15.0	1.6 3.6	0	20	625	231/231	$\partial\rho/\partial H, \Phi_{MA}, A_{mt.}$	288, 291, 292
				444			288, 292
19.05	3.6	0	20	1015	199/199	$\partial\rho/\partial H$	284
			20	919	200/200	$\partial\rho/\partial H$	284
			20	811	201/201	$\partial\rho/\partial H$	284
			20	769	202/202	$\partial\rho/\partial H$	284
			20	661	203/203	$\partial\rho/\partial H$	284
			20	571	204/204	$\partial\rho/\partial H$	284
			20	487	205/205	$\partial\rho/\partial H$	284
			20	411	206/206	$\partial\rho/\partial H$	284
			20	349	207/207	$\partial\rho/\partial H$	284
			20	313	208/208	$\partial\rho/\partial H$	284

Table 1.2 Regularly perturbed lattices of type Xn

All the measurements on perturbed lattices of type Xn were performed at a fuel enrichment of 3.6%, lattice pitches 12.7 and 11.0mm, and the moderator did not contain boric acid.



Typical core map of Type X7

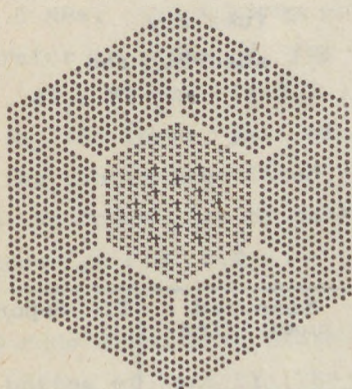
- - fuel rod
- + - absorber rod or water hole

Lat-tice pitch [mm]	Type of pert-urba.	Numb. of pert-urba.	T [°C]	Number of fuel rods	Core iden-tifica-tion	Measured quantities	TIC reports
12.7	F7	31	20 130	1488	155/155	$\partial\rho/\partial T, \Phi_{MA}, \Phi_{MI}$ $\partial\rho/\partial T, \Phi_{MA}, \Phi_{MI}$	349, 350, 360 349, 350, 360
12.7	E3	91	20	726	176/176	$\partial\rho/\partial H, \Phi_{MA}, A_{me}, \Phi_{MI}$	271, 351, 353 354
12.7	C5	55	20	1320	177/177	$\partial\rho/\partial H, \Phi_{MA}, \Phi_{MI}$	271, 351, 353
12.7	G3	37	20	1764	241/241	$\partial\rho/\partial H, \Phi_{MA}$	288, 358
12.7	G5	37	20	1765	242/242	$\partial\rho/\partial H, \Phi_{MA}$	288, 358
12.7	G7	31	20 130	1488	244/244	$\partial\rho/\partial H, \Phi_{MA}$	288, 358
12.7	E7	31	130	1488	245/245	$\partial\rho/\partial H, \Phi_{MA}$	288, 349
11.0	E7	31	20	1488	189/189	$\partial\rho/\partial H, \Phi_{MA}, A_{me}, \Phi_{MI}$	284, 355, 357
11.0	E3	169	20	1350	190/190	$\partial\rho/\partial H, \Phi_{MA}, \Phi_{MI}$	284, 355

Table 1.3 Lattices imitating fuel assemblies of type K331

All the lattices of type K331 investigated had a lattice pitch of 11.0mm and the moderator did not contain boric acid. The temperature was 20°C.

In one case (core 197/197), the assembly contained fuel rods of 4.4% enrichment surrounded by rods of 3.6% enrichment. In the other case (core 198/198), the peripheral row of the assembly was replaced by fuel rods of 3.6% enrichment otherwise the core was identical to core 197/197.



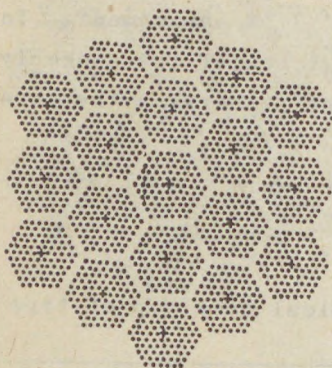
Typical core map of type K331

- - fuel rod
- + - absorber rod
- o - water hole

Type/N ^o of per- turba- tion	Enrich- ment [%]	Number of fuel rods	Core iden- tifica- tion	Measured quantities	TIC reports
13/F3	3.6 4.4	1380 318	197/197	$\partial \rho / \partial H, \Phi_{MA}, A_{mt.}$	284, 356, 357
13/F3	3.6 4.4	1440 258	198/198	$\partial \rho / \partial H, \Phi_{MA}, A_{mt.}$	284, 356, 357

Table 1.4 Lattices imitating fuel assemblies of type K91

All the lattices of type K91 investigated had a lattice pitch of 12.7mm, fuel enrichment of 3.6% and the moderator did not contain boric acid. The temperature was 20°C.



Typical core map of type K331

- - fuel rod
- + - absorber rod

Type/ N^0 of per- turba- tion	Assembly wall	Number of fuel rods	Core iden- tifica- tion	Measured quantities	TIC reports
no	water	1729	179/179	$\partial\rho/\partial H$	271
19/ D_∞	water	1710	180/179	$\partial\rho/\partial H, \Phi_{MA}, \Phi_{MI}$	271, 353

2. CRITICAL ASSEMBLY ZR-6M

2.1. TECHNICAL DATA

The investigations reported in the present volume were carried out on critical assembly ZR-6M (see Fig.2.1.), which is a modified version of ZR-6, described in Volume 1.

The core is accommodated inside a stainless steel cylindrical tank (core tank, further abbreviated as ZT, see Fig.2.1.) of 1070mm diameter, which is inside another cylindrical tank (reactor tank, further abbreviated as RT, see Fig.2.1.). Its designed pressure is 0.5 MPa, the maximum operational temperature is 135 °C. The moderator is prepared for the experiments in auxiliary vessels (AT₁, AT₂, FT see Fig.2.2.). It flows from these vessels to tank RT, in the lower part of which the electrical heater and the cooling system are placed. The filling of core tank (ZT) is done from the lower part of tank RT. The technological system of ZR-6M is shown in Fig. 2.2.

Fuel rods stand on a plate, placed at 250mm height, measured from the bottom of tank ZT. The hexagonal fuel lattice is defined by a set of perforated grid plates. Each set contains three grid plates with pitches: 11.0 ± 0.03 , 12.7 ± 0.02 and 15.0 ± 0.03 mm. In the first period of experiments on ZR-6M, i.e. from 1979 to the middle of 1982, all three grid plates were made of stainless steel, and had a thickness of 5 mm. After the middle of 1982 the intermediate grid plate was made of aluminum and was 3 mm thick.

Criticality was reached by varying the moderator height. The possibility of regulation by a manually moved absorber rod was also given (for cases of full top reflector). The fine regulation of moderator height in the 300 - 800 mm interval was after 1985 accomplished by a spacer.

The emergency shut down of the critical assembly takes place by means of absorber rods and fast working valves. In an emergency the water falls from core tank ZT to tank RT through these valves, which are driven pneumatically. The valves are opened when the rods do not stop the reactor. Up to the middle of 1982 9 star formed rods, made of borated stainless steel were used as emergency absorber rods. After that the original control rods, used in critical assembly ZR-6, came into operation again. These control rods consisted of two parts: the upper part was a zirconium tube filled with boron carbide, the lower part was a usual fuel rod. In this way, no perturbation occurred in the core after the control rods were pulled out. The efficiency of these rods is much higher than that of the star formed rods, as a consequence of which three rods were always enough.

2.2. CONTROL AND MEASURING SYSTEM

The control and measuring system of the critical assembly is based on three impulse and three current neutron detectors; four of them are operated in linear and two of them in logarithmic range. This measuring system informs the operator on the power of the critical assembly and gives signals to the emergency shut down system should the previously given parameter values be exceeded. The detector systems are fully independent of each other. The impulse detectors are fission chambers of KNT-31 type, while the current detectors are ionization chambers of RWKJ-8 type. The measuring system is built of NIMCS modules (the abbreviation means Nuclear Industrial Device Family). These modules were developed by the Central Research Institute for Physics Budapest (KFKI).

The technological measuring system consists of temperature and pressure meters, pressure difference meters and water level meters.

The water temperature in tank RT is measured by means of two platinum thermocouples, one of which is connected to the thermoregulator. The values measured by the two thermocouples are shown on the operator's panel, and they are recorded by means of $x(t)$ recorders.

The first experiments on critical assembly ZR-6M at high temperatures showed that the distribution of the temperature in the core is not sufficiently homogeneous. The inhomogeneity of temperature in the first $\partial\rho/\partial T$ measurements exceeded $\pm 1^\circ\text{C}$. The use of a special heater in the core did not help. At the same time the measurement of temperature was also insufficiently accurate as the measurement was based on a freezing ice-water mixture.

Based on previous experience, the technological system of the critical assembly was modified and the moderator now flows into the central part of the active core, below the central fuel assembly. The outlet of the moderator is accomplished by an electromagnetic valve. The special heater was removed. In this way the possibility of mixing the water in the core is given. As a side effect, the water level in the core can rapidly be decreased without operating the fast valves. The temperature measuring system was based on an ultrathermostat, which improved the accuracy of the temperature measurement.

The above mentioned changes lead to homogeneously distributed and sufficiently accurately measured temperatures. Now, the procedure for temperature determination is as follows. The previously calibrated thermocouples are mounted inside the core, at different radii and heights, with positions depending on the core size. The temperature of the thermostat (T_0) is measured and recorded, by means of an officially calibrated mercury thermometer. The difference in temperature (ΔT) is measured and

recorded for each thermocouple. The sum $T_0 + \Delta T$ gives the temperature of the core at each point. On this basis the average temperature of the core is calculated.

In the core tank ZT, 6-9 (depending on core size) thermocouples are inserted between the fuel rods at different radii and heights during the measurements. By means of these the temperature of the core can be kept within the limit of 0.2 - 0.5°C during operation (maximum 2-3 hours).

The pressure of the core is measured by means of sensors placed in tank ZT. The values measured by these sensors are shown and recorded on the operator's panel. In order to detect fast changes in pressure inside the RT the pressure difference measuring system is used. A buffer tank PT is joined to tank RT by a tube of small cross section. Under normal conditions, the pressure in PT is equal to that in RT. If the pressure in RT decreases rapidly, a remarkable difference in pressures of RT and PT can be detected as the pressure in PT decreases only after a certain delay.

Two level meters serve for the rough measurement of moderator level, indication of these meters is shown on the operator's panel by means of TV cameras.

Accurate measurement of the moderator level is performed by means of a contact type levelmeter. Its working principle is the measurement of the electric conductivity of the moderator. This fine levelmeter is mounted either on the reactor cap (for high temperature measurements, performed under pressure) or on the top plate. The accuracy of the contact type levelmeter is $\pm 0.02\text{mm}$, within an interval of 0 - 150mm. To reach the same accuracy within the whole height of the core, reference needles were placed along a quartz rod.

To convert the operator's commands to emergency systems, and to accomplish the prescribed blocking conditions, as well as to fulfil the emergency level conditions of the nuclear and technological system, a self controlled system is used.

The dosimetric control system is based on a six channel gamma and neutron radiation measuring system, the detectors of which are placed in the reactor hall and in the auxiliary rooms.

2.3. MODERATOR

The moderator was distilled water. In some of the experiments, boric acid was dissolved in it.

After the reconstruction of the critical assembly, measurements of reactivity coefficient $\partial\rho/\partial C_B$ started at various boron concentrations and temperatures. For the purpose of these experiments the measurement of boric acid concentration by titration is insufficient: a more accurate measurement of relative concentrations in a narrow range is necessary (see in Section 3.3 for more detail).

The possibility of increasing and decreasing the boron concentration was established. It was also essential to keep the boric concentration constant. Should the reactor vessel (RT) be opened the boric acid concentration always increases as a consequence of evaporation. This effect increases with increasing temperature. Earlier it was impossible to establish the previous boron concentration, therefore the accuracy of the experimental results was insufficient. This problem has been solved in the following way. Before each measurement at higher temperatures, the critical height was measured, and afterwards, in accordance with the known $\rho(C_B)$ and $\rho(H)$ curves, correction of the boron concentration was made by using calibrated vessels. In this process it was essential to keep the temperature constant.

The water density at 130°C is 0.93153 g/cm³ (an overpresssure of 0.36 MPa is assumed) resulting in the following nuclear densities:

$$\text{for } ^1\text{H} : N_{\text{H}} (0) = 0.062489 \cdot 10^{24}/\text{cm}^3$$

$$\text{for } ^{16}\text{O} : N_{\text{O}} (0) = 0.031244 \cdot 10^{24}/\text{cm}^3$$

The water density at 80°C is 0.97182 g/cm³ (an overpresssure of 0.36 MPa is assumed) resulting in the following nuclear densities:

$$\text{for } ^1\text{H} : N_{\text{H}} (0) = 0.064979 \cdot 10^{24}/\text{cm}^3$$

$$\text{for } ^{16}\text{O} : N_{\text{O}} (0) = 0.032489 \cdot 10^{24}/\text{cm}^3$$

It is mentioned, that the nuclear densities at room temperature are given in Volume 1.

2.4. LATTICES

In the experiments, besides the lattices with pitches 11.0 and 12.7mm, described in Volume 1, the following two were used:

- lattice with 15.0mm lattice pitch, where the upper and lower grid plates were made of stainless steel and the intermediate grid plate was made of aluminum.
- lattice with 19.05mm lattice pitch, which was made of grid plates with 11.0mm lattice pitch, where the fuel rods were placed as shown in Fig. 2.3.

2.5. PRESSURE AND ITS INFLUENCE ON THE SAFETY OF THE MEASUREMENTS

The high temperature measurements were performed at a pressure of 0.36MPa.

In the period of the preparatory experiments it was necessary to show that a decrease of pressure does not lead to an increase in reactivity, even at the maximum temperature. In order to carry out these experiments the pressure vessel of the reactor was supplied with magnetic valves and with a special pressure measuring system. The first series of these measurements, described in detail in report [815] proved, that the reactivity change is always negative.

The second series of experiments confirmed quantitatively that a decrease of pressure leads to a remarkable decrease in reactivity in lattices, with pure water as moderator, at different critical heights. To illustrate this (Fig.2.4) the results of these experiments are shown for $H_{cr}=819\text{mm}$. The third series of experiments was performed with a moderator whose boric acid concentration was 4.0g/kg. As can be seen from Fig.2.5, in this case the reactivity effect is still negative, but the reactivity coefficient is less in absolute value.

2.6. SENSITIVITY OF SOME NEUTRON PHYSICS PARAMETERS TO TECHNICAL UNCERTAINTIES

The sensitivities were calculated in multigroup asymptotic approximation [821].

In Volume 1 sensitivity data are given as an illustration for a selected lattice. To make use of the experimental results given here, it is essential to know these sensitivities for different lattices. In Tables 2.1 - 2.10 sensitivity data of neutron physics parameters are given for lattices of different lattice

pitch (11.0, 12.7 and 15.0mm), different fuel enrichments (3.6 and 4.4%), different boron concentrations in the moderator (0, 4.0 and 7.2 g/l), and calculated for different temperatures (20 and 130°C).

The calculations performed show that the uncertainty in temperature, which is assumed to be 1°C, changes the values given in Tables 2.1 - 2.10 only to a negligible extent.

Note that the results presented in Table 2.2.5 of Volume 1 and those in Table 2.1 are somewhat different. The results presented in Volume 1 are taken from the report [807], while the actual results from [821]. The difference between the sensitivities is not greater, than the presumed error of the calculation (~5%).

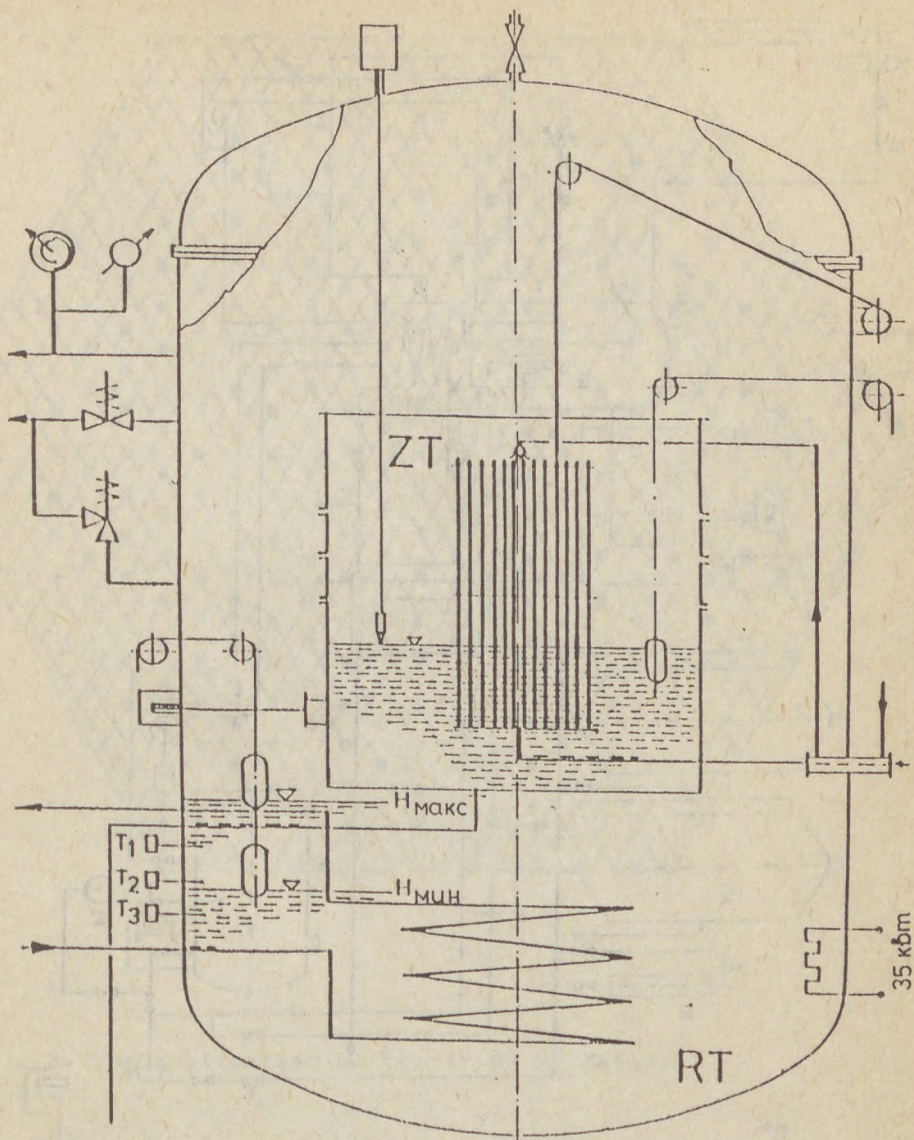


Fig. 2.1. Scheme of the critical assembly ZR-6M

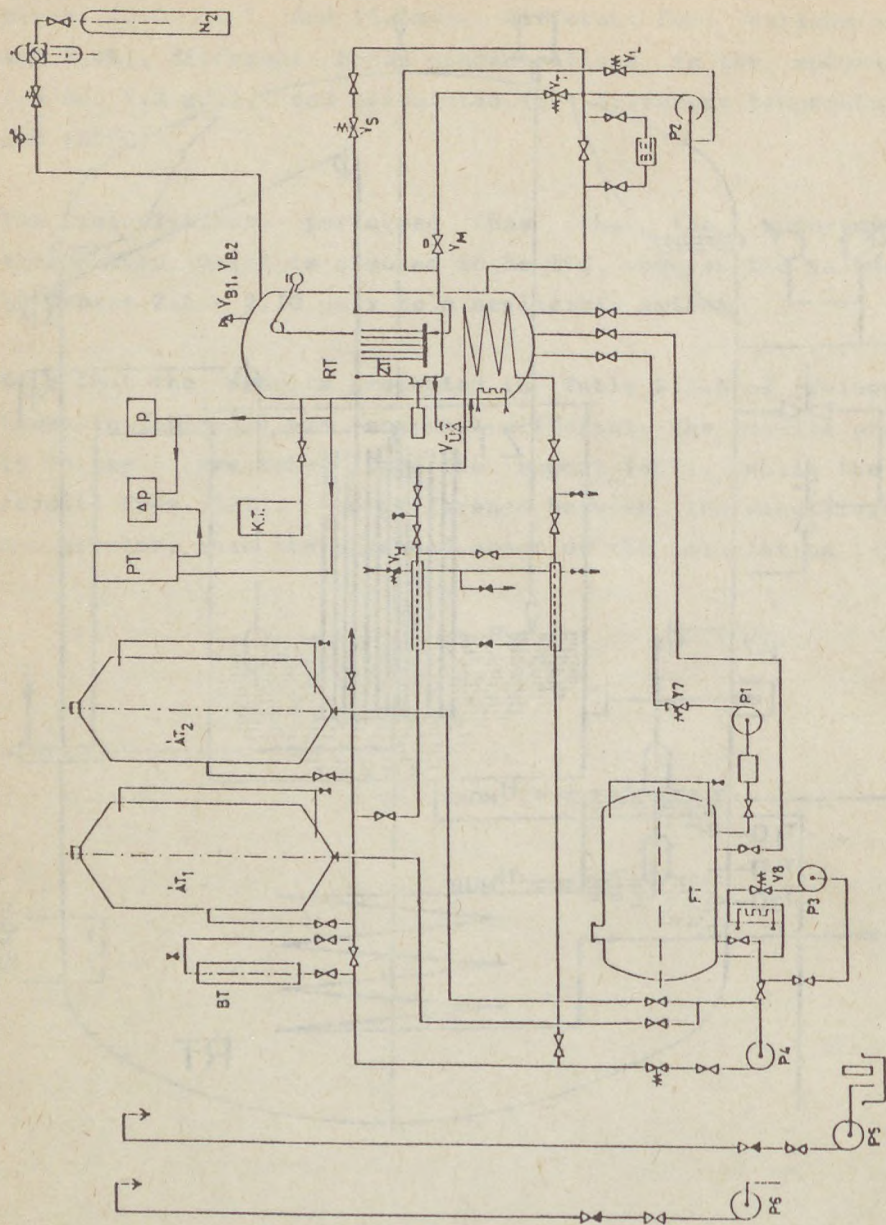


Fig. 2.2. The technological system of the critical assembly ZR-6M

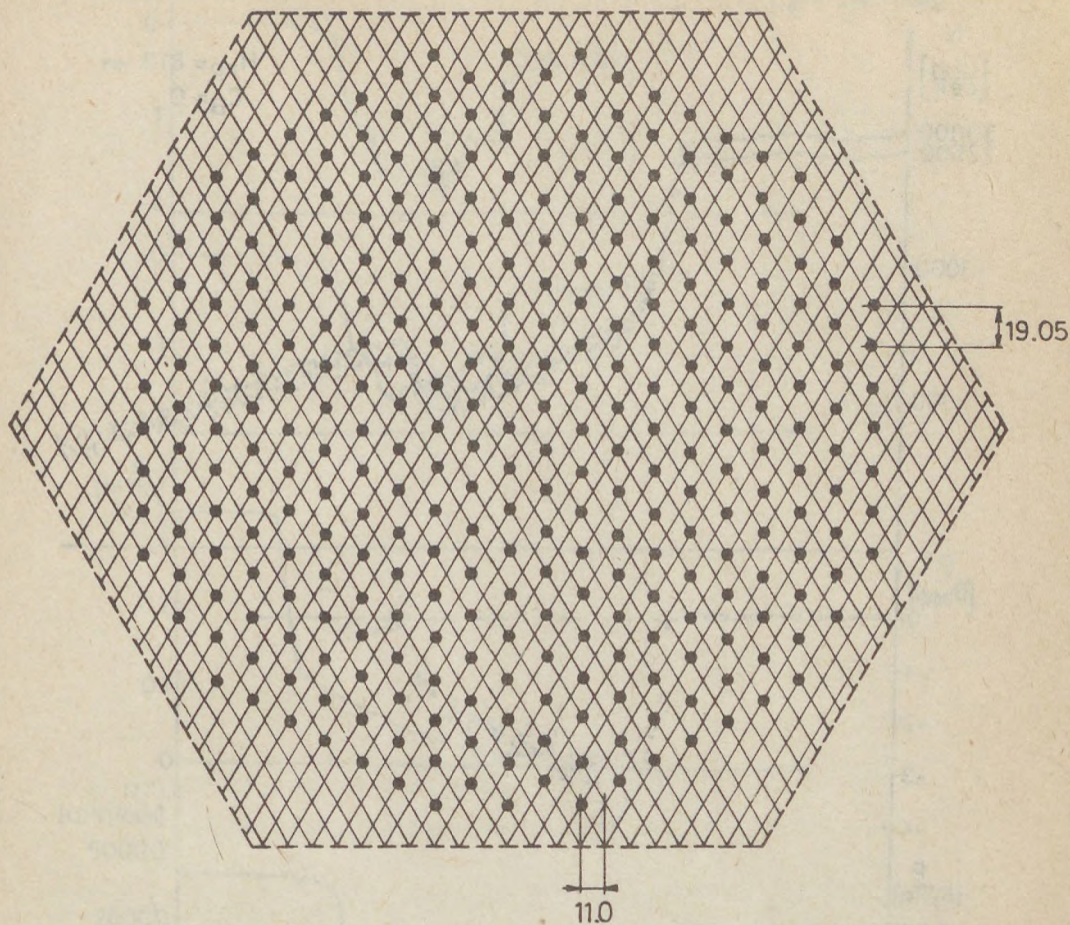


Fig. 2.3. The realization of the 19.05 mm lattice

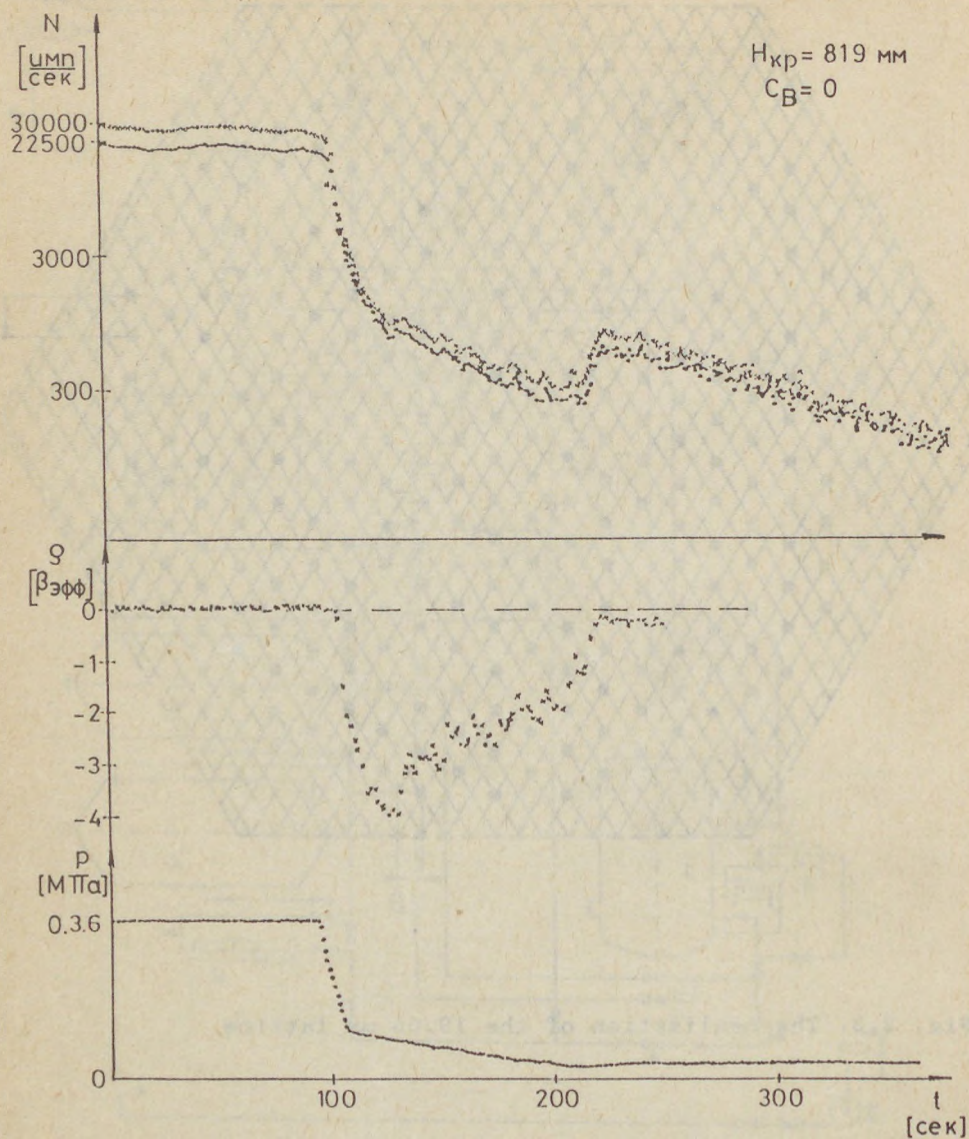


Fig. 2.4. Pressure drop experiment, performed in critical state without boron in the assembly

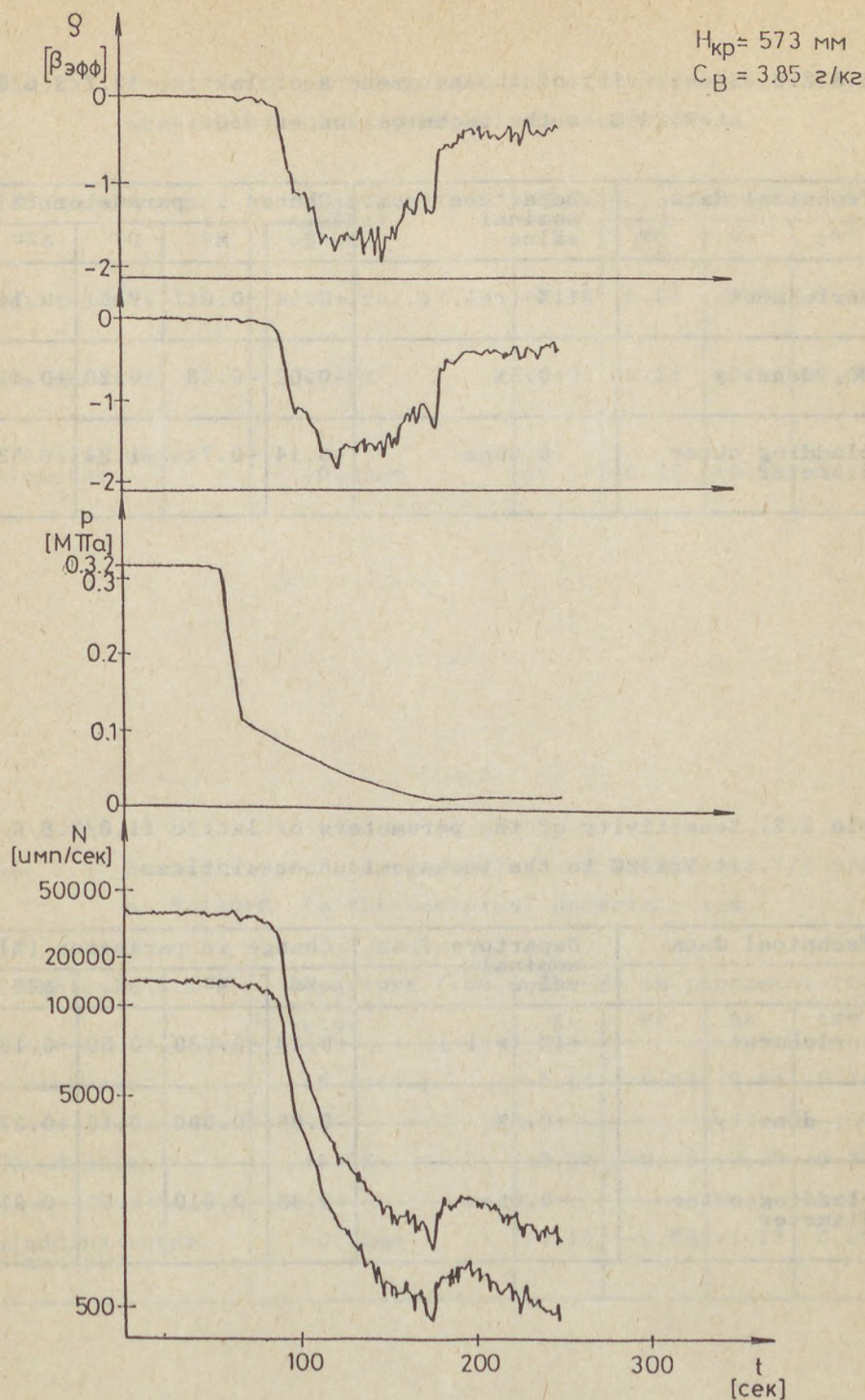


Fig. 2.5. Pressure drop experiment, performed in critical state with boron in the assembly

Table 2.1. Sensitivity of the parameters of lattice 12.7/3.6/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.14	-0.017	+0.51	-0.14
UO ₂ density	+0.5%	-0.02	-0.28	+0.20	+0.41
cladding outer diameter	-0.05mm	+0.14	-0.74	+1.24	-0.53

Table 2.2. Sensitivity of the parameters of lattice 11.0/3.6/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.13	-0.030	+0.59	-0.13
UO ₂ density	+0.5%	-0.06	-0.390	+0.15	+0.37
cladding outer diameter	-0.05mm	+0.38	-0.010	+2.81	-0.91

Table 2.3. Sensitivity of the parameters of lattice 15.0/3.6/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.18	-0.01	+0.58	-0.16
UO ₂ density	+0.5%	+0.01	-0.21	+0.25	+0.42
cladding outer diameter	-0.05mm	+0.03	-0.47	+0.58	-0.29

Table 2.4. Sensitivity of the parameters of lattice 12.7/3.6/0.0
at T=130°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.14	-0.02	+0.54	-0.14
UO ₂ density	+0.5%	-0.03	-0.30	+0.20	+0.40
cladding outer diameter	-0.05mm	+0.16	-0.69	+1.27	-0.52

Table 2.5. Sensitivity of the parameters of lattice 12.7/4.4/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δz_8
enrichment	+1% (rel.)	+0.12	-0.03	+0.41	-0.09
UO ₂ density	+0.5%	-0.03	-0.29	+0.20	+0.45
cladding outer diameter	-0.05mm	+0.14	-0.72	+1.19	-0.52

Table 2.6. Sensitivity of the parameters of lattice 11.0/3.6/0.0
at T=130°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δz_8
enrichment	+1% (rel.)	+0.13	-0.03	+0.65	-0.21
UO ₂ density	+0.5%	-0.06	-0.40	+0.13	+0.37
cladding outer diameter	-0.05mm	+0.41	-1.08	+3.05	-0.90

Table 2.7. Sensitivity of the parameters of lattice 12.7/3.6/7.2
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.24	+0.02	+1.28	+0.27
UO ₂ density	+0.5%	+0.03	-0.27	+0.45	+0.37
cladding outer diameter	-0.05mm	+0.01	-0.76	+0.83	-0.42
C _B	+0.5%	-0.37	-1.04	-0.97	-0.05

Table 2.8. Sensitivity of the parameters of lattice 15.0/3.6/4.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δ^{28}
enrichment	+1% (rel.)	+0.26	+0.03	+1.26	-0.11
UO ₂ density	+0.5%	+0.06	-0.19	+0.49	+0.44
cladding outer diameter	-0.05mm	-0.02	-0.49	+0.39	-0.20
C _B	+0.5%	-0.06	-0.02	-0.29	+0.10

Table 2.9. Sensitivity of the parameters of lattice 12.7/1.6/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δz_8
enrichment	+1% (rel.)	+0.27	+0.03	+1.67	-0.19
UO ₂ density	+0.5%	+0.01	-0.28	+0.32	+0.39
cladding outer diameter	-0.05 _{mm}	+0.11	-0.74	+1.40	-0.48

Table 2.10. Sensitivity of the parameters of lattice 15.0/1.6/0.0
at T=20°C to the technical uncertainties

Technical data	Departure from nominal value	Change in parameter [%]			
		K_{∞}	M^2	B^2	δz_8
enrichment	+1% (rel.)	+0.33	+0.04	+2.12	-0.23
UO ₂ density	+0.5%	+0.06	-0.19	+0.56	+0.39
cladding outer diameter	-0.05 _{mm}	+0.01	-0.48	+0.52	-0.26

3. EXPERIMENTAL METHODS

This chapter is devoted to the experimental methods used with critical assembly ZR-6M, and not described in Volume 1.

Volume 1 of the present work describes the following experimental methods:

- in section 3.1, determination of criticality parameters H_{cr} and $\partial\rho/\partial H$,
- in section 3.2, measurement of reaction rate distributions,
- in section 3.3, determination of spectral ratios.

These experimental methods were used, without modification, for the measurements discussed in the present volume too. New measured parameters are the reactivity coefficients on temperature and on boron concentration, i.e. $\partial\rho/\partial T$ and $\partial\rho/\partial C_B$. The method for experimentally determining these two coefficients is described here. This description is based on the report [430].

In the following sections only those experimental methods are discussed in detail, which produced results, sufficiently worth while including in the present Volume.

The principles and methods of the data handling and evaluating system are discussed in Section 3.5 of Volume 1. The evaluation and data handling techniques have not been changed since then so no discussion of these is necessary here.

3.1 DETERMINATION OF CRITICALITY PARAMETERS H_{cr} AND $\partial\rho/\partial H$

In the present Section two problems are discussed, the solving of

which was essential for the $\partial\rho/\partial H$ measurements, performed on new configurations: determination of the intermediate grid plate's influence on H_{cr} and $\partial\rho/\partial H$, and the calculation of the delayed neutron fraction β_{eff} .

It should be noted that, similarly to Volume 1, the reactivity of the system has been determined in units of β_{eff} on the basis of the inhour equation from doubling time (T_{2x}) measurements, using calculated values of parameters for each lattice [501 and 567].

3.1.1 Effect of the intermediate grid plate on H_{cr} and $\partial\rho/\partial H$

As mentioned in Volume 1, in the experiments discussed an intermediate grid plate was applied to ensure the regularity of the fuel lattice along the whole length of the fuel rods. The influence of the intermediate grid plate has to be taken into account in the data evaluation process. The correction for this effect is described in detail in Section 3.1.5 of Volume 1. The new corrections are described in report [423].

The correction factor η was calculated according to the method described in Volume 1. The results of the diffusion calculations for room temperature are given in Table 3.1.1. These values were used in the evaluation. The results of the asymptotic calculations show that coefficient η depends only slightly on temperature. Therefore this dependence was neglected.

3.1.2 Calculation of β_{eff}

In order to convert the measured reactivities into absolute units, the values of β_{eff} were needed.

As was mentioned in Section 3.1.6 of Volume 1, for the determination of β_{eff} the nuclear constants were taken from Amiel, 1973, and Keepin, 1965.

The calculations, performed according to the method described in Volume 1, show that β_{eff} depends on the temperature (in the interval 20 - 130°C) only through the buckling B^2 .

The results of the calculation of β_{eff} (including the results presented in Volume 1) are given in Table 3.1.2.

3.2 MEASUREMENT OF $\partial\rho/\partial T$

In cases where the investigated interval is small in reactivity, the direct measurement of $\rho(T)$ is possible. In the experiments performed on critical assembly ZR-6M, the reactivity changes were investigated in a rather large interval. Two experimental methods were applied: the first one was based on reactivity compensation by means of control rods, the second one was based on reactivity compensation by means of the water level.

The first method [265] was used only in a few experiments, performed at the beginning of the TIC work. Practice has shown that this method presents more problems from the point of view of the interpretation than the other one, therefore the details of this method are not discussed here.

The second method [265] was changed to some extent on the basis of experimental practice [350]. This was the method mainly used in $\partial\rho/\partial T$ measurements, therefore it is discussed here in more detail.

The measurement of reactivity - temperature dependence based on reactivity compensation by means of the water level means, that $\partial\rho/\partial H$ is measured for a series of temperatures. In this procedure it is essential that all the experimental conditions are kept under strict control.

The measurements were performed for each temperature T_i (T_i - is the mean temperature of the entire core. The temperatures T_i were determined as averages of 6 - 9 temperatures, measured in characteristic positions.) as follows:

1. The temperature was reached (in half the cases during heating up, in the other half during the cooling down procedure) in the reactor tank (RT in Fig.2.1), below the core.
2. The water, the temperature of which reached the temperature required (i.e. the water temperature had always to be a little higher) was pumped by an auxiliary pump into the core tank (ZT in Fig.2.1). In this step the reactor was not made critical; only a water level a few centimeters less than the critical one was reached.
3. After a few minutes (in this time the temperature differences between the core structure, i.e. fuel rods, grid plates, etc., and the water decreased) the water was again let out from the core tank.
4. The operations described in 2 and 3 above were repeated two-three times. After this the temperature of the core could be treated as homogeneous.
5. The $\partial\rho/\partial H$ measurement was performed.

The result of these measurements is a series of values, T_i , $H_{crit}(T_i)$, $\partial\rho/\partial H(T_i)$. The interpretation of these results is given in [424]. The homogeneity of the temperature plays a very important role in these measurements. The temperature was within the interval of $\pm 1^\circ\text{C}$, in the entire core, for all the investigated cases (see [816] for details). The change of temperature in the time interval required for the measurement of $\partial\rho/\partial H$ corresponding to the temperature T_i was within the limits of

$\pm 1^\circ\text{C}$ as well. Note that the active core always cooled down during the time in which the $\partial\rho/\partial H$ measurements were performed. This cooling down leads to a systematic error in the measured results, but this error can be corrected.

The second important correction has to be performed to compensate the effect caused by the intermediate grid plate. The grid plate has a remarkable influence on the results, as with changing temperature the relative position of the grid plate is changed. As a consequence of this the influence of the grid plate is different for different temperatures. The influence of the grid plates was taken into account in the final evaluation [424] of the results.

The complexity of the evaluation makes it necessary to describe here the entire procedure. In each series of measurement the following set of data was obtained:

$$H_i^k, \Delta H_i^k, \rho_i^k, \Delta\rho_i^k, T_i^k, \Delta T_i^k,$$

where

H_i^k is the water level, ΔH_i^k - its error,

ρ_i^k is the reactivity, $\Delta\rho_i^k$ - its error,

T_i^k is the temperature, ΔT_i^k - its error,

k stands for the critical states, and i stands for the supercritical states in the vicinity of the k -th critical state.

In the measurements performed at supercritical states, the stability of temperature could not always be maintained. The temperature changed slightly with time in these measurements. This is the reason why index i appears in the temperature values

too. As in the majority of the cases the reactor cooled down during the measurement, temperature instability may lead to systematic error. This sort of error can be corrected [Сатмарин 3. 1985] by introducing the following correction to ρ_i^k :

$$\rho_i^k = \rho_i^k + \frac{\partial \rho^k}{\partial T} \left(T_i^k - T^k \right), \quad (3.2.1)$$

which corrects it for the temperature change in the k -th measurement.

To get this correction one has to determine T^k and $\frac{\partial \rho^k}{\partial T}$. The T^k values are determined so that they are equal to the temperature recorded at the measurement of the first supercritical state. The $\frac{\partial \rho^k}{\partial T}$ value for the temperature correction can be determined from the assumption:

$$d\rho = \frac{\partial \rho}{\partial H} dH + \frac{\partial \rho}{\partial T} dT = 0, \quad (3.2.2)$$

according to the formula:

$$\frac{\partial \rho^k}{\partial T} = - \frac{\partial \rho^k}{\partial H} \frac{dH}{dT} (T=T^k). \quad (3.2.3)$$

It is clear that this correction leads to an iteration. Knowing T^k and having an initial guess for H^k , one can fit a polynomial of third degree [Сатмарин 3. 1985] to H^k as a function of T^k :

$$H^k(T^k) = a_1 T^3 + a_2 T^2 + a_3 T + a_4. \quad (3.2.4)$$

In this fit the experimental errors of H^k and T^k are taken into account so we get an approximation for $\frac{\partial \rho^k}{\partial T}$ according to formula (3.2.3):

$$\frac{\partial \rho^k}{\partial T} = - \frac{\partial \rho^k}{\partial H} \left[3a_1 (T^k)^2 + 2a_2 T^k + a_3 \right], \quad (3.2.5)$$

where $\frac{\partial \rho^k}{\partial H}$ is the result of the fit $\rho(H)$, fitted in accordance with function No 41 of the RFIT code [Szatmáry Z., 1977], mentioned above. Afterwards one has to apply formula (3.2.1), and in this way one can get the corrected values of ρ_i^k and perform the next step of the iteration.

This iteration process was performed using a slightly modified version of the program RFIT. Practice has shown that the convergence of this iteration is excellent, as the correction is small. Two steps of the iteration were always sufficient.

In the above described process it was assumed that there was no intermediate grid plate in the core. If there is one one has to introduce a further correction, to be applied during the iteration process. The grid plate correction involves $\partial \rho / \partial H$ values in absolute units, so β_{eff} values should be applied already at this stage. Fortunately, as is described in report [423], both the correction factor for the grid plate, and the value of β_{eff} depend only slightly on the temperature, within the investigated range of temperature. Therefore these values can be considered to be constant, and the iteration procedure is modified as:

- Before the fit according to formula (3.2.4), the H^k values are corrected.
- Before the determination of $\frac{\partial \rho^k}{\partial T}$ according to formula (3.2.5), the $\frac{\partial \rho^k}{\partial H}$ values are corrected.

The correction formulae are given in the report [424].

It is mentioned that

- in the present section it is assumed that λ_z does not depend on temperature (cf. Section 4.4),

- $\frac{\partial \rho^k}{\partial H}$ does not correspond exactly to the water level H^k , but this effect is neglected.

3.3 MEASUREMENT OF $\partial \rho / \partial C_B$

The experimental method of the $\partial \rho / \partial C_B$ measurement is described in report [275].

The measurement of reactivity - boron concentration dependence based on the reactivity compensation by means of the water level means that $\partial \rho / \partial H$ is measured for a series of boron concentrations. In this procedure it is essential that all the experimental conditions are kept under strict control.

The measurements were performed for each boron concentration as follows:

1. The boron concentration was changed either by adding pure water (in most of the cases) or by adding borated water to the reactor tank (RT in Fig.2.1). For this operation a high pressure pump was used.

2. The moderator containing the additional water (or in some cases boric acid) was pumped into the core tank (ZT in Fig.2.1) from the reactor tank (RT in Fig.2.1) and then allowed to flow back. These operations were repeated a few times, so they produced homogeneity in temperature and in boron concentration as well.

3. The $\partial\rho/\partial H$ measurement was performed.

The boron concentration is normally determined using chemical titration. The accuracy of the titration is only 0.5%, this is insufficient for the purposes of $\partial\rho/\partial C_B$ measurements. Besides that, there arises another problem: i.e. at high temperatures it is not easy to get the necessary liquid samples for the titration so the boron concentration was measured by adding a definite volume of additional liquid (pure or borated water) by means of the fine pump. If to a liquid of the volume V_0 and of the boron concentration C_{B0} pure water of the volume δ is added, the boron concentration of the mixture can be expressed as:

$$C_B = \frac{C_{B0}}{1+\delta/V_0}.$$

The values V_0 and δ were always measured at room temperature. As the reactor was operated in a pressurized mode, the change of boron concentration is not an easy technical problem to solve. But note that the first useful results for $\partial\rho/\partial C_B$ were obtained when the operation under pressure, i.e. with closed tank, started. This can be explained by the fact that if the tank is open during the measurement, the boron concentration may change by means of the evaporation of the water.

The correction for the cooling down during the measurement (see Section 3.2 for details) was taken into account for the measurement performed at $T=130^\circ\text{C}$. The correction for the intermediate grid plate was taken into account (see Section 3.2 for details) in all cases where the grid plate was present (12.7/3.6/1.0 and 12.7/3.6/5.8). The boron concentration change in the investigated cases led to a 4 to 10 mm change in critical water level. It was assumed therefore that the reactivity coefficient $\partial\rho/\partial H$ is constant, while the critical water level H

is a linear function of the boron concentration ($H(C_B) = a_1 C_B + a_2$) in this interval. Therefore:

$$\frac{\partial \rho}{\partial C_B} = \frac{\partial \rho}{\partial H} \cdot \frac{dH}{dC_B} = \frac{\partial \rho}{\partial H} a_1$$

For data evaluation the RFIT program was used.

Table 3.1.1. Values of correcton factor η for different types of grid plates in different lattices

Grid plate material*	Grid plate thickness [mm]	Lattice	η [cm]
AL	3	11.0/3.6/0.0	-0.097
AL	3	11.0/3.6/1.0	-0.093
PLEXI	5	12.7/3.6/0.0	-0.037
SS	5	12.7/3.6/5.8	-0.314
AL	4	12.7/3.6/5.8	-0.079
AL	3	15.0/1.6/0.0	-0.060
AL	3	15.0/3.6/0.0	-0.102
AL	3	15.0/3.6/4.0	-0.053
AL	3	15.0/4.4/0.0	-0.104
AL	3	19.05/3.6/0.0	-0.106

* SS - stainless steel KO-36

AL - aluminum

PLEXI - plexiglass

Table 3.1.2. Formulae for the dependence of $\beta_{\text{эфф}}$
on geometrical buckling

Enrichment [%]	Lattice pitch [mm]	$\beta_{\text{эфф}}$ [%]
1.6	12.7	$0.6886 + 9.166 \cdot 10^{-4} B^2$
	15.0	$0.6804 + 8.675 \cdot 10^{-4} B^2$
3.6	11.0	$0.6997 + 9.406 \cdot 10^{-4} B^2$
	12.7	$0.6957 + 7.969 \cdot 10^{-4} B^2$
	15.0	$0.6916 + 7.256 \cdot 10^{-4} B^2$
	19.05	$0.6822 + 7.030 \cdot 10^{-4} B^2$
4.4	11.0	$0.7004 + 9.374 \cdot 10^{-4} B^2$
	12.7	$0.6967 + 7.779 \cdot 10^{-4} B^2$
	15.0	$0.6945 + 7.020 \cdot 10^{-4} B^2$

B^2 - geometrical buckling [m^{-2}]

4. RESULTS

4.1. REVIEW OF THE EXPERIMENTAL PROGRAM

4.1.1. General remarks

The measurements results presented in this volume complete the series of experiments described in Volume 1. The aim of the experiments did not change: it remained that of validating and improving the computer codes used or being developed to analyse WWER-1000 power reactors. Some remarks concerning the experimental program may be of interest. The following points were taken into account:

- characteristics of WWER-1000 type lattices,
- characteristics of computer codes,
- experimental conditions,
- simple interpretability of the measured results,
- making the results as independent as possible of the computer codes to be tested.

The region of investigated configurations was enlarged in three directions:

- experiments at different lattice pitches (15.0mm and 19.05mm),
- experiments at higher temperatures (up to 130°C),
- experiments in perturbed configurations at the lattice pitch 11.0mm.

In the present volume, the results of measurements, performed on 57 core configurations are presented (a configuration studied at different temperatures is considered as only one configuration). The following groups of quantities were measured:

- criticality parameters $\partial\rho/\partial H$ and H_{cr} , partially as a function

- of the temperature and of boron concentration (Section 4.2),
- reaction rate distributions (Sections 4.3 and 4.4),
- spectral ratios (Section 4.5).

The criticality parameters were determined for all core configurations, among them for 7 configurations as a function of temperature, for 4 configurations as a function of boron concentration at room temperature, and for 3 configurations as a function of boron concentration at higher temperature. Reaction rate distributions were measured for 22 configurations, spectral ratios for 13. The most detailed and complete documentation of the measurements carried out is given in Ref. [818].

The results of the measurements were summarized and were taken into consideration for different groups; on this basis reports [422, 423, 424, 425, 427, 428, 429, 431 and 432] were compiled.

Schematic core maps have been prepared to facilitate the interpretation of the measurements [820], their symmetry elements are presented in Appendix A. The core maps may be divided into two groups. The first one consists of 46 (one- or two- region) cores with regular lattices. The second group consists of 12 perturbed cores. The 3 two-region cores are considered as part of both groups.

4.1.2. Regular lattices

Regular lattices are schematically depicted in core map 1 of Appendix A. Those investigated in critical assembly ZR-6 are listed in Table 4.1.1. As can be seen from the table, measurements were performed at four lattice pitches and three fuel enrichments.

Lattice 12.7/3.6 (lattice pitch 12.7mm, fuel enrichment 3.6 atomic %) was considered as the reference case. Earlier, this

lattice was investigated in detail at room temperature. In the present volume, results of the following measurements are presented:

- criticality parameters as a function of the temperature at four boron concentrations ($C_B = 0, 1.1, 4.0$ and 5.8 g/kg),
- criticality parameters as a function of the boron concentration for $C_B = 1.1, 4.0$ and 5.8 g/kg at 20°C and 130°C ,
- reaction rate distributions and spectral ratios at higher temperatures.

The lattice containing only fuel rods of 4.4% enrichment (12.7/3.6) as well as the same lattice surrounded by a driver core of 12.7/3.6 type were investigated at different temperatures ($C_B=0$).

The lattice with pitch 11.0mm and fuel enrichment 3.6% (11.0/3.6) was investigated at room temperature in the first period of the experiments. In the period reported in the present volume, a full set of measurements was performed in this lattice.

The results of the following measurements are presented:

- criticality parameters, measured at room temperature for cores of different radii,
- criticality parameters as a function of the temperature at boron concentration $C_B = 0$, as a function of boron concentration at room temperature,
- reaction rate distributions and spectral ratios for $C_B = 0$ at different temperatures and for $C_B = 1.0 \text{ g/kg}$ at room temperature.

The lattices with pitch 15.0mm were investigated only in the second period. These lattices were investigated only at temperatures below 100°C (measurements above 100°C were not allowed for safety reasons). Serial measurements of criticality parameters were performed for the lattices 15.0/3.6 (for $C_B = 0$ and 4.0 g/kg) and 15.0/4.4. Reaction rate distributions and

spectral ratios were determined for one selected lattice of each series. As a consequence of the small number of fuel rods of 1.6% enrichment, lattice 15.0/3.6 was investigated only as a two-region lattice, surrounded by the driver lattice 15.0/3.6. In this lattice the neutron spectrum is the most thermal among the lattices investigated in critical assembly ZR-6M.

In the lattice with pitch 19.05mm only one series of criticality parameters was performed, for $C_B = 0$ at room temperature (lattice 19.05/3.6).

As was done earlier too - based on the measurements of reaction rate (mainly energy release) distributions, measured in regular lattices - material bucklings as well as radial and axial reflector savings were determined.

The full list of regular lattices (including two-region cores) is given in Table A1. of Appendix A.

4.1.3. Perturbed lattices

As described in Volume 1, the systematic investigation of regularly perturbed lattices is an essential aim of the experimental program. The systematicness of the investigations means that the investigated configurations allow us to test the modelling of perturbations of WWER-1000 types, for different complexity.

In the reported period experiments were performed in the following lattices types:

- cores of type Xn,
- cores of type K331,
- cores of type K91.

a) Cores of type Xn

These cores contain regular lattices in which every n^2 th fuel rod is substituted by a pointwise lattice perturbation of type X (absorber rod or water hole). Such cores may be considered as consisting of macrocells of type Xn with the perturbation in the centre surrounded by fuel rods.

The investigated cores of type Xn are characterized by the generalized core maps 2, 11, 20 and 21, shown in Appendix A.

All the investigated cores of type Xn were built of fuel elements of 3.6% enrichment, at $C_B = 0$.

Using lattice pitch 12.7mm the experiments performed in the first period were completed. Reaction rate distributions were measured for C5. The serial measurements of criticality parameters for this lattice were performed in the first period. For lattices G7, F7 and E7 reaction rate distributions were measured at 130°C. New configurations such as G5, G3 and E3 were investigated too. The spectral ratios for different positions were measured for lattice E3. In case of the G3 lattice, the central part of the core consisted of G3 type macrocells, it was surrounded by a 12.7/3.6 regular lattice, as the driver zone.

Using lattice pitch 11.0mm, Xn type lattices were also created - but only at room temperature. In such lattices, the water holes were applied as perturbation. For lattices E7 and E3 reaction rate distributions, and for E7 spectral ratios for different positions were measured.

As was mentioned in Volume 1, radial reaction rate distributions can be described by the product $J_0(B_r r)\Phi_{1x}$, so the radial bucklings B_r^2 as well as the intra macrocell distributions Φ_{1x} can be determined. Using the axial bucklings B_z^2 , from axial

distribution measurements, the material bucklings B_m^2 could be determined too, if we neglect the anisotropy of migration area.

The full list of Xn type perturbed lattices is given in Table A2. of Appendix A.

b) Cores of type K331

The K331 cores are perturbed lattices and include WWER-1000 type fuel assembly imitators. In these configurations the central part of the core is a hexagon built of 331 elementary cells, which imitates the fuel assembly. The assembly walls were imitated by water gaps obtained by removing a row of fuel elements. The central part is surrounded by six half assemblies.

In the first period of measurements, the K331 type cores were built in lattices of 12.7mm lattice pitch, while in the second period (reported here) of 11.0mm lattice pitch. Two cores were investigated: at room temperature and at $C_B = 0$. The central region of the core consisted of fuel rods of 4.4% enrichment, the outer half hexagons of 3.6% enrichment. Into the central region 13 absorber rods of F type were inserted. The two investigated cores differed in that in one case the radial distribution was smoothened by changing some of the fuel rods in the central region for 3.6% enriched rods, in the other case this was not done. In both lattices criticality parameters, reaction rate distributions and spectral ratios were measured.

The cores of K331 type are depicted schematically in generalized core map 17 of Appendix A; a list of the core configurations is given in Table A3 of Appendix A.

c) Cores of type K91

Cores of type K91 consist of fuel assembly imitators with 91

positions. The assembly walls were imitated by water gaps obtained by removing a row of fuel elements. 19 assemblies of this size could be studied simultaneously resulting in more realistic cores than for those of K331 type.

The measurements performed in the second period completed the set of results from the first period. The first aim was to determine criticality parameters for the basic variant of K91 type, the second to study K91/D_∞ lattices. The latter means that into the central position of each assembly a D type absorber rod was inserted. The lattice parameters were measured at room temperature and at $C_B = 0$. In this case the radial reaction rate distributions can be described by the product $J_0(B_r r)\Phi_{1x}$ too. So the radial bucklings B_r^2 as well as the intra macrocell distributions Φ_{1x} can be determined.

The cores of the type K91 are depicted schematically in generalized core map 15 of Appendix A, a list of the cores is given in Table A4 of Appendix A.

Table 4.1.1. List of regular lattices

Lattice pitch [mm]	Enrichment [%]	C_B [g/kg]	Number of cores used to measure	
			criticality	re.rates
11.0	3.6	0.0	7	1
11.0	3.6	1.0	1	1
12.7	3.6	0.0	1	1
12.7	3.6	1.1	1	0
12.7	3.6	4.0	1	1
12.7	3.6	5.8	1	1
12.7	4.4	0.0	1	1
15.0	1.6	0.0	1	1
15.0	3.6	0.0	9	1
15.0	3.6	4.0	9	1
15.0	4.4	0.0	9	1
19.05	3.6	0.0	10	0

4.2. REACTIVITY COEFFICIENTS

The present section is devoted to the results of different reactivity coefficient measurements ($\partial\rho/\partial H$, $\partial\rho/\partial H$, $\partial\rho/\partial C_B$). The critical water level H_{cr} and $\partial\rho/\partial H$, also called criticality parameters, were measured for all the lattices investigated. The method of measuring these parameters is described in Section 3.1 of Volume 1. The results of these measurements are summarized in Section 4.2.1. The reactivity coefficient $\partial\rho/\partial T$ was measured for the majority of lattices investigated here. The method of measuring $\partial\rho/\partial T$ is described in Section 3.1; the results of the measurements are given in Section 4.2.2.

The reactivity coefficient for boron concentration $\partial\rho/\partial C_B$ was measured for some lattices. The method of measuring $\partial\rho/\partial C_B$ is described in Section 3.2, the results of the measurements are given in Section 4.2.3.

4.2.1. Results of the measurements of H_{cr} and $\partial\rho/\partial H$

The measurements of criticality parameters are described in references [275, 276, 283, 284, 288, 290 and 292]; the results are summarized in report [423].

The criticality parameters measured for regular lattices and for perturbed cores are given in Tables 4.2.1 and 4.2.2. respectively. The quantities and the notation given in these tables are the same as the quantities and notation used in the corresponding tables of Volume I. A description of the correction used for the intermediate grid plate, together with the values of the correction and with the β_{eff} values are given in the report [567] and in Section 3.1 (see Tables 3.1.1 and 3.1.2).

Ast was mentioned in Volume I, it should be noted that both

$\overline{\partial\rho/\partial H}$ and H correspond to the core without the intermediate grid plate but they do not belong to one another. In fact, H is the critical moderator height whereas $\overline{\partial\rho/\partial H}$ belongs to a moderator height H_{cr} (which is not necessarily equal to H). The statistical errors given for H and $\overline{\partial\rho/\partial H}$ include the inaccuracy of the correction factor for the grid plate, but they do not include the contribution of the inaccuracy of β_{eff} . (See Section 4.2.1 of Volume I for more details.)

For some lattices (11.0/3.6/0.0, 15.0/3.6/0.0, 15.0/3.6/4.0, 15.0/4.4/0.0 and 19.1/3.6/0.0) serial measurements of $\partial\rho/\partial H$ were carried out for a series of moderator heights.

In asymptotic theory, $\overline{\partial\rho/\partial H}$ and H_{cr} satisfy the relation

$$\overline{\partial\rho/\partial H} = 2\pi^2 \left| \partial\rho/\partial B_z^2 \right| (H_{cr} + \lambda_z)^{-3}, \quad (4.2.1)$$

where λ_z is the axial reflector saving, assumed as independent of H_{cr} (see Volume I for more details).

Fitting on the series of results $\overline{\partial\rho/\partial H}$ for different H_{cr} the function:

$$f(x, \underline{a}) = 2\pi^2 a_1 (x + a_2)^{-3} \quad (4.2.2)$$

of program RFIT, one can determine $\left| \partial\rho/\partial B_z^2 \right| = a_1$ and $\lambda_z = a_2$.

The results from a fit of formula (4.2.2) are presented in Table 4.2.3. Although the mathematical expectation would be $\langle Q/(N-M) \rangle = 1$ (see [Szatmáry Z. 1977] for more details), on evaluating the results by means of RFIT in the majority of cases $\langle Q/(N-M) \rangle \gg 1$. This shows that the asymptotic formula (4.2.1) is not fully satisfied by the experimental results using the given experimental errors. One possible explanation may be the underestimation of the experimental errors; another one is the failure of asymptotic theory for small core sizes. Nevertheless the values of the axial reflector saving, obtained by virtue of formula (4.2.1) and from the activation distribution measurements (see Table 4.4.6), correspond to each other within the limits of the experimental errors. Therefore the fits were repeated at fixed λ_z values, taken from activity measurements (cf. Table 4.2.3).

4.2.2. Results of $\partial\rho/\partial T$ measurements

The measurement of parameter $\partial\rho/\partial T$ is described in references [275, 276, 283, 285, 290 and 292], the results are summarized in report [424].

The measurement of parameter $\partial\rho/\partial T$ was performed according to the method described in Section 3.2.

Table 4.2.4 contains the characteristics of the lattices on which $\partial\rho/\partial T$ was measured.

The results of $\partial\rho/\partial T$ measurements are presented in Tables 4.2.5 - 4.2.11. These results are characteristic for the configuration with a given number of fuel rods, as the influence of temperature on the reflector is included.

The dependence of H on temperature is shown in Fig.4.2.1. The

results of the fit show that the function $H(T)$ can be well described by a polynomial of third degree (see [Саттари 3. 1985] for more detail).

4.2.3. Results of $\partial\rho/\partial C_B$ measurements

The measurement of parameter $\partial\rho/\partial C_B$ is described in references [275, 276, and 283], the results are summarized in report [425].

The results of the $\partial\rho/\partial C_B$ measurements are given in Table 4.2.12. These results are characteristic for the configuration with a given number of fuel rods, as the influence of temperature on the reflector is included.

The dependence of $\partial\rho/\partial C_B$ on the boric acid concentration is illustrated in Fig.4.2.2 both for $T=20^\circ\text{C}$ and $T=130^\circ\text{C}$.

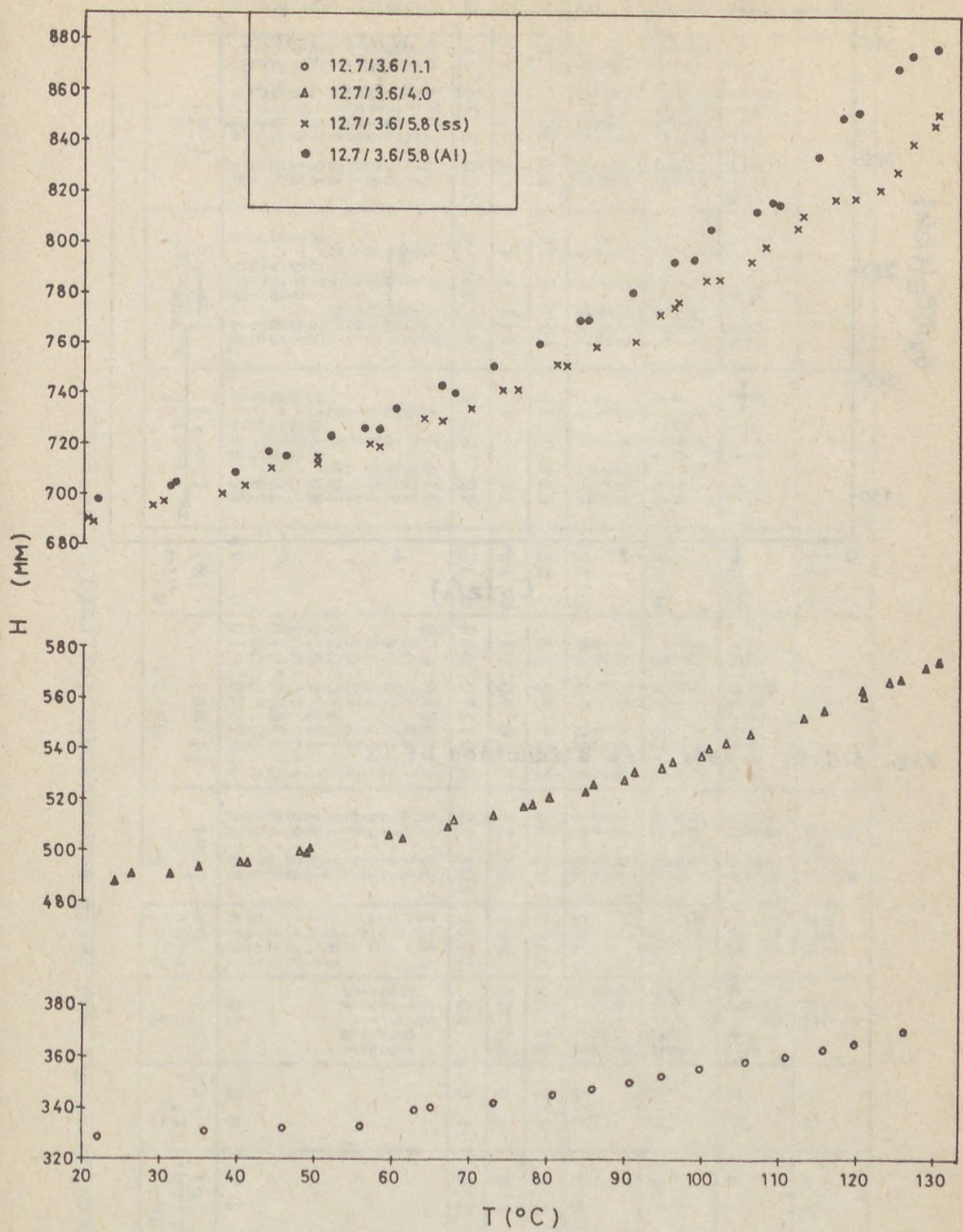


Fig. 4.2.1. $\bar{H}$ - as a function of T for different lattices

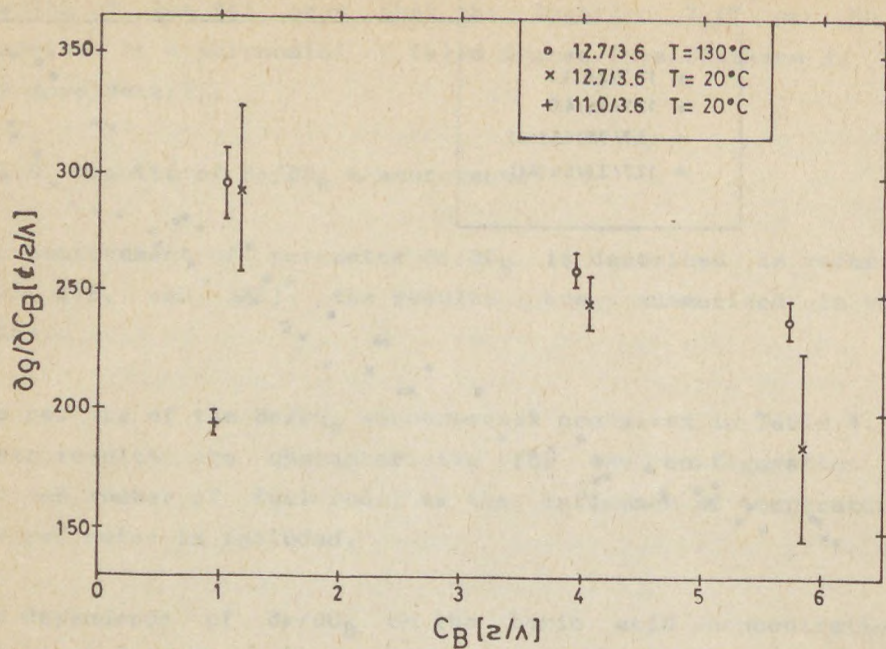


Fig. 4.2.2. $\partial \rho / \partial C_B$ - as a function of C_B

Table 4.2.1. Results of H_{cr} and $\partial\rho/\partial H$ measurements for regular lattices

N° of core map	Lat. pit. [mm]	En- rich. [%]	C_p [$\frac{g}{kg}$]	T [°C]	N° of fuel rods	H_{cr} [cm]	$\partial\rho/\partial H$ [$\frac{g}{mm}$]	β_{eff} [%]	$\partial\rho/\partial H \times 10^5$ [cm^{-1}]	$\partial\rho/\partial H \times 10^5$ [cm^{-1}]	H [cm]	Refe- rence
196/196	11.0	3.6	0.0	20	1639	98.76	0.650±0.010	0.762	49.5±0.8	47.8±0.8	95.24±0.35	284
195/39					1675	92.87	0.781±0.007		59.5±0.5	58.1±0.5	89.81±0.31	284
194/194					1711	87.73	0.930±0.010		70.9±0.8	69.8±0.8	85.09±0.27	284
193/193					1747	83.82	1.037±0.008		79.3±0.6	78.3±0.6	81.43±0.24	284
192/192					1801	78.47	1.120±0.010		85.3±0.8	85.4±0.8	76.26±0.22	284
188/40					1855	74.18	1.407±0.020		107 ± 2	108 ± 2	72.46±0.17	284
- "				18.46	- "	74.33	1.42 ± 0.01		108 ± 1	109 ± 1	72.62±0.17	288
- "				23.21	- "	74.64	1.43 ± 0.04		109 ± 3	110 ± 3	72.94±0.17	288
- "				22.22	- "	74.17	1.33 ± 0.04		101 ± 3	102 ± 3	72.34±0.18	288
- "				16.18	- "	74.03	1.32 ± 0.02		101 ± 2	102 ± 2	72.21±0.18	288
191/191				20	1891	71.71	1.496±0.008		114 ± 1	116 ± 1	70.13±0.16	284
209/40	11.0	3.6	1.0	20	1855	104.32	0.617±0.008	0.757	46.7±0.6	45.0±0.6	100.93±0.34	283
246/154	12.7	3.6	0.0	22.08	805	62.29	1.76 ± 0.01	0.775	136 ± 1	141 ± 1	61.32±0.10	290
162/162	12.7	3.6	1.1	21.00	1765	32.92	8.24 ± 0.19	0.770	634 ± 15	634 ± 15	32.92±0.03	275
161/161	12.7	3.6	4.0	23.10	1765	48.57	3.50 ± 0.08	0.756	265 ± 6	265 ± 6	48.57±0.03	275
				23.65		48.79	3.77 ± 0.23		285 ± 17	285 ± 17	48.79±0.03	275
				25.96		48.97	3.60 ± 0.04		272 ± 3	272 ± 3	48.97±0.03	275
163/163	12.7	3.6	5.8	20.90	1765	70.12	1.27 ± 0.01	0.746	94.7±0.7	113 ± 2	68.03±0.21	276
247/163				20.40	1765	70.18	1.22 ± 0.01		91.0±0.7	109 ± 2	68.01±0.22	276
				21.30		71.05	1.39 ± 0.06		104 ± 4	106 ± 4	69.65±0.14	290
164/110	12.7	4.4	0.0	24.87	625	82.85	0.954±0.016	0.783	74.7±1.3	68.5±1.4	66.4 ± 1.6	285
165/110				20.37	625	82.80	0.934±0.011		73.1±0.9	66.9±1.1	66.0 ± 1.7	285
				20		83.80	~0.9		-	-	-	817
166/166	12.7	4.4 +3.6	0.0	20	625	48.0	~3	0.751	-	-	-	817
				79	186	52.2	~4.5	0.749	-	-	-	817
				129		60.9	~5.3	0.745	-	-	-	817

Table 4.2.1. (continued)

N° of core map	Lat. pit. [mm]	En- rich. [%]	C _B [g/ kg]	T [°C]	N° of fuel rods	H _{Cr} [cm]	$\partial\rho/\partial H$ [ϕ /mm]	β_{eff} [%]	$\partial\rho/\partial H \times 10^5$ [cm ⁻¹]	$\partial\rho/\partial H \times 10^5$ [cm ⁻¹]	H [cm]	Refe- rence
212/212	15.0	3.6	0.0	20	409	98.95	0.589±0.002	0.780	45.9±0.2	44.0±0.3	94.77±0.42	284
213/213					487	57.51	2.237±0.012		174±1.1	182±1.1	56.85±0.07	284
214/214				20.2	571	44.55	4.369±0.060		341±1.5	341±1.5	44.55±0.03	284
220/220				93.6	637	39.48	5.839±0.061		455±1.5	455±1.5	39.48±0.03	292
215/215				20	661	42.46	6.057±0.094		472±1.7	472±1.7	42.46±0.03	819
216/216					769	38.10	8.17±0.12		637±1.9	637±1.9	38.10±0.03	284
217/217					811	33.48	8.79±0.07		686±1.5	686±1.5	33.48±0.03	284
218/218					919	32.21	9.45±0.26		737±2.0	737±2.0	32.21±0.03	284
219/219					1015	29.74	11.18±0.153		872±1.2	872±1.2	29.74±0.03	284
220/220					1015	28.13	11.18±0.153		872±1.2	872±1.2	28.13±0.03	284
230/230	15.0	4.4	0.0	20	349	90.45	0.714±0.017	0.790	56.4±1.3	55.0±1.3	86.78±0.37	288
229/229					361	78.94	0.990±0.009		78.2±0.7	78.4±0.7	76.27±0.27	288
228/228					396	59.62*	1.95±0.03		154±1.2*	161±1.2*	58.75±0.09	288
227/227					439	48.77*	3.22±0.04*		254±1.3*	254±1.3*	48.77*	288
226/226					500	40.57	4.89±0.007		386±1.1	386±1.1	40.57±0.03	288
225/225					547	36.80	7.05±0.17		557±1.3	557±1.3	36.80±0.03	288
224/224					583	34.69	7.30±0.009		577±1.4	577±1.4	34.69±0.03	288
223/223					637	32.20	8.80±0.31		695±2.4	695±2.4	32.20±0.03	288
223/223					691	30.35	10.04±0.27		793±2.1	793±2.1	30.35±0.03	288
231/231		1.6 +3.6	0.0	20	625 444	76.90	1.247±0.015	0.723	91.9±1.1	92.3±1.1	75.60±0.13	292

* value uncertain

Table 4.2.1. (continued)

N° of core map	Lat. pit. [mm]	En- rich. [%]	C _B [g] kg	T [°C]	N° of fuel rods	H _{cr} [cm]	$\partial \rho / \partial H$ [g/mm]	β_{eff} [%]	$\partial \rho / \partial H \times 10^5$ [cm ⁻¹]	$\partial \rho / \partial H \times 10^5$ [cm ⁻¹]	H [cm]	Refe- rence
233/233	15.0	3.6	4.0	20	985	92.33	0.726±0.017	0.745	54.1±1.3	53.3±1.3	90.43±0.19	288
232/232					1069	74.68	1.219±0.009		90.8±0.7	91.5±0.7	73.53±0.12	288
240/240					1147	65.63	1.708±0.035		127±3	129±3	64.93±0.08	288
234/234					1213	60.20	2.184±0.081		163±3	167±3	59.76±0.05	288
235/235					1339	56.64*	2.787±0.013		208±1	213±1	53.43±0.04	288
236/236					1519	47.03	6.73±0.16*		502±1	506±1	47.01	292
237/237					1687	43.42	4.476±0.098		333±7	333±7	43.42±0.03	288
238/238					1800	41.33	4.962±0.089		370±7	370±7	41.33±0.03	288
239/239					1931	39.56	5.855±0.230		436±17	436±17	39.56±0.03	288
208/208	19.1	3.6	0.0	20	313	103.93	0.514±0.002	0.772	39.7±0.2	37.6±0.3	99.12±0.48	284
207/207					349	70.67	1.37±0.01		106±1	108±1	68.78±0.19	284
206/206					409	52.28	2.93±0.04		226±3	236±3	51.94±0.05	284
205/205					487	42.34	5.01±0.11		387±8	387±8	42.34±0.03	284
204/204					571	36.94	6.26±0.20		483±15	483±15	36.94±0.03	284
203/203					661	33.58	8.99±0.54		694±42	694±42	33.58±0.03	284
202/202					769	30.19	9.81±0.19		757±15	757±15	30.83±0.03	284
201/201					811	30.19	9.84±0.24		760±19	760±19	30.19±0.03	284
200/200					919	28.57	10.99±0.26		848±20	848±20	28.57±0.03	284
199/199					1015	27.49	13.20±0.23		1019±18	1019±18	27.49±0.03	284

* value uncertain

Table 4.2.2. Results of H_{cr} and $\partial\rho/\partial H$ measurements for perturbed lattices

N° of core map	Lat. pit; [mm]	N° of gener c.map	T [°C]	Type of perturba- tion	H_{cr} [cm]	$\partial\rho/\partial H$ [t/mm]	β_{eff} [%]	$\partial\rho/\partial H \times 10^5$ [cm ⁻¹]	$\partial\rho/\partial H \times 10^5$ [cm ⁻¹]	H [cm]	Refe- rence
189/189	11.0	2	20	E7	95.67	0.69 ± 0.01	0.766	52.9 ± 0.8	51.3 ± 0.8	92.29 ± 0.34	284
243/243	12.7	2	20	G7	54.81	2.569 ± 0.051	0.754	194 ± 4	205 ± 4	54.26 ± 0.06	288
244/156			20	G7	54.11	2.547 ± 0.092	0.754	192 ± 7	203 ± 7	53.60 ± 0.06	288
			130	G7	70.33	1.508 ± 0.024	0.748	113 ± 2	116 ± 2	68.38 ± 0.20	288
245/58	12.7	2	130	E7	35.07	7.90 ± 0.18	0.770	608 ± 14	608 ± 14	35.07 ± 0.03	288
177/75	12.7	11	20	C5	64.69	1.876 ± 0.01	0.753	141 ± 1	139 ± 1	64.05 ± 0.07	271
242/242	12.7	20	20	G5	66.77	1.615 ± 0.014	0.743	120 ± 1	125 ± 1	65.08 ± 0.17	288
176/176	12.7	21	20	E3	50.46	3.19 ± 0.02	0.779	249 ± 2	247 ± 2	49.98 ± 0.06	271
190/190	11.0	21	20	E3	56.50	2.41 ± 0.01	0.776	187 ± 1	194 ± 1	55.88 ± 0.07	284
241/241	12.7	21	20	G3	63.95	1.684 ± 0.038	0.744	125 ± 3	131 ± 3	62.47 ± 0.15	288
179/101	12.7	15	20	K91	28.84	12.65 ± 0.26	0.778	984 ± 20	984 ± 20	28.84 ± 0.03	271
180/180	12.7	15	20	K91/D∞	30.25	9.65 ± 0.11	0.775	748 ± 9	748 ± 9	30.25 ± 0.03	271
197/144	11.0	17	20	K331/F3	75.52	1.34 ± 0.02	0.762	102 ± 2	103 ± 2	73.68 ± 0.18	284
198/145	11.0	17	20	K331/F3	77.84	1.296 ± 0.011	0.762	98.8 ± 0.8	98.9 ± 0.8	75.93 ± 0.19	284

Table 4.2.3. Results of serial measurements of $\partial\rho/\partial H$
(fit according to formula (4.2.2))

Lattice	Considered core configurations	λ_z [cm]	$ \partial\rho/\partial B_z^2 $ [cm ²]
11.0/3.6/0.0	196,195,194,193, 188,191	11.96±5.24 15.37	33.97±5.68 37.78±0.51
15.0/3.6/0.0	212,213,214,220, 215,216,217,218, 219	12.53±0.48 11.00	31.19±0.71 29.07±0.35
15.0/3.6/4.0	233,232,240,234, 235,237,238,239	13.04±1.11 11.00	31.69±1.52 29.00±0.23
15.0/4.4/0.0	230,229,228,225, 221,224,223	12.16±0.45 11.00	30.07±0.85 27.95±0.12
19.05/3.6/0.0	208,207,206,205, 204,203,202,201, 200,199	11.47±0.57 10.0	29.58±0.71 27.91±0.36

The fixed values of λ_z (values in the table above given without errors) are taken from the results of axial reaction rate distribution measurements (see Table 4.4.6). For lattice 19.05/3.6/0.0, $\lambda_z = 10.0$ cm is based on extrapolation, as in this case no axial reaction rate distribution measurement was made.

Table 4.2.4 List of $H_{cr}(T)$ and $\partial\rho/\partial T$ measurements

Lattice	Core identi- fication	Number of fuel rods	Number of crit. states	Position [mm] of intermediate grid plate	Material*
12.7/3.6/0.0	246/154	805	25	486	AL
12.7/3.6/1.1	162/161	1765	17	712	AL
12.7/3.6/4.0	161/161	1765	35	712	AL
12.7/3.6/5.8	163/161	1765	36	607	SS
12.7/3.6/5.8	247/161	1765	28	486	AL
11.0/3.6/0.0	188/188	1855	45	479	AL
15.0/3.6/0.0	220/220	637	34	483	AL

* AL - aluminium

SS - stainless steel KO-36

Table 4.2.5 Results of $\partial\rho/\partial T$ measurements for the core
245/154 (lattice 12.7/3.6/0.0)

H [mm]	$\overline{\partial\rho/\partial H}$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
615.16 $\pm$ 0.05	1.949 $\pm$ 0.012	22.3 $\pm$ 0.24	-0.60 $\pm$ 0.49
618.91 $\pm$ 0.23	1.993 $\pm$ 0.038	31.4 $\pm$ 0.12	-0.98 $\pm$ 0.58
623.65 $\pm$ 0.39	1.625 $\pm$ 0.062	43.6 $\pm$ 0.31	-1.21 $\pm$ 0.57
632.94 $\pm$ 0.24	1.787 $\pm$ 0.043	51.8 $\pm$ 0.31	-1.64 $\pm$ 0.71
640.52 $\pm$ 0.30	1.696 $\pm$ 0.048	59.9 $\pm$ 0.27	-1.85 $\pm$ 0.76
650.96 $\pm$ 0.06	1.763 $\pm$ 0.010	67.6 $\pm$ 0.35	-2.22 $\pm$ 0.87
668.70 $\pm$ 0.25	1.734 $\pm$ 0.036	79.9 $\pm$ 0.13	-2.66 $\pm$ 1.02
675.97 $\pm$ 0.22	1.578 $\pm$ 0.032	85.3 $\pm$ 0.11	-2.61 $\pm$ 0.99
685.58 $\pm$ 0.24	1.513 $\pm$ 0.032	91.2 $\pm$ 0.12	-2.70 $\pm$ 1.02
695.04 $\pm$ 0.42	1.467 $\pm$ 0.052	96.2 $\pm$ 0.14	-2.79 $\pm$ 1.06
702.64 $\pm$ 0.61	1.291 $\pm$ 0.060	101.4 $\pm$ 0.13	-2.61 $\pm$ 0.99
715.54 $\pm$ 0.34	1.346 $\pm$ 0.034	106.4 $\pm$ 0.14	-2.88 $\pm$ 1.09
729.04 $\pm$ 0.25	1.367 $\pm$ 0.028	112.1 $\pm$ 0.10	-3.10 $\pm$ 1.18
738.30 $\pm$ 0.55	1.194 $\pm$ 0.048	116.9 $\pm$ 0.13	-2.85 $\pm$ 1.09
752.77 $\pm$ 0.24	1.181 $\pm$ 0.020	122.2 $\pm$ 0.13	-2.96 $\pm$ 1.14
764.02 $\pm$ 0.10	1.055 $\pm$ 0.007	127.0 $\pm$ 0.21	-2.77 $\pm$ 1.07
779.62 $\pm$ 0.47	1.034 $\pm$ 0.034	131.6 $\pm$ 0.15	-2.83 $\pm$ 1.10
616.70 $\pm$ 0.20	1.848 $\pm$ 0.041	29.1 $\pm$ 0.23	-0.85 $\pm$ 2.24
623.56 $\pm$ 0.43	1.922 $\pm$ 0.090	40.5 $\pm$ 0.47	-1.29 $\pm$ 2.77
634.12 $\pm$ 0.37	1.665 $\pm$ 0.055	55.0 $\pm$ 0.34	-1.60 $\pm$ 2.97
650.45 $\pm$ 0.25	1.679 $\pm$ 0.041	68.3 $\pm$ 0.17	-2.10 $\pm$ 3.61
674.32 $\pm$ 0.49	1.535 $\pm$ 0.066	85.0 $\pm$ 0.25	-2.53 $\pm$ 4.11
694.78 $\pm$ 0.32	1.804 $\pm$ 0.052	94.1 $\pm$ 0.39	-3.39 $\pm$ 5.40
719.64 $\pm$ 0.40	1.152 $\pm$ 0.030	109.9 $\pm$ 0.35	-2.65 $\pm$ 4.15
749.30 $\pm$ 0.09	1.150 $\pm$ 0.007	121.0 $\pm$ 0.19	-3.01 $\pm$ 4.67

Note: The H and $\overline{\partial\rho/\partial H}$ values are corrected for the influence of the intermediate grid plate.

Table 4.2.6 Results of $\partial\rho/\partial T$ measurements for the core
162/161 (lattice 12.7/3.6/1.1)

H_{cr} [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
329.15 $\pm$ 0.05	8.253 $\pm$ 0.186	22.0 $\pm$ 0.20	-1.29 $\pm$ 0.47
331.58 $\pm$ 0.11	6.090 $\pm$ 0.257	35.9 $\pm$ 0.17	-1.38 $\pm$ 0.44
334.21 $\pm$ 0.22	5.326 $\pm$ 0.398	45.6 $\pm$ 0.17	-1.46 $\pm$ 0.46
335.80 $\pm$ 0.41	4.185 $\pm$ 0.423	54.8 $\pm$ 0.11	-1.33 $\pm$ 0.42
339.77 $\pm$ 0.18	5.689 $\pm$ 0.453	63.3 $\pm$ 0.19	-2.03 $\pm$ 0.64
341.00 $\pm$ 0.09	8.504 $\pm$ 0.382	65.7 $\pm$ 0.10	-3.13 $\pm$ 0.97
343.41 $\pm$ 0.15	5.992 $\pm$ 0.325	73.4 $\pm$ 0.15	-2.41 $\pm$ 0.76
346.73 $\pm$ 0.16	6.323 $\pm$ 0.430	80.7 $\pm$ 0.13	-2.75 $\pm$ 0.89
348.67 $\pm$ 0.28	5.746 $\pm$ 0.506	86.0 $\pm$ 0.13	-2.63 $\pm$ 0.88
350.92 $\pm$ 0.25	5.510 $\pm$ 0.463	90.7 $\pm$ 0.16	-2.63 $\pm$ 0.90
352.88 $\pm$ 0.50	5.918 $\pm$ 0.985	94.7 $\pm$ 0.15	-2.92 $\pm$ 1.09
356.09 $\pm$ 0.13	6.503 $\pm$ 0.374	100.0 $\pm$ 0.30	-3.35 $\pm$ 1.17
358.69 $\pm$ 0.16	6.016 $\pm$ 0.379	105.6 $\pm$ 0.24	3.23 $\pm$ 1.16
361.80 $\pm$ 0.14	5.685 $\pm$ 0.306	111.3 $\pm$ 0.20	-3.18 $\pm$ 1.16
364.54 $\pm$ 0.05	6.320 $\pm$ 0.125	115.7 $\pm$ 0.40	-3.64 $\pm$ 1.34
367.39 $\pm$ 0.31	6.825 $\pm$ 0.911	120.4 $\pm$ 0.50	-4.05 $\pm$ 1.62
370.73 $\pm$ 0.02	5.959 $\pm$ 0.049	126.1 $\pm$ 0.40	-3.66 $\pm$ 1.42

Table 4.2.7 Results of $\partial\rho/\partial T$ measurements for the core161/161 (lattice 12.7/3.6/4.0)

H_{cr} [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
494.78 $\pm$ 0.14	2.872 $\pm$ 0.080	40.5 $\pm$ 0.20	-1.44 $\pm$ 0.47
497.45 $\pm$ 1.22	3.516 $\pm$ 0.708	49.3 $\pm$ 0.20	-1.96 $\pm$ 0.76
504.57 $\pm$ 0.10	3.639 $\pm$ 0.079	60.3 $\pm$ 0.10	-2.33 $\pm$ 0.79
509.08 $\pm$ 0.25	3.760 $\pm$ 0.215	66.6 $\pm$ 0.35	-2.60 $\pm$ 0.91
513.54 $\pm$ 0.07	3.818 $\pm$ 0.077	72.8 $\pm$ 0.20	-2.85 $\pm$ 0.99
518.52 $\pm$ 0.05	4.092 $\pm$ 0.047	79.2 $\pm$ 0.24	-3.31 $\pm$ 1.16
523.28 $\pm$ 0.10	3.836 $\pm$ 0.089	84.7 $\pm$ 0.25	-3.31 $\pm$ 1.16
528.41 $\pm$ 0.25	3.945 $\pm$ 0.219	90.5 $\pm$ 0.30	-3.66 $\pm$ 1.30
533.33 $\pm$ 0.42	3.500 $\pm$ 0.437	94.8 $\pm$ 0.30	-3.41 $\pm$ 1.28
538.37 $\pm$ 0.34	4.094 $\pm$ 0.316	100.0 $\pm$ 0.30	-4.24 $\pm$ 1.53
543.10 $\pm$ 0.22	3.388 $\pm$ 0.132	104.1 $\pm$ 0.32	-3.68 $\pm$ 1.31
556.52 $\pm$ 0.15	2.984 $\pm$ 0.090	116.2 $\pm$ 0.30	-3.70 $\pm$ 1.32
562.37 $\pm$ 0.14	2.929 $\pm$ 0.074	121.4 $\pm$ 0.26	-3.84 $\pm$ 1.37
568.97 $\pm$ 0.33	3.352 $\pm$ 0.213	126.2 $\pm$ 0.29	-4.63 $\pm$ 1.67
573.55 $\pm$ 0.22	3.589 $\pm$ 0.146	129.6 $\pm$ 0.27	-5.13 $\pm$ 1.83
487.88 $\pm$ 0.26	3.756 $\pm$ 0.231	23.8 $\pm$ 0.24	-0.83 $\pm$ 0.06
490.28 $\pm$ 0.16	3.283 $\pm$ 0.107	31.5 $\pm$ 0.34	-1.28 $\pm$ 0.06
494.94 $\pm$ 0.19	3.264 $\pm$ 0.115	41.5 $\pm$ 0.16	-1.74 $\pm$ 0.07
499.37 $\pm$ 0.14	3.496 $\pm$ 0.104	49.3 $\pm$ 0.10	-2.06 $\pm$ 0.06
489.72 $\pm$ 0.05	3.622 $\pm$ 0.038	26.0 $\pm$ 0.11	-1.20 $\pm$ 0.16
493.28 $\pm$ 0.07	3.703 $\pm$ 0.054	35.3 $\pm$ 0.10	-1.52 $\pm$ 0.19
498.94 $\pm$ 0.05	3.354 $\pm$ 0.031	47.5 $\pm$ 0.10	-1.75 $\pm$ 0.20
505.50 $\pm$ 0.30	3.090 $\pm$ 0.132	59.5 $\pm$ 0.13	-1.95 $\pm$ 0.24
511.05 $\pm$ 0.24	3.312 $\pm$ 0.147	68.2 $\pm$ 0.10	-2.36 $\pm$ 0.29
517.49 $\pm$ 0.12	3.370 $\pm$ 0.073	76.1 $\pm$ 0.08	-2.66 $\pm$ 0.31
521.28 $\pm$ 0.15	3.349 $\pm$ 0.113	80.7 $\pm$ 0.10	-2.79 $\pm$ 0.33
526.04 $\pm$ 0.25	3.331 $\pm$ 0.185	86.2 $\pm$ 0.20	-2.96 $\pm$ 0.38
531.10 $\pm$ 0.18	3.511 $\pm$ 0.144	91.5 $\pm$ 0.14	-3.31 $\pm$ 0.41
535.77 $\pm$ 0.06	3.154 $\pm$ 0.041	96.5 $\pm$ 0.28	-3.14 $\pm$ 0.37
540.76 $\pm$ 0.12	3.343 $\pm$ 0.073	101.2 $\pm$ 0.14	-3.48 $\pm$ 0.42
546.59 $\pm$ 0.30	3.310 $\pm$ 0.198	106.5 $\pm$ 0.16	-3.64 $\pm$ 0.48
554.18 $\pm$ 0.18	3.117 $\pm$ 0.096	113.9 $\pm$ 0.14	-3.67 $\pm$ 0.46
563.36 $\pm$ 0.28	3.250 $\pm$ 0.150	120.8 $\pm$ 0.15	-4.07 $\pm$ 0.53
567.96 $\pm$ 5.18	3.033 $\pm$ 2.154	125.3 $\pm$ 0.18	-3.94 $\pm$ 2.84
575.98 $\pm$ 0.20	2.841 $\pm$ 0.096	130.8 $\pm$ 0.19	-3.87 $\pm$ 0.50

Table 4.2.8 Results of $\partial\rho/\partial T$ measurements for the core
163/161 (lattice 12.7/3.6/5.8)

H [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [ϕ / $^{\circ}$ C]
689.75 $\pm$ 0.09	1.638 $\pm$ 0.009	20.9 $\pm$ 0.05	-0.88 $\pm$ 0.46
695.80 $\pm$ 0.13	1.599 $\pm$ 0.011	30.6 $\pm$ 0.15	-1.09 $\pm$ 0.53
703.50 $\pm$ 0.23	1.480 $\pm$ 0.019	41.3 $\pm$ 0.15	-1.25 $\pm$ 0.58
712.40 $\pm$ 0.24	1.493 $\pm$ 0.022	50.2 $\pm$ 0.15	-1.48 $\pm$ 0.67
719.97 $\pm$ 0.46	1.418 $\pm$ 0.035	58.2 $\pm$ 0.20	-1.59 $\pm$ 0.72
729.10 $\pm$ 0.93	1.349 $\pm$ 0.077	66.7 $\pm$ 0.15	-1.70 $\pm$ 0.78
740.78 $\pm$ 0.15	1.344 $\pm$ 0.012	74.1 $\pm$ 0.13	-1.87 $\pm$ 0.86
750.86 $\pm$ 0.54	1.229 $\pm$ 0.039	82.7 $\pm$ 0.15	-1.89 $\pm$ 0.88
761.30 $\pm$ 0.55	1.208 $\pm$ 0.032	88.7 $\pm$ 0.10	-1.99 $\pm$ 0.94
775.55 $\pm$ 0.34	1.197 $\pm$ 0.021	96.1 $\pm$ 0.10	-2.13 $\pm$ 1.02
786.20 $\pm$ 0.29	1.117 $\pm$ 0.014	102.4 $\pm$ 0.10	-2.12 $\pm$ 1.02
799.23 $\pm$ 0.25	1.083 $\pm$ 0.012	108.2 $\pm$ 0.13	-2.18 $\pm$ 1.06
811.49 $\pm$ 0.31	1.054 $\pm$ 0.015	112.9 $\pm$ 0.14	-2.21 $\pm$ 1.09
819.67 $\pm$ 0.08	0.906 $\pm$ 0.003	119.3 $\pm$ 0.15	-2.02 $\pm$ 1.01
829.05 $\pm$ 0.54	0.812 $\pm$ 0.015	125.4 $\pm$ 0.17	-1.91 $\pm$ 0.97
853.01 $\pm$ 0.49	0.848 $\pm$ 0.016	130.5 $\pm$ 0.17	-2.08 $\pm$ 1.06
689.73 $\pm$ 0.10	1.580 $\pm$ 0.009	20.4 $\pm$ 0.11	-0.98 $\pm$ 0.49
695.46 $\pm$ 0.22	1.499 $\pm$ 0.016	29.3 $\pm$ 0.15	-1.09 $\pm$ 0.54
699.97 $\pm$ 0.50	1.357 $\pm$ 0.031	37.8 $\pm$ 0.20	-1.14 $\pm$ 0.56
710.06 $\pm$ 1.42	1.586 $\pm$ 0.109	45.3 $\pm$ 0.21	-1.49 $\pm$ 0.73
714.35 $\pm$ 0.24	1.501 $\pm$ 0.019	50.5 $\pm$ 0.18	-1.52 $\pm$ 0.74
720.25 $\pm$ 0.62	1.434 $\pm$ 0.042	56.9 $\pm$ 0.12	-1.58 $\pm$ 0.78
730.55 $\pm$ 0.10	1.476 $\pm$ 0.009	63.9 $\pm$ 0.10	-1.78 $\pm$ 0.89
734.99 $\pm$ 0.37	1.349 $\pm$ 0.023	69.8 $\pm$ 0.10	-1.75 $\pm$ 0.88
741.55 $\pm$ 0.08	1.275 $\pm$ 0.006	75.5 $\pm$ 0.10	-1.77 $\pm$ 0.90
752.95 $\pm$ 0.16	1.298 $\pm$ 0.011	80.8 $\pm$ 0.15	-1.92 $\pm$ 0.98
759.39 $\pm$ 0.25	1.233 $\pm$ 0.013	85.7 $\pm$ 0.10	-1.92 $\pm$ 0.99
772.14 $\pm$ 0.39	1.273 $\pm$ 0.023	91.3 $\pm$ 0.15	-2.11 $\pm$ 1.10
776.85 $\pm$ 0.33	1.146 $\pm$ 0.016	96.6 $\pm$ 0.15	-2.01 $\pm$ 1.06
785.91 $\pm$ 0.40	1.110 $\pm$ 0.019	100.6 $\pm$ 0.15	-2.02 $\pm$ 1.07
794.30 $\pm$ 0.80	1.038 $\pm$ 0.035	106.2 $\pm$ 0.15	-2.00 $\pm$ 1.07
807.47 $\pm$ 0.26	0.973 $\pm$ 0.012	112.5 $\pm$ 0.20	-1.99 $\pm$ 1.08
818.73 $\pm$ 0.31	0.910 $\pm$ 0.012	117.8 $\pm$ 0.16	-1.95 $\pm$ 1.07
821.63 $\pm$ 0.99	0.796 $\pm$ 0.026	122.7 $\pm$ 0.15	-1.79 $\pm$ 0.99
840.05 $\pm$ 0.40	0.806 $\pm$ 0.012	127.2 $\pm$ 0.16	-1.88 $\pm$ 1.04
847.07 $\pm$ 0.05	0.764 $\pm$ 0.001	130.5 $\pm$ 0.12	-1.83 $\pm$ 1.02

Note: The H and $\partial\rho/\partial H$ values are corrected for the influence of the intermediate grid plate.

Table 4.2.9 Results of $\partial\rho/\partial T$ measurements for the core
247/161 (lattice 12.7/3.6/5.8)

H [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
697.67 $\pm$ 0.19	1.532 $\pm$ 0.025	22.0 $\pm$ 0.13	-1.07 $\pm$ 0.36
704.14 $\pm$ 0.87	1.344 $\pm$ 0.106	32.0 $\pm$ 0.22	-1.09 $\pm$ 0.39
717.02 $\pm$ 0.12	1.445 $\pm$ 0.017	44.1 $\pm$ 0.21	-1.42 $\pm$ 0.49
723.33 $\pm$ 0.16	1.316 $\pm$ 0.014	52.2 $\pm$ 0.26	-1.46 $\pm$ 0.50
733.85 $\pm$ 0.41	1.327 $\pm$ 0.035	60.1 $\pm$ 0.22	-1.66 $\pm$ 0.57
743.27 $\pm$ 0.80	1.302 $\pm$ 0.070	67.0 $\pm$ 0.13	-1.80 $\pm$ 0.63
750.95 $\pm$ 0.52	1.251 $\pm$ 0.042	72.9 $\pm$ 0.14	-1.88 $\pm$ 0.65
760.86 $\pm$ 0.37	1.223 $\pm$ 0.032	79.1 $\pm$ 0.13	-2.01 $\pm$ 0.69
769.83 $\pm$ 0.27	1.141 $\pm$ 0.021	85.4 $\pm$ 0.61	-2.04 $\pm$ 0.70
781.76 $\pm$ 0.27	1.154 $\pm$ 0.023	90.9 $\pm$ 0.14	-2.22 $\pm$ 0.76
793.12 $\pm$ 0.15	1.121 $\pm$ 0.012	96.5 $\pm$ 0.24	-2.32 $\pm$ 0.79
806.28 $\pm$ 0.34	1.156 $\pm$ 0.028	101.3 $\pm$ 0.12	-2.55 $\pm$ 0.86
813.57 $\pm$ 0.92	1.024 $\pm$ 0.064	106.5 $\pm$ 0.13	-2.41 $\pm$ 0.83
816.69 $\pm$ 1.62	0.844 $\pm$ 0.071	110.2 $\pm$ 0.18	-2.08 $\pm$ 0.72
835.47 $\pm$ 0.28	0.907 $\pm$ 0.018	115.3 $\pm$ 0.34	-2.37 $\pm$ 0.80
851.89 $\pm$ 0.61	0.921 $\pm$ 0.034	120.6 $\pm$ 0.18	-2.56 $\pm$ 0.86
868.93 $\pm$ 1.12	0.918 $\pm$ 0.058	125.4 $\pm$ 0.17	-2.70 $\pm$ 0.92
876.37 $\pm$ 0.98	0.748 $\pm$ 0.035	130.0 $\pm$ 0.20	-2.31 $\pm$ 0.78
703.53 $\pm$ 0.34	1.466 $\pm$ 0.038	31.7 $\pm$ 0.23	-1.13 $\pm$ 1.17
709.43 $\pm$ 0.28	1.416 $\pm$ 0.032	39.4 $\pm$ 0.34	-1.23 $\pm$ 1.26
715.38 $\pm$ 0.64	1.372 $\pm$ 0.063	46.0 $\pm$ 0.35	-1.32 $\pm$ 1.34
726.17 $\pm$ 0.18	1.306 $\pm$ 0.015	55.8 $\pm$ 0.28	-1.47 $\pm$ 1.46
740.06 $\pm$ 0.39	1.202 $\pm$ 0.035	68.2 $\pm$ 0.28	-1.66 $\pm$ 1.58
769.77 $\pm$ 0.14	1.107 $\pm$ 0.011	85.6 $\pm$ 0.17	-2.00 $\pm$ 1.81
793.82 $\pm$ 0.51	0.956 $\pm$ 0.028	98.9 $\pm$ 0.25	-2.10 $\pm$ 1.83
816.78 $\pm$ 0.55	0.875 $\pm$ 0.025	109.4 $\pm$ 0.26	-2.21 $\pm$ 1.88
850.37 $\pm$ 0.86	1.016 $\pm$ 0.048	118.2 $\pm$ 0.28	-2.89 $\pm$ 2.40
872.24 $\pm$ 0.43	0.787 $\pm$ 0.020	127.9 $\pm$ 0.26	-2.52 $\pm$ 2.05

Note: The H and $\partial\rho/\partial H$ values are corrected for the influence of the intermediate grid plate.

Table 4.2.10 Results of $\partial\rho/\partial T$ measurements for the core
188/188 (lattice 11.0/3.6/0.0)

H [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
726.30 $\pm$ 0.25	1.354 $\pm$ 0.027	23.9 $\pm$ 0.24	-0.56 $\pm$ 1.22
733.32 $\pm$ 0.29	1.415 $\pm$ 0.032	34.4 $\pm$ 0.40	-1.10 $\pm$ 1.65
744.20 $\pm$ 0.26	1.366 $\pm$ 0.028	45.2 $\pm$ 0.47	-1.51 $\pm$ 2.02
754.62 $\pm$ 0.28	1.265 $\pm$ 0.027	53.8 $\pm$ 0.66	-1.68 $\pm$ 2.24
769.15 $\pm$ 0.81	1.185 $\pm$ 0.072	64.1 $\pm$ 0.21	-1.85 $\pm$ 2.58
782.47 $\pm$ 0.40	1.087 $\pm$ 0.029	73.6 $\pm$ 0.28	-1.89 $\pm$ 2.80
801.35 $\pm$ 0.82	1.048 $\pm$ 0.078	81.3 $\pm$ 0.34	-1.94 $\pm$ 3.07
727.38 $\pm$ 0.80	1.604 $\pm$ 0.114	22.2 $\pm$ 0.29	-0.53 $\pm$ 1.48
726.82 $\pm$ 0.46	1.324 $\pm$ 0.047	30.6 $\pm$ 0.23	-0.71 $\pm$ 1.39
738.19 $\pm$ 0.10	1.362 $\pm$ 0.012	38.3 $\pm$ 0.41	-1.01 $\pm$ 1.60
739.25 $\pm$ 0.31	1.193 $\pm$ 0.024	46.9 $\pm$ 0.52	-1.17 $\pm$ 1.59
747.43 $\pm$ 0.43	1.189 $\pm$ 0.032	54.3 $\pm$ 0.25	-1.43 $\pm$ 1.76
756.34 $\pm$ 0.62	1.142 $\pm$ 0.052	61.3 $\pm$ 0.30	-1.63 $\pm$ 1.87
764.88 $\pm$ 0.32	1.144 $\pm$ 0.024	66.6 $\pm$ 0.28	-1.83 $\pm$ 2.01
777.75 $\pm$ 0.37	1.339 $\pm$ 0.037	70.3 $\pm$ 0.30	-2.31 $\pm$ 2.47
784.70 $\pm$ 0.34	1.222 $\pm$ 0.031	75.4 $\pm$ 0.15	-2.33 $\pm$ 2.42
796.33 $\pm$ 0.52	1.237 $\pm$ 0.046	80.5 $\pm$ 0.18	-2.58 $\pm$ 2.61
802.21 $\pm$ 0.38	1.067 $\pm$ 0.025	85.8 $\pm$ 0.24	-2.44 $\pm$ 2.41
819.50 $\pm$ 0.18	1.178 $\pm$ 0.014	90.9 $\pm$ 0.27	-2.92 $\pm$ 2.83
819.96 $\pm$ 2.00	0.841 $\pm$ 0.090	95.9 $\pm$ 0.30	-2.25 $\pm$ 2.16
844.51 $\pm$ 0.23	0.982 $\pm$ 0.014	101.6 $\pm$ 0.26	-2.86 $\pm$ 2.68
861.89 $\pm$ 0.10	0.954 $\pm$ 0.007	107.3 $\pm$ 0.31	-3.00 $\pm$ 2.78
905.02 $\pm$ 0.28	0.801 $\pm$ 0.012	120.3 $\pm$ 0.39	-2.97 $\pm$ 2.69
929.68 $\pm$ 0.68	0.799 $\pm$ 0.027	125.6 $\pm$ 0.44	-3.16 $\pm$ 2.84
955.26 $\pm$ 0.49	0.812 $\pm$ 0.019	130.4 $\pm$ 0.45	-3.39 $\pm$ 3.03
729.93 $\pm$ 0.18	1.622 $\pm$ 0.024	26.1 $\pm$ 0.44	-0.95 $\pm$ 0.66
728.14 $\pm$ 0.39	1.280 $\pm$ 0.037	34.7 $\pm$ 0.48	-0.95 $\pm$ 0.60
736.93 $\pm$ 0.52	1.301 $\pm$ 0.048	43.5 $\pm$ 0.16	-1.21 $\pm$ 0.71
741.54 $\pm$ 1.01	1.124 $\pm$ 0.073	51.8 $\pm$ 0.35	-1.28 $\pm$ 0.70
757.84 $\pm$ 0.25	1.284 $\pm$ 0.023	60.1 $\pm$ 0.18	-1.76 $\pm$ 0.91
768.94 $\pm$ 0.33	1.236 $\pm$ 0.029	68.0 $\pm$ 0.13	-2.00 $\pm$ 0.99
780.81 $\pm$ 0.17	1.203 $\pm$ 0.014	74.9 $\pm$ 0.23	-2.23 $\pm$ 1.06
794.12 $\pm$ 0.27	1.178 $\pm$ 0.021	80.6 $\pm$ 0.18	-2.43 $\pm$ 1.13
804.61 $\pm$ 0.29	1.138 $\pm$ 0.021	85.7 $\pm$ 0.21	-2.57 $\pm$ 1.17
816.10 $\pm$ 0.18	1.089 $\pm$ 0.012	90.8 $\pm$ 0.19	-2.68 $\pm$ 1.19
829.38 $\pm$ 1.78	1.097 $\pm$ 0.125	95.3 $\pm$ 0.28	-2.91 $\pm$ 1.31
842.21 $\pm$ 0.22	1.064 $\pm$ 0.014	100.1 $\pm$ 0.16	-3.05 $\pm$ 1.31
854.63 $\pm$ 0.26	0.992 $\pm$ 0.016	104.9 $\pm$ 0.33	-3.06 $\pm$ 1.30
863.57 $\pm$ 0.52	0.892 $\pm$ 0.026	108.7 $\pm$ 0.26	-2.92 $\pm$ 1.22
877.91 $\pm$ 0.70	0.900 $\pm$ 0.037	112.2 $\pm$ 0.31	-3.09 $\pm$ 1.29
893.46 $\pm$ 0.21	0.880 $\pm$ 0.010	116.4 $\pm$ 0.29	-3.21 $\pm$ 1.31
906.08 $\pm$ 0.32	0.820 $\pm$ 0.013	120.3 $\pm$ 0.32	-3.16 $\pm$ 1.28
930.47 $\pm$ 0.19	0.824 $\pm$ 0.009	124.8 $\pm$ 0.34	-3.37 $\pm$ 1.35
942.08 $\pm$ 0.42	0.801 $\pm$ 0.017	128.2 $\pm$ 0.38	-3.43 $\pm$ 1.36
941.97 $\pm$ 1.59	0.620 $\pm$ 0.037	131.0 $\pm$ 0.36	-2.76 $\pm$ 1.10

Note: The H and $\partial\rho/\partial H$ values are corrected for the influence of the intermediate grid plate.

Table 4.2.11 Results of $\partial\rho/\partial T$ measurement for core

220/220 (lattice 15.0/3.6/0.0)

H_{cr} [mm]	$\partial\rho/\partial H$ [ϕ /mm]	T [$^{\circ}$ C]	$\partial\rho/\partial T$ [$\phi/^{\circ}$ C]
397.08 $\pm$ 0.12	5.04 $\pm$ 0.16	24.35 $\pm$ 0.23	-1.15 $\pm$ 0.97
400.56 $\pm$ 0.07	5.26 $\pm$ 0.15	38.17 $\pm$ 0.05	-1.59 $\pm$ 1.30
402.94 $\pm$ 0.07	5.35 $\pm$ 0.12	44.63 $\pm$ 0.22	-1.80 $\pm$ 1.48
404.60 $\pm$ 0.11	5.49 $\pm$ 0.18	48.80 $\pm$ 0.24	-1.97 $\pm$ 1.63
406.34 $\pm$ 0.18	5.19 $\pm$ 0.25	54.19 $\pm$ 0.05	-2.01 $\pm$ 1.69
408.27 $\pm$ 0.10	5.09 $\pm$ 0.15	58.10 $\pm$ 0.12	-2.08 $\pm$ 1.77
410.34 $\pm$ 0.01	5.31 $\pm$ 0.01	63.22 $\pm$ 0.05	-2.31 $\pm$ 2.00
413.03 $\pm$ 0.01	5.21 $\pm$ 0.02	67.62 $\pm$ 0.25	-2.39 $\pm$ 2.11
415.25 $\pm$ 0.13	5.03 $\pm$ 0.17	73.58 $\pm$ 0.18	-2.46 $\pm$ 2.23
417.96 $\pm$ 0.35	4.96 $\pm$ 0.47	77.69 $\pm$ 0.32	-2.54 $\pm$ 2.35
420.86 $\pm$ 0.07	5.02 $\pm$ 0.08	80.18 $\pm$ 0.07	-2.64 $\pm$ 2.46
424.23 $\pm$ 0.12	4.79 $\pm$ 0.14	86.26 $\pm$ 0.05	-2.67 $\pm$ 2.56
426.70 $\pm$ 0.06	5.43 $\pm$ 0.08	91.24 $\pm$ 0.05	-3.17 $\pm$ 3.10
429.59 $\pm$ 0.01	5.25 $\pm$ 0.02	95.39 $\pm$ 0.19	-3.18 $\pm$ 3.18
401.88 $\pm$ 0.05	5.83 $\pm$ 0.09	39.59 $\pm$ 0.06	-1.81 $\pm$ 1.47
403.64 $\pm$ 0.04	5.66 $\pm$ 0.07	44.88 $\pm$ 0.16	-1.91 $\pm$ 1.57
404.59 $\pm$ 0.22	4.93 $\pm$ 0.31	48.56 $\pm$ 0.09	-1.76 $\pm$ 1.46
406.06 $\pm$ 0.12	4.78 $\pm$ 0.16	52.65 $\pm$ 0.14	-1.81 $\pm$ 1.52
408.44 $\pm$ 0.21	5.83 $\pm$ 0.42	57.34 $\pm$ 0.19	-2.36 $\pm$ 2.01
410.24 $\pm$ 0.02	5.38 $\pm$ 0.04	61.75 $\pm$ 0.32	-2.30 $\pm$ 1.98
412.59 $\pm$ 0.02	5.53 $\pm$ 0.04	66.47 $\pm$ 0.19	-2.50 $\pm$ 2.20
414.44 $\pm$ 0.06	5.79 $\pm$ 0.11	70.00 $\pm$ 0.14	-2.73 $\pm$ 2.43
416.96 $\pm$ 0.07	5.27 $\pm$ 0.10	75.39 $\pm$ 0.12	-2.63 $\pm$ 2.40
420.01 $\pm$ 0.12	5.40 $\pm$ 0.22	80.97 $\pm$ 0.06	-2.86 $\pm$ 2.68
423.06 $\pm$ 0.06	5.44 $\pm$ 0.09	85.73 $\pm$ 0.09	-3.02 $\pm$ 2.88
426.41 $\pm$ 0.33	5.01 $\pm$ 0.54	91.41 $\pm$ 0.07	-2.93 $\pm$ 2.89
429.62 $\pm$ 0.07	5.19 $\pm$ 0.10	95.11 $\pm$ 0.42	-3.14 $\pm$ 3.13
432.10 $\pm$ 0.01	5.60 $\pm$ 0.03	99.00 $\pm$ 0.05	-3.50 $\pm$ 3.55
409.81 $\pm$ 0.23	4.97 $\pm$ 0.34	60.42 $\pm$ 0.14	-2.09 $\pm$ 1.80
412.86 $\pm$ 0.04	5.06 $\pm$ 0.06	66.96 $\pm$ 0.10	-2.30 $\pm$ 2.03
415.63 $\pm$ 0.09	5.21 $\pm$ 0.14	72.36 $\pm$ 0.09	-2.52 $\pm$ 2.27
422.57 $\pm$ 0.03	5.68 $\pm$ 0.06	83.70 $\pm$ 0.10	-3.09 $\pm$ 2.92
424.39 $\pm$ 0.50	3.94 $\pm$ 0.47	88.25 $\pm$ 0.07	-2.24 $\pm$ 2.18
407.05 $\pm$ 0.24	5.31 $\pm$ 0.37	54.05 $\pm$ 0.09	-2.05 $\pm$ 1.73

Table 4.2.12. Results of $\partial\rho/\partial C_H$ measurements

Lattice	T [°C]	a_1 [mm/g/kg]	a_2 [mm]	$\frac{\partial\rho}{\partial H}$ [ϕ /mm]	$\frac{\partial\rho}{\partial C_B}$ [ϕ /g/kg]
12.7/3.6/1.1	21	37.79 $\pm$ 1.7	289.8 $\pm$ 1.8	7.84 $\pm$ 0.13	296.3 $\pm$ 14.3
12.7/3.6/1.1	130	46.38 $\pm$ 5.3	324.2 $\pm$ 5.4	6.24 $\pm$ 0.18	294.0 $\pm$ 34.6
12.7/3.6/4.0	21	70.54 $\pm$ 1.8	202.4 $\pm$ 6.9	3.69 $\pm$ 0.05	260.3 $\pm$ 7.5
12.7/3.6/4.0	130	94.32 $\pm$ 3.5	196.0 $\pm$ 13.8	2.62 $\pm$ 0.06	247.1 $\pm$ 10.8
12.7/3.6/5.8	21	144.74 $\pm$ 4.6	-149.8 $\pm$ 26.3	1.65 $\pm$ 0.02	238.2 $\pm$ 8.0
12.7/3.6/5.8	130	213.11 $\pm$ 4.7	-380.3 $\pm$ 258.	0.87 $\pm$ 0.01	185.4 $\pm$ 38.9
11.0/3.6/1.0	20	316.15 $\pm$ 7.8	700.6 $\pm$ 7.4	0.61 $\pm$ 0.01	193.2 $\pm$ 5.1

4.3 REACTION RATE DISTRIBUTIONS

The present and the following sections are devoted to the results of reaction rate measurements. In this section, the measured distributions are described; on the basis of these distributions Section 4.4 presents the bucklings and reflector savings.

4.3.1 File of evaluated reaction rate distributions

The measurements of reaction rate distributions are listed in Table 4.3.1. The evaluated distributions are stored in file EDF (Evaluated Data File, see Volume 1 for more detail) [427]. This file is generated by program RFIT as a result of fitting the function

$$f(x, \underline{a}) = a_j \psi_I,$$

to the primary data where

- a_j is the normalization factor for irradiation j ,
- ψ_I is the value of reaction rate distribution in position I .

The normalization of the evaluated distribution is arbitrary but these distributions can be normalized to the calculated distribution, this is useful when they are compared with one another. This can also be done by using program RFIT.

File EDF can be used either by program RFIT for further evaluations and for comparisons with calculated distributions, or by other programs. For further details, see report [414] and Ref. [Szatmáry Z., 1977].

4.3.2 Examples of measured reaction rate distributions

The examples of measured radial reaction rate distributions considered below illustrate some interesting effects observed in the investigated lattices.

The influence of temperature on the energy release distribution in regular lattices is illustrated in Figs. 4.3.1, 4.3.2 and 4.3.3. These figures present distributions measured at the 20°C, 80°C and 130°C respectively.

In Figs. 4.3.4 and 4.3.5 the energy release distributions in the perturbed lattices F7 and G7 are shown, as measured 20°C and 130°C.

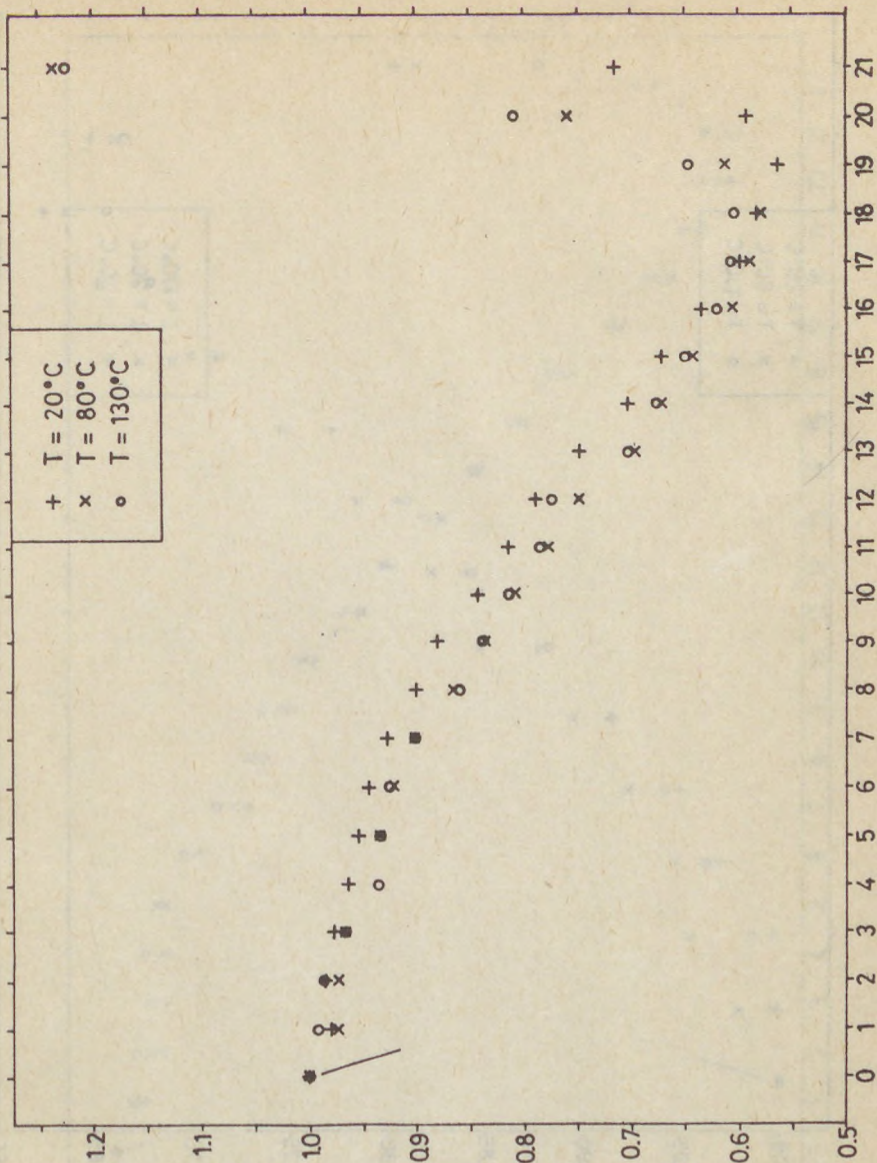


Fig. 4.3.1. Radial energy release distributions at different temperatures in the 11.0/3.6/0.0 regular lattice

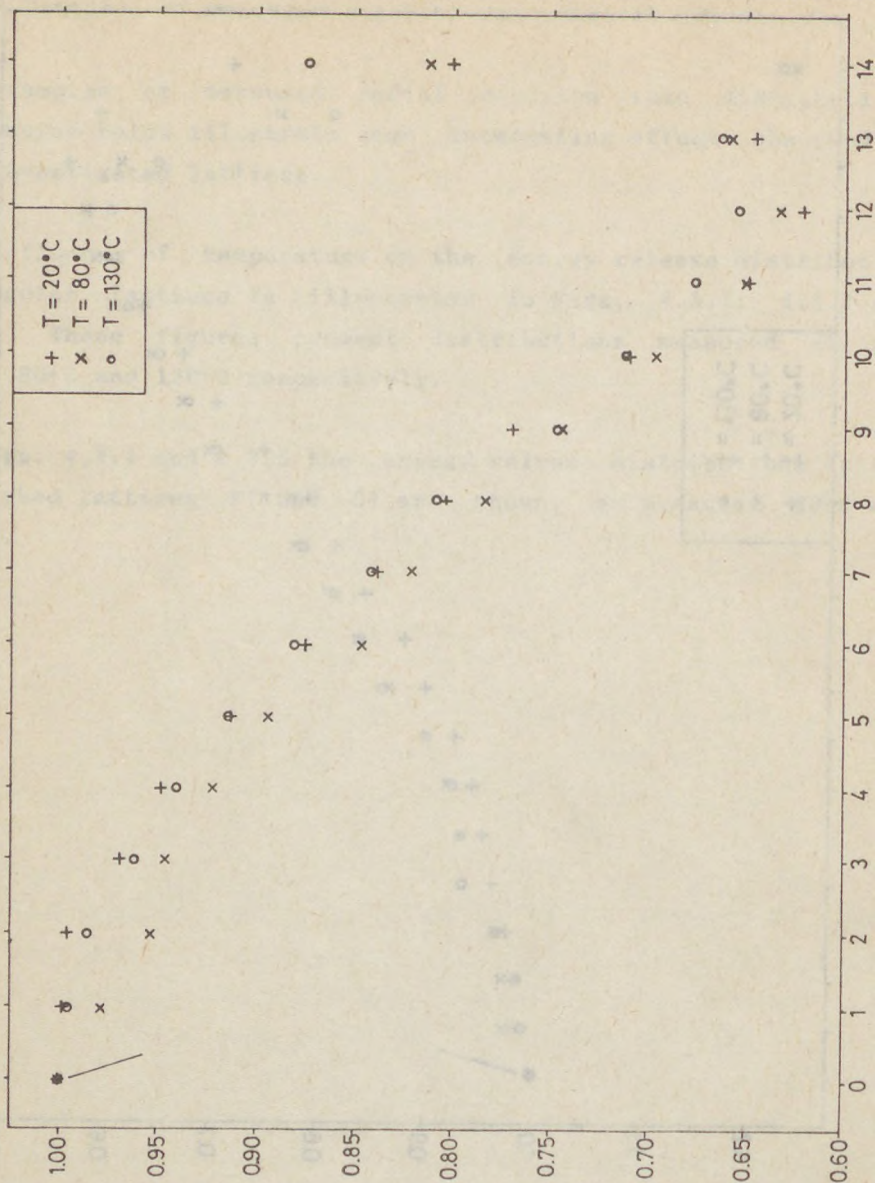


Fig. 4.3.2. Radial energy release distributions at different temperatures in the 12.7/3.6/0.0 regular lattice

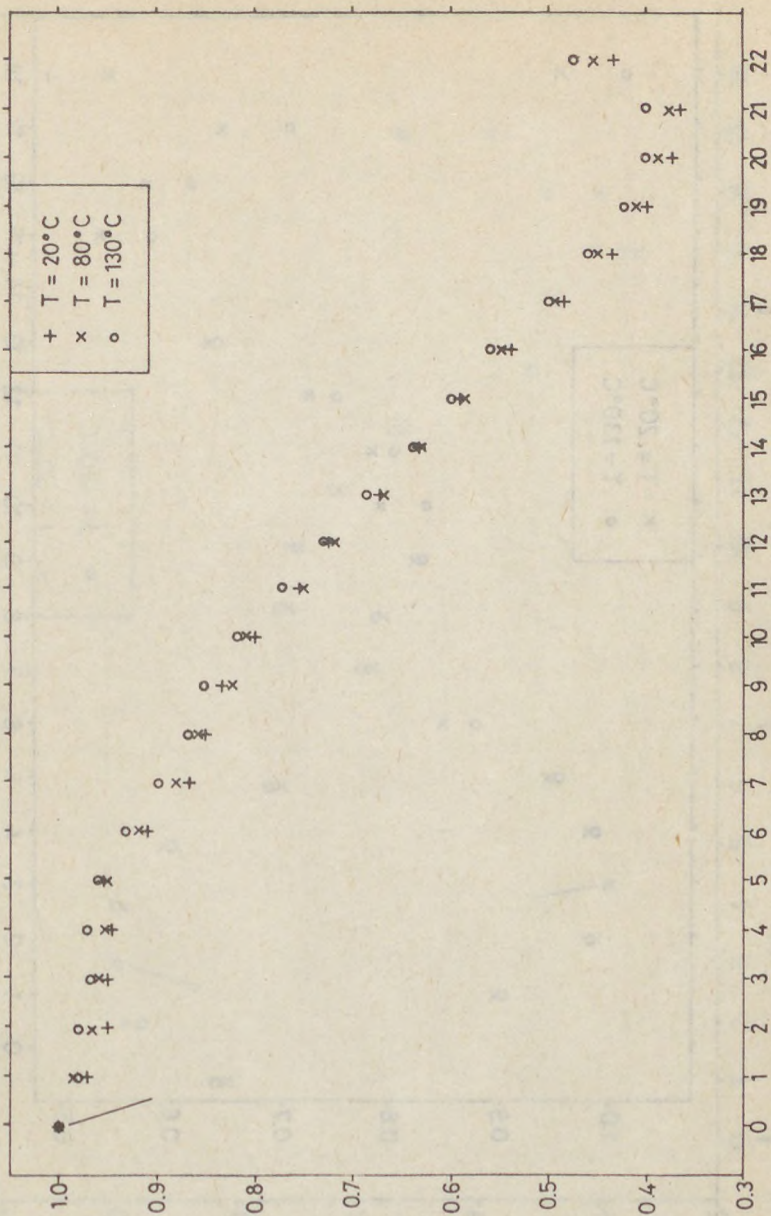


Fig. 4.3.3. Radial energy release distributions at different temperatures in the 12.7/3.6/5.8 regular lattice

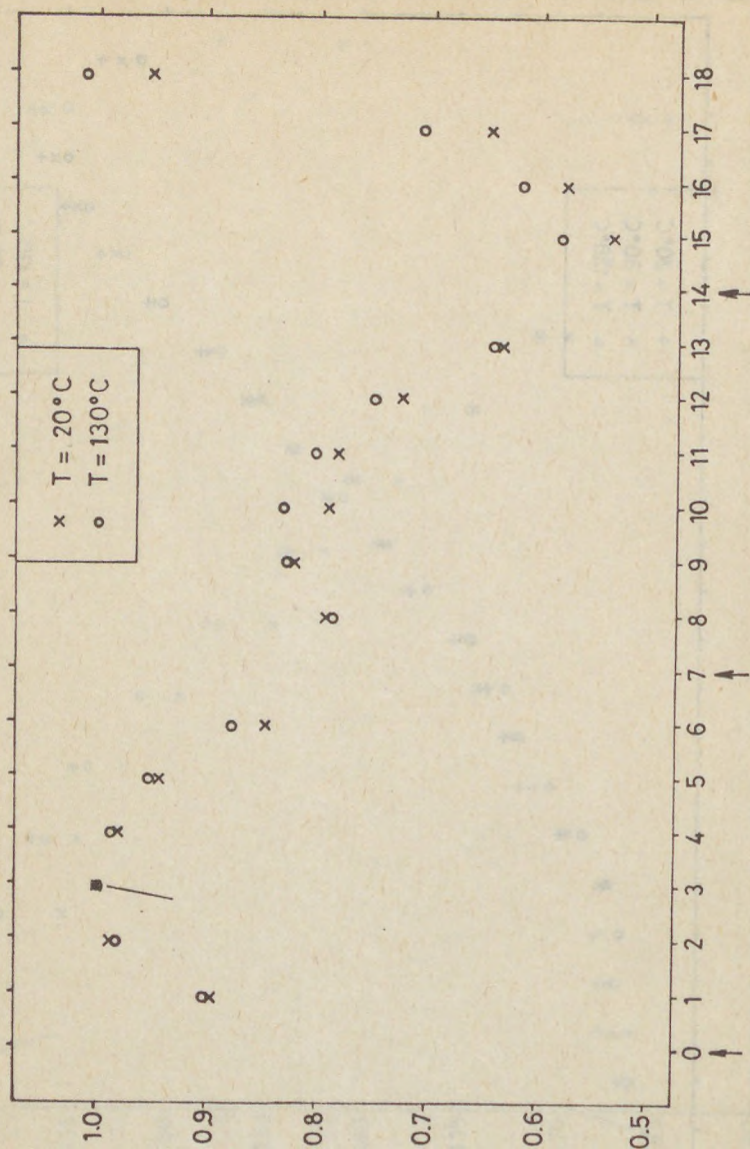


Fig. 4.3.4. Radial energy release distributions at different temperatures in the 12.7/3.6-F7 perturbed lattice

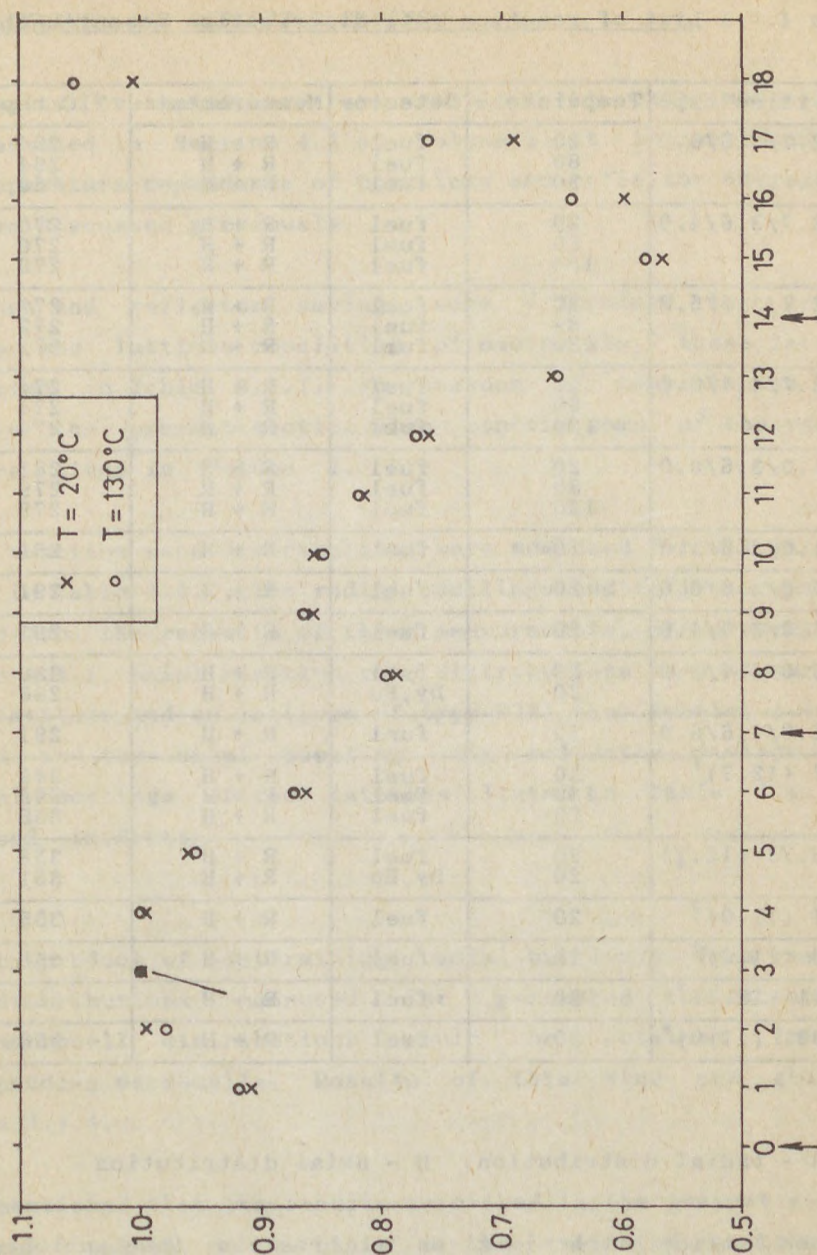


Fig. 4.3.5. Radial energy release distributions at different temperatures in the 12.7/3.6-G7 perturbed lattice

Table 4.3.1 List of reaction rate distribution measurements

Lattice type	Temperature	Detector	Measurement*	TIC report
12.7/3.6/0.0	20	fuel	R + H	264
	80	fuel	R + H	264
	130	fuel	R + H	264
12.7/3.6/4.0	20	fuel	R + H	270
	80	fuel	R + H	270
	130	fuel	R + H	270
12.7/3.6/5.8	20	fuel	R + H	272
	80	fuel	R + H	272
	130	fuel	R + H	272
12.7/4.4/0.0	20	fuel	R + H	274
	80	fuel	R + H	274
	130	fuel	R + H	274
11.0/3.6/0.0	20	fuel	R + H	281
	80	fuel	R + H	279
	130	fuel	R + H	279
11.0/3.6/1.0	20	fuel	R + H	281
15.0/3.6/0.0	20	fuel	R + H	291
15.0/3.6/4.0	20	fuel	R + H	291
15.0/4.4/0.0	20	fuel	R + H	286
	20	Dy, Eu	R + H	286
15.0/1.6/0.0	20	fuel	R + H	291
X7 (12.7)*	20	fuel	R + H	349
	130	fuel	R + H	349
	20	fuel	R + H	358
X3, X5 (12.7)*	20	fuel	R + H	358
	20	Dy, Eu	R + H	351
E7 (11.0)*	20	fuel	R + H	355
E3 (11.0)*	20	fuel	R + H	355
K91 (12.7)*	20	fuel	R + H	353
K331 (11.0)*	20	fuel	R + H	356

* R - radial distribution, H - axial distribution

* the lattice pitch is given in brackets (the enrichment was 3.6% in all cases, and there was no boric acid in the moderator)

4.4. BUCKLINGS AND REFLECTOR SAVINGS

The results presented here are complete the experimental data set presented in Section 4.4 of Volume 1. It is mentioned that the temperature dependence of bucklings and reflector savings has not been discussed previously.

Bucklings and reflector savings were determined for regular lattices and lattices consisting of macrocells; these lattices are listed in Table 4.4.1. For reasons of completeness other tables of the present section also contain some of the results that are given in Volume 1.

Radial reaction rate distributions were measured for all lattices listed in Table 4.4.1. The radial bucklings and reflector savings derived from the results of these measurements, are presented in Section 4.4.1. Axial reaction rate distributions were measured on these lattices and on lattices of type K331 too. Section 4.4.2 is devoted to the axial bucklings and reflector savings. The material bucklings of the lattices listed in Table 4.4.1 are discussed in Section 4.4.3.

As a by-product of determining radial bucklings from reaction rate distributions measured for perturbed configurations, intra-macrocell distributions could be obtained for the corresponding macrocells. Results of this kind are given in Section 4.4.4.

It is mentioned that the results described in the present section have been obtained on the basis of the evaluated reaction rate distributions stored in file EDF (see Section 4.3). The data handling techniques applied are discussed in Section 3.5 of Volume 1.

The measured reaction rate distributions and their evaluations are discussed in a number of reports [264, 270, 272, 274, 279, 281, 289, 291, 349, 351, 353, 355, 356 and 358], and in particular in the summarizing reports [428 and 429].

4.4.1. Radial bucklings and reflector savings

Radial bucklings B_r^2 were determined by fitting the appropriate functions to the measured reaction rate distributions. The evaluation, including the point drop technique, was the same as used in Volume 1. therefore it is not described here again (see Sections 3.5.4 and 4.4.1 of Volume 1 for more detail).

The results of the evaluation of radial reaction rate distributions, i.e. the radial bucklings and reflector savings, for room temperature are given for regular lattices in Table 4.4.2., and for configurations containing macrocells in Table 4.4.3.

As the measuring techniques of foil activation were not utilized for higher temperatures (due to technical difficulties), only the energy release distribution was measured. The measuring technique and data evaluation correspond fully to the techniques used at room temperature measurements.

The radial bucklings and reflector savings for different temperatures are given in Table 4.4.4.

The temperature dependence of bucklings and reflector savings was studied in such a way that measurements were performed at three different temperatures: 20, 80 and 130°C.

Table 4.4.5 contains average values for λ_r , based on the measurements presented both in Volume 1 and in Volume 3. It can

be seen that λ_r increases for all the lattices investigated with increasing temperature.

The data presented in Table 4.4.5 show that λ_r depends on the boric acid concentration in the strongest way.

4.4.2. Axial bucklings and reflector savings

The method of determining axial bucklings B_z^2 and reflector savings λ_z , based on the reaction rate measurements performed along the height of the fuel rods, is described in Section 3.2.4 of Volume 1.

The measuring technique and data evaluation for high temperature measurements are exactly the same as the techniques applied at room temperature measurements.

One of the main conclusions of Volume 1 - that the axial reflector saving λ_z depends only on the lattice pitch - is confirmed on the basis of the results performed in an enlarged range of measurements. The results of λ_z , averaged for the different lattice pitches, are given in Table 4.4.6. These results are based on all the measurements performed, i.e. they include results from Volume 1 too.

The experiments do not show any dependence of λ_z on the temperature. For example, for the lattice with pitch 12.7mm at $T=130^\circ\text{C}$, one gets $\lambda_z = 13.69 \pm 0.51\text{cm}$, the averaged value for these lattices, including measurements for all the investigated temperatures, is $\lambda_z = 13.27 \pm 0.08\text{cm}$. The values correspond to each other within the limits of the experimental errors.

4.4.3. Material bucklings

The material bucklings of the investigated lattices, based on the assumption that no anisotropy of the migration area is present, are summarized in Table 4.4.7. The data presented in Table 4.4.7 include the results of Volume 1 too. Table 4.4.7 completes Table 4.4.8 of Volume 1.

The results of serial measurements, performed on lattices 12.7/3.6/0.0, 12.7/3.6/0.0-C5 and 11.0/3.6/0.0 proved, as was said in Volume 1, that the anisotropy of the migration area can be neglected.

Figure 4.4.1 shows the dependence of B_z^2 on B_r^2 for the lattices 11.0/3.6/0.0, 15.0/3.6/0.0, 15.0/3.6/4.0 and 15.0/4.4/0.0. The departure of some measured points from the linear function $B_r^2 = B_m^2 - B_z^2$ is probably due to the lack of applicability of one group approximation; it is not due to anisotropy.

4.4.6. Intra-macrocell distributions

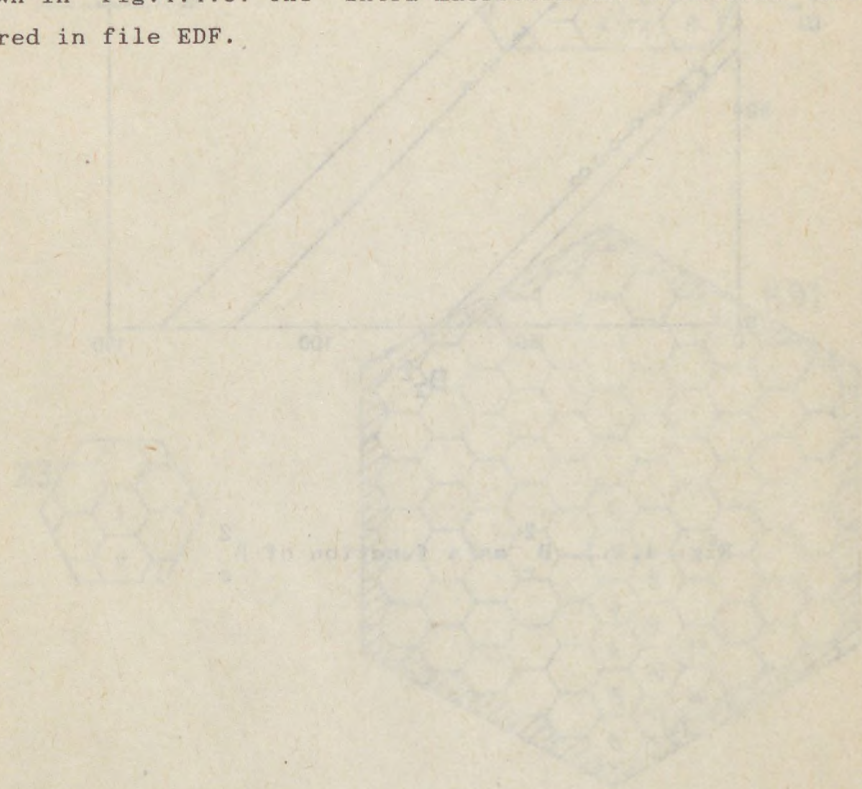
Intra-macrocell distributions of reaction rates were determined in the course of the evaluation of the reaction rate distributions measured for cores consisting of macrocells as discussed in Section 3.2.4 of Volume 1. The distributions obtained in this way are presented in Tables 4.4.8 to 4.4.17.

Some remarks are necessary concerning Tables 4.4.8 - 4.4.17 :

- The numeration of the positions corresponds to the numeration shown in Fig.4.4.2.
- The detector identification corresponds to the nomenclature, given in Table 3.2.1 of Volume 1.

- Normalization of the distributions: in the Xn type lattices the position of normalization is the furthest position from the perturbation; in the K91 lattices the position of normalization is the first neighbour of the absorber rod (type D).

The dependence of the intra-macrocell distributions on the temperature and on the lattice pitch for X7 type macrocells is shown in Fig.4.4.3. The intra-macrocell distributions are also stored in file EDF.



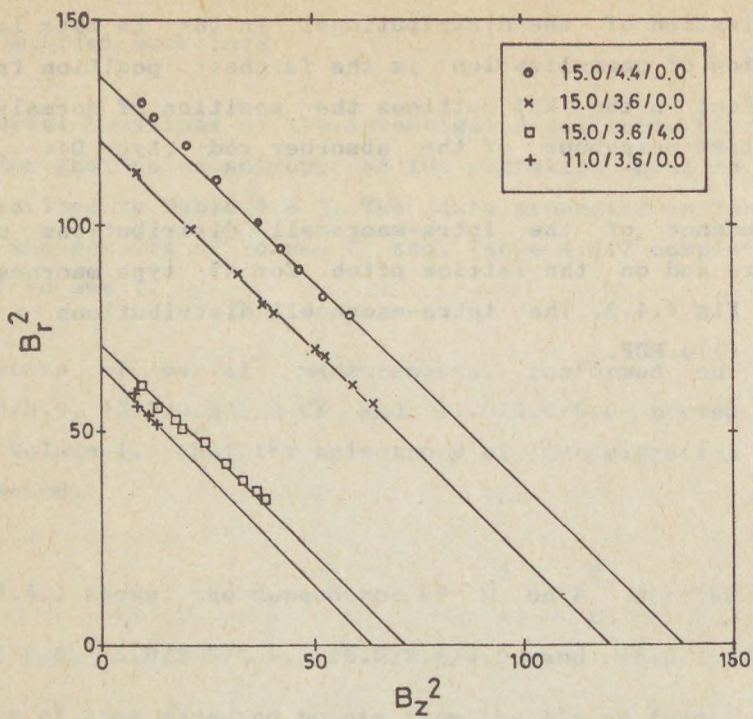


Fig. 4.4.1. B_r^2 as a function of B_z^2

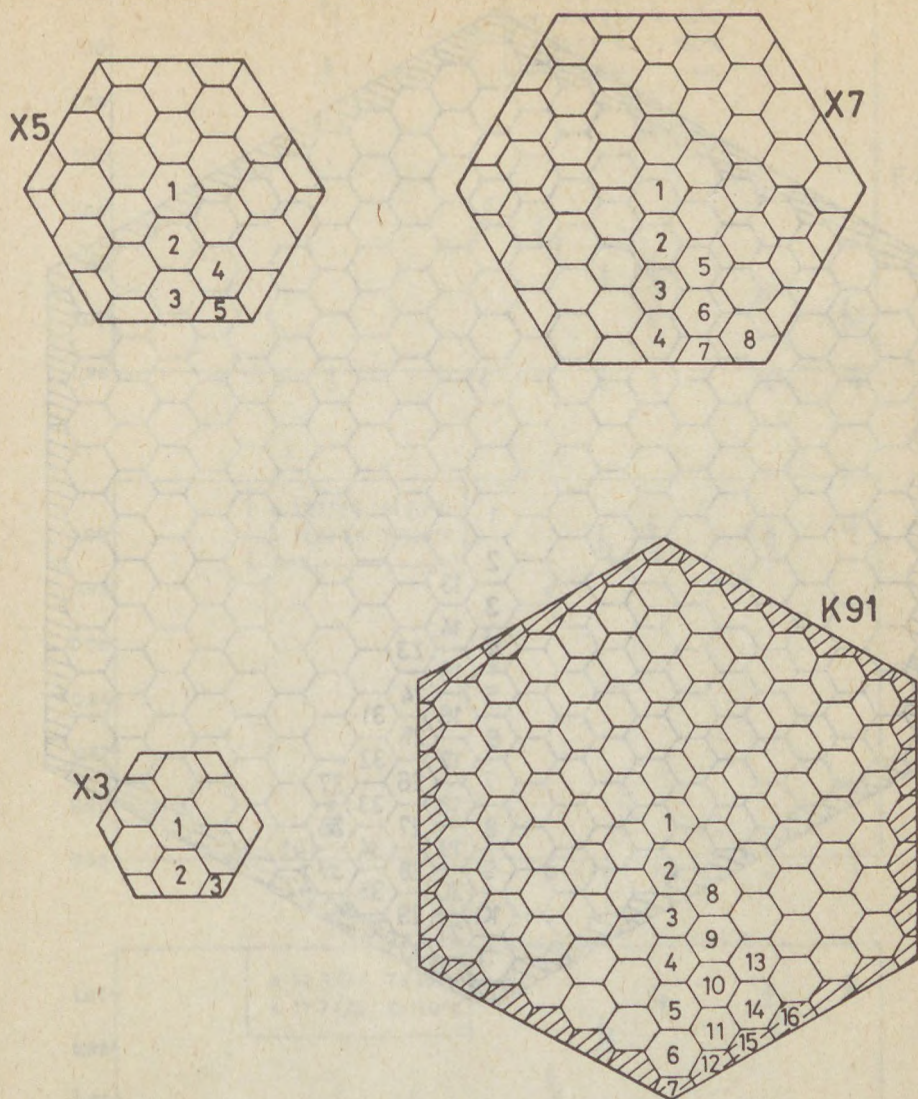


Fig. 4.4.2.a Numeration of elementary cells in macrocells X3, X5, X7 and K91

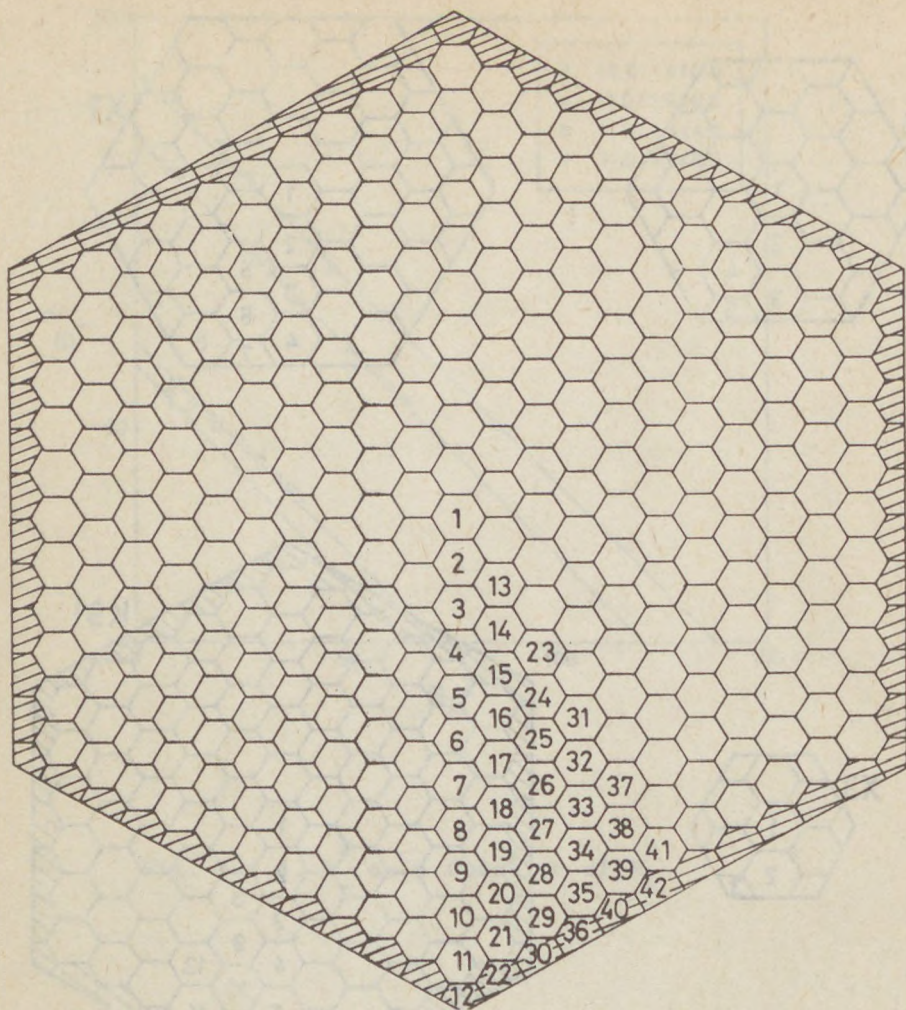


Fig. 4.4.2.b Numeration of elementary cells in macrocell K331

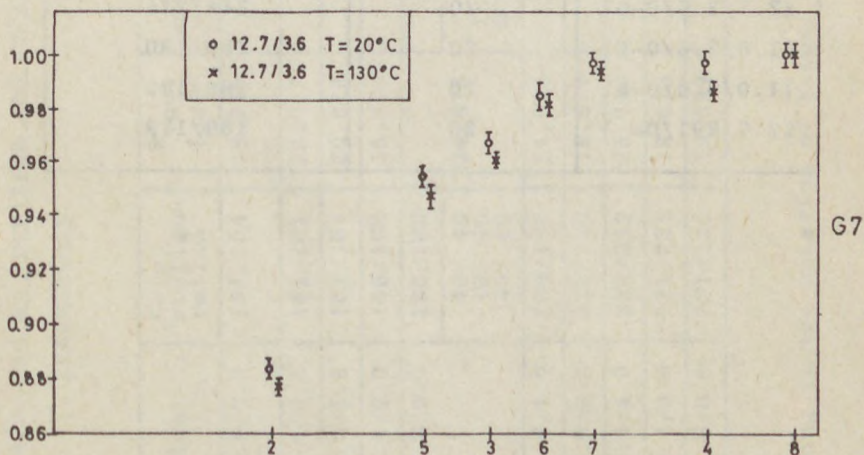
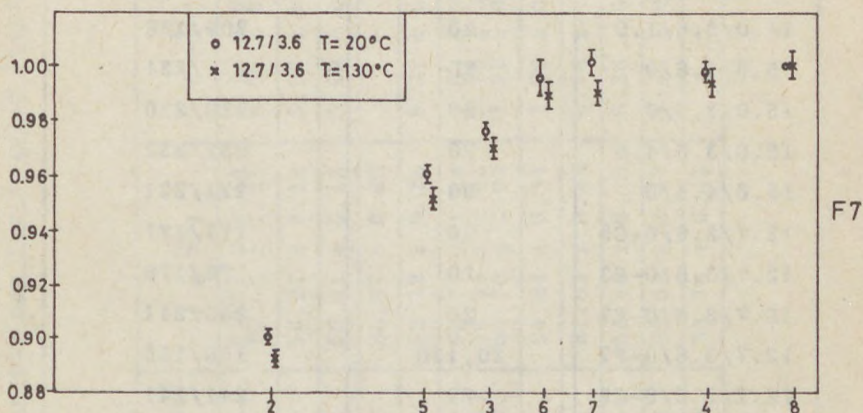
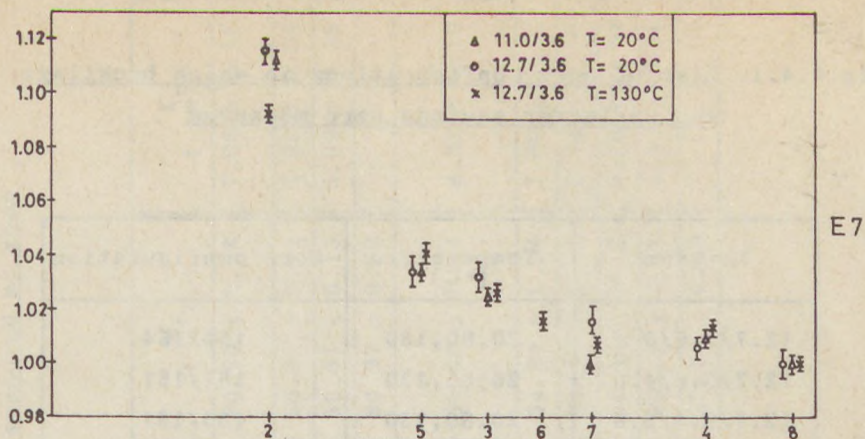


Fig. 4.4.3. Intra-macrocell distribution of energy release in different X7 type macrocells (see Fig. 4.4.2.a for positions)

Table 4.4.1. List of core configurations in which bucklings
and reflector savings were measured

Lattice	Temperature [°C]	Core configuration
12.7/3.6/0	20,80,130	154/154
12.7/3.6/4.0	20,80,130	161/161
12.7/3.6/5.8	20,80,130	163/161
12.7/4.4/0	20,80,130	166/166
11.0/3.6/0	20,80,130	188/188
11.0/3.6/1.0	20	209/188
15.0/1.6/0	20	231/231
15.0/3.6/0	20	220/220
15.0/3.6/4.0	20	232/232
15.0/4.4/0	20	221/221
12.7/3.6/0-C5	20	177/177
12.7/3.6/0-E3	20	176/176
12.7/3.6/0-E7	20	245/244
12.7/3.6/0-F7	20,130	155/155
12.7/3.6/0-G3	20	241/241
12.7/3.6/0-G5	20	242/242
12.7/3.6/0-G7	20	244/244
11.0/3.6/0-E3	20	190/190
11.0/3.6/0-E7	20	189/189
12.7/K91/D ∞	20	180/179

Table 4.4.2. Radial bucklings and reflector savings for regular lattices, measured at room temperature

Lattice	Core configuration	Requ. [cm]	Detector*	B_r^2 [m ⁻² r]	λ_r [cm]	B_r^2 [m ² r ²]	$\bar{\lambda}_r$ [cm ^r]
12.7/3.6/0.0	154/154	18.919	fuel	81.39 ± 1.14 79.42 ± 1.25	7.74 ± 0.19 8.06 ± 0.21	80.50 ± 0.98	7.88 ± 0.16
12.7/3.6/4.0	161/161	28.013	fuel	50.21 ± 0.11	5.92 ± 0.04	50.21 ± 0.11	5.92 ± 0.04
12.7/3.6/5.8	163/161	28.013	fuel	50.01 ± 0.13	5.99 ± 0.05	50.01 ± 0.13	5.99 ± 0.05
12.7/4.4/0.0	166/166	16.670	fuel	80.97 ± 0.68	-	80.97 ± 0.68	-
11.0/3.6/0.0	188/188		fuel	52.32 ± 0.26	8.37 ± 0.08		
	40/40 40/40 40/40	24.875	fuel INAL.43 DYAL10.	54.71 ± 1.24 54.54 ± 1.86 54.10 ± 2.01	7.64 ± 0.37 7.79 ± 0.56 7.82 ± 0.61	52.48 ± 0.34	8.32 ± 0.10
11.0/3.6/1.0	209/188	24.875	fuel	54.84 ± 0.34	7.60 ± 0.10	54.84 ± 0.34	7.60 ± 0.10
15.0/3.6/0.0	220/220	19.877	fuel	81.63 ± 0.49	6.74 ± 0.08	81.63 ± 0.49	6.74 ± 0.08
15.0/3.6/4.0	232/232	25.750	fuel	56.44 ± 0.15	6.26 ± 0.04	56.44 ± 0.15	6.26 ± 0.04
15.0/4.4/0.0	221/221	19.016	fuel	89.52 ± 0.47	6.40 ± 0.08	89.52 ± 0.47	6.40 ± 0.08
15.0/1.6/0.0	231/231	19.689	fuel	35.74 ± 0.49	-	35.74 ± 0.49	-

* According to the notation of Volume 1.

Table 4.4.3. Radial bucklings and reflector savings of the lattices consisting of macrocells, measured at room temperature

Lattice	Core configuration	Requ. [cm]	Detector*	B^2 [m ⁻² r]	λ_r [cm]	B^2 [m ⁻² r]	λ_r [cm]
12.7/3.6/0-E3	176/176	19.059	fuel DYAL5.0 EUAL10.	82.62 ± 0.60 82.96 ± 1.43 82.92 ± 1.24	7.40 ± 0.10 7.34 ± 0.23 7.35 ± 0.20	82.71 ± 0.51	7.38 ± 0.08
12.7/3.6/0-C5	177/177	24.726	DYAL5.0 EUAL10.	54.00 ± 0.39 54.12 ± 0.43	8.00 ± 0.11 7.96 ± 0.13	54.05 ± 0.29	7.98 ± 0.08
12.7/3.6/0-G5	242/242	20.214	fuel	24.54 ± 0.57	-	24.54 ± 0.57	-
12.7-K91-D _∞	180/179	29.543	fuel	42.18 ± 0.15	7.48 ± 0.16	42.18 ± 0.15	7.48 ± 0.16
11.0/3.6/0-E7	189/189	22.509	fuel	58.77 ± 0.34	8.86 ± 0.09	58.77 ± 0.34	8.86 ± 0.09
11.0/3.6/0-E3	190/190	22.513	fuel	64.03 ± 0.48	7.54 ± 0.13	64.03 ± 0.48	7.54 ± 0.13

* According to the notation of Volume 1.

Table 4.4.4. Radial bucklings and reflector savings for different temperatures

Lattice	Core configuration	Temperature [C°]	B_r^2 [m ⁻²]	λ_r [cm]
12.7/3.6/0.0	154/154	20	80.50 ± 0.98	7.88 ± 0.16
12.7/3.6/0.0	154/154	80	81.18 ± 1.29	7.77 ± 0.21
12.7/3.6/0.0	154/154	130	78.27 ± 0.91	8.26 ± 0.16
12.7/3.6/4.0	161/161	20	50.21 ± 0.11	5.92 ± 0.04
12.7/3.6/4.0	161/161	80	48.90 ± 0.20	6.38 ± 0.07
12.7/3.6/4.0	161/161	130	47.91 ± 0.19	6.73 ± 0.07
12.7/3.6/5.8	163/161	20	50.01 ± 0.13	5.99 ± 0.05
12.7/3.6/5.8	163/161	80	49.06 ± 0.20	6.32 ± 0.07
12.7/3.6/5.8	163/161	130	48.80 ± 0.11	6.41 ± 0.04
12.7/3.6-E7	245/244	130	48.01 ± 0.21	8.72 ± 0.08
12.7/3.6-F7	141/138	20	50.62 ± 0.30	7.81 ± 0.10
12.7/3.6-F7	155/155	130	47.89 ± 0.28	8.76 ± 0.10
11.0/3.6/0.0	188/188	20	52.48 ± 0.34	8.32 ± 0.10
11.0/3.6/0.0	188/188	80	53.06 ± 0.48	8.14 ± 0.15
11.0/3.6/0.0	188/188	130	51.64 ± 0.29	8.59 ± 0.09

Table 4.4.5 Average results of λ_r for all the lattices

(including results of Volume 1)

Lattice	C_B [g/kg]	T [°C]	$\bar{\lambda}_r$ [cm]
12.7/3.6	0.0	20	7.87 ± 0.09
12.7/3.6	0.0	80	7.77 ± 0.21
12.7/3.6	0.0	130	8.26 ± 0.16
12.7/4.4	0.0	20	7.44 ± 0.20
12.7/3.6-D7, F7, E7	0.0	20	7.67 ± 0.06
12.7/3.6-F7, E7	0.0	130	8.74 ± 0.06
12.7/3.6-E3	0.0	20	7.38 ± 0.08
12.7/3.6-C5	0.0	20	7.98 ± 0.08
12.7/3.6-K91, K91-D ∞	0.0	20	7.73 ± 0.11
11.0/3.6	0.0	20	8.26 ± 0.12
11.0/3.6	0.0	80	8.14 ± 0.15
11.0/3.6	0.0	130	8.59 ± 0.09
11.0/3.6-E7	0.0	20	8.86 ± 0.09
11.0/3.6-E3	0.0	20	7.54 ± 0.13
15.0/3.6	0.0	20	6.74 ± 0.08
15.0/4.4	0.0	20	6.40 ± 0.08
12.7/4.4	0.64	20	7.31 ± 0.22
11.0/3.6	1.0	20	7.60 ± 0.10
11.0/3.6	1.4	20	7.73 ± 0.13
12.7/3.6-F7, E7	1.8	20	6.47 ± 0.09
12.7/3.6	4.0	20	5.96 ± 0.08
12.7/3.6	4.0	80	6.38 ± 0.07
12.7/3.6	4.0	130	6.73 ± 0.07
12.7/3.6-K91	4.0	20	6.26 ± 0.07
15.0/3.6	4.0	20	6.26 ± 0.04
12.7/3.6	5.8	20	5.99 ± 0.05
12.7/3.6	5.8	80	6.32 ± 0.07
12.7/3.6	5.8	130	6.41 ± 0.04
12.7/3.6	7.2	20	6.26 ± 0.16

Table 4.4.6. Axial reflector savings as a function of
lattice pitch

Lattice pitch	Number of investigated cases	λ_z
11.0	22	15.37 ± 0.40
12.7	193	13.27 ± 0.09
15.0	6	11.00 ± 0.43

Table 4.4.7. Material bucklings of the investigated core configuration

Lattice	T [°C]	H [cm]	B^2 [m ⁻²]	B^2 [m ⁻²]
12.7/3.6/0.0	20	61.32±0.10	98.26 ± 0.99	98.26 ± 0.99
12.7/3.6/0.0	80	66.87±0.03	96.55 ± 1.29	96.55 ± 1.29
12.7/3.6/0.0	130	77.42±0.05	90.27 ± 0.91	90.27 ± 0.91
12.7/3.6/4.0	20	48.57±0.03	76.03 ± 0.14	76.03 ± 0.14
12.7/3.6/4.0	80	51.99±0.02	72.07 ± 0.21	72.07 ± 0.21
12.7/3.6/4.0	130	57.48±0.02	67.63 ± 0.20	67.63 ± 0.20
12.7/3.6/5.8	20	68.03±0.21	64.95 ± 0.26	64.95 ± 0.26
12.7/3.6/5.8	80	75.12±0.02	61.69 ± 0.20	61.69 ± 0.20
12.7/3.6/5.8	130	85.00±0.30	59.02 ± 0.13	59.02 ± 0.13
12.7/3.6- E3	20	49.98±0.06	107.38 ± 0.52	107.38 ± 0.52
12.7/3.6- C5	20	64.05±0.07	70.56 ± 0.31	70.56 ± 0.31
12.7/3.6- G5	20	65.08±0.17	40.62 ± 0.60	40.62 ± 0.60
12.7/3.6- G7	20	53.60±0.06	-	73.11 ± 0.21
12.7/3.6- G7	130	68.38±0.20	-	62.75 ± 0.28
12.7/3.6- E7	130	35.07±0.03	90.25 ± 0.23	90.19 ± 0.19
12.7/3.6- F7	20	46.91±0.03	77.87 ± 0.31	78.29 ± 0.20
12.7-K91-D _∞	20	30.25±0.03	94.29 ± 0.36	93.73 ± 0.27
11.0/3.6/0.0	20	72.46±0.17	65.27 ± 0.55	65.27 ± 0.55
11.0/3.6/0.0	80	79.52±0.10	64.02 ± 0.49	64.02 ± 0.49
11.0/3.6/0.0	130	94.86±0.70	59.76 ± 0.31	59.76 ± 0.31
11.0/3.6/1.0	20	110.93±0.34	62.14 ± 0.62	62.14 ± 0.62
11.0/3.6- E7	20	92.29±0.34	67.29 ± 0.62	67.29 ± 0.62
11.0/3.6- E3	20	55.88±0.07	83.47 ± 0.74	83.47 ± 0.74
15.0/3.6/0.0	20	39.48±0.03	120.36 ± 0.65	120.36 ± 0.65
15.0/3.6/4.0	20	73.53±0.12	70.25 ± 0.81	70.25 ± 0.81
15.0/4.4/0.0	20	34.69±0.03	136.80 ± 0.64	136.80 ± 0.64
15.0/1.6/0.0	20	75.60±0.13	48.90 ± 0.65	48.90 ± 0.65

The B_m^2 values are based on average values λ_z and λ_r .

(see Tables 4.4.5 and 4.4.6)

Table 4.4.8. Intra-macrocell distributions within macrocell
12.7/3.6/0-E3

Detector* position	fuel T=20°C	DYAL5.(s) T=20°C	EUAL10.(s) T=20°C
1	-	-	-
2	1.0455±0.0031	1.0480±0.0055	1.0380±0.0046
3	1.0000±0.0034	1.0000±0.0067	1.0000±0.0056

Table 4.4.9 Intra-macrocell distributions within macrocell
12.7/3.6/0-C5

Detector* position	DYAL5.(s) T=20°C	EUAL10.(s) T=20°C
1	-	-
2	0.9322±0.0031	0.9465±0.0035
3	0.9919±0.0030	0.9958±0.0034
4	0.9851±0.0040	0.9856±0.0045
5	1.0000±0.0041	1.0000±0.0044

* The notation of the detectors is given in Volume 1.

Table 4.4.10. Intra-macrocell distribution within macrocell
12.7/3.6/0-G3

Detector* position	fuel T=20°C
1	-
2	0.9622±0.0029
3	1.0000±0.0036

Remark: In this case the function $I_0 \cdot \Psi_I$ was fitted by RFIT
 (see reference [428]).

Table 4.4.11. Intra-macrocell distribution within macrocell
12.7/3.6/0-G5

Detector* position	fuel T=20°C
1	-
2	0.9077±0.0023
3	0.9848±0.0025
4	0.9846±0.0029
5	1.0000±0.0031

* The notation of the detectors is given in Volume 1.

Table 4.4.12. Intra-macrocell distributions within macrocell
12.7/3.6/0-G7

Detector [*] position	fuel T = 20C°	fuel T = 130C°
1	-	-
2	0.8828±0.0025	0.8785±0.0026
3	0.9666±0.0029	0.9615±0.0030
4	0.9978±0.0028	0.9885±0.0028
5	0.9531±0.0036	0.9472±0.0035
6	0.9846±0.0044	0.9823±0.0040
7	0.9983±0.0034	0.9955±0.0035
8	1.0000±0.0034	1.0000±0.0034

Table 4.4.13. Intra-macrocell distributions within macrocell
12.7/3.6/0-E7

Detector [*] position	fuel T = 20°C	fuel T = 130°C
1	-	-
2	1.1149 ± 0.0045	1.0925±0.0024
3	1.0323 ± 0.0050	1.0259±0.0023
4	1.0062 ± 0.0042	1.0139±0.0022
5	1.0339 ± 0.0052	1.0414±0.0028
6	-	1.0164±0.0031
7	1.0150 ± 0.0045	1.0070±0.0025
8	1.0000 ± 0.0051	1.0000±0.0028

Table 4.4.14. Intra-macrocell distributions within macrocell
12.7/3.6/0-F7

Detector [*] position	fuel T = 20C°	fuel T = 130C°
1	-	-
2	0.9009±0.0045	0.8929±0.0028
3	0.9773±0.0057	0.9705±0.0033
4	0.9962±0.0068	0.9937±0.0039
5	0.9667±0.0055	0.9520±0.0031
6	0.9951±0.0088	0.9872±0.0045
7	1.0051±0.0070	0.9886±0.0038
8	1.0000±0.0067	1.0000±0.0042

Table 4.4.15. Intra-macrocell distribution within macrocell
12.7/3.6-K91/0-D_∞

Detector [*] position	fuel T=20°C
1	-
2	1.0000±0.0044
3	1.1539±0.0067
4	1.3051±0.0129
5	1.5219±0.0099
6	1.9671±0.0091
7	-
8	1.1393±0.0063
9	1.2498±0.0094
10	1.4511±0.0136
11	1.8222±0.0112
12	-
13	1.3998±0.0065
14	1.7352±0.0083
15	-
16	-

* The notation of the detectors is given in Volume 1.

Table 4.4.16. Intra-macrocell distribution within macrocell
11.0/3.6/0-E7

Detector* position	fuel T=20°C
1	-
2	1.1131±0.0023
3	1.0256±0.0020
4	1.0104±0.0019
5	1.0340±0.0032
6	-
7	1.0006±0.0029
8	1.0000±0.0033

Table 4.4.17. Intra-macrocell distribution within macrocell
11.0/3.6/0-E3

Detector* position	fuel T=20°C
1	-
2	1.0447±0.0029
3	1.0000±0.0027

* The notation of the detectors is given in Volume 1.

4.5 SPECTRAL RATIOS

The present section is devoted to the results of spectral ratio measurements. As described in Section 3.3.1 of volume 1, spectral ratios were determined by activating foils and UO_2 pellets.

The measurement of spectral ratio is described in reports [266, 267, 268, 269, 273, 277, 278, 280, 282, 287, 354 and 357] and in summarizing reports [422, 431 and 432].

A complete list of the measurements performed on regular and perturbed lattices is given in Table 4.5.1.

4.5.1 Spectral ratios in regular lattices

In all of the regular lattices, the spectral ratios were measured in the asymptotic elementary cells (in the central part of the core). The data set obtained allows one to study the dependence of the spectral ratios on the following lattice parameters:

- fuel enrichment (for 1.6%, 3.6% and 4.4%),
- boron concentration up to 5.8 g/l,
- lattice pitch (for 11.0, 12.7 and 15.0mm),
- temperature (for 20°C and 130°C).

The measured spectral ratios (ratio of the detector activation measured in the investigated core to that measured in the thermal column) are given in Table 4.5.2. The notation in Table 4.5.2 is the same as the notation used in Volume 1.

Table 4.5.3 gives spectral indices calculated according to Section 4.5.4 of Volume I on the basis of spectral ratios shown in Table 4.5.2 and the correlation coefficients given in Appendix C.

As can be seen from Table 4.5.2, and also from the analogous Table 4.5.2 of Volume 1, spectral measurements were carried out in many lattices. This collection of experimental results allows us to analyse different trends.

For the analysis let us select the spectral indices $SI(Np/Ce)$ and $SI(Pu/U)$, as characteristic for UO_2-H_2O lattices. These indices increase with increasing enrichment and decreasing lattice pitch. It is thus possible to assume that these spectral indices do not depend on fuel enrichment and lattice pitch separately, but they depend on the H/U ratio. The dependence of the spectral indices $SI(Np/Dy)$ and $SI(Np/Ce)$ on H/U, shown in Fig.4.5.1, confirms quantitatively this assumption within the limit of the experimental errors. Qualitative analysis of this dependence is given in [Видовски И., 1989].

The results, presented in Volume 1 have already proved that these spectral indices increase with increasing boron concentration. The new results do not contradict this tendency.

Analysis of the first results [Видовски И., 1982] of the temperature dependence of spectral parameters indicated that these spectral indices depend only slightly on the temperature, in the investigated range (20-130°C). Such dependence was confirmed on the basis of the results of all the measurements performed. This means that the decision that spectral parameters were measured only for the minimal and maximal temperatures seems to have been right.

The average increase of the spectral indices $SI(Np/Ce)$ and $SI(Pu/U)$ due to the temperature increase in the range 20-130°C are 1.044 ± 0.016 and 1.089 ± 0.065 respectively.

4.5.2 Spectral ratios in perturbed lattices

Spectral ratios were determined for two perturbed lattices of type Xn: E3 with lattice pitch 12.7mm, and E7 with a lattice pitch 11.0mm. In both lattices, the foil activation technique and the UO_2 pellet activation were used. The spectral ratios (only using the UO_2 pellet irradiation) were determined in two perturbed lattices of type K331, at lattice pitch 11.0mm, with and without fuel enrichment smoothing, too.

In Table 4.5.4, in accordance with Fig.4.4.2, the coordinates of the positions of the measurements are given. These coordinates are needed when the measurements are compared with calculations performed for the whole core, but they are useful for comparing these results with the results given in Volume 1 too.

The measured spectral ratios for perturbed lattices are given in Table 4.5.5.

Table 4.5.6 gives spectral indices calculated in accordance with Section 4.5.4 of Volume 1 on the basis of the spectral ratios shown in Table 4.5.5 and the correlation coefficients given in Appendix C.

The set of results of spectral measurements is enlarged compared with the results given in Volume 1, from two aspects: measurements were carried out for the E3 lattices (in Volume 1 measurements on lattices of type X7 are presented); perturbed lattices were investigated with the pitch 11.0mm (earlier only with lattice pitch 12.7mm).

Analysis of the experimental results for the E7 lattice showed that the spectral indices for lattice pitches 11.0 and 12.7mm do not differ from their asymptotic value at distances of two and three lattice pitches, respectively.

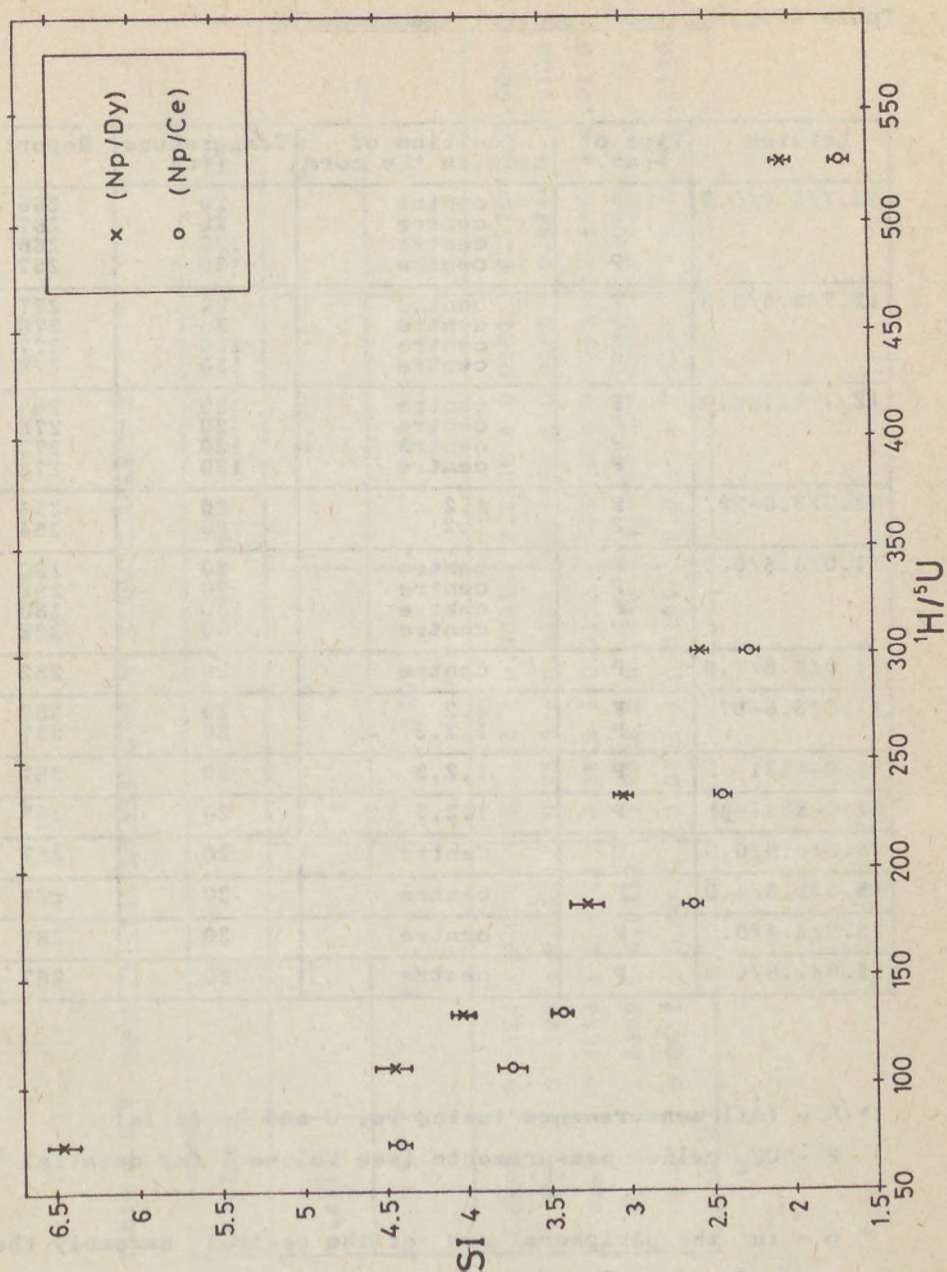


Fig. 4.5.1. Spectral indices SI(Np/Dy) and SI(Np/Ce) as function of H/U for regular lattices

Table 4.5.1 List of spectral measurements

Lattice	Type of meas.*	Position of meas.in the core	Temperature [°C]	Report
12.7/3.6/0.0	F	centre	20	266
	P	centre	20	267
	F	centre	130	266
	P	centre	130	267
12.7/3.6/5.8	F	centre	20	277
	P	centre	20	278
	F	centre	130	277
	P	centre	130	278
12.7/4.4/0.0	F	centre	20	269
	P	centre	20	278
	F	centre	130	273
	P	centre	130	278
12.7/3.6-E3	F	1,2	20	354
	P	1,2	20	354
11.0/3.6/0.0	F	centre	20	280
	P	centre	20	282
	F	centre	130	280
	P	centre	130	282
11.0/3.6/1.0	P	centre	20	282
11.0/3.6-E7	F	1,2	20	357
	P	1,2,3	20	357
11.0-K331	P	1,2,3	20	357
11.0-K331-p*	P	1,2,3	20	357
15.0/3.6/0.0	P	centre	20	287
15.0/3.6/4.0	P	centre	20	287
15.0/4.4/0.0	P	centre	20	287
15.0/1.6/0.0	P	centre	20	287

* F - foil measurements (using Pu, U and Dy foils)

P - UO₂ pellet measurements (see Volume 1 for details)

+ p - in the peripheral row of the central assembly the fuel rods of 4.4% enrichment were replaced by fuel rods of 3.6% enrichment

Table 4.5.2 Spectral ratios measured in regular lattices

Lattice	12.7/3.6				
	0.0	0.0	5.8	5.8	
C_B [g/l]					5.8
T [°C]	20	130	20	130	
Dy-T	0.7020 ± 0.0091	0.8100 ± 0.0081	0.7839 ± 0.0187	0.7709 ± 0.0093	
U-T	0.7996 ± 0.0028	0.9323 ± 0.0081	0.8762 ± 0.0056	0.9713 ± 0.0100	
Pu-T	1.1653 ± 0.0042	1.5819 ± 0.0138	1.3778 ± 0.0081	1.5935 ± 0.0170	
Np-T	2.8199 ± 0.0316	3.2335 ± 0.0340	3.4825 ± 0.0948	3.5230 ± 0.0362	
Ce-T	0.8277 ± 0.0091	0.9291 ± 0.0105	0.9671 ± 0.0237	0.9243 ± 0.0100	

Table 4.5.2 (continued)

Lattice	12.7/4.4	
C_B [g/l]	0.0	0.0
T [°C]	20	130
Dy-T	0.6996 ± 0.0140	0.8017 ± 0.0152
U-T	0.8472 ± 0.0063	0.9147 ± 0.0104
Pu-T	1.2614 ± 0.0035	1.5216 ± 0.0176
Np-T	2.9754 ± 0.0672	3.7840 ± 0.0834
Ce-T	0.7996 ± 0.0154	0.9660 ± 0.0176

Table 4.5.2 (continued)

Lattice	11.0/3.6		
C_B [g/l]	0.0	0.0	1.0
T [°C]	20	130	20
Dy-T	0.7221 ± 0.0051	0.6594 ± 0.0050	0.8602 ± 0.0065
U-T	0.8528 ± 0.0092	0.8536 ± 0.0095	-
Pu-T	1.5019 ± 0.0151	1.5199 ± 0.0157	-
Np-T	4.4088 ± 0.0694	4.4945 ± 0.0706	5.4285 ± 0.0780
Ce-T	0.9437 ± 0.0106	0.9114 ± 0.0096	1.1480 ± 0.0069

Table 4.5.2 (continued)

Lattice	pitch=15.0 mm			T=20°C		
	C_a [g/l]	0.0	0.0	4.0	0.0	
Enrich- ment [%]	1.6		3.6	3.6	4.4	
Dy-T	0.7872 ± 0.0104	0.6381 ± 0.0063	0.7905 ± 0.0060	0.8120 ± 0.0168		
Np-T	1.6544 ± 0.0328	1.9755 ± 0.0180	2.6945 ± 0.0213	2.6280 ± 0.0632		
Ce-T	0.9952 ± 0.0184	0.8163 ± 0.0081	1.0421 ± 0.0077	1.0096 ± 0.0192		

Table 4.5.3 Derived quantities for regular lattices
Spectral indices (relative to Dy)

Lattice	12.7/3.6			
	0.0	0.0	5.8	5.8
C_a [g/l]				
T [°C]	20	130	20	130
U-T	1.1390 ± 0.0151	1.1510 ± 0.0148	1.1178 ± 0.0272	1.2600 ± 0.0194
Pu-T	1.6600 ± 0.0216	1.9530 ± 0.0252	1.7577 ± 0.0425	2.0671 ± 0.0322
Np-T	4.0170 ± 0.0287	3.9920 ± 0.0253	4.4428 ± 0.0667	4.5700 ± 0.0254
Ce-T	1.1791 ± 0.0062	1.1470 ± 0.0054	1.2337 ± 0.0114	1.1990 ± 0.0067

Table 4.5.3 (continued)

Lattice	12.7/4.4	
C_B [g/l]	0.0	0.0
T [°C]	20	130
U-T	1.2110 ± 0.0253	1.1410 ± 0.0245
Pu-T	1.8030 ± 0.0361	1.8980 ± 0.0410
Np-T	4.2530 ± 0.0540	4.7200 ± 0.0573
Ce-T	1.1429 ± 0.0097	1.2049 ± 0.0092

Table 4.5.3 (continued)

Lattice	11.0/3.6		
C_B [g/l]	0.0	0.0	1.0
T [°C]	20	130	20
U-T	1.1810 ± 0.0152	1.2945 ± 0.0149	-
Pu-T	2.0799 ± 0.0221	2.3050 ± 0.0246	-
Np-T	6.1055 ± 0.0911	6.8162 ± 0.0993	6.3107 ± 0.0878
Ce-T	1.3069 ± 0.0131	1.3821 ± 0.0122	1.3346 ± 0.0095

Table 4.5.3 (continued)

Lattice	pitch=15.0 mm			T=20°C	
	0.0	0.0	4.0	0.0	0.0
C_s [g/l]					
Enrich- ment [%]	1.6	3.6	3.6	4.4	
Np-T	2.1016 ± 0.0426	3.0959 ± 0.0343	3.4086 ± 0.0289	3.2365 ± 0.0799	
Ce-T	1.2642 ± 0.0214	1.2793 ± 0.0130	1.3183 ± 0.0099	1.2433 ± 0.0250	

Table 4.5.4 Positions of the spectral measurements in perturbed lattices

Lattice	Confi- gura- tion	Po- si- tion	Foil			UO ₂ pellets		
			ZR-6	Gener.	Macro.	ZR-6	Gener.	Macro.
12.7-E3	176/176	1	36/36	1/2	2	39/38	1/2	2
		2	35/35	1/3	3	38/38	1/3	3
11.0-E7	189/189	1	36/33	1/2	2	36/33	1/2	2
		2	35/32	1/3	3	35/32	1/3	3
		3	-	-	-	34/30	3/6	8
11.0-K331	197/197	1	-	-	-	28/36	1/11	11
		2	-	-	-	31/38	3/10	28
		3	-	-	-	33/41	6/11	41
11.0-K331-pr	198/198	1	-	-	-	28/36	1/11	11
		2	-	-	-	31/38	3/10	28
		3	-	-	-	33/41	6/11	41

ZR-6 - position in the ZR-6 core map

Gener. - position in the generalized core map

(N° 21 for E3, N° 2 for E7 and N° 17 for K331)

Macro. - position in the macrocell (Fig. 4.4.1)

Table 4.5.5 Spectral ratios measured in perturbed lattices

Lattice	12.7-E3	
Position	1	2
Dy-T	0.7719 ± 0.0108	0.6927 ± 0.0097
Dy-M	-	0.8589 ± 0.0097
U-T	0.9618 ± 0.0255	0.8077 ± 0.0229
U-M	-	0.9206 ± 0.0166
Pu-T	1.2667 ± 0.0301	1.1152 ± 0.0249
Pu-M	-	1.2101 ± 0.0194
Np-T	2.7889 ± 0.0239	2.5457 ± 0.0215
Ce-T	0.9317 ± 0.0069	0.8305 ± 0.0062

Lattice	11.0-E7		
Position	1	2	3
Dy-T	0.8345 ± 0.0091	0.7636 ± 0.0082	0.7019 ± 0.0082
U-T	1.0176 ± 0.0112	0.9376 ± 0.0102	-
Pu-T	1.6814 ± 0.0180	1.5374 ± 0.0169	-
Np-T	5.0831 ± 0.0408	4.5855 ± 0.0372	4.5773 ± 0.0381
Ce-T	1.2267 ± 0.0109	1.0715 ± 0.0109	1.0388 ± 0.0109

Lattice	11.0-K331		
Position	1	2	3
Dy-T	1.1133 ± 0.0243	0.6795 ± 0.0144	0.8883 ± 0.0189
Np-T	4.8852 ± 0.1161	3.9699 ± 0.0945	4.4181 ± 0.1044
Ce-T	1.5273 ± 0.0306	0.9747 ± 0.0198	1.2060 ± 0.0243

Lattice	11.0-K331-pr		
Position	1	2	3
Dy-T	1.1364 ± 0.0115	0.9705 ± 0.0194	0.6936 ± 0.0073
Np-T	4.9231 ± 0.0721	4.5087 ± 0.0994	4.0010 ± 0.0586
Ce-T	1.7486 ± 0.0132	1.1628 ± 0.0217	1.1158 ± 0.0090

Table 4.5.6 Derived quantities for the perturbed lattices
Spectral indices (relative to Dy)

Lattice	12.7-E3	
Position	1	2
U-T	1.2460 $\pm$ 0.0356	1.1660 $\pm$ 0.0359
U-M	-	1.0718 $\pm$ 0.0204
Pu-T	1.6410 $\pm$ 0.0428	1.6099 $\pm$ 0.0407
Pu-M	-	1.4089 $\pm$ 0.0264
Np-T	3.6130 $\pm$ 0.0519	3.6750 $\pm$ 0.0582
Ce-T	1.2070 $\pm$ 0.0161	1.1989 $\pm$ 0.0185

Lattice	11.0-E7		
Position	1	2	3
U-T	1.2194 $\pm$ 0.0170	1.2279 $\pm$ 0.0161	-
Pu-T	2.0149 $\pm$ 0.0274	2.0134 $\pm$ 0.0283	-
Np-T	6.0912 $\pm$ 0.0759	6.0051 $\pm$ 0.0739	6.5213 $\pm$ 0.0858
Ce-T	1.4700 $\pm$ 0.0191	1.4032 $\pm$ 0.0197	1.4800 $\pm$ 0.0219

Lattice	11.0-K331		
Position	1	2	3
Np-T	4.3880 $\pm$ 0.1259	5.8424 $\pm$ 0.1560	4.9737 $\pm$ 0.1413
Ce-T	1.3719 $\pm$ 0.0359	1.4344 $\pm$ 0.0342	1.3576 $\pm$ 0.0353

Lattice	11.0-K331-pr		
Position	1	2	3
Np-T	4.3323 $\pm$ 0.0692	4.6460 $\pm$ 0.1159	5.7685 $\pm$ 0.0936
Ce-T	1.5388 $\pm$ 0.0172	1.1982 $\pm$ 0.0265	1.6088 $\pm$ 0.0192

5. CONCLUSIONS

The experiments described here, together with the experiments described in Volume 1 of the Final Report of TIC, represent a complex of systematic investigations into the neutron physics of regular and perturbed $\text{UO}_2 - \text{H}_2\text{O}$ lattices. To this complex belong results of the measurements of criticality data, reactivity coefficients, reaction rate distributions and spectral ratios. Based on the data obtained by evaluating primary experimental data, using universal programs, for configurations of different fuel enrichments (1.6, 3.6 and 4.4%), lattice pitches (11.0, 12.7, 15.0 and 19.05mm), boric acid concentration in the moderator (0 - 7.2 g/kg) and temperature (20 - 130°C), taking the experimental errors into account one can formulate the following conclusions (in addition to the conclusions drawn in Volume 1):

- as the existence of the asymptotic neutron spectrum in cores of small size ($R_{\text{equ.}} < 20\text{cm}$ and/or $H_{\text{cr}} < 40\text{cm}$) seems to be problematic, the use of one-group theory to interpret the experimental results in these cores can be treated only as a first approximation,
- the dependence of the critical moderator height on the temperature can be well described by a third degree polynomial,
- the results of serial $\partial\rho/\partial H$ measurements allowed us to determine the reactivity coefficients $\partial\rho/\partial T$ and $\partial\rho/\partial C_B$,
- material bucklings decrease from 8 - 14% with increasing temperature,
- radial reflector saving λ_r depends on the fuel enrichment,

lattice pitch, boric acid concentration in the moderator (mostly), temperature,

- axial reflector saving λ_z depends only on the lattice pitch,
- the intra-macrocell distributions change by 1 - 2% depending on the type of perturbation,
- the spectral indices change by 4-8% depending on the temperature,
- the spectral indices in regular lattices without boron in the moderator, at room temperature, depend mainly on the nuclear density ratio $^1\text{H}/^{235}\text{U}$.

The accuracy of the results is satisfactory from the viewpoint of the accuracy requirements of the calculations to be tested. The typical experimental errors are the following:

- 1% for reaction rate distributions,
- 2 to 4% for spectral ratios,
- 0.1% - 0.5% for bucklings if their errors are propagated to errors of K_{eff} ,
- 3-33% for the coefficients $\partial\rho/\partial T$ and $\partial\rho/\partial C_B$ (in these cases the errors in critical heights are 0.2-1.0mm).

All the conclusions formulated above were obtained by means of statistical criteria. The following confidence probabilities were used throughout the evaluations:

- 99% for testing the identity of two quantities,
- 99% for picking up outliers,

- 95% for finding asymptotic regions (according to the point drop technique).

The experiments performed demonstrated the possibility of performing experiments at high temperatures on critical assembly ZR-6, using water level regulation.

The given experimental data can be used for benchmarking programs and group constant libraries in a wide range of lattice parameters for UO_2 - H_2O lattices. If necessary the evaluation can be repeated using the primary experimental data, stored in file EDF.

The investigations of lattices with mixed steel-water reflectors, absorber rods containing the burnable poison gadolinium, and fuel rods of enlarged diameter, performed on critical assembly ZR-6M are due to be published in Volume 4.

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- 819 К.Алмаши, Л.Гачи, З.Сатмари: Список конфигураций ЗР-6М, исследованных в рамках ВМК в период с июля 1983 г. по июль 1984 г., 1984
- 820 Я.Гадо: Вспомогательный материал для расчетчиков: Критические конфигурации ЗР-6 в 1980-1985 гг., 1987
- 821 Р.Беккер: Влияние неопределенностей технических данных на рассчитанные нейтронно-физические параметры, 1990

APPENDICES

to Volume 3 of the Final Report of TIC

Appendix A

CRITICALITY DATA AND MAPS OF THE INVESTIGATED CORES

The cores investigated in critical assembly ZR-6M are documented in Reports [814, 817, 819]. These reports contain the core maps and the main data related to these cores, viz. boron concentration, H_{Cr} , $\partial\rho/\partial H$, etc. The same core map may belong to several core configurations differing from one another in boron concentration or in the type of absorber rod investigated. Therefore, each core is identified by two numbers: configuration number/ core number.

In order to facilitate the use of the large number of existing core maps, a compact representation was elaborated which is described in detail in Refs. [813 and 820].

In the second period of experiments, the same fuel and absorber rods were used as in the first one. As a consequence of this no data related to them are presented here.

In Tables A1 - A4 the data related to the content of core maps (number and position of fuel and absorber rods of various types and water holes) are presented. For every configuration the numbers of configuration/core are given according to the basic data presented in References [814, 817, 819]. The number of the corresponding general core map is always given as well. The generalized core maps are presented partially here (*new ones*), partially in Volume 1 (*old ones*). Tables A1 - A2 contain the data of lattice pitches and boron concentrations too.

Table A1. List of regular core configurations

Core number/ map number as in [814, 817, 819]	Fuel rod positions		R _{equ} [cm]		C _B [g/kg]	Lattice pitch [mm]
	T1.6	T3.6	T4.4	inner	core	
196/196 *	-	1-142, 145-151, 157-161	-	-	23.382 (23.375)	11.0
195/195 *	-	1-143, 145-152, 157-162	-	-	23.637	11.0
194/194	-	1-143, 145-152, 157-162 170-172	-	-	23.890	11.0
193/193	-	1-143, 145-153, 157-163 170-173	-	-	24.140	11.0
192/192	-	1-154, 157-165, 170-174	-	-	24.510	11.0
188/188 ++	-	1-154, 157-165, 170-175 183-186	-	-	24.875	11.0
191/191	-	1-155, 157-166, 170-176 183-186	-	-	25.115	11.0
209/209	-	1-154, 157-165, 170-175 183-186	-	-	24.875	11.0
246/246 *	-	1-71, 73-78, 82-83	-	-	18.919	12.7
162/161	-	1-154, 157-164, 170-172	-	-	28.014	12.7
161/161 **	-	1-154, 157-164, 170-172	-	-	28.014	12.7
163/161, 247/247	-	1-154, 157-164, 170-172	-	-	28.014	12.7

* No fuel rod in position №132 (in one of the 6 sectors)

++ identical with 40/40

* identical with 154/154

+ identical with configuration 39/39

** identical with 29/29

Table A1. (continued)

Core number/ map number as in [814, 817, 819]	Fuel rod position		Requ [cm]		C _B [g/kg]	Lattice pitch [mm]
	T1.6	T3.6	T4.4	inner	core	
164/159, 165/165 *	-	62-64, 67-78, 82-83	1-61, 65-66 1-61, 65-66	16.670	16.670 18.989	12.7 12.7
212/212	-	1-40, 43-45	-	-	15.987	15.0
213/213	-	1-47, 50-52	-	-	17.380	15.0
214/214	-	1-54, 57-60	-	-	18.819	15.0
220/220	-	1-62, 65-66	-	-	19.877	15.0
215/215	-	1-62, 65-68	-	-	20.248	15.0
216/216	-	1-71, 73-77	-	-	21.840	15.0
217/217	-	1-78, 82-83	-	-	22.428	15.0
218/218	-	1-87, 91-93	-	-	23.875	15.0
219/219	-	1-88, 91-96, 101-104	-	-	25.091	15.0
230/230	-	-	1-38	-	14.713	15.0
229/229	-	-	1-39	-	14.964	15.0
228/228 +	-	-	1-40, 43-44	-	15.692	15.0
227/227 *	-	-	1-46	-	(15.892)	15.0
226/226 *	-	-	1-48, 50-52	-	16.501	15.0
225/225	-	-	1-54, 57-58	-	(17.593)	15.0
221/221	-	-	1-55, 57-60	-	18.420	15.0
224/224	-	-	1-62, 65-66	-	19.016	15.0
223/223	-	-	1-69	-	19.877	15.0
					20.401	15.0

* identical with configurations 110/110 and 159/159

+ No fuel rod in position N°36 (in one of the 6 sectors)

* Fuel rod is inserted in position N°49 (in one of the 6 sectors)

Table A1. (continued)

Core number/ map number as in [814, 817, 819]	Fuel rod position		Requ [cm]		C _B [g/kg]	Lattice pitch [mm]
	T1.6	T3.6	T4.4	inner	core	
231/231	1-61, 65-66	62-64, 67-98, 101-105	-	19.689	25.750	15.0
233/233	-	1-96	-	-	24.717	15.0
232/232	-	1-98, 101-105	-	-	25.750	15.0
240/240 *	-	1-99, 101-107, 111-114	-	-	26.673	15.0
234/234	-	1-108, 111-116, 122-123	-	-	(26.684)	15.0
235/235	-	1-120, 122-128	-	-	27.429	15.0
236/236	-	1-131, 133-140, 145-148	-	-	28.819	15.0
237/237	-	1-143, 145-151, 157-163	-	-	30.635	15.0
238/238 *	-	1-154, 157-165, 170-174	-	-	32.232	15.0
239/239 *	-	1-167, 170-177, 183-188	-	-	33.423	15.0
					(33.413)	
					34.733	15.0
					(34.608)	
208/208	-	1-34	-	-	17.698	19.05
207/207	-	1-35, 37-38	-	-	18.688	19.05
206/206	-	1-40, 43-45	-	-	20.231	19.05
205/205	-	1-47, 50-52	-	-	22.076	19.05
204/204	-	1-54, 57-60	-	-	23.904	19.05
203/203	-	1-62, 65-68	-	-	25.719	19.05
202/202	-	1-71, 73-77	-	-	27.740	19.05
201/201	-	1-78, 82-83	-	-	28.488	19.05
200/200	-	1-87, 91-93	-	-	30.235	19.05
199/199	-	1-88, 91-96, 101-104	-	-	31.870	19.05

* Fuel rod is inserted in position 100 (in one of the 6 sectors)

+ No fuel rod in position 154 (in one of the 6 sectors)

* No fuel rod in positions 154, 175-177, 188 (in one of the 12 sectors),

in position 166 (in two of the 12 sectors),

in positions 155 and 167 (in three of the 12 sectors),

and in position 156 (in one of the 6 sectors)

Table A2. List of core configurations of type Xn

Core number/ map number as in [814, 817, 819]	Number of generalized core map	Rod type in position						C _B [g/kg]	Lattice pitch [mm]
		1	2	3	4	5	6		
189/189	2	T3.6	E	E	-	-	-	0.0	11.0
243/243	2 +	T3.6	G	G	-	-	-	0.0	12.7
244/244 *	2	T3.6	G	G	-	-	-	0.0	12.7
245/244 **	2	T3.6	E	E	-	-	-	0.0	12.7
177/177 *	11	T3.6	C	C	-	-	-	0.0	12.7
242/242	20	T3.6	G	G	-	-	-	0.0	12.7
176/176	21	T3.6	E	E	E	E	E	0.0	12.7
190/190	21	T3.6	E	E	E	E	E	0.0	11.0
241/241	21	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	0.0	12.7

* No fuel rod at position (10,26) (in none of the 12 sectors)

* identical with configuration 156/155

** identical with configurations 58/57, 138/138, 157/155

* identical with configuration 75/75

Table A3. List of core configurations of type K331 (generalized core map N°17)

Core number/ map number as in [817]	Rod type in position								C _B [g/kg]	Lattice pitch [mm]
	1	2	3	4	5	6	7	8		
197/197 *	T4.4	T3.6	T4.4	E	T3.6	F	T4.4	T3.6	0.0	11.0
198/198 *	T4.4	T3.6	T3.6	E	T3.6	F	T4.4	T3.6	0.0	11.0

* identical with configuration 144/144

* identical with configuration 145/145

Table A4. List of core configurations of type K91 (generalized core map N°18)

Core number/ map number as in [817]	Rod type in position										C _B [g/kg]	Lattice pitch [mm]
	1	2	3	4-5	6-7	8-9	10-11	12-13	14-15	16		
197/197 *	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	E	0.0	12.7
198/198	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	T3.6	E	0.0	12.7

* identical with configuration 101/100

2
 1
 1 1
 1 1
 1 1 1
 1 1 3
 1 1 1 1
 1 1 1 1
 1 1 1 1 1
 1 1 1 1 1
 3 1 1 1 1 3
 1 1 1 1 1 1
 1 1 1 1 1 1 1
 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1
 1 1 3 1 1 1 1 3
 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1
 1 1 1 1 1 1 1 1 1 1 1 1

Core map № 20

Core map N° 21

Appendix B

EVALUATED RADIAL REACTION RATE DISTRIBUTIONS

Appendix B reproduces the printouts prepared by program RFIT on the basis of file EDF of the evaluated radial reaction rate distributions. File EDF is described in Section 4.3.1. The reaction rate distributions measurements are listed in Table 4.3.1. Axial distributions are also stored in file EDF but their printouts are not reproduced here since they are meant mainly for determining the axial bucklings needed by 2D radial calculations. Table B1 contains the recommended values of the axial bucklings (based on the results discussed in Sections 4.4.2 and 4.4.4) to be used in analysing the different radial distributions.

In EDF, the lattice positions are identified by hexagonal coordinates (h_1, h_2) (See Volume 1 of the present work for more details). In each lattice position, two quantities are printed: the value of reaction rate (ψ) above, and its standard deviation $(\Delta\psi)$ below.

Table B1. List of evaluated radial reaction rate distributions

Lattice	Number of ZR-6 con- figu- ration	Number of genera- lized core map	Tempe- rature [°C]	Detec- tors*	2 B_z [m ⁻²]
12.7/3.6/0.0	154/154	1	20	1	17.74 ± 0.13
12.7/3.6/0.0	154/154	1	80	1	15.37 ± 0.04
12.7/3.6/0.0	154/154	1	130	1	12.00 ± 0.03
12.7/3.6/4.0	161/161	1	20	1	25.81 ± 0.09
12.7/3.6/4.0	161/161	1	80	1	23.17 ± 0.07
12.7/3.6/4.0	161/161	1	130	1	19.72 ± 0.05
12.7/3.6/5.8	163/161	1	20	1	14.93 ± 0.23
12.7/3.6/5.8	163/161	1	80	1	12.63 ± 0.03
12.7/3.6/5.8	163/161	1	130	1	10.22 ± 0.07
E3	176/176	21	20	0,1,6	24.67 ± 0.11
C5	177/177	11	20	0,1,6	16.51 ± 0.11
12.7/3.6-G3	241/241	21	20	1	16.35 ± 0.11
12.7/3.6-G5	242/242	20	20	1	15.56 ± 0.11
12.7/3.6-G7	244/244	2	20	1	22.12 ± 0.12
12.7/3.6-G7	244/244	2	130	1	14.38 ± 0.14
12.7/3.6-E7	245/244	2	20	1	40.88 ± 0.36
12.7/3.6-F7	155/155	2	20	1	26.44 ± 0.15
12.7/3.6-F7	155/155	2	130	1	18.59 ± 0.14
12.7-K91-D _∞	180/179	15	20	1	52.77 ± 0.80
11.0/3.6/0.0	188/188	1	20	1	12.03 ± 0.05
11.0/3.6/0.0	188/188	1	80	1	10.09 ± 0.04
11.0/3.6/0.0	188/188	1	130	1	7.35 ± 0.02
11.0/3.6/1.0	209/188	1	20	1	6.94 ± 0.02
11.0/3.6-E7	189/189	2	20	1	7.87 ± 0.02
11.0/3.6-E3	190/190	21	20	1	19.61 ± 0.12
11.0-K331	197/197	17	20	1	11.98 ± 0.04
11.0-K331-pr	198/198	17	20	1	11.38 ± 0.05
15.0/3.6/0.0	220/220	1	20	1	39.06 ± 0.21
15.0/3.6/4.0	232/232	1	20	1	12.98 ± 0.03
15.0/4.4/0.0	221/221	1	20	0,1,6	47.82 ± 0.21
15.0/1.6/0.0	231/231	1	20	1	12.62 ± 0.03

- * 0 - EUAL10. rectangular foils \
- 1 - fuel } according to notations in Vol.1.
- 6 DYAL5. rectangular foils /

EVALUATED RADIAL DISTRIBUTIONS FOR REGULAR
LATTICES WITH 11.0mm LATTICE PITCH

DATE: 4/3/87

MANIPULATIONS WITH THE STORED DATA

*** PROGRAM \REFIT ***

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1881

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1246
  4
1 1221
  4
2 1242 1227
  4 3
3 1213
  4
4 1241 ** 1201
  4 ** 4
5 1187
  4 ** 1187
  4
6 1185 ** 1173
  4 ** 4
7 1154
  4 ** 1154
  4
8 1145 ** 1120
  4 ** 4
9 1097
  4 ** 1097
  4
10 1112 ** 1049
  4 ** 4
11 1049 ** 1011
  4 ** 3
12 1031 ** 978
  3 ** 2
13 931
  3 ** 3
14 982 ** 877
  3 ** 3
15 834
  3 ** 3
16 886 ** 791
  3 ** 3
17 746
  3 ** 2
18 806 ** 724
  3 ** 2
19 698
  3 ** 2
20 736 ** 730
  3 ** 2
21 891
  3 ** 2
22 676 ** 891
  3 ** 2
23 891
  3 ** 2
24 711 ** 891
  3 ** 2
25 891
  3 ** 2
26 1239 ** 891
  4 ** 2

```

H2/H1 13 12 11 10 9 8 7 6 5 4 3 2 1 0

TE: 4/3/87 MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1082

IDE=IXS CORE DATA (37,37) 1.000 0

```

0  **
  **
1  1189
   5
2  1187 1181
   8   5
3  ** 1132
   **   5
4  1168 ** 1148
   8   **   7
5  ** ** 1239
   **   **   7
6  1126 ** ** 1108
   8   **   **   6
7  ** ** ** 1076
   **   **   **   7
8  1088 ** ** ** 1072
   8   **   **   **   6
9  ** ** ** ** ** 1032
   **   **   **   **   6
10 1062 ** ** ** ** 996
   7   **   **   **   **   6
11 ** ** 989 ** ** 963
   **   **   8   **   **   6
12 987 ** ** ** ** 925
   7   **   **   **   **   5
13 ** ** ** - 889
   **   **   **   **   **   5
14 936 ** ** ** - 830
   7   **   **   **   **   **   5
15 ** ** 881 ** ** - 801
   **   **   10  **   **   **   5
16 851 ** ** ** - 767
   6   **   **   **   **   **   5
17 ** ** ** - 723
   **   **   **   **   **   **   4
18 771 ** ** ** - 706
   6   **   **   **   **   **   **   4
19 ** ** ** - 690
   **   **   **   **   **   **   **   4
20 706 ** ** ** - 728
   6   **   **   **   **   **   **   **   4
21 ** ** ** - 905
   **   **   **   **   **   **   **   **   4
22 663 ** ** ** - 1468
   5   **   **   **   **   **   **   **   **   6
23 ** ** ** - 
   **   **   **   **   **   **   **   **   **   **
24 729 ** ** ** - 
   6   **   **   **   **   **   **   **   **   **   **
25 ** ** ** - 
   **   **   **   **   **   **   **   **   **   **
26 1229 ** ** ** - 
      8   **   **   **   **   **   **   **   **   **   **

```

H2/H1 13 12 11 10 9 8 7 6 5 4 3 2 1 0

TE: 4/3/87

*** PROGRAM REIT ***

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1893

CODE=IXS CORE DATA (37,37) 1.000 0

```

0  **
  **
1  1180
   3
2  1165 1173
   4 3
3  ** 1165
   ** 3
4  1151 ** 1141
   4 ** 4
5  ** ** 1105
   ** ** 3
6  1114 ** ** 1101
   4 ** ** 3
7  ** ** ** 1092
   ** ** ** 3
8  1079 ** ** ** 1064
   4 ** ** ** 3
9  ** ** ** ** 1026
   ** ** ** 3
10 1061 ** ** ** 989
   4 ** ** ** 3
11  ** ** 997 ** ** 961
   ** ** 3 ** ** 3
12 986 ** ** ** ** 928
   4 ** ** ** 2
13  ** ** ** ** 884
   ** ** ** 3
14 934 ** ** ** 829
   3 ** ** ** 3
15  ** ** ** 801
   ** ** ** 2
16 850 ** ** ** 767
   3 ** ** ** 2
17  ** ** ** 729
   ** ** ** 2
18 770 ** ** ** 717
   3 ** ** ** 2
19  ** ** ** 712
   ** ** ** 2
20 720 ** ** ** 767
   3 ** ** ** 2
21  ** ** ** 952
   ** ** ** 2
22 681 ** ** ** 1492
   3 ** ** ** 3
23  ** ** ** 
   ** ** ** 
24 763 ** ** ** 
   3 ** ** ** 
25  ** ** ** 
   ** ** ** 
26 1278 ** ** ** 
   4 ** ** ** 

```

H2/H1 13 12 11 10 9 8 7 6 5 4 3 2 1 0

E: 4/3/87 MANIPULATIONS WITH THE STORED DATA
PLOT OF THE NORMALIZED DISTRIBUTION NO. 2091

```

DE=IXS CORE DATA (37,37) 1.000 0
0 1245
5
1 1246
5
2 1253 1232
5 4
3 ** 1217
** 5
4 1217 ** 1196
5 ** 5
5 ** ** 1191
** ** 5
6 1193 ** ** 1169
5 ** ** 4
7 ** ** ** 1152
** ** ** 4
8 1138 ** ** ** 1124
5 ** ** ** 4
9 ** ** ** ** 1087
** ** ** 4
10 1102 ** ** ** 1041
4 ** ** ** 4
11 ** ** 1025 ** ** 999
** ** 4 ** ** 4
12 1012 ** ** ** ** 967
4 ** ** ** 2
13 ** ** ** 929
** ** ** 4
14 945 ** ** ** 875
4 ** ** ** 3
15 ** ** ** 821
** ** ** 3
16 876 ** ** ** 759
3 ** ** ** 3
17 ** ** ** 717
** ** ** 3
18 782 ** ** ** 679
3 ** ** ** 3
19 ** ** ** 662
** ** ** 3
20 698 ** ** ** 703
3 ** ** ** 3
21 ** ** ** 833
** ** ** 3
22 645 ** ** ** 1276
3 ** ** ** 4
23 ** ** ** 
** ** ** 
24 671 ** ** ** 
3 ** ** ** 
25 ** ** ** 
** ** ** 
26 1105 ** ** ** 
4 ** ** ** 

```

H2/H1 13 12 11 10 9 8 7 6 5 4 3 2 1 0

EVALUATED RADIAL DISTRIBUTIONS FOR REGULAR
LATTICES WITH 12.7mm LATTICE PITCH

DATE: 9/3/87
 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 15411
 MODE=IXS CORE DATA (35,35) 1,000 0

```

0 1212
  4
1 1209
  3
2 1210 1207
  4 4
3 ** 1173
  ** 3
4 1211 ** 1151
  4 ** 3
5 ** ** 1109
  ** ** 3
6 1115 ** ** 1059
  4 ** ** 4
7 ** ** ** 1016
  ** ** ** 3
8 1042 ** ** ** 973
  3 ** ** ** 3
9 ** ** ** ** ** 934
  ** ** ** 3
10 944 ** ** ** ** 859
  3 ** ** ** 3
11 ** ** ** ** 788
  ** ** ** 1
12 ** ** ** ** 754
  ** ** ** 3
13 ** ** ** 783
  ** ** ** 3
14 ** ** ** 971
  ** ** ** 2
15 ** ** ** 
  ** ** ** 
16 825 ** ** ** 
  2 ** ** ** 

```

H2/H1 8 7 6 5 4 3 2 1 0

DATE: 9/3/87 *** PROGRAM KF1T ***
 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 15412
 MODE=IXS CORE DATA (35,35) 1,000 0

```

0      1229
      5
1      1205
      3
2      1199 1173
      5      4
3      ** 1165
      **      3
4      1181 ** 1137
      4 **      3
5      ** ** 1101
      ** **      4
6      1087 ** ** 1041
      4 ** **      4
7      ** ** ** 1014
      ** ** **      4
8      1028 ** ** ** 962
      3 ** ** **      3
9      ** ** ** ** ** ** ** 915
      ** ** ** ** **      3
10     940 ** ** ** ** ** ** ** 856
      3 ** ** ** **     3
11     ** ** ** **     801
      ** ** **     1
12     ** ** **     785
      ** ** **     2
13     ** ** **     809
      ** ** **     3
14     ** ** **     947
      ** ** **     3
15     ** ** **     **
      ** ** **     **
16     869 ** ** **     **
      3 ** ** **     **

```

H2/H1 8 7 6 5 4 3 2 1 0

DATE: 6/3/86 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 15413
 MODE=IXS CORE DATA (35,35) 1.000 0

```

0    1198
    4
1    1194
    3
2    1187 1179
    4    4
3    ** 1150
    **    3
4    1162 ** 1126
    4 **    3
5    ** ** 1093
    ** **    4
6    1078 ** ** 1056
    4 ** **    4
7    ** ** ** 1007
    ** ** **    3
8    1024 ** ** ** 968
    4 ** ** **    3
9    ** ** ** ** ** 898
    ** ** **    3
10   929 ** ** ** ** 849
    3 ** ** **    3
11   ** ** ** ** 810
    ** ** **    1
12   ** ** ** ** 786
    ** ** **    3
13   ** ** ** 828
    ** ** **    3
14   ** ** ** ** 1047
    ** ** **    3
15   ** ** ** ** ** ** 
    ** ** ** 
16   914 ** ** ** 
    2 ** ** ** 

```

H2/H1 8 7 6 5 4 3 2 1 0

TE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1611
 ODE=IXS CORE DATA (37,37) 1.000 0

```

0 1495
  4
1 1495
  5
2 1463 1480
  4 4
3 ** 1431
  ** 4
4 1472 ** 1371
  4 ** 4
5 ** ** 1366
  ** ** 4
6 1395 ** ** 1368
  4 ** ** 4
7 ** ** ** 1378
  ** ** ** 4
8 1348 ** ** ** 1310
  4 ** ** ** 4
9 ** ** ** ** ** 1220
  ** ** ** 4
10 1275 ** ** ** ** ** 1186
  4 ** ** ** 4
11 ** ** ** ** ** 1125
  ** ** ** 3
12 1179 ** ** ** 1076
  3 ** ** ** 3
13 ** ** ** 1026
  ** ** ** 3
14 1090 ** ** ** 954
  3 ** ** ** 3
15 ** ** ** 880
  ** ** ** 1
16 973 ** ** ** 815
  2 ** ** ** 2
17 ** ** ** 736
  ** ** ** 2
18 835 ** ** ** 667
  3 ** ** ** 2
19 ** ** ** 604
  ** ** ** 1
20 717 ** ** ** 552
  2 ** ** ** 2
21 ** ** ** 560
  ** ** ** 2
22 607 ** ** ** 692
  2 ** ** ** 2
23 ** ** ** 
  ** ** ** 
24 579 ** ** ** 
  2 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

TE: 4/3/87

KAD. DISTR FUEL 163/161 INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1612

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1492
  7
1 1505
  7
2 1435 1441
  7 7
3 ** 1418
  ** 7
4 1459 ** 1387
  7 ** 7
5 ** ** 1364
  ** ** 6
6 1400 ** ** 1371
  7 ** ** 6
7 ** ** ** 1336
  ** ** ** 6
8 1336 ** ** ** 1286
  6 ** ** ** 6
9 ** ** ** ** ** 1206
  ** ** ** 6
10 1251 ** ** ** 1175
  6 ** ** ** 6
11 ** ** ** ** 1118
  ** ** ** 5
12 1177 ** ** ** 1073
  5 ** ** ** 5
13 ** ** ** 1008
  ** ** ** 5
14 1099 ** ** ** 950
  5 ** ** ** 4
15 ** ** ** 879
  ** ** ** 2
16 974 ** ** ** 820
  3 ** ** ** 4
17 ** ** ** 738
  ** ** ** 3
18 843 ** ** ** 673
  4 ** ** ** 3
19 ** ** ** 605
  ** ** ** 2
20 721 ** ** ** 571
  3 ** ** ** 3
21 ** ** ** 588
  ** ** ** 3
22 625 ** ** ** 720
  3 ** ** ** 4
23 ** ** ** 
  ** ** ** 
24 588 ** ** ** 
  3 ** ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

TE: 4/3/87

*** PROGRAM RFIT ***

RAD DISTR FUEL 163/161 INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1613

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1462
  5
1 1440
  5
2 1424 1398
  5 5
3 1410
  ** 5
4 1452 ** 1368
  5 ** 5
5 1378
  ** ** 5
6 1391 ** ** 1352
  5 ** ** 5
7 1352
  ** ** ** 5
8 1328 ** ** ** 1290
  5 ** ** ** 5
9 1214
  ** ** ** ** 5
10 1260 ** ** ** ** 1163
  5 ** ** ** 4
11 1109
  ** ** ** ** 4
12 1142 ** ** ** ** 1053
  4 ** ** ** 4
13 995
  ** ** ** 4
14 1088 ** ** ** ** 961
  4 ** ** ** 4
15 879
  ** ** ** 2
16 970 ** ** ** ** 814
  2 ** ** ** 3
17 739
  ** ** ** 2
18 835 ** ** ** * 690
  3 ** ** ** 3
19 622
  ** ** ** 2
20 728 ** ** ** * 576
  2 ** ** ** 3
21 604
  ** ** ** 3
22 631 ** ** ** * 754
  3 ** ** ** 3
23 754
  ** ** ** **
24 618 ** ** ** *
  3 ** ** **

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1631
 MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1501
  5
1 1459
  6
2 1467 1436
  5 5
3 ** 1432
  ** 5
4 1462 ** 1424
  5 ** 5
5 ** ** 1437
  ** ** 5
6 1396 ** ** 1364
  5 ** ** 5
7 ** ** ** 1305
  ** ** ** 5
8 1336 ** ** ** 1284
  5 ** ** ** 4
9 ** ** ** ** ** ** 1248
  ** ** ** 5
10 1257 ** ** ** 1209
  4 ** ** ** 4
11 ** ** ** ** ** ** 1134
  ** ** ** 5
12 1172 ** ** ** 1090
  4 ** ** ** 4
13 ** ** ** ** 1013
  ** ** ** 4
14 1078 ** ** ** 942
  4 ** ** ** 3
15 ** ** ** 878
  ** ** ** 2
16 972 ** ** ** 809
  2 ** ** ** 3
17 ** ** ** 728
  ** ** ** 2
18 836 ** ** ** 653
  3 ** ** ** 2
19 ** ** ** 605
  ** ** ** 2
20 715 ** ** ** 562
  2 ** ** ** 2
21 ** ** ** 546
  ** ** ** 2
22 593 ** ** ** 651
  2 ** ** ** 3
23 ** ** ** 
  ** ** ** 
24 544 ** ** ** 
  2 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

DATE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1632
 MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1499
  6
1 1478
  5
2 1471 1452
  6 5
3 ** 1435
  ** 5
4 1447 ** 1428
  5 ** 5
5 ** ** 1428
  ** ** 4
6 1389 ** ** 1374
  5 ** ** 4
7 ** ** ** 1320
  ** ** ** 4
8 1350 ** ** ** 1287
  4 ** ** ** 5
9 ** ** ** ** ** 1236
  ** ** ** 4
10 1259 ** ** ** ** 1214
  4 ** ** ** 4
11 ** ** ** ** ** 1130
  ** ** ** 4
12 1157 ** ** ** 1072
  4 ** ** ** 4
13 ** ** ** 1003
  ** ** ** 3
14 1085 ** ** ** 944
  3 ** ** ** 3
15 ** ** ** 883
  ** ** ** 1
16 974 ** ** ** 821
  2 ** ** ** 2
17 ** ** ** 738
  ** ** ** 2
18 844 ** ** ** 670
  2 ** ** ** 2
19 ** ** ** 612
  ** ** ** 2
20 718 ** ** ** 579
  2 ** ** ** 2
21 ** ** ** 567
  ** ** ** 2
22 610 ** ** ** 681
  2 ** ** ** 2
23 ** ** ** 
  ** ** ** 
24 563 ** ** ** 
  2 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

TE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1633
 CODE=IXS CORE DATA (37,37) 1.000 0

```

0 1461
  5
1 1435
  5
2 1436 1437
  5 5
3 ** 1415
  ** 5
4 1430 ** 1418
  5 ** 5
5 ** ** 1403
  ** ** 4
6 1385 ** ** 1360
  5 ** ** 5
7 ** ** ** 1314
  ** ** ** 4
8 1335 ** ** ** 1269
  4 ** ** ** 4
9 ** ** ** ** 1246
  ** ** ** 4
10 1258 ** ** ** ** ** 1195
  4 ** ** ** 4
11 ** ** ** ** 1129
  ** ** ** 4
12 1150 ** ** ** 1064
  4 ** ** ** 4
13 ** ** ** 997
  ** ** ** 4
14 1079 ** ** ** 927
  4 ** ** ** 3
15 ** ** ** 875
  ** ** ** 1
16 961 ** ** ** 813
  2 ** ** ** 2
17 ** ** ** 734
  ** ** ** 2
18 840 ** ** ** 670
  3 ** ** ** 2
19 ** ** ** 617
  ** ** ** 2
20 719 ** ** ** 586
  2 ** ** ** 2
21 ** ** ** 583
  ** ** ** 2
22 613 ** ** ** 691
  2 ** ** ** 3
23 ** ** ** 
  ** ** 
24 577 ** ** 
  2 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1661
 MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1228
  5
1 1238
  5
2 1237 1229
  5 4
3 ** 1201
  ** 4
4 1181 ** 1166
  3 ** 3
5 ** ** 1153
  ** ** 3
6 1134 ** ** 1114
  5 ** ** 4
7 ** ** ** 1050
  ** ** ** 4
8 1058 ** ** ** 973
  3 ** ** ** 3
9 ** ** ** ** ** 935
  ** ** ** 2
10 953 ** ** ** ** 869
  3 ** ** ** 3
11 ** ** ** ** 802
  ** ** ** 2
12 836 ** ** ** 761
  3 ** ** ** 3
13 ** ** ** 789
  ** ** ** 2
14 753 ** ** ** 798
  2 ** ** ** 2
15 ** ** ** 1190
  ** ** ** 3
16 760 ** ** ** 
  2 ** ** ** 

```

H2/H1 8 7 6 5 4 3 2 1 0

DATE: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1662

MODE=IXS CORE DATA (37,37) 1.000 0

```

0    1216
    6
1    1211
    5
2    1212 1220
    6    4
3    ** 1200
    **    4
4    1168 ** 1165
    4    **    4
5    ** ** 1126
    ** **    3
6    1128 ** ** 1036
    5    ** **    4
7    ** ** ** 1024
    ** ** **    4
8    1043 ** ** ** 973
    3    ** ** **    4
9    ** ** ** ** ** ** ** 918
    ** ** ** ** ** 2
10   948 ** ** ** ** 863
    3    ** ** **    4
11   ** ** ** ** 820
    ** ** ** ** 3
12   843 ** ** ** 782
    4    ** ** **    3
13   ** ** ** 829
    ** ** ** 2
14   776 ** ** ** 643
    3    ** ** **    2
15   ** ** ** 1200
    ** ** ** 3
16   791 ** ** ** 
    3    ** ** ** 

```

H2/H1 8 7 6 5 4 3 2 1 0

DATE: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1663

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1211
  5
1 1201
  4
2 1195 1201
  5 3
3 ** 1169
  ** 3
4 1164 ** 1149
  3 ** 3
5 ** ** 1107
  ** ** 3
6 1110 ** ** 1072
  4 ** ** 4
7 ** ** ** 1024
  ** ** ** 3
8 1028 ** ** ** 968
  3 ** ** ** 3
9 ** ** ** ** ** 924
  ** ** ** 2
10 936 ** ** ** ** 868
  2 ** ** ** 3
11 ** ** ** ** 807
  ** ** ** 2
12 840 ** ** ** 789
  3 ** ** ** 3
13 ** ** ** 844
  ** ** ** 2
14 785 ** ** ** 875
  2 ** ** ** 2
15 ** ** ** 1237
  ** ** ** 3
16 827 ** ** ** 
  2 ** ** ** 

```

H2/H1 8 7 6 5 4 3 2 1 0

TE: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2311

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1138
  3
1 1144
  3
2 1131 1132
  3 3
3 ** 1119
  ** 3
4 1120 ** 1107
  3 ** 4
5 ** ** 1092
  ** ** 3
6 1035 ** ** 1064
  3 ** ** 2
7 ** ** ** 1040
  ** ** ** 3
8 1031 ** ** ** 1003
  3 ** ** ** 3
9 ** ** ** ** 961
  ** ** ** 2
10 975 ** ** ** ** 907
  3 ** ** ** 2
11 ** ** ** ** 849
  ** ** ** 2
12 901 ** ** ** 764
  2 ** ** ** 2
13 ** ** ** 651
  ** ** ** 2
14 761 ** ** ** 1006
  2 ** ** ** 2
15 ** ** ** 891
  ** ** ** 2
16 1069 ** ** ** 885
  3 ** ** ** 2
17 ** ** ** 1107
  ** ** ** 2
18 911 ** ** ** 
  2 ** ** ** 

```

H2/H1 9 8 7 6 5 4 3 2 1 0

E: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2216

DE=IXS CORE DATA (38,38) 1.000 0

```

0  **
   **
1  **
   **
2  ** 1281
   ** 5
3  ** 1252
   ** 4
4  ** ** 1219
   ** ** 4
5  ** ** 1176
   ** ** 4
6  ** ** ** 1105
   ** ** ** 4
7  ** ** ** 1020
   ** ** ** 4
8  ** ** ** ** ** 952
   ** ** ** 4
9  ** ** ** ** 885
   ** ** ** 3
10 ** ** ** ** 819
   ** ** ** 3
11 ** ** ** 741
   ** ** ** 3
12 ** ** ** 707
   ** ** ** 3
13 ** ** ** 810
   ** ** ** 3

```

H2/H1 6 5 4 3 2 1 0

ATE: 4/3/87 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 2210
 MODE=IXS CORE DATA (38,38) 1.000 0

```

0    **
    **
1    **
    **
2    ** 1282
    ** 5
3    ** 1257
    ** 5
4    ** ** 1217
    ** ** 5
5    ** ** ** 1177
    ** ** ** 5
6    ** ** ** ** 1115
    ** ** ** 4
7    ** ** ** ** ** 1021
    ** ** ** 4
8    ** ** ** ** ** 962
    ** ** ** 4
9    ** ** ** * 893
    ** ** ** 4
10   ** ** ** * 815
    ** ** ** * 3
11   ** ** ** * 744
    ** ** ** * 3
12   ** ** ** * 697
    ** ** ** * 3
13   ** ** ** * 777
    ** ** ** * 3
    
```

H2/H1 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

DATE: 4/3/87

RAD DISTR FUEL 162/161 INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2211

MODE=IXS CORE DATA (38,38) 1.000 0

```

0  **
  **
1  1316
   2
2  1292 1280
   3 3
3  1242 **
   3 **
4  ** 1216 **
   ** 2 **
5  ** 1150 1095
   ** 3 2
6  ** 1154 1090 1144
   ** 3 3 3
7  ** ** 1008 **
   ** ** 3 **
8  ** 1018 ** 922 **
   ** 3 ** 2 **
9  ** ** ** 830 **
   ** ** ** 2 **
10 ** 860 ** ** 757 **
   ** 1 ** ** 2 **
11 ** ** ** ** 711 **
   ** ** ** 2 **
12 ** 734 725 ** 743 811 **
   ** 2 2 ** 2 2 **
13 737 ** ** ** ** ** ** ** 
   2 ** ** ** ** ** ** 
14 ** 902 ** ** ** ** ** 
   ** 2 ** ** ** 

```

H2/H1 7 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

DATE: 4/3/87

RAD DISTR FUEL 163/161

INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO.

2321

MODE=IXS

CORE DATA (37,37)

1.000

0

```

0 1361
  3
1 1357
  3
2 1346 1351
  3 3
3 ** 1324
  ** 3
4 1317 ** 1288
  3 ** 3
5 ** ** 1253
  ** ** 3
6 1237 ** ** 1120
  3 ** ** 2
7 ** ** ** 1170
  ** ** ** 3
8 1166 ** ** ** 1100
  3 ** ** ** 3
9 ** ** ** ** 1045
  ** ** ** 2
10 1062 ** ** ** ** 962
  2 ** ** ** 2
11 ** ** ** ** 885
  ** ** ** 2
12 940 ** ** ** 807
  3 ** ** ** 2
13 ** ** ** ** 724
  ** ** ** 2
14 794 ** ** ** 647
  2 ** ** ** 2
15 ** ** ** 572
  ** ** ** 1
16 649 ** ** ** 528
  2 ** ** ** 1
17 ** ** ** 576
  ** ** ** 1
18 550 ** ** ** 
  2 ** ** ** 

```

H2/H1 9 8 7 6 5 4 3 2 1 0

4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRUBUTION NO. 2201
 DE=IXS CORE DATA (37,37) 1.000 0

```

0 1313
  5
1 1293
  5
2 1293 1267
  5 5
3 ** 1253
  ** 4
4 1252 ** 1224
  4 ** 4
5 ** ** 1181
  ** ** 3
6 1146 ** ** 1094
  4 ** ** 3
7 ** ** ** 1040
  ** ** ** 4
8 1034 ** ** ** 952
  4 ** ** ** 3
9 ** ** ** ** ** 864
  ** ** ** 3
10 896 ** ** ** ** 776
  2 ** ** ** 3
11 ** ** ** ** 730
  ** ** ** 3
12 758 ** ** ** 713 714
  3 ** ** ** 3 3
13 ** 722 ** 724 ** ** 894
  ** 3 ** 3 ** ** 3
14 705 ** ** ** ** ** ** 
  3 ** ** ** ** 

```

H2/H1 7 6 5 4 3 2 1 0

EVALUATED RADIAL DISTRIBUTIONS FOR PERTURBED
LATTICES WITH 11.0mm LATTICE PITCH

TE: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1891

ODE=IXS CORE DATA (37,34) 1.000 0

```

0  **
  **
1  1257
   4
2  ** 1160
  **  2
3  ** 1125
  **  3
4  ** ** 1094
  ** **  3
5  ** ** 1091
  ** **  3
6  1074 ** ** 1172
   3 ** **  3
7  ** ** ** ** ** ** ** 
  ** ** ** 
8  1038 ** ** ** 1122
   4 ** ** **  3
9  ** ** ** ** ** 994
  ** ** **  3
10 982 ** ** ** ** 955
   3 ** ** **  3
11 ** ** ** ** 908
  ** ** **  2
12 956 ** ** ** * 879
   3 ** ** ** *  2
13 ** ** ** * 906
  ** ** ** *  2
14 ** ** ** * ** 
  ** ** ** * ** 
15 ** ** ** * ** 863
  ** ** ** *  2
16 799 ** ** ** * ** 830
   2 ** ** ** * **  2
17 ** ** ** * ** ** 991
  ** ** ** * **  2
18 692 ** ** ** * ** ** 1553
   2 ** ** ** * ** **  3
19 ** ** ** * ** ** 
  ** ** ** * ** ** 
20 644 ** ** ** * ** ** 
   2 ** ** ** * ** ** 
21 ** ** ** * ** ** 
  ** ** ** * ** ** 
22 687 ** ** ** * ** ** 
   2 ** ** ** * ** ** 

```

H2/H1 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87

*** PROGRAM REIT ***

MANIPULATIONS WITH THE STORED DATA
PLOT OF THE NORMALIZED DISTRIBUTION NO. 1901

MODE=IXS CORE DATA (37,37) 1.000 0

```

0 1210
  4
1 1205
  2
2 ** **
  ** **
3 1160 1251
  3 3
4 ** ** 1194
  ** ** 4
5 ** ** **
  ** ** **
6 ** ** ** 1128
  ** ** ** 3
7 1079 ** ** 1105
  3 ** ** 3
8 ** ** ** ** ** ** 
  ** ** ** 
9 1063 ** 1054 ** 1030
  2 ** 3 ** 3
10 ** ** ** ** ** 975
  ** ** ** ** ** 2
11 ** ** ** ** ** ** 
  ** ** ** 
12 ** ** ** ** 952 970
  ** ** ** 2 2
13 876 ** ** ** 
  2 ** ** ** 828
  ** ** ** 2
14 ** ** ** ** 
  ** ** ** 
15 795 ** ** ** 
  2 ** ** ** 703
  ** ** ** 2
16 ** ** ** ** 666
  ** ** ** 2
17 ** ** ** 
  ** ** ** 
18 ** ** ** 638
  ** ** ** 2
19 755 ** ** ** 
  2 ** ** ** 693
  ** ** ** 2
20 ** ** ** 
  ** ** ** 
21 1201 ** ** ** 1246
  4 ** ** ** 3

```

H2/H1

10 9 8 7 6 5 4 3 2 1 0

E: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1971

DE=IXS CORE DATA (38,36) 1.000 0

```

0  **
  **
1  670
   3
2  693 647
   3 2
3  669 **
   2 **
4  715 687 682
   3 2 3
5  705 ** 778
   2 ** 3
6  ** 772 797 834
   ** 3 2 3
7  806 847 871 922
   2 3 3 4
8  907 916 ** 969 1028
   1 4 ** 4 4
9  1057 1076 1083 1125 1197
   4 4 4 3 5
10 1347 1339 1355 1405 1453 1628
   6 6 6 4 5 6
11 ** ** ** ** ** ** ** ** 
   ** ** ** ** ** ** ** 
12 1040 1191 1195 1200 1248 1399 **
   3 5 5 5 4 4 **
13 ** 964 949 984 1038 1234 **
   ** 4 4 4 4 3 **
14 825 ** ** ** ** ** ** ** 
   3 ** ** ** ** ** ** 
15 ** ** ** ** ** ** 
   ** ** ** *
16 695 ** ** ** *
   2 ** ** ** *
17 ** ** ** *
   ** ** ** *
18 629 ** ** ** *
   2 ** ** ** *
19 ** ** ** *
   ** ** ** *
20 568 ** ** ** *
   2 ** ** ** *
21 ** ** ** *
   ** ** ** *
22 621 ** ** ** *
   2 ** ** ** *
23 ** ** ** *
   ** ** ** *
24 1097 ** ** ** *
   4 ** ** ** *

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

2: 4/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1981

DE=IXS CORE DATA (38,36) 1.000 0

```

0      **
      **
1      667
      3
2      698 641
      3 3
3      674 **
      2 **
4      716 698 703
      3 3 3
5      697 ** 793
      2 ** 4
6      ** 780 815 857
      ** 4 3 4
7      828 860 900 962
      3 4 5 5
8      930 954 ** 1042 1136
      2 5 ** 5 6
9      1123 1127 1174 1284 1472
      6 6 6 5 8
10     1220 1198 1206 1275 1338 1468
      7 8 8 5 8 12
11     ** ** ** ** ** ** ** 
      ** ** ** ** ** 
12     1231 1214 1257 1289 1356 1507 **
      7 7 7 7 6 6 **
13     969 992 996 1018 1101 1291 **
      5 5 5 6 6 5 **
14     834 ** ** ** ** ** ** 1124 **
      4 ** ** ** ** ** 6 **
15     ** ** ** ** ** ** ** 
      ** ** ** *
16     708 ** ** ** *
      3 ** ** ** *
17     ** ** ** ** 
      ** ** ** 
18     632 ** ** ** 
      3 ** ** ** 
19     ** ** ** 
      ** ** ** 
20     571 ** ** ** 
      2 ** ** ** 
21     ** ** ** 
      ** ** ** 
22     619 ** ** ** 
      3 ** ** ** 
23     ** ** ** 
      ** ** ** 
24     1090 ** ** ** 
      5 ** ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

EVALUATED RADIAL DISTRIBUTIONS FOR PERTURBED
LATTICES WITH 12.7mm LATTICE PITCH

DATE: 26/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1760

MODE=IXS CORE DATA (39,37) 1.000 0

```

0    **
    **
1    1232
    6
2    1202 1230
    6 6
3    1270 **
    7 **
4    1168 1224 1204
    6 6 7
5    1205 1126 1186
    6 6 7
6    ** 1152 ** **
    ** 6 ** **
7    ** 1065 ** 1050
    ** 6 ** 6
8    ** ** 1042 998 983
    ** ** 6 6 5
9    ** ** 998 974 **
    ** ** 6 5 **
10   ** ** 931 903 ** 878
    ** ** 5 5 ** 5
11   ** 867 ** ** 808 798
    ** 5 ** ** 5 5
12   ** 844 ** ** 792 774 **
    ** 5 ** ** 5 5 **
13   798 778 ** 758 717 ** 690
    5 5 ** 4 4 ** 4
14   765 766 ** 720 728 ** 668 676
    4 4 ** 4 4 ** 4 4
15   ** ** ** ** ** ** ** ** 
    ** ** ** ** ** ** ** 
16   1046 ** ** ** 954 ** ** 1026
    6 ** ** ** 6 ** ** 6

```

H2/H1 8 7 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

8: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1761
 DE=IXS CORE DATA (39,37) 1.000 0

```

0  **
  **
1  1281
   4
2  1257 1330
   5 7
3  1277 **
   5 **
4  1231 1296 1241
   5 5 3
5  1259 1199 1198
   5 5 5
6  ** 1209 ** **
   ** 5 ** **
7  ** 1098 ** 1107
   ** 4 ** 3
8  ** ** 1075 1055 1089
   ** ** 4 4 4
9  ** ** 1049 1053 **
   ** ** 4 4 **
10 987 ** 1002 932 ** 939
    4 ** 4 3 ** 3
11 ** 904 ** ** 838 850
    ** 3 ** ** 3 3
12 ** 886 ** ** 806 791 **
    ** 4 ** ** 4 4 **
13 842 798 ** 790 736 ** 728
    3 2 ** 3 3 ** 3
14 797 817 ** 742 0 ** 699 718
    3 3 ** 3 ** 3 2
15 ** ** ** ** ** ** ** ** ** 
    ** ** ** ** ** ** ** 
16 1070 ** ** ** ** ** 988 ** 982 1079
    3 ** ** ** ** 4 ** 3 3

H2/H1      8      7      6      5      4      3      2      1      0
  
```

DATE: 26/3/87 MANIPULATIONS WITH THE STORED DATA
PLOT OF THE NORMALIZED DISTRIBUTION NO. 1766
MODE=IXS CORE DATA (29,37) 1.000 0

H2/H1	8	7	6	5	4	3	2	1	0
-------	---	---	---	---	---	---	---	---	---

DATE: 26/3/87 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1770

MODE=IXS CORE DATA (39,36) 1.000 0

```

0      **
      **
1      1224
      4
2      1270 1272
      5      5
3      ** 1267
      **      4
4      1268 ** 1159
      7 **      4
5      1225 ** **
      5 ** **
6      1218 ** ** 1113
      4 ** **      4
7      1181 ** ** 1158
      4 ** **      4
8      ** ** ** ** ** 1105
      ** ** **     4
9      ** 1102 ** ** 1025
      **      4 **     4
10     ** ** ** ** ** ** ** ** ** ** ** ** 
      ** ** **     ** 
11     ** ** **     ** 927
      ** ** **     **     4
12     997 ** ** **     ** 905
      4 ** ** **     **     4
13     ** ** **     ** ** 856
      ** ** **     ** **     3
14     916 883 ** ** **     ** 757
      4      3 ** ** **     **     3
15     ** ** **     ** ** ** 
      ** ** **     ** ** ** 
16     799 ** ** **     751 ** ** ** 706
      3 ** ** **     3 ** ** **     3
17     ** ** **     ** 701 ** ** ** 869
      ** ** **     3 ** ** **     3
18     684 ** ** **     ** ** ** 
      3 ** ** **     ** ** ** 
19     ** ** **     ** ** ** 
      ** ** **     ** ** ** 
20     ** ** **     ** ** ** 
      ** ** **     ** ** ** 
21     ** ** **     ** ** ** 
      ** ** **     ** ** ** 
22     801 ** ** **     ** ** ** 
      3 ** ** **     ** ** ** 

```

H2/H1 11 10 9 8 7 6 5 4 3 2 1 0

E: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1771
 DE=IXS CORE DATA (39,36) 1.000 0

```

0    **
    **
1    1265
    6
2    1360 1357
    6 4
3    ** 1347
    ** 6
4    1356 ** 1232
    6 ** 5
5    1286 ** **
    6 ** **
6    1278 ** ** 1209
    6 ** ** 5
7    1251 ** ** 1200
    6 ** ** 4
8    1162 ** ** ** 1173
    5 ** ** ** 5
9    ** 1197 ** ** 1149
    ** 5 ** ** 5
10   ** ** ** ** ** ** ** ** ** ** ** ** ** 
    ** ** ** ** ** ** 
11   ** ** ** ** ** ** ** 912
    ** ** ** ** ** 4
12   1075 ** ** ** 948
    5 ** ** ** 4
13   ** ** ** 903
    ** ** ** 4
14   959 961 ** ** ** 783
    3 4 ** ** 3
15   ** ** ** ** ** 
    ** ** ** 
16   844 ** ** 754 ** ** 725
    4 ** ** 3 ** 2
17   ** ** ** 713 ** ** 935
    ** ** 3 ** ** 2
18   707 ** ** ** 687 ** ** 
    2 ** ** 2 ** 
19   ** ** ** 640 ** ** 
    ** ** 3 ** ** 
20   ** 657 ** ** 
    ** 3 ** ** 
21   ** 711 ** ** 755 ** 
    ** 3 ** 4 ** 
22   857 ** 948 ** ** 1147 ** 
    3 ** 4 ** 4 ** 

```

H2/H1 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 26/3/87

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1776

MODE=IXS CORE DATA (39,36) 1.000 0

```

0    **
    **
1    1205
    6
2    1263 1262
    8 7
3    ** 1255
    ** 6
4    1252 ** 1142
    14 ** 6
5    1238 ** **
    8 ** **
6    1213 ** ** 1101
    7 ** ** 6
7    1192 ** ** 1142
    7 ** ** 6
8    ** ** ** ** 1097
    ** ** ** 6
9    ** 1106 ** ** 1012
    ** 6 ** ** 6
10   ** ** ** ** ** ** ** ** 
    ** ** ** 
11   ** ** ** 
    ** ** ** 906
    ** ** ** 5
12   990 ** ** ** 911
    5 ** ** ** 5
13   ** ** ** 
    ** ** ** 853
    ** ** ** 5
14   914 895 ** ** ** 745
    5 5 ** ** ** 4
15   ** ** ** 
    ** ** ** 
16   796 ** ** 746 ** ** 735
    5 ** ** 4 ** ** 4
17   ** ** ** 704 ** ** 942
    ** ** ** 4 ** ** 5
18   684 ** ** ** 
    4 ** ** ** 
19   ** ** ** 
    ** ** ** 
20   ** ** ** 
    ** ** ** 
21   ** ** ** 
    ** ** ** 
22   897 ** ** 
    5 ** ** 

```

H2/H1 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 2411
 CODE=IXS CORE DATA (37,37) 1.000 0

```

0  **
  **
1  763
  2
2  795 752
  3 3
3  754 **
  3 **
4  796 777 812
  3 3 3
5  782 858 823
  3 3 3
6  ** 845 ** **
  ** 3 ** **
7  ** 890 ** 880
  ** 3 ** 1
8  925 ** 867 935 914
  3 ** 3 3 3
9  ** ** 952 980 **
  ** ** 5 4 **
10 1091 ** 1019 1084 ** 1080
  4 ** 3 4 ** 3
11 ** ** ** ** ** ** 1260
  ** ** ** ** ** 4
12 1239 ** ** ** ** ** ** 1323
  4 ** ** ** ** ** 4
13 ** ** ** ** ** ** ** ** ** 
  ** ** ** * **
14 1312 ** ** ** * 938 ** 1293
  4 ** ** ** 4 ** 4
15 ** ** ** ** ** * ** ** 
  ** ** ** * ** ** 
16 1292 ** ** ** * ** * 1195
  4 ** ** ** * ** * 4
17 ** ** ** * ** * ** 
  ** ** ** * ** * ** 
18 ** ** ** * ** * ** 1107
  ** ** ** * ** * ** 3
19 ** ** ** * ** * ** 
  ** ** ** * ** * ** 
20 1125 ** ** ** * ** * 957
  4 ** ** ** * ** * 3
21 ** ** ** * ** * 894
  ** ** ** * ** * 3
22 1102 ** ** ** * ** * 907
  4 ** ** ** * ** * 3
23 ** ** ** * ** * 1063
  ** ** ** * ** * 3
24 1681 ** ** ** * ** * 1479
  5 ** ** ** * ** * 4
  
```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87

RAD DISTR FUEL 163/161 INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2421

MODE=IXS CORE DATA (37,37) 1.000 0

```

0  **
  **
1  1089
   3
2  1191 1187
   4 4
3  ** 1185
   ** 4
4  1200 ** 1093
   4 ** 4
5  1186 ** **
   4 ** **
6  1184 ** ** 1053
   4 ** ** 4
7  1159 ** ** 1140
   4 ** ** 4
8  1130 1140 ** ** 1090
   4 4 ** ** 4
9  ** 1131 ** ** 1006
   ** 4 ** ** 3
10 ** 1014 1113 ** ** **
   ** 3 4 ** ** **
11 ** ** ** ** ** ** ** 989
   ** ** ** ** ** 3
12 1062 ** ** ** ** ** ** 1026
   4 ** ** ** 3
13 ** ** ** ** ** 983
   ** ** ** 2
14 1029 1013 ** ** ** 899
   3 3 ** ** 3
15 ** ** ** 889 1091 ** **
   ** ** ** 3 6 ** **
16 968 ** ** ** 929 ** ** 796
   3 ** ** 3 ** 2
17 ** ** ** 920 ** ** 847
   ** ** ** 3 ** 3
18 938 ** ** ** ** 824
   3 ** ** ** 3
19 ** ** ** 772
   ** ** ** 2
20 863 ** ** ** 728
   2 ** ** ** 3
21 ** ** ** 700
   ** ** ** 2
22 859 ** ** ** 701
   3 ** ** 2
23 ** ** ** 817
   ** ** ** 2
24 1288 ** ** ** 1131
   5 ** ** 4

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

TE DATE: 4/3/87

*** PROGRAM REIT ***

OD MODE=IXS PLOT OF THE NORMALIZED DISTRIBUTION NO. 2441

CORE DATA (37,37) 1.000 0

```

0    **
    **
1    1187
    5
2    1295 1299
    6 6
3    1307 1304
    6 5
4    1322 1310 1306
    5 5 5
5    1316 1293 1252
    5 5 5
6    1308 ** ** 1125
    5 ** ** 5
7    ** ** ** **
    ** ** **
8    1230 ** ** ** 1023
    5 ** ** ** 4
9    ** ** ** ** 1115
    ** ** ** 4
10   1182 ** ** ** ** 1117
    5 ** ** ** 4
11   ** ** ** ** ** 1062
    ** ** ** 2
12   1056 ** ** ** 983
    4 ** ** ** 4
13   937 ** ** ** 856
    4 ** ** ** 3
14   ** 883 944 ** ** ** 
    ** 4 4 ** ** 
15   822 ** ** ** 734
    3 ** ** ** 3
16   841 ** ** ** 775
    3 ** ** ** 3
17   ** ** ** 899
    ** ** ** 3
18   783 ** ** ** 1310
    3 ** ** ** 5
19   ** ** 707 ** ** ** 
    ** ** 3 ** ** 
20   676 ** ** 589 ** ** 
    3 ** ** 2 ** ** 
21   ** ** ** ** ** ** ** 
    ** ** ** 
22   651 ** ** 559 ** ** 
    3 ** ** 2 ** ** 
23   ** ** 610 697 ** ** 
    ** ** 3 3 ** ** 
24   ** ** 773 1004 ** ** 
    ** ** 4 5 ** ** 
25   ** ** 1077 ** ** 
    ** ** 5 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

TE: 4/3/87

RAD DISTR FUEL 163/161

*** PROGRAM RFIT ***

INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2443

JDE=IXS CORE DATA (37,37) 1.000 0

```

0    **
    **
1    1171
    5
2    1256 1251
    5 5
3    1286 1271
    5 5
4    1296 1291 1278
    5 5 5
5    1291 1262 1217
    5 5 4
6    1269 ** ** 1113
    5 ** ** 4
7    ** ** ** **
    ** ** **
8    1205 ** ** ** 1013
    4 ** ** ** 4
9    ** ** ** ** 1104
    ** ** ** 4
10   1169 ** ** ** 1081
    4 ** ** ** 4
11    ** ** ** ** ** 1043
    ** ** ** 2
12   1037 ** ** ** ** 978
    4 ** ** ** 4
13    925 ** ** ** 837
    2 ** ** ** 3
14    ** 862 927 ** ** **
    ** 3 4 ** ** **
15    813 ** ** ** 742
    3 ** ** ** 3
16    820 ** ** ** 815
    3 ** ** ** 3
17    ** ** ** 965
    ** ** ** 3
18    782 ** ** ** 1345
    3 ** ** ** 5
19    ** ** 710 ** ** **
    ** ** 3 ** ** **
20    692 ** ** 614 ** ** **
    3 ** ** 3 ** ** **
21    ** ** ** ** ** ** **
    ** ** ** 
22    688 ** ** ** 616 ** ** 
    3 ** ** 2 ** ** 
23    ** ** ** 690 798 ** ** 
    ** ** ** 2 3 ** ** 
24    ** ** ** 860 ** 1137 ** ** 
    ** ** ** 3 ** 5 ** ** 
25    ** ** ** 1176 ** ** 
    ** ** ** 5 ** ** 

```

H2/H1

12 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 9/3/87 *** PROGRAM RFLI ***
 MANIPULATIONS WITH THE STORED DATA
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1551
 MODE=IXS CORE DATA (38136) 1.000 0

```

0  **
  **
1  1261
   0
2  1367 1392
   9 1
3  1398 1413
   1 1
4  1344 1380 1385
   7 1 1
5  1335 1349 1352
   1 7 1
6  1313 ** 1278 1199
   7 ** 0 0
7  ** ** 1106 **
   ** ** 0 **
8  1284 ** 1232 1140 1120
   6 ** 0 0 0
9  ** ** ** 1101 1159
   ** ** ** 0 0
10 1215 ** ** ** ** 1111
   0 ** ** ** 5
11  ** ** ** ** ** ** ** 1108
   ** ** ** 5
12 1092 1055 ** ** ** 1020
   5 5 ** ** ** 5
13 956 ** ** ** 970 888
   5 ** ** ** 5 5
14 ** 904 978 ** ** ** 837 **
   ** 5 5 ** ** 4 **
15 804 ** ** 941 ** 851 718 150
   4 ** ** 4 ** 4 4 4
16 869 869 ** ** ** ** 801 814
   4 4 ** ** ** 4
17 845 820 ** 844 ** ** 911
   4 4 ** 4 ** ** 4
18 804 ** ** ** ** ** 1341
   3 ** ** ** ** 5
19 ** ** 110 093 ** ** ** ** ** 
   ** ** 3 3 ** ** ** 
20 695 ** ** 571 ** 601 ** ** ** 
   3 ** ** 3 ** 3 ** ** 
21 ** ** ** 604 ** ** ** 
   ** ** 3 ** ** 
22 657 ** ** 551 563 ** 1031 ** ** 
   3 ** ** 5 2 ** 4 ** ** 
23 ** ** ** 622 645 ** ** ** 
   ** ** 3 3 ** ** 
24 ** ** ** 184 ** 1032 ** ** 
   ** ** 3 ** 1 ** ** 
25 ** ** ** 1100 ** ** 
   ** ** 4 ** ** 

```

H2/H1 14 11 10 9 8 7 6 5 4 3 2 1 0
 END OF RUN

TE: 6/3/86

MANIPULATIONS WITH THE STORED DATA

PLOT OF THE NORMALIZED DISTRIBUTION NO. 1553

MODE=IXS CORE DATA (38,38) 1.000 0

```

0      **
      **
1      1217
      7
2      1307 1325
      7 7
3      1359 1346
      7 7
4      1344 1297 1332
      7 7 7
5      1287 1307 1285
      7 6 6
6      1286 ** 1263 1187
      6 ** 6 5
7      ** ** 1157 **
      ** ** 5 **
8      1244 ** 1181 1089 1055
      5 ** 5 5 5
9      ** ** ** 1136 1116
      ** ** ** 5 5
10     1185 ** ** ** ** ** ** 1117
      5 ** ** ** 5
11     ** ** ** ** ** ** 1083
      ** ** ** 5
12     1051 1071 ** ** ** 1011
      5 5 ** ** 5
13     946 ** ** ** 938 863
      4 ** ** 4 4
14     ** 899 974 ** ** 824 **
      ** 4 4 ** 4 **
15     849 ** ** 941 ** 863 803 781
      4 ** ** 4 ** 4 4 4
16     853 878 ** ** ** 922 829
      4 4 ** ** 4 4
17     840 839 ** 853 ** ** 952
      4 4 ** 4 ** ** 4
18     809 ** ** ** ** ** 1367
      3 ** ** ** 5
19     ** ** 739 722 ** ** ** 
      ** ** 3 3 ** ** 
20     725 ** ** 633 ** 730 ** ** 
      3 ** ** 3 ** 3 ** 
21     ** ** ** 656 ** ** 
      ** ** 3 ** 
22     709 ** ** 599 637 ** 1123 ** 
      3 ** ** 3 3 4 ** 
23     ** ** ** 715 810 ** ** 
      ** ** 3 3 ** 
24     ** ** ** 883 ** 1149 ** 
      ** ** 3 4 ** 
25     ** ** ** 1187 ** 
      ** ** 4 ** 

```

H2/H1

12 11 10 9 8 7 6 5 4 3 2 1 0

*** PROGRAM RFIT ***

E: 4/3/87

RAD DISTR FUEL 163/161 INTERMED TEMP

PLOT OF THE NORMALIZED DISTRIBUTION NO. 2453

DE=IXS CORE DATA (37,37) 1.000 0

```

0      **
      **
1      1388
      6
2      1318 1268
      4      4
3      1246 1223
      4      4
4      1219 1223 1234
      4      4      4
5      1216 1235 1220
      4      4      4
6      1214 ** ** ** 1274
      4 ** ** ** 4
7      ** ** ** ** ** ** ** ** 
      ** ** ** 
8      1142 ** ** ** 1196
      4 ** ** ** 4
9      ** ** ** ** 1103
      ** ** ** 4
10     1093 ** ** ** 1060
      4 ** ** ** 4
11     ** ** ** ** 991
      ** ** ** 2
12     1040 ** ** ** 954
      3 ** ** ** 3
13     1069 ** ** ** 950
      3 ** ** ** 2
14     ** 1009 919 ** ** ** 
      ** 3 3 ** ** 
15     964 ** ** ** 863
      3 ** ** ** 3
16     858 ** ** ** 794
      3 ** ** ** 2
17     ** ** ** 877
      ** ** ** 3
18     732 ** ** ** 1179
      3 ** ** ** 4
19     ** ** 688 ** ** 
      ** ** 2 ** ** 
20     645 ** ** 683 ** ** 
      2 ** ** 2 ** ** 
21     ** ** ** 
      ** ** ** 
22     626 ** ** 684 ** ** 
      2 ** ** 2 ** ** 
23     ** ** ** 667 723 ** ** 
      ** ** ** 2 2 ** ** 
24     ** ** ** 775 ** 985 ** ** 
      ** ** ** 3 ** 4 ** ** 
25     ** ** ** 1033 ** ** 
      ** ** ** 4 ** ** 

```

H2/H1 12 11 10 9 8 7 6 5 4 3 2 1 0

DATE: 4/3/87 RAD DISTR FUEL 163/161 INTERMED TEMP
 PLOT OF THE NORMALIZED DISTRIBUTION NO. 1801
 MODE=IXS CORE DATA (37,38) 1.000 0

```

0  **
  **
1  1147
  5
2  1285 1300
  6 8
3  1395 1465
  9 9
4  1571 1618 1679
  7 10 10
5  1921 1995 2195
  11 11 12
6  ** ** ** ** **
  ** ** ** *
7  1848 ** 0 **
  10 ** **
8  1454 ** ** ** **
  9 ** ** ** *
9  ** ** ** 1733 **
  ** ** ** 10 **
10 1162 ** ** ** **
  7 ** ** ** *
11 994 ** ** ** 1688 **
  7 ** ** ** 7 **
12 ** 935 ** ** ** 1747 **
  ** 6 ** ** ** 13 **
13 900 ** ** ** ** 1672
  6 ** ** ** ** 9
14 967 ** ** ** ** 1208
  6 ** ** ** * 7
15 ** ** ** * 0
  ** ** ** *
16 1086 ** ** ** * 818
  7 ** ** ** * 4
17 ** ** ** * 663
  ** ** ** * 4
18 ** ** ** 1327 ** ** **
  ** ** ** 6 ** ** **
19 ** ** ** ** 522
  ** ** ** * 3
20 917 ** ** ** 798 ** ** 550
  6 ** ** ** 4 ** ** 3
21 ** ** ** 987 ** 944 ** ** 575
  ** ** ** 7 ** 5 ** ** 3
22 634 ** ** 738 ** 911 ** ** 677
  5 ** ** 4 ** 5 ** ** 3
23 531 ** 609 ** 858 ** 1053 ** 921 ** 847 976
  5 ** 4 ** 6 ** 5 ** 4 4
24 ** 441 ** 583 ** 1003 ** ** **
  ** 4 ** 4 ** 5 ** ** **
25 383 ** 521 ** 896 ** ** **
  3 ** 4 ** 5 ** ** **
26 401 ** ** 554 ** ** **
  1 ** ** 4 ** ** **
27 ** ** ** 755 ** ** **
  ** ** 5 ** ** **
28 425 ** ** ** ** **
  4 ** ** ** *
29 564 ** 722 ** ** **
  4 ** 5 ** ** **

```

H2/H1 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

Appendix C

CORRELATION MATRICES OF SPECTRAL RATIOS

The measured spectral ratios are given in Section 4.5. The correlation matrices of these values are tabulated here. Section 4.5.5 of Volume 1 discusses how they can be used for various purposes.

The detectors which were used and the positions where the measurements were performed are denoted by symbols of the general form

XXNY

where XX - identifies the detector material (Pu, U, Dy, Np, Ce),

N - identifies the position of the measurement. For regular lattices "-" stands for N.

Y - identifies the region of the elementary cell to which the spectral ratio is related. T stands for the fuel, and M stands for the moderator.

12.7/3.6/0.0

T=20°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2009	0.0611	0.0551	0.0577
U-T	0.2009	1.0000	0.0599	0.0501	0.0588
Dy-T	0.0611	0.0599	1.0000	0.8352	0.9176
Np-T	0.0551	0.0501	0.8352	1.0000	0.8095
Ce-T	0.0577	0.0588	0.9176	0.8095	1.0000

12.7/3.6/0.0

T=130°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.1911	0.0587	0.0553	0.0604
U-T	0.1911	1.0000	0.0601	0.0522	0.0599
Dy-T	0.0587	0.0601	1.0000	0.8107	0.9077
Np-T	0.0553	0.0522	0.8107	1.0000	0.8123
Ce-T	0.0604	0.0599	0.9077	0.8123	1.0000

12.7/3.6/5.8

T=20°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2016	0.0631	0.0553	0.0614
U-T	0.2016	1.0000	0.0606	0.0531	0.0590
Dy-T	0.0631	0.0606	1.0000	0.8352	0.9277
Np-T	0.0553	0.0531	0.8352	1.0000	0.8595
Ce-T	0.0614	0.0590	0.9277	0.8595	1.0000

12.7/3.6/5.8

T=130°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.1996	0.0636	0.0509	0.0600
U-T	0.1996	1.0000	0.0596	0.0528	0.0591
Dy-T	0.0636	0.0596	1.0000	0.8882	0.8997
Np-T	0.0509	0.0528	0.8882	1.0000	0.8585
Ce-T	0.0600	0.0591	0.8997	0.8585	1.0000

12.7/4.4/0.0

T=20°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2001	0.0733	0.0550	0.0594
U-T	0.2001	1.0000	0.0606	0.0509	0.0579
Dy-T	0.0733	0.0606	1.0000	0.8291	0.9071
Np-T	0.0550	0.0509	0.8291	1.0000	0.8505
Ce-T	0.0594	0.0579	0.9071	0.8505	1.0000

12.7/4.4/0.0

T=130°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2016	0.0631	0.0553	0.0611
U-T	0.2016	1.0000	0.0608	0.0499	0.0602
Dy-T	0.0631	0.0608	1.0000	0.8352	0.9175
Np-T	0.0553	0.0499	0.8352	1.0000	0.8500
Ce-T	0.0611	0.0602	0.9175	0.8500	1.0000

11.0/3.6/0.0

T=20°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2098	0.2971	0.1324	0.1854
U-T	0.2098	1.0000	0.2675	0.1192	0.1669
Dy-T	0.2971	0.2675	1.0000	0.3385	0.4741
Np-T	0.1343	0.1192	0.3385	1.0000	0.4311
Ce-T	0.1854	0.1669	0.4741	0.4311	1.0000

11.0/3.6/0.0

T=130°C

	Pu-T	U-T	Dy-T	Np-T	Ce-T
Pu-T	1.0000	0.2345	0.3259	0.1583	0.2350
U-T	0.2345	1.0000	0.2982	0.1448	0.2150
Dy-T	0.3259	0.2982	1.0000	0.3871	0.5747
Np-T	0.1583	0.1448	0.3871	1.0000	0.4836
Ce-T	0.2350	0.2150	0.5747	0.4836	1.0000

11.0/3.6/1.0

T=20°C

	Dy-T	Np-T	Ce-T
Dy-T	1.0000	0.3227	0.4700
Np-T	0.3227	1.0000	0.3283
Ce-T	0.4700	0.3283	1.0000

15.0/1.6/0.0 T=20°C

	Dy-T	Np-T	Ce-T
Dy-T	1.0000	0.3008	0.4679
Np-T	0.3008	1.0000	0.3180
Ce-T	0.4679	0.3180	1.0000

15.0/3.6/0.0 T=20°C

	Dy-T	Np-T	Ce-T
Dy-T	1.0000	0.3205	0.4709
Np-T	0.3205	1.0000	0.3301
Ce-T	0.4709	0.3301	1.0000

15.0/3.6/4.0 T=20°C

	Dy-T	Np-T	Ce-T
Dy-T	1.0000	0.4001	0.5011
Np-T	0.4001	1.0000	0.3404
Ce-T	0.5011	0.3404	1.0000

15.0/4.4/0.0 T=20°C

	Dy-T	Np-T	Ce-T
Dy-T	1.0000	0.3991	0.4913
Np-T	0.3991	1.0000	0.3501
Ce-T	0.4913	0.3501	1.0000

12.7-E3

	Dy1T	U1T	Pu1T	Np1T	Ce1T	Dy2T	Dy2M	U2T	U2M	Pu2T	Pu2M	Np2T	Ce2T
Dy1T	1.0000	0.1091	0.1199	0.2625	0.3545	0.1912	0.1917	0.1083	0.1735	0.0992	0.1007	0.1125	0.0827
U1T	0.1091	1.0000	0.4397	0.1332	0.0935	0.0831	0.0699	0.0678	0.0679	0.1079	0.0907	0.0679	0.0559
Pu1T	0.1199	0.4397	1.0000	0.1889	0.0987	0.0916	0.1403	0.0835	0.0877	0.0872	0.0922	0.0871	0.0834
Np1T	0.2625	0.1332	0.1889	1.0000	0.3555	0.3453	0.0619	0.0811	0.0702	0.0994	0.0695	0.0701	0.0761
Ce1T	0.3545	0.0935	0.0987	0.3555	1.0000	0.3075	0.0812	0.1378	0.0726	0.0923	0.0499	0.0643	0.0746
Dy2T	0.1912	0.0831	0.0916	0.3453	0.3075	1.0000	0.1074	0.0631	0.0729	0.0902	0.0752	0.0683	0.0652
Dy2M	0.1917	0.0699	0.1403	0.0619	0.0812	0.1074	1.0000	0.2087	0.2201	0.0930	0.0911	0.0700	0.0716
U2T	0.1083	0.0678	0.0835	0.0811	0.1378	0.0631	0.2087	1.0000	0.4060	0.1017	0.0947	0.0693	0.0811
U2M	0.1735	0.0679	0.0877	0.0702	0.0726	0.0729	0.2201	0.4060	1.0000	0.0892	0.0907	0.0666	0.0701
Pu2T	0.0992	0.1079	0.0872	0.0994	0.0923	0.0902	0.0930	0.1017	0.0892	1.0000	0.1107	0.0966	0.0895
Pu2M	0.1007	0.0907	0.0922	0.0695	0.0499	0.0752	0.0911	0.0947	0.0907	0.1107	1.0000	0.0683	0.0907
Np2T	0.1125	0.0679	0.0871	0.0701	0.0643	0.0683	0.0700	0.0693	0.0666	0.0966	0.0683	1.0000	0.0726
Ce2T	0.0827	0.0559	0.0834	0.0761	0.0746	0.0652	0.0716	0.0811	0.0701	0.0895	0.0907	0.0726	1.0000

	Dy1T	U1T	Pu1T	Np1T	Ce1T	Dy2T	U2T	Pu2T	Np2T	Ce2T	Dy3T	Np3T	Ce3T
Dy1T	1.0000	0.1883	0.2092	0.1601	0.1542	0.1001	0.0908	0.0883	0.0733	0.0922	0.0943	0.0744	0.0771
U1T	0.1883	1.0000	0.3066	0.1661	0.1725	0.1801	0.1188	0.1670	0.1609	0.1077	0.0917	0.0699	0.0702
Pu1T	0.2092	0.3066	1.0000	0.2029	0.1983	0.1911	0.1202	0.1800	0.1871	0.1301	0.1107	0.1071	0.0899
Np1T	0.1601	0.1661	0.2029	1.0000	0.2887	0.1995	0.1602	0.1811	0.1791	0.1902	0.1907	0.1683	0.1726
Ce1T	0.1542	0.1725	0.1983	0.2887	1.0000	0.3081	0.1512	0.1168	0.1732	0.1900	0.1107	0.0682	0.0698
Dy2T	0.1001	0.1801	0.1911	0.1995	0.3081	1.0000	0.2679	0.1602	0.1712	0.1008	0.1007	0.1152	0.1616
U2T	0.0908	0.1188	0.1202	0.1602	0.1512	0.2679	1.0000	0.2918	0.2001	0.1772	0.2207	0.1121	0.1730
Pu2T	0.0883	0.1670	0.1800	0.1811	0.1168	0.1602	0.2918	1.0000	0.1872	0.1867	0.1905	0.1165	0.1006
Np2T	0.0733	0.1609	0.1871	0.1791	0.1732	0.1712	0.2001	0.1872	1.0000	0.0903	0.0937	0.0983	0.0726
Ce2T	0.0922	0.1077	0.1301	0.1902	0.1900	0.1008	0.1772	0.1867	0.0903	1.0000	0.0997	0.0902	0.0699
Dy3T	0.0943	0.0917	0.1107	0.1907	0.1107	0.1007	0.2207	0.1905	0.0937	0.0997	1.0000	0.1688	0.1116
Np3T	0.0744	0.0699	0.1071	0.1683	0.0682	0.1152	0.1121	0.1165	0.0983	0.0902	0.1688	1.0000	0.1726
Ce3T	0.0771	0.0702	0.0899	0.1726	0.0698	0.1616	0.1730	0.1006	0.0726	0.0699	0.1116	0.1726	1.0000

11.0-K331

	Dy1T	Np1T	Ce1T	Dy2T	Np2T	Ce2T	Dy3T	Np3T	Ce3T
Dy1T	1.0000	0.2097	0.2199	0.0605	0.0545	0.0902	0.0907	0.0683	0.0725
Np1T	0.2097	1.0000	0.4097	0.1121	0.0735	0.0811	0.0688	0.0671	0.0679
Ce1T	0.2199	0.4097	1.0000	0.1029	0.0983	0.0912	0.1101	0.0890	0.0871
Dy2T	0.0605	0.1121	0.1029	1.0000	0.3004	0.3401	0.0622	0.0811	0.0791
Np2T	0.0545	0.0735	0.0983	0.3004	1.0000	0.3988	0.0512	0.1068	0.0732
Ce2T	0.0902	0.0811	0.0912	0.3401	0.3988	1.0000	0.0674	0.0606	0.0752
Dy3T	0.0907	0.0688	0.1101	0.0622	0.0512	0.0674	1.0000	0.2027	0.2121
Np3T	0.0683	0.0671	0.0890	0.0811	0.1068	0.0606	0.2027	1.0000	0.4165
Ce3T	0.0725	0.0679	0.0871	0.0791	0.0732	0.0752	0.2121	0.4165	1.0000

11.0-K331-pr

	Dy1T	Np1T	Ce1T	Dy2T	Np2T	Ce2T	Dy3T	Np3T	Ce3T
Dy1T	1.0000	0.2084	0.2255	0.0678	0.0555	0.0901	0.0878	0.0699	0.0703
Np1T	0.2084	1.0000	0.3901	0.0991	0.0705	0.0806	0.0696	0.0688	0.0673
Ce1T	0.2255	0.3901	1.0000	0.1007	0.0975	0.0905	0.1103	0.0897	0.0870
Dy2T	0.0678	0.0991	0.1007	1.0000	0.2987	0.3468	0.0697	0.0802	0.0799
Np2T	0.0555	0.0705	0.0975	0.2987	1.0000	0.4003	0.0511	0.1071	0.0754
Ce2T	0.0901	0.0806	0.0905	0.3468	0.4003	1.0000	0.0567	0.0603	0.0765
Dy3T	0.0878	0.0696	0.1103	0.0697	0.0511	0.0567	1.0000	0.2011	0.1967
Np3T	0.0699	0.0688	0.0897	0.0802	0.1071	0.0603	0.2011	1.0000	0.3966
Ce3T	0.0703	0.0673	0.0870	0.0799	0.0754	0.0765	0.1967	0.3966	1.0000



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